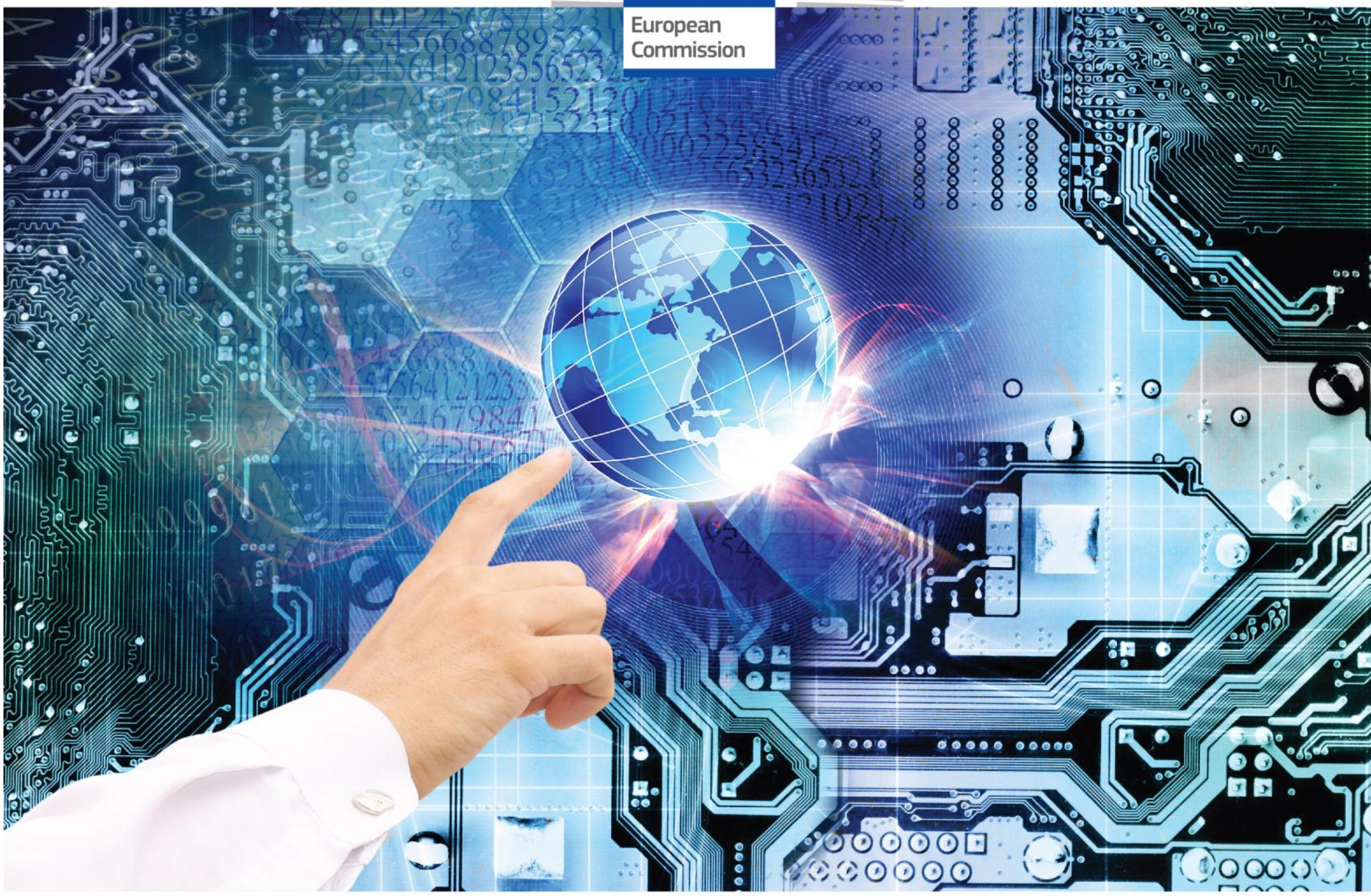
European Commission



RO-cKETs

Roadmap for cross-cutting KETs activities in Horizon 2020

November 2014

Prepared by:

D'APPOLONIA

cea

JIIP Joint Institute for Innovation Policy

National Research Council of Italy

Fraunhofer ISI

ibec Institute for bioengineering of Catalonia

TNO innovation for life

VTT

tecnalia Inspiring Business

Enterprise and Industry

EUROPEAN COMMISSION

Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs
Directorate H — Service Industries
Unit H.3 — Key Enabling Technologies and Digital Economy

Contact: Heidi Moens

E-mail: *ENTR-KETS-AND-DIGITAL-ECONOMY@ec.europa.eu*

European Commission
B-1049 Brussels

EUROPEAN COMMISSION

Roadmap for cross-cutting KETs activities in Horizon 2020

Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs
Key Enabling Technologies and Digital Economy

2014

Europe Direct is a service to help you find answers
to your questions about the European Union.

Freephone number (*):

00 800 6 7 8 9 10 11

(*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

LEGAL NOTICE

This document has been prepared for the European Commission however it reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

More information on the European Union is available on the Internet (http://www.europa.eu).

Luxembourg: Publications Office of the European Union, 2014

ISBN 978-92-79-36383-2
doi:10.2769/92111

PREFACE AND PURPOSE OF THIS DOCUMENT

This document has been produced within the framework of Service Contract SI2.ACPROCE052968300 in response to Tender 214/PP/ENT/CIP/12/C/N01C012, being the responsibility of the coordinator of this project, D'Appolonia, and a joint effort from the consortium partners.

It provides an overview of the roadmapping exercise executed within the framework of the project "Methodology, work plan and roadmap for cross-cutting KETs activities in Horizon 2020" (RO-cKETs) aimed at the development of a **roadmap for cross-cutting KETs activities** that should provide input to the preparation of the cross-cutting KETs work programme of Horizon 2020.

Please note, this exercise does not intend to substitute any former roadmapping activity carried out under the framework of specific initiatives, but rather intends to **complement those activities by providing a focus on developments that might be implemented benefitting from the cross-fertilization of different Key Enabling Technologies** in a way that creates value beyond the sum of the individual technologies.

CONTENTS

1. INTRODUCTION

Key Enabling Technologies (KETs) are the technologies of the future that have been identified as strategic to Europe. KETs have applications in multiple industries, in both emerging and traditional sectors. They comprise micro- and nano-electronics, nanotechnology, industrial biotechnology, advanced materials, photonics and advanced manufacturing systems. The European Commission has established an EU strategy to boost the industrial production of KETs-based products, i.e. innovative products and applications of the future. The strategy aims to keep pace with the EU's main international competitors, restore growth in Europe and create jobs in industry, at the same time addressing today's burning societal challenges. KETs are at the core of the EU's Industrial Policy flagship initiative, as confirmed in the Communication 'For a European Industrial Renaissance' (COM(2014)14 final).

KETs provide the technological building blocks that enable a wide range of product applications. While each of the KETs individually already has huge potential for innovation, their cross-fertilization is particularly important as combinations of KETs offer even greater possibilities to foster innovation and create new markets. The concept of 'cross-cutting KETs' refers to the integration of different key enabling technologies in a way that creates value beyond the sum of the individual technologies.

'Cross-cutting KETs' activities bring together and integrate different Key Enabling Technologies (KETs) and reflect the interdisciplinary nature of technological development. They have the potential to lead to unforeseen advances and new markets, and are important contributors to new technological components or products.

The integration of different KETs represents a vital activity in Horizon 2020. Over the course of Horizon 2020, around 30% of the budget allocated to KETs will go to integrated KETs projects. Cross-cutting KETs activities will, in general, include activities closer to market and applications.

Within this framework, the main scope of the RO-cKETs study has been to produce a shared methodology and a proposal for a cross-cutting KETs roadmap and work plan for the European Commission, which will provide input to the preparation of the cross-cutting KETs part of Horizon 2020. Taking the demand side as a starting point, the study should help the Commission to identify the most promising areas of innovation for cross-cutting KETs that address clear industrial and market needs in a broad number of industrial sectors.

The scope of this document is to describe the developed roadmap for cross-cutting KETs activities, which identifies the potential innovation fields of industrial interest relevant for cross-cutting KETs, outlining how the combination of different Key Enabling Technologies could contribute to addressing the challenges facing European industry, economy and society.

In Chapter 2, the background and strategic vision behind Key Enabling Technologies, as well as the cross-fertilization between Key Enabling Technologies are described, and the purpose for developing a roadmap for cross-cutting KETs activities is introduced. Moreover, the role of the RO-cKETs study in this regard is explained briefly.

Chapter 3 describes concisely the methodology designed for the definition of the potential innovation fields of industrial interest relevant for cross-cutting KETs, highlighting the major practical steps. It also introduces the structure of the roadmap prior to entering the details of each innovation field as classified within the relevant cross-sectoral domains in which the roadmap has been organized.

Finally, in the Annex, individual results are provided for each of the potential areas of industrial interest relevant for cross-cutting KETs identified throughout the study.

2. BACKGROUND, VISION AND PURPOSE FOR A ROADMAP ON CROSS-CUTTING KETS ACTIVITIES

2.1. Key Enabling Technologies

On 26 June 2012, the European Commission tabled its strategy to boost the industrial production of innovative products, goods and services based on Key Enabling Technologies (KETs)[1]. The strategy aims to keep pace with the EU's main international competitors, restore growth in Europe and create jobs in industry, at the same time addressing today's burning societal challenges.

According to this strategy, KETs are defined as 'knowledge intensive technologies associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration. KETs can assist technology leaders in other fields to capitalise on their research efforts[1].'

Based on current research, economic analyses of market trends and their contribution to solving societal challenges, micro- and nano-electronics, nanotechnology, photonics, advanced materials, industrial biotechnology and advanced manufacturing systems (the latter recognized as a horizontal KET) have been identified as the EU's Key Enabling Technologies.

KETs provide the technological building blocks that enable a wide range of product applications, including those required for developing low carbon energy technologies, improving energy and resource efficiency, boosting the fight against climate change, or allowing for healthy ageing.

KETs already play an important role in the R&D, innovation and cluster strategies of many industries and are regarded as crucial for ensuring the competitiveness of European industries in the knowledge economy. KETs are therefore at the core of the EU's Industrial Policy flagship initiative, as confirmed in the recent communication 'For a European Industrial Renaissance' (COM(2014)14 final).

By enabling product, process and service innovation and having the inherent ability to enable advances in all industries and sectors, KETs are of systemic relevance as they will drive restructuring of industrial processes needed to modernise EU industry and secure the research, development and innovation base in Europe. Mastering these technologies means being at the forefront of managing the transition to a knowledge-based and low carbon, resource-efficient economy. Although the EU has very good research and development capacities in some key enabling technology areas, it has not been as successful at translating research results into commercialized manufactured goods and services.

2.2. Cross-cutting Key Enabling Technologies

Whilst each of the Key Enabling Technologies individually already has huge potential for innovation, their cross-fertilization is particularly important as combinations of KETs offer even greater possibilities to foster innovation and create new markets. The concept of 'cross-cutting KETs' refers to the integration of different key enabling technologies in a way that creates value beyond the sum of the individual technologies.

---

[1] 'A European strategy for Key Enabling Technologies – A bridge to growth and jobs' (COM/2012/0341 final)

‘Cross-cutting KETs’ activities bring together and integrate different Key Enabling Technologies (KETs) and reflect the interdisciplinary nature of technological development. They have the potential to lead to unforeseen advances and new markets, and are important contributors to new technological components or products.

The integration of different KETs represents a vital activity in Horizon 2020. Over the course of Horizon 2020, around 30% of the budget allocated to KETs will go to cross-cutting KETs projects.

In order to tap into the high cross-fertilization potential of these technologies, in the last quarter of 2012 the European Commission launched a study to define a methodology by which to identify potential areas of industrial interest relevant for cross-cutting KETs and to develop a roadmap for cross-cutting KETs activities.

2.3. The RO-cKETs study at a glance

The main scope of the study “Methodology, work plan and roadmap for cross-cutting KETs activities in Horizon 2020”, briefly called RO-cKETs, has been to produce a shared methodology and a proposal for a cross-cutting KETs roadmap and work plan for the European Commission, which will provide input to the preparation of the cross-cutting KETs part of Horizon 2020.

Taking the demand side as a starting point, the study should help the Commission to identify the most promising areas of innovation for cross-cutting KETs that address clear industrial and market needs in a broad number of industrial sectors. This has been based, among other things, on desk research and interviews, as well as workshops with industrial stakeholders, workshops with policy makers, and the validation of findings through surveys involving both KETs experts as well as industrial stakeholders.

Integration between Key Enabling Technologies (KETs) will be essential for economic growth, competitiveness and innovation in Europe in the coming years. As input to Horizon 2020, the study “Methodology, work plan and roadmap for cross-cutting KETs activities in Horizon 2020” (RO-cKETs) outlines how the combination of different Key Enabling Technologies could contribute to addressing the challenges facing European industry, economy and society.

2.4. The roadmap for cross-cutting KETs activities at a glance

The roadmap for cross-cutting KETs activities identifies the potential innovation fields of industrial interest relevant for cross-cutting KETs. The roadmap has been developed starting from actual market needs and industrial challenges in a broad range of industrial sectors relevant for the European economy. The roadmapping activity has focused on exploring potential innovation areas in terms of products, processes or services with respect to which the cross-fertilization between KETs could provide an added value, taking into account the main market drivers for each of those innovation areas, as well as their societal and economic context.

Cross-cutting KETs activities are accordingly expected to fulfil two main requirements: on the one side they are expected to bring together and integrate different KETs and reflect the interdisciplinary nature of technological development; on the other side they are expected to contribute significantly to restoring growth in Europe and creating jobs in industry, contributing at the same time to tackling today’s major societal challenges.

Taking the demand side as a starting point, cross-cutting KETs activities will in general include activities closer to the market and applications. The study focused on identifying potential innovation areas of industrial interest, implying Technology Readiness Levels of between 4 and 8.

3. THE ROADMAP FOR CROSS-CUTTING KETS ACTIVITIES

3.1. Roadmapping approach

Within the framework of the RO-cKETs study a methodological approach has been developed, which has led to the definition of a proposal for a roadmap for cross-cutting KETs activities that will provide input to the European Commission to the preparation of the cross-cutting KETs part of Horizon 2020.

Taking the demand side as a starting point, the study has focussed on identifying the most promising areas of innovation for cross-cutting KETs that address clear industrial and market needs in a broad number of industrial sectors. This has been based, among other things, on desk research and interviews, as well as workshops with industrial stakeholders, workshops with policy makers, and the validation of findings through surveys involving both KETs experts as well as industrial stakeholders. Throughout all phases of this roadmapping process, more than 700 technology and industry experts were involved.

Notably, this roadmapping exercise does not intend to substitute any former roadmapping activity carried out under the framework of specific initiatives, but rather intends to **complement those activities by providing a focus on developments that might be implemented benefitting from the cross-fertilization of different Key Enabling Technologies** in a way that creates value beyond the sum of the individual technologies.

The first action in this methodology has been the identification of innovation fields of potential interest for industry starting from a thorough demand analysis in a broad range of industrial sectors comprehensively representing the industrial base in Europe.

Once identified, innovation fields were subject to assessment by both KETs experts as well as industrial representatives. Whilst KETs experts were called to assess whether the cross-fertilization between KETs could provide added value to innovative developments within the framework of each of the identified potential innovation areas as well as to indicate which of the KETs could jointly play a role with respect to such innovative developments, industrial representatives were surveyed in order to assess the converging industrial interest with their respect and the relevance of the identified innovation fields with respect to industrial growth and job creation.

As a fundamental cornerstone in executing the study activities, a market perspective was adopted, meaning that the demand side has been the starting point for the work.

The implemented methodology hence consisted of three main steps:

1. **Identification of innovation fields of industrial interest**. To this aim a broad analysis of the demand was undertaken in regard to 28 manufacturing sectors as classified according to NACE (Rev. 2) codes. Activities consisted initially of a broad desk analysis aimed at mapping potential innovation areas along with their associated market needs and industrial challenges thanks to a thorough screening of Strategic Research (and Innovation) Agendas and Strategic Roadmaps developed by European Technology Platforms and other European initiatives (such as Joint Technology Initiatives or Undertakings) as well as of other available acknowledged sources of information with European relevance (e.g. market studies, foresight studies, sector analyses, etc.). This desk analysis was subsequently complemented by further input from more than 80 representatives of key industrial players, collected through interviews and workshops. From this

initial activity, 257 innovation fields were identified, which were further classified into 13 cross-sectoral domains.

2. **Matching of the identified innovation fields with the technological offering to be provided by KETs and more specifically by the cross-fertilization between KETs**, thanks to the extensive involvement of high level experts in Key Enabling Technologies. The analysis leveraged views of 272 experts in the six KETs, mobilized via a dedicated Europe-wide online-based survey. Technology experts were called to provide input regarding the identification of which KETs could contribute to each innovation field and moreover to assess whether the integration of the potentially contributing KETs beyond their mere combination could constitute an additional success factor for the effective bridging of the "Valley of Death" of highly innovative products. This second activity resulted in a shortlist of innovation fields with cross-cutting KETs relevance.
3. **Identification of the most promising areas of converging industrial interest for cross-cutting KETs**. A second Europe-wide online-based survey was launched in order to gain industrial experts' opinions with regard to market demand aspects. This second survey was addressed at CEOs, CTOs, R&D managers, technology managers, and development directors, who were called to assess the identified innovation fields in terms of market impact and opportunity toward industrial growth and job creation. The results leveraged opinions of 285 industry experts.

The combined results of the two surveys were furthermore complemented with results of patent scenario analyses that were carried out for each of the identified innovation fields of industrial interest.

This approach allowed the definition of a **shortlist of 117 key innovation fields of industrial interest with the highest potential for answering market, industry and society demands from cross-cutting KETs developments**, which constitute the nodes of the roadmap for cross-cutting KETs activities.

Thanks to the KETs experts' input, the innovation fields comprised in the roadmaps have been furthermore split into two main blocks. The first block (short-term) identifies cross-cutting KETs developments for which experts have foreseen a necessary time of up to 5 years (from end 2013) for solving the main technological issues holding back the achievement of cross-cutting KETs based products, prior to any time required in order to actually introduce those products to the market. The second block (medium-term) identifies cross-cutting KETs developments for which experts have indicated a necessary time for solving main technological issues longer than 5 years. **Despite this grouping, however, many of the innovation fields can be considered as being subject to continuous, incremental improvement as they are associated with well-established market needs driving the development of new products, processes and services as soon as new enabling technologies or technological solutions become available**.

Each roadmap displays the **key innovation fields of industrial interest for Europe with the highest potential for cross-cutting KETs developments** relevant for the specific domain, also highlighting cross-sectoral development opportunities and relevance for short-term or medium-term developments.

3.2. Roadmaps for cross-cutting KETs activities

The roadmap is organized in several views according to the thirteen cross-sectoral domains in which innovation fields of industrial interest have been classified, namely:

- **Electronics and communication systems**;
- **Chemical processes, chemicals, chemical products and materials;**
- **Manufacturing and automation** (including robotics);
- **Energy** (including energy generation, storage, transmission and distribution);
- **Transport and mobility** (including road, rail, marine and air transport as well as logistics, besides space);
- **Construction**;
- **Civil security** (including dual use applications);
- **Mining, quarrying and extraction**;
- **Environment** (including water supply, sewerage, waste management and remediation);
- **Health and healthcare**;
- **Training, education and edutainment**;
- **Textiles**;
- **Agro-food**.

Among the above cross-sectoral domains, three domains, namely Electronics and communication systems; Chemical processes, chemicals, chemical products and materials; and Manufacturing and automation (including robotics) can be distinguished from the other, more application-oriented domains, as being themselves enablers of downstream applications in other domains. These three highly cross-sectoral domains qualify in fact as suppliers of general purpose technology to other domains and are therefore characterized by high pervasiveness.

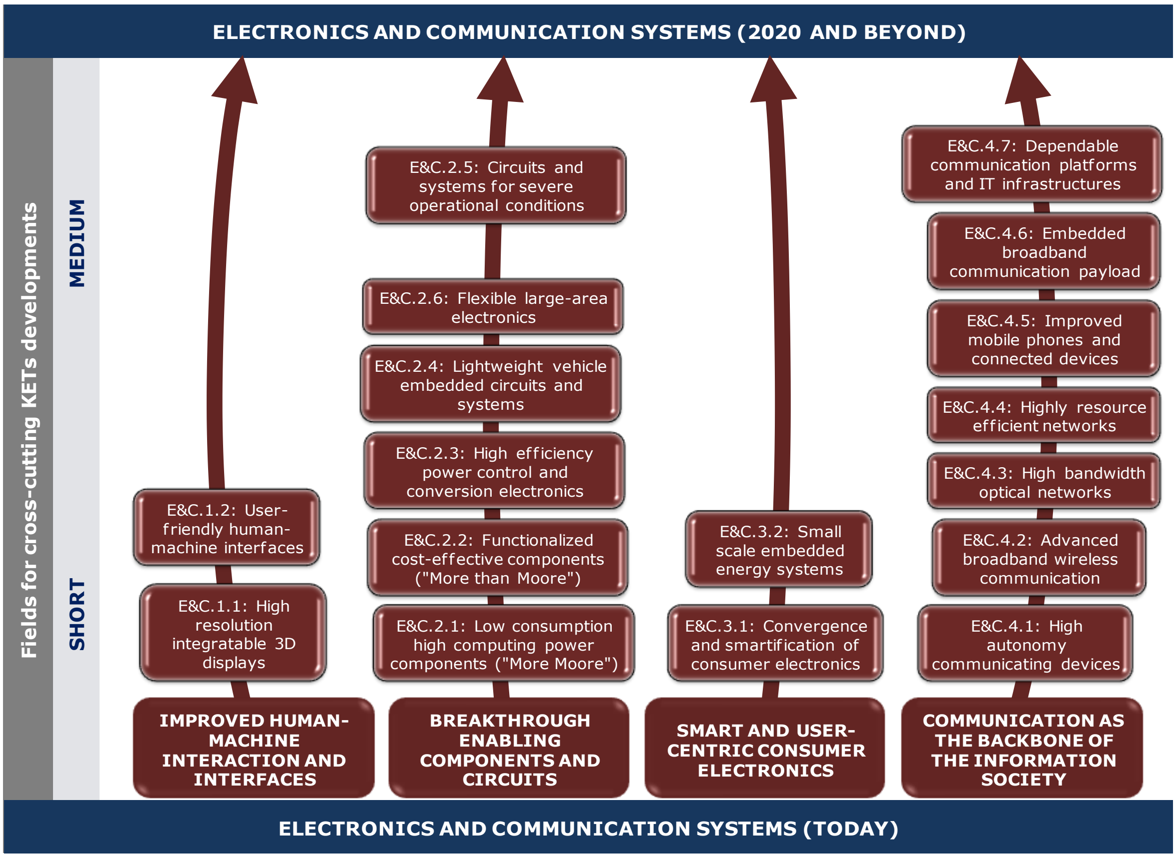
3.2.1. Potential areas of industrial interest relevant for cross-cutting KETs in the Electronics and Communication Systems domain

The manufacture of computer, electronic and optical products, classifying as NACE code C26 (NACE Rev. 2), accounted for 290 billion Euro of turnover and 77.6 billion Euro of value added in Europe in 2010, and furthermore employed 1.1 million people[2]. With an average number of persons employed per enterprise of 26, this industry appears to be largely populated by small and medium sized enterprises employing fewer than 50 employees. The sector comprises the manufacture of electronic components and boards, computers and peripheral equipment, communication equipment, consumer electronics, instruments and appliances for measuring, testing and navigation, watches and clocks, irradiation, electro-medical and electro-therapeutic equipment, optical instruments and photographic equipment, and, last but not least, magnetic and optical media.

Qualifying as a supplier of general purpose technology, this domain is characterized by high pervasiveness, being capable of providing components for several product, process and organizational innovations in a number of downstream applications such as, for example, manufacturing and automation, transport, healthcare, ICT services, and many more. The sector is characterized by short product life cycles, strong global competition and a comparatively strong emphasis on R&D[3].

Within this framework, among the many potential innovations in this domain, the integration between Key Enabling Technologies is deemed to be of highest benefit to innovation fields in the following sub-domains.

[2] Eurostat, Annual enterprise statistics for special aggregates of activities (SBS)
[3] Computers, electronic and optical products, Comprehensive sectoral analysis of emerging competences and economic activities in the European Union, Report submitted to the European Commission, DG Employment, Social Affairs and Equal Opportunities, 2009



❖ Improved Human-Machine interaction and interfaces

Interaction between humans and machines is becoming increasingly important in today's society, finding not only applications within workers' environments but even in people's everyday lives. Market demand for improved human machine interaction systems and interfaces, allowing for smooth, ergonomic and personalized interfacing and improved user experience, is therefore increasing. Improved interaction systems between machines and humans are levers for breaching barriers towards the adoption and deployment of many technologies, including robots, enhanced reality, multi-service converged equipment, connective devices, etc. This calls for well-designed interfaces with more advanced functionalities and user-friendly approaches, allowing humans to interact easily with the surrounding environment in which they live or operate. Within this framework, **improved displays offering realistic and immersive 3D video reproduction** (E&C.1.1), supported by energy-efficient, flexible/wearable and easily integrated technologies, or supported by methods of immersive sound reproduction, as well as file formats and adequate video processing hardware, can fulfil the market requirement for truly immersive experiences, with main market impacts expected in the entertainment businesses, including cinema and TV, videogames, and all sorts of individual or social games (linking also with the Training, education and edutainment domain). Such improved displays are deemed to be one field in which the cross-fertilization between Key Enabling Technologies, with particular reference to photonics, advanced materials, advanced manufacturing technologies, micro- and nano-electronics and even nanotechnologies could provide an advantage. This same combination of KETs is expected to provide added value to the development of **enhanced human-machine interfaces** (E&C.1.2), allowing for easier human-machine interactions, which respond to the market requirement of an increased user-friendliness through for example real-time human language technologies, multimodal interfaces mimicking human communication skills, safe natural proximity and hands-free interaction, up to virtual reality for highly complex systems, an area which finds strong cross-sectoral application opportunities, e.g. in the manufacturing sector, the entertainment sector, and in any other application requiring humans to interact with machines.

❖ Breakthrough enabling components and circuits

With electronic and telecommunication systems getting more and more complex, developing circuits and components dedicated to specific applications is key for the competitiveness of entire industries. Keeping caught-up with Moore's law (computing power doubles every two years) as well as with new trends (non-computing capabilities grouped under the "More-than-Moore" concept) is a survival issue for the European electronics industry facing huge global competition. Moreover, setting up the "Internet of Things", "Cloud computing" or "Big data" services are major requirements for many industries and services in Europe, requiring developments in components as well as from upper technical layers. Within this framework, cost is key and all component design and production has to integrate competitive production aspects from the earliest phase.

In this context, in the short term, the development of affordable and sustainable, **high computing power, low consumption components and circuits**, **basically "more Moore"** (E&C.2.1) (e.g. based on CMOS and Silicon technology), responding to market requirements such as further miniaturization, higher performance, increased energy efficiency and better heat management of computing systems, supported by a shift to renewable, abundant and non-toxic materials (see also innovation field 'Metamaterials or novel chemistries for the substitution of rare elements and other critical raw materials', CH.1.2, in the Chemical processes, chemicals, chemical products and materials domain), more cost-effective production processes, and higher transistor density, is becoming increasingly important for industry. These developments might greatly benefit from the integration of almost all KETs, namely micro- and nano-electronics, advanced materials, nanotechnologies, photonics and advanced manufacturing technologies. The same combination of Key Enabling Technologies is expected to contribute as well to the development of **components and circuits going beyond CMOS technologies ("more than Moore")** to deliver powerful low cost and/or functionalized computing, sensing and actuation capabilities (E&C.2.2), as increasingly demanded by several industrial applications, building on the functionalization of the semi-conductor substrate to enrich the non-digital capabilities of the circuits, manage their growing complexity, enable alternative computer architectures (e.g. self-organizing, reconfigurable, defect and fault tolerant architectures), or high performance solutions for radiofrequency, sensing and control/actuation micro-systems, making all these potentially integratable/coupleable with CMOS ("system on chip").

As today, power control and conversion are at the heart of many energy-related applications, namely e-mobility, power generation, transmission, distribution, and management, energy efficiency in transport, manufacturing, buildings, etc., the market demand for improved power control and conversion electronics is increasing rapidly. Within this framework, **higher efficiency solid-state fast dynamics power control and conversion electronics** (E&C.2.3) might benefit from the cross-fertilization of micro- and nano-electronics, advanced materials, advanced manufacturing technologies and, to a lesser extent, nanotechnologies, in order to provide for more efficient, effective, reliable and sustainable control and conversion of electric power, mainly for power grid (see also sub-domain 'Smart grid enforcement' within the Energy domain) or transport applications (see also innovation field 'Vehicle embedded power and heat systems', T.1.5, in sub-domain 'More sustainable and green vehicles' within the Transport and mobility domain).

On the other side, **flexible large-area electronics** (E&C.2.6), answering the market need for lower cost of circuits (compared to Silicon electronics), despite the lesser performance they provide, and enabling large scale and flexible integration of smart capabilities into textiles/wearable products (see also related innovation fields 'Wearable active textiles and clothing for improved human performance aimed at human safety and protection', TX.2.1, as well as 'Active textiles with embedded sensing capabilities for "large area" applications', TX.2.2, in the Textiles domain), packaging (see also innovation field 'Food packaging systems for preserving food from microbial contamination and for improving shelf life', AF.2.1, in the Agro-food domain), buildings (see also innovation field 'Flexible solar cells (modules) enabling improved PV integrability', E.1.1, in the Energy domain), lighting (see also innovation field 'Energy-efficient interconnected and versatile lighting', CS.1.1, in the Construction domain), and many more applications, as increasingly demanded by several markets, might take advantage of the development of semi-conductive inks, substrate treatments and related manufacturing processes enabling printed and thin film electronics, eventually organic. In this respect, the integration of advanced materials, advanced manufacturing technologies, micro- and nano-electronics, nanotechnologies and, though less fundamentally, photonics could provide added value.

Related to the Transport domain, **electronic components and circuits adapted to (and qualified for) the specific constraints of vehicle embedded systems** (E&C.2.4) also constitute an opportunity for cross-cutting KETs developments integrating micro- and nano-electronics, advanced materials, advanced manufacturing, and nanotechnologies and photonics, with a less fundamental input. According to current market requirements, these need to be lightweight and energy efficient, modular (as much as possible), and easily upgraded/retrofitted, resistant/resilient to vibrations and other operational constraints (dynamics, temperature, etc.), long campaign life and fit for architectures offering the best operational safety. In the medium term, dedicated **circuits and systems for severe environmental conditions of operation** (E&C.2.5), which are essential components in several specialized applications (such as in space, underground, underwater, in nuclear plants, etc.), obtained as much as possible from the adaptation of standard high performance electronic, electric and electro-mechanical (EEE) components to extreme operational conditions (extreme temperatures, out of atmosphere radiation, space launch acceleration and vibrations, nuclear environment, etc.) are also expected to benefit from the integration between Key Enabling Technologies, with special emphasis on micro- and nano-electronics, advanced materials, advanced manufacturing technologies, nanotechnologies and photonics.

❖ **Smart and user-centric consumer electronics**

The development of Europe's society into an inclusive, innovative and reflective society supporting smart capabilities, personalized services and high performance systems to be made available to consumers and citizens, will continue to leverage much consumer electronics. It will support a wide variety of services, including for entertainment, education, sports, well-being, lifestyle, communication, home services, connected mobility, etc. This short-term scenario will lead to an overall **convergence and smartification of consumer electronics** (E&C.3.1) that will include the development of high usability and multi-functional consumer lifestyle products (including goods such as washing machines, televisions), supported by high degrees of connectivity and convergence of all home/consumer equipment and devices, so as to support advanced consumer services, e.g. more automation of housekeeping, assisted living, etc. Within this framework, the integration especially of micro- and nano-electronics with advanced manufacturing technologies, and with an important but less fundamental contribution of advanced materials, nanotechnologies and photonics, is expected to be advantageous. All of this will additionally be enabled by more advanced **power systems and solutions**, such as battery or fuel cell systems, for supplying mobile and autonomous devices **with embedded energy** (E&C.3.2) in an operational, safe, cost-effective, user-friendly and long-lasting format as increasingly demanded by the market. The latter is an innovation field that integrates very much with the Energy domain and that could gain profit from the cross-fertilization between advanced materials, advanced manufacturing technologies, nanotechnologies, micro- and nano-electronics and photonics.

❖ Communication as the backbone of the Information Society

Reaching an inclusive society is also about closing the digital divide. Within an inclusive European society, furthermore, skills or services need to be supported by communication technology. Yet, to achieve this goal, technological developments are required in broadband wireless communications, very high broadband wireline communications, networks interfacing and systems autonomous connectivity, besides user-friendliness. With ubiquitous digitalization, cyber-security and protection of communications are also crucial requirements for a safe, secure and free society.

Triggered by an increased use of the internet and the increasing market deployment of services supported by the internet, volumes of data exchanges have been subject to continuing growth in recent years, while European telecommunication operators have been experiencing a drop. These operators expect improved communication networks to provide them with capabilities for new services to be offered on the market that might constitute important growth and profitability relays. Potentially benefitting from the cross-fertilization between KETs, and particularly between micro- and nano-electronics, advanced manufacturing technologies, advanced materials, photonics and nanotechnologies, **high autonomy communicating devices** (E&C.4.1), such as cost-effective and all-size embedded sensors with high connectivity for the Internet of Things, with embedded sensor systems and observation/detection instrument chains or autonomous sensors/devices making use of remote power supply/storage and/or micro-energy harvesting, are required by the telecommunication industry as part of these services enabled by enhanced communication capabilities. Along with these systems, **advanced broadband wireless communication** (E&C.4.2), enabled by radio-frequency technologies for seamless, high-performance (broadband), reliable, interoperable, efficient and secure wireless communication would be required by the market. The latter shall include cognitive radio and new radio technologies to make better use of the limited radio spectrum and advanced wireless networks with increased bandwidth and energy efficiency and multiple communication chips in single platforms, all of which is expected to take advantage from the cross-fertilization between micro- and nano-electronics, photonics, advanced manufacturing technologies, advanced materials and nanotechnologies. **Advanced network infrastructures with ultrahigh bandwidth**, **mainly based on an optical backbone** (E&C.4.3) and taking advantage of solutions such as radio over fibre or other seamless network technologies, would further enhance communication capabilities in the Information Society, thus responding to the increasing market demand for smartification. In addition to the most obvious and consensual contribution from photonics, KETs experts' opinions have also allowed the identification of an expected contribution from the integration of micro- and nano-electronics, advanced manufacturing technologies, nanotechnologies, and advanced materials in this respect. Additionally, in order to decrease energy consumption of ICT, thus bringing benefit to the environment besides responding to the industrial requirement of lower costs to be sustained by operators to guarantee ICT services, the development of **resource efficient networks and infrastructures** (E&C.4.4) with a low use of energy (i.e. limited heat dissipation), spectrum and processing power, including through concepts such as multi-hop mesh solutions, multi-criteria routing and cognitive/self-organization, context-based sleep/active cycles, low power infrastructure chipsets and modules and a special effort on developing distributed cloud computing and data centre eco-efficiency, is expected to benefit from the cross-fertilization between micro- and nano-electronics, advanced materials, advanced manufacturing technologies, photonics and nanotechnologies. **Improved mobile phones and connected mobile devices** (E&C.4.5) that go beyond current devices and smart phones, responding to market requirements such as improved functionalities, convergence with other devices (supported by virtualization and cloud computing), higher connectivity (through universal systems), weight reduction, more autonomy (with increased energy efficiency, better batteries or micro-energy harvesting), long campaign life, and damage resistance, and recycling by design as additionally required by industry, would further complete the picture, making profit from the combination of micro- and nano-electronics, advanced manufacturing and advanced materials, and, to a lesser extent, of nanotechnologies and photonics.

In the longer term, the development of **transponder systems enabling embedded communication payloads** (E&C.4.6) of satellites, airships or any flying or otherwise moving platforms might provide a better broadband communication service at a reasonable cost, thus responding to industrial requirements of players in the telecommunications sector that, in order to enhance their services palette, need to guarantee universal and seamless access to the internet even in hard to access areas, with a limited energy consumption (and heat dissipation) and including with all protection systems for preventing unwanted spoofing and jamming of other systems. In this respect, a combined contribution by advanced materials, micro- and nano-electronics, nanotechnologies, photonics and advanced manufacturing technologies is expected. Last but not least, building secure and **dependable communication platforms and IT infrastructures and services** (E&C.4.7), relying on cryptography, authentication, authorization and accounting methods, deperimeterized firewalling, pro-active STDP (security, trust, dependability and privacy) solutions, physical hardening, etc., as increasingly demanded by both industry and the market as information-based services take deeper root in European societies, might take advantage from the cross-fertilization of micro- and nano-electronics, photonics, nanotechnologies, and, to a lesser extent, advanced manufacturing technologies.

3.2.2. Potential areas of industrial interest relevant for cross-cutting KETs in the Chemical Processes, Chemicals, Chemical Products and Materials domain

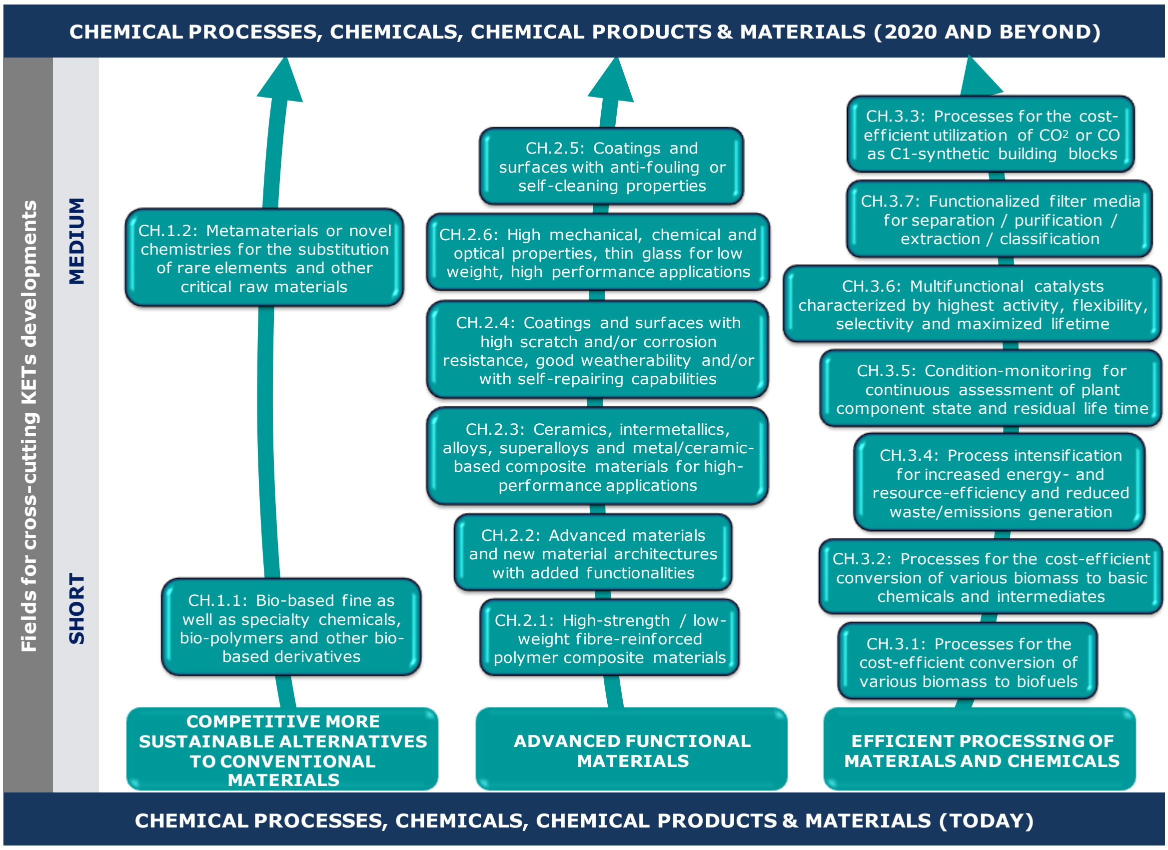
The European chemical industry was worth 673 billion Euro in 2011. The sector produced 21.5% of the world's chemicals in 2011, employing 1.2 million workers and contributing 558 billion Euro to Europe's economy. Despite losing its top spot in world chemicals sales in favour of China, whose world chemicals sales market share reached 30.5% in 2012, the European chemical industry still holds a very important position. Germany is the largest chemicals producer in Europe, followed by France, The Netherlands and Italy, which together generated 62.6% of Europe's chemicals sales in 2012, valued at 349 billion Euro. The share rises to nearly 87.7% when including the UK, Spain, Belgium and Poland, while the other European countries generated together 12.3% of Europe's chemicals sales in 2012. The European chemical industry is furthermore a highly diversified sector. In terms of structure, a large number of small and medium sized enterprises dominate the scene besides fewer important large multinational players. As regards markets, the chemical industry underpins virtually all sectors of the economy, having a direct strategic impact on downstream chemicals' users such as rubber and plastics, construction, pulp and paper, and the automotive industry, to name the biggest industrial users of chemicals. Other important users of chemicals are agriculture, textiles, metals, and the food and beverages industry[4].

Over the years, chemical processes have continually improved in terms of their greater utilization of raw materials, improved safety and increased productivity whilst minimising waste and energy use. Yet, the European chemical industry is still facing the need to restructure and modernize by continuing to reduce consumption of energy as well as resources (i.e. both raw materials and water) besides reducing waste as well as emissions. On the other hand, the European chemical industry faces the need to reduce time-to-market for new products, and a need to increase operational flexibility to enable swift responses to changing market trends in order to remain competitive in the global market[5].

---

[4] The European Chemical Industry Council, The European Chemical Industry Facts and Figures Report, 2013, www.cefic.org
[5] SusChem, www.suschem.org

Within this framework, among the many potential innovations in this domain, the integration between Key Enabling Technologies is deemed to be of highest benefit to innovation fields in the following sub-domains.



❖ **Competitive more sustainable alternatives to conventional materials**

One of the trends of the chemical industry is to move toward more sustainable alternatives to conventional materials. Within this framework, the integration between Key Enabling Technologies could provide added value, for instance for the further development, in the short term, of **bio-based fine, as well as specialty chemicals, bio-polymers and other bio-based derivatives** (CH.1.1), which is a high priority for Europe and increasingly demanded by several markets, driven by several forces, including high oil prices, consumer preference, corporate commitment, and government mandates and support. In this respect, the combination between industrial biotechnology, advanced manufacturing, advanced materials and, in certain instances, nanotechnologies, might provide for the development of innovative formulations for bio-based materials or derivatives aimed at widening their application potential either in non-durable or durable goods. This might occur through the modification (e.g. by alloying and fortification with impact modifiers, reinforcing fillers, nano-additives, etc.) to overcome most bio-polymers' inherent brittleness, low heat resistance, and processability limitations so as to widen their application potential, particularly in durable goods.

Rare earth elements and other critical raw materials are essential to industrial production and thus to many key market sectors. They are involved in wind turbines, solar cells, electric vehicles, energy efficient lighting, many other electric and electronic devices, catalysts for chemical production, to name a few. Yet, the production of some of these rare earth elements and other critical raw materials is concentrated in a few specific geographic locations (predominantly outside Europe), which could result in supplies becoming tight and costs prohibitive as markets grow. If this were to occur, there would be serious impacts in key market sectors as a consequence of the restricted supply of these materials. Within this framework, in the medium term, the combination of advanced materials, nanotechnologies and advanced manufacturing technologies might benefit from the development of **metamaterials or novel chemistries to be applied as safe and cost-effective equivalents to rare and toxic adjuvants** (CH.1.2) to various productions, or provide for their minimal use, with applications for example in catalysts without precious metals (especially without Platinum), permanent magnets and battery electrodes without rare earths, replacement of Tin-doped Indium Oxide (ITO) where thin transparent oxides are needed as in screens and displays, etc.

❖ **Advanced functional materials**

Advanced functional materials are another domain in which the cross-fertilization between Key Enabling Technologies might be leveraged. One option is in order to provide for the development of **enhanced fibre-reinforced polymer composite materials with superior strength and lower weight** (CH.2.1) for application in transport (to reduce fuel consumption while guaranteeing strength), civil engineering (to provide for steel substitution in structures requiring strength combined with lightweightness or low maintenance), sports equipment, etc. Fibre- reinforced polymer composite materials actually offer a number of advantages over some of the traditional materials they can replace, which has led to these materials gaining much attention from several industries and markets. Such advantages mainly comprehend high structural efficiency (meaning strength- to- weight ratio) and corrosion resistance to a wide range of chemicals. As a result, the range of applications of these materials has increased exponentially in the last thirty years and today they find application mainly in the space, aeronautics, marine/naval, automotive, industrial equipment, energy equipment (mainly wind turbines), electrical equipment, and general consumer commodities' sectors (mainly sports equipment). Another option is represented by **advanced, mainly structural, materials with added functionalities**, e.g. for sensing or self-repair, **and new material architectures**, incorporating for example novel fibres, nanomaterials, etc., **capable of providing added functionalities** (CH.2.2) especially to large structures, responding to the industrial requirement of achieving added functionalities and 'unique' material properties, and finding application in niche markets in which the added functionality represents a competitive advantage over conventional materials. In both these fields, the combination between advanced materials, nanotechnologies and advanced manufacturing is expected to provide benefit in the short term.

Other fields where cross-cutting KETs, with particular attention to advanced materials, nanotechnologies and advanced manufacturing, might contribute mainly in the short term are represented by **ceramics**, **intermetallics**, **alloys**, **supealloys as well as metal-matrix, ceramic-matrix or metal-ceramic composites for high-performance applications** (CH.2.3) characterized by lower cost, lower density, high strength, high temperature or corrosion resistance, which are important industrial requirements mainly in the fields of energy and transport.

Coatings and surfaces with anti-fouling or self-cleaning properties (CH.2.5), whose market is expected to grow on account of their increasing usage in end-uses such as industrial engineering, marine, food manufacturing, automotive and energy among others, long-lasting protective **coatings and surfaces with high scratch and/or corrosion resistance and good weatherability, as well as coatings and surfaces with self-healing, self-repairing or self-replicating properties** (CH.2.4), which, along with paints and finishes, are widely used in many industrial sectors such as transport, construction and other various industrial applications, are all expected to receive benefit from the combined contribution of advanced materials, nanotechnologies and advanced manufacturing.

Finally, cost-effective, **high mechanical, chemical and optical properties, thin glass layers for low weight, high performance applications** (CH.2.6), allowing the improvment or replacement of costly coatings and surface treatments whilst maintaining mechanical and chemical properties such as purity, anti-reflectiveness, spectral behaviour, anti-fog, anti-dust, etc., which are important requirements for industries such as the electronics industry, among others, are furthermore expected to gain market and, from a technological point of view, to gain from the cross-fertilization between advanced manufacturing as combined with advanced materials and nanotechnologies.

❖ **Efficient processing of materials and chemicals**

The integration of Key Enabling Technologies is also expected to contribute to achieving more efficient processing in the chemical industry. The same market drivers that apply to the demand for chemicals and materials having specific characteristics or properties reflect upstream in the need for industrial processes by which these products can be profitably produced. Some of these processes may benefit from the cross-fertilization of Key Enabling Technologies. Examples thereof are represented by **processes for the cost-efficient conversion of various types of biomass** (e.g. agro-biomass, organic waste, forestry, etc.) **to basic chemicals and intermediates** (CH.3.2), which are characterized by high performance, stability and selectivity, paying special attention to coping with the natural variability in the quality of biomass-derived raw materials, which are essential requirements for this type of industry. In this respect, the combination of industrial biotechnology, advanced manufacturing technologies as well as advanced materials could provide for the integration, into the industrial production within integrated biorefineries, of novel bio, chemical and catalytic processes allowing for the introduction of novel, **improved synthetic routes for the efficient conversion of biomass-derived raw materials to obtain diverse high-value bio-products, including biofuels** (CH.3.1), in the short term. To this end, advances in **intensified processes for increased energy- as well as resource-efficiency and reduced waste as well as emissions' generation** (CH.3.4), as increasingly demanded by the chemical industry in order to face the need to comply with regulatory requirements and simultaneously reduce plant operation costs, leveraging performance and control options and also new reaction pathways and conditions, integration of reaction steps, integration of reaction and purification/separation/extraction steps, and intensification in the energy input, could clearly benefit from the integration of advanced manufacturing technologies, advanced materials and industrial biotechnology, and also of nanotechnologies.

Higher performance functionalized filter media for liquids and gases for application in purification/separation/ extraction/classification processes (CH.3.7) for use e.g. in chemical, pharmaceutical and biotechnological processes, as well as environmental treatment and water purification, are only one clear example of a specific component enabling process intensification in which the cross-fertilization of Key Enabling Technologies such as advanced materials, nanotechnology and advanced manufacturing technologies could prove advantageous. From the integration between advanced materials, nanotechnology, industrial biotechnology and advanced manufacturing technologies, the development of the next generation of **multifunctional organic and inorganic catalysts** (CH.3.6) (including hybrid catalysts and biocatalysts), whose increasing demand reflects the mounting demand for polymers and chemicals worldwide, could particularly benefit. They shall be characterized by highest activity and flexibility, possibly be even regenerative/rejuvenable and in any case have maximized lifetime, and be capable of achieving near 100% selectivity in multi-step and complex syntheses.

Though less mature than currently available options, the development of **processes for the cost-efficient utilization of carbon dioxide or its reduced forms, such as carbon monoxide, as C1-synthetic building blocks** (CH.3.3) is expected to gain attention, driven by similar market forces as is the case today for bio-materials, namely high oil prices, consumer preference, corporate commitment, and, possibly, government mandates and support. From the result of carbon capture technologies, carbon dioxide (CO_2) is increasingly becoming available in vast quantities and of high purity as an economically attractive resource for chemical syntheses. New routes and processes (e.g. based on incorporation of CO_2 in polymers, hydrogenation, activation, as well as catalytic, organo-catalytic, photo-catalytic, electro-catalytic processes, etc.) are therefore needed for the profitable exploitation of either CO_2 or CO for the production of materials and chemicals, in whose respect the combination of advanced manufacturing technologies, industrial biotechnology and advanced materials is expected to be beneficial.

Another field that involves already commercial products, especially in the framework of large industrial and power plants, is represented by **condition-monitoring for the continuous assessment of the state/condition as well as residual life time of plant components** (CH.3.5). This technology has attracted much attention from industry in the past years as companies critically focused on asset utilization and productivity. Today, however, even in smaller size industrial plants, industrial demand for production flexibility is driving an increasing interest in new, simplified and more flexible approaches that fulfil condition monitoring requirements at lower costs, relying on simple, yet efficient solutions, which can analyze and provide insight into machine conditions without having to interpret large volumes of data. In this respect, the cross-fertilization between advanced manufacturing technologies, advanced materials and micro- and nano-electronics is expected to constitute an interesting asset.

3.2.3. Potential areas of industrial interest relevant for cross-cutting KETs in the Manufacturing and Automation domain

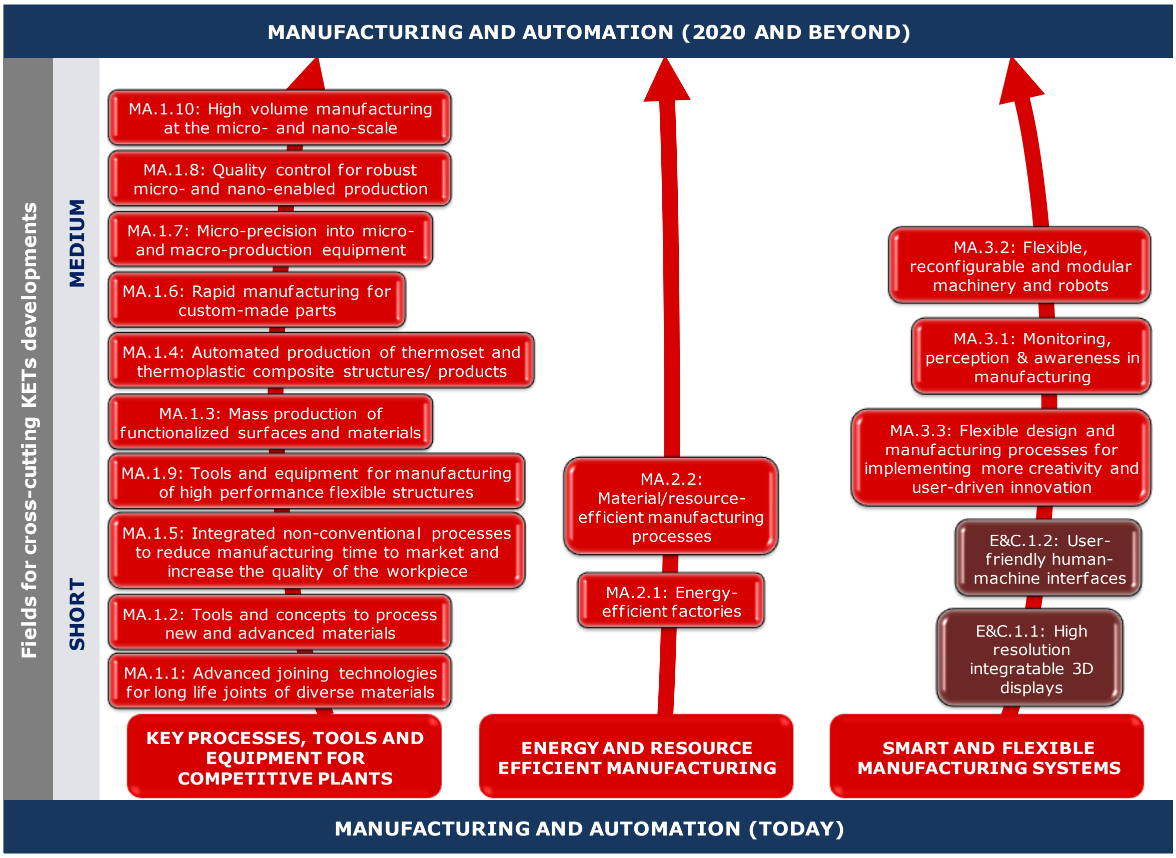
Manufacturing is a vitally important sector for the EU economy, representing about 15% of GDP and 14% of the EU's employment with 30 million direct employees. Despite its relevance, the EU's manufacturing sector has experienced a decline over the last 30 years as a result of many factors. The sector has experienced radical changes throughout this period, becoming heavily integrated with and mutually dependent on other parts of the economy, such as, in particular, the services sector, and shifting as a result towards higher value-added activities. This shift is the result of a strategy of creating value by adding services to products and also correlates with a greater innovation capacity of the sector and with a change towards higher-skilled and better-paid manufacturing jobs. As a result, despite its relative decline, the manufacturing sector is a major contributor to productivity growth: the sector accounts for 65% of Europe's business R&D and 60% of its productivity growth. Manufactured goods moreover amount to more than 80% of total EU exports[6].

Today, manufacturing still faces important drivers of change such as the increasing scarcity of resources, the availability of big data, and mass customization which have the potential to modify the global industrial landscape. Anticipating and reacting to these trends will be a major challenge for the European manufacturing sector[7].

Within this framework, among the many potential innovations in the manufacturing sector, the integration between Key Enabling Technologies is deemed to be of highest benefit to innovation fields in the following sub-domains within the Manufacturing and automation domain.

---

[6] Manufacturing Europe's future, Bruegel Blueprint Series, 2013
[7] http://europa.eu/rapid/press-release_MEMO-14-193_en.htm



❖ Key processes, tools and equipment for competitive plants

The capability of producing durable and high quality products, together with the reduction of operational costs are two of the fundamental issues to be addressed by the manufacturing sector. They can be achieved by introducing (among other measures) more advanced processes, tools and equipment enhancing the productivity and thus the competitiveness of manufacturing plants. Advanced manufacturing technologies are of cross-cutting nature in this respect, potentially providing crucial input for process innovation in any manufacturing sub-sector. Their uptake in production processes would significantly contribute to increasing the competitiveness of the EU's manufacturing industry. Moreover, besides advanced manufacturing technologies, according to the RO-cKETs study, several other KETs could provide input with advanced manufacturing systems.

Driven by the vital necessity of enhancing productivity while reducing operational costs, in order to remain competitive, the manufacturing industry could benefit, in the short term, from the cross-fertilization between several KETs, which could particularly contribute, as one option, to the **development of tools, concepts and equipment to process new and advanced materials** (MA.1.2), whose demand is pulled by the increasing demand for advanced materials by several high added value industrial applications, as reported in the framework of the Chemical processes, chemicals, chemical products and materials domain (see innovation field 'Advanced materials and new material architectures with added functionalities', CH.2.2). In this respect, the cross-fertilization between advanced manufacturing technologies, advanced materials, micro- and nano-electronics, photonics, and nanotechnologies, is expected to be advantageous. Another option in whose respect the integration of KETs has emerged as being beneficial is represented by the **mass production of functionalized surfaces and materials** (MA.1.3), which is expected to benefit majorly from the combination of advanced manufacturing, advanced materials and nanotechnologies (see also innovation fields 'Coatings and surfaces with high scratch and/or corrosion resistance, good weatherability and/or with self-repairing capabilities', CH.2.4, and 'Coatings and surfaces with anti-fouling or self-cleaning properties', CH.2.5, in the

Chemical processes, chemicals, chemical products and materials domain). Surface engineering, namely the tailored modification of surfaces to impart specific functional properties, including physical, chemical, electrical, electronic, magnetic, mechanical, wear-resistant and corrosion-resistant properties, has attracted much attention from industry over the past 20 years. As a result, today it contributes very significantly to the industrial manufacture of a vast variety of products, being particularly relevant in sectors like automotive, aerospace, power generation, electronics, biomedical, textile, steel, construction and even machine tools manufacturing. Linked to this, there is the development of **processes for the automated production of thermoset and thermoplastics composites** (MA.1.4), which are particularly relevant for mass production as well as for the cost-efficient production of large structures (see also the closely related innovation field 'High-strength/low-weight fibre-reinforced polymer composite materials', CH.2.1, in the in the Chemical processes, chemicals, chemical products and materials domain), in respect to which the integration of advanced manufacturing technologies and advanced materials is crucial. Automated production is becoming increasingly relevant for the composites industry, which serves a wide range of different industrial applications mainly in the space, aeronautics, marine/naval, automotive, industrial equipment, energy equipment (mainly wind turbines), electrical equipment, and general consumer commodities' sectors (mainly sports equipment), all having strong market relevance.

The integration of advanced manufacturing technologies, advanced materials, micro- and nano-electronics, photonics, and nanotechnologies is expected to be advantageous for the development of **integrated non-conventional processes to reduce manufacturing time-to-market and increase the quality of the workpieces** (MA.1.5) (e.g. lasers, waterjet, electro-discharge machining, ultrasonic, printing) towards the development of new multifunctional manufacturing processes, while the cross-fertilization between advanced manufacturing technologies and advanced materials is expected to contribute to the development of **processes for the rapid manufacturing of custom made parts** (MA.1.6). These innovation fields could provide for rapid and flexible production capabilities, a characteristic which is becoming increasingly relevant for the manufacturing industry, helping to integrate design specifications flexibly into efficient operational routines by keeping a comparable throughput time in different configurations. They could moreover provide for fast product/service systems able to combine rapid and flexible production with enhanced product design capabilities and exploit minimal distribution lead-times to match supply with the volatile demand of today's rapidly changing markets, thus helping industry to be highly responsive to the market. Cross-cutting KETs could furthermore help in facing the industrial need to develop **more advanced tools and equipment for the automated manufacture of high performance flexible structures** (MA.1.9), which are being increasingly used in diverse fields such as printed electronics and flexible PVs (see also innovation fields 'Flexible large-area electronics', E&C.2.6, in the Electronics and communication systems domain as well as 'Flexible solar cells (modules) enabling improved PV integrability', E.1.1, in the Energy domain), thus serving markets that are experiencing strong growth. Within this framework, the cross-fertilization among advanced manufacturing technologies especially combined with advanced materials is also expected to provide benefits.

In the medium term, the development of improved **tools and equipment enabling highest precision at the micro-scale** (MA.1.7) along with systems and equipment for the **high volume manufacture of micro-components characterized by complex 3D shapes at the micro- and nano-scale** (MA.1.10) might benefit from the integration of advanced manufacturing technologies, advanced materials, micro- and nano-electronics, photonics, and nanotechnologies. These, along with the introduction of **advanced quality control systems and methods capable of high 3D resolution and accuracy measurements** (MA.1.8), allow the manufacture and subsequent quality examination at a speed/throughput compatible with industrial standards, as essentially required by industry in order to serve the market of 3D micro-products profitably, with special emphasis on MEMS, which, due to commoditization especially in the consumer electronics segment, are driving advances in this domain.

Also in the medium term, the adoption of **advanced joining technologies for long life joints of diverse materials** (MA.1.1) can increase the lifetime of assemblies, thus allowing the reduction of maintenance costs that is a very important asset for industry, and furthermore responding to market requirements calling for products adapted to extreme environments (such as for use in deep sea, space, engines, medical). In respect to this innovation field, the cross-fertilization especially among advanced manufacturing technologies and advanced materials is expected to be crucial.

❖ **Energy and resource efficient manufacturing**

Besides more advanced processes, tools and equipment helping to enhance productivity, introducing advanced concepts for energy and resource efficient manufacturing can also contribute to making the manufacturing and production sectors more competitive. The reduction in the energy consumption of manufacturing and processing plants can result in important savings over the conventional energy purchase for industrial end-users, as well as in an overall reduction of the energy demand globally. Manufacturing and process industries, and in particular energy-intensive industries, are strongly incentivized to reduce their energy intensity due to the high share that electricity as well as heat usage have in their operational costs for production. In order to decrease their total energy bill, which represents an important advantage for such industries, thus converting manufacturing and processing plants in **energy efficient factories** (MA.2.1), optimized energy management approaches can be successfully applied. These may include optimized self-adaptive and fault-tolerant strategies encompassing a number of sensors along with ICT solutions to monitor and optimally manage energy, the use of alternative materials and/or energy sources that can substitute their counterparts in the production, and a variety of other approaches, in whose respect the cross-fertilization between, especially, advanced manufacturing technologies and advanced materials can provide advantageous.

Similarly, the reduction in the consumption of resources, which include raw materials as well as water and other utilities required during production, can also result in savings over conventional raw materials as well as utilities purchase for industrial end-users and in the overall reduction of raw materials as well as other resources (including water) demand globally. Within this framework, the introduction of **material/resource efficient manufacturing processes** (MA.2.2) could be a positive factor to meet the requirement by industry to decrease production costs including by reducing their resource input intensity due to the high share that raw materials as well as other resources necessary to the production (e.g. water) play in their total production costs. This may be achieved by the introduction of new manufacturing/processing approaches allowing for intrinsic material-saving (including optimization of material consumption at the design level), a better use of waste streams through recovery of materials or other resources (including water), and efficiency improvements in manufacturing or processing equipment. The flexible use of substitute materials, near-net-shaped concepts and/or additive manufacturing, remanufacturing, recycling, hybrid processes, and a better management of waste streams either within the factory or through process interactions can also be an opportunity. The mix between advanced manufacturing technologies and advanced materials could particularly reap benefits in this respect.

❖ **Smart and flexible manufacturing systems**

Smart and flexible manufacturing systems will have a crucial role to play in providing for rapid and flexible production capabilities to match supply with the volatile demand of today’s rapidly changing markets. In this respect, the involvement of Information Technology in manufacturing processes, which has increased over the last years, responding to the demand by industry of optimized plant performance, has played and will continue to play a relevant role, besides the introduction of new and better performing manufacturing concepts, tools and equipment. Information Technology is not only used for improved management of energy as well as resources in manufacturing and in monitoring and controlling processing operations, but also to monitor data and support in decision taking (thanks to decision support systems) or to plan maintenance thanks to condition monitoring, thus constituting an important asset for industry. All of this performance is possible today thanks to in-line monitoring of process parameters and other monitored data. In-line condition monitoring, which is an advanced major component of predictive maintenance, is capable of identifying deviations from the standard operating conditions which are indicative of a developing fault. Condition monitoring allows maintenance to be scheduled, or other actions to be taken in order to prevent failures, thus avoiding consequences in terms of downturns or even accidents, which inevitably translate into costs for industry. Condition monitoring can therefore have significant benefits in terms of cost savings and productivity enhancement. Furthermore, Manufacturing Execution Systems (MES) have helped industry to move towards more sustainable approaches, thanks to having changed manual operations into automatic operations for faster data transfer and more real time decision making, in order to respond to the important industry requirement of major flexibility to face today's rapidly changing markets. In this respect, according to the RO-cKETs study results, there are several innovations that could benefit from the cross-fertilization between KETs: in the short term, **monitoring, perception and awareness on manufacturing** (MA.3.1) could be enhanced by the combination of advanced manufacturing technologies and micro- and nano-electronics in the first instance. These could lead to the development of novel large-scale control-intensive applications for high yield performance and energy efficiency, both of which being highly important to industry.

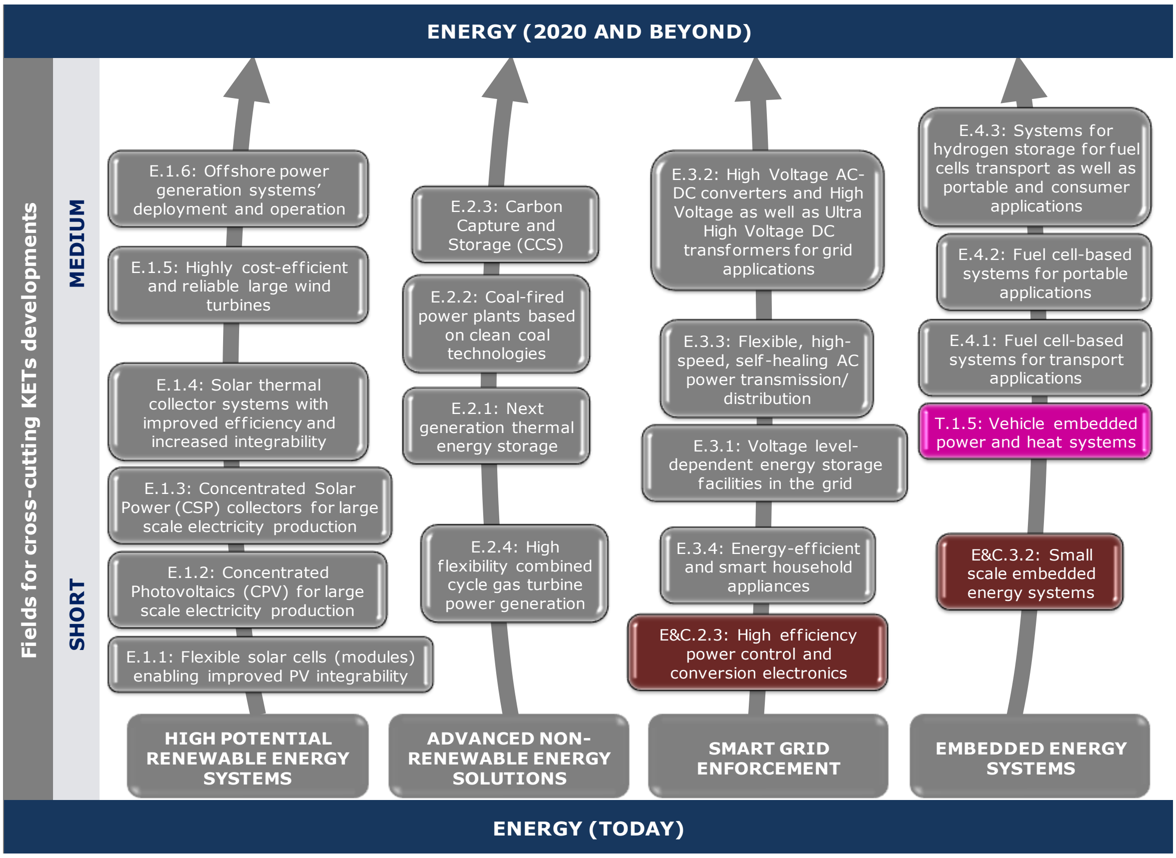
Also responding to the crucial industry requirement for major flexibility and agility in order to rapidly satisfy market requirements, in the medium term, **flexible, reconfigurable and modular machinery and robots** (MA.3.2) could be enhanced by the fusion of several KETs. Combining in a smart way advanced manufacturing technologies and micro- and nano-electronics can lead to advancements in this respect. As an example, this integration could lead to the development of intelligent plug-and-play systems which feature sensing and actuator structures integrated with adaptive control systems and with active compensation features for fully optimizing the performance of manufacturing systems in terms of autonomy, reliability and efficiency along their lifecycle. Furthermore, **flexible design and manufacturing processes for implementing more creativity and user-driven innovation** (MA.3.3) can lead to a better response to today's consumer demands for individualized performance of products and today's purchasing mechanisms relying on a close selection of products on the global product market. In this respect, the cross-fertilization between not only advanced manufacturing technologies and advanced materials, but also micro- and nano-electronics as combined with the pervasive use of Information Technology as associated to various hardware than can enable exchange of data, images, and product features in general terms, as well as of money, is expected to play a relevant role.

3.2.4. Potential areas of industrial interest relevant for cross-cutting KETs in the Energy domain

Technology and innovation are crucial to achieving more competitive, sustainable and secure energy in line with Europe's energy challenges. According to the Communication on Energy Technologies and Innovation (COM(2013)253 final) putting forward the development of an Integrated Roadmap for the SET Plan, the EU needs to do more to bring new, high performance low-cost, low-carbon sustainable energy technologies to the market in line with the Europe 2020 targets. As a result, EU energy policies (i.e. on the internal energy market, energy efficiency and renewable energy), strongly support technology innovation in the market along with new business models, market and social adaptation and energy system improvements. Within this context, the future energy landscape will build on a more sustainable energy mix boosting locally available resources and taking into account local markets' specificities.

As regards the sector, in 2011, the roughly 63 200 enterprises in the EU28's energy sector, comprising electricity, gas, steam and air conditioning supply according to NACE (Rev. 2) code D35, generated 1350 billion Euro of turnover and employed over 1.2 million workers. At the same time, these enterprises generated a value added of 215 billion Euro. Adding to this, in 2011, the manufacture of electrical equipment, which, for the scope of this analysis, has been considered within the framework of the highly cross-sectoral Energy domain, generated 303.8 billion Euro of turnover, 86.6 billion Euro of value added, and employed over 1.45 million workers[8].

Within this framework, among the many potential innovations in energy technologies, the integration between Key Enabling Technologies is deemed to be of highest benefit to innovation fields in the following sub-domains within the Energy domain.



❖ High potential renewable energy systems

The market of renewable energy systems will be very much driven by legislation. In order to achieve levels of renewable energy consumption within the European Union of 20% (as mandated by the Renewable Energy Directive (2009/28/EC)) and to achieve the largest proportion of renewables in the final energy consumption by 2050 (as identified in the Energy Roadmap 2050), high performance low-cost renewable energy systems will have to be deployed massively in the energy generation market. Moreover, the need to achieve net zero-energy buildings in the future (according to the Energy Performance of Buildings Directive (2010/31/EU)) will also serve as a driver to boost the market for novel renewable energy applications in the residential

[8] Eurostat, Annual enterprise statistics for special aggregates of activities (SBS)

sector. In order to enable this, however, new technologies and solutions must compete on cost and reliability against current energy systems, thus the following important challenges need to be solved:

- Increase efficiency of energy generation systems and equipment in order to maximize yield,
- Increase reliability of energy generation systems and equipment,
- Reduce cost/payback of energy generation systems and equipment,
- Reduce cost of installation as well as of operation and maintenance.

Technology innovations in renewable energy are many and diverse. Those that could benefit the most from the cross-fertilization between Key Enabling Technologies according to the RO-cKETs study results are, in the shorter term, **flexible solar cells** (modules) **enabling improved Photovoltaics (PV) integration** (E.1.1), major modularity, easier installation and better aesthetics, besides higher conversion efficiencies and reduced costs, as currently required by the several applications that flexible solar cells (modules) can have and corresponding markets. Flexible PV installations can in fact be foreseen in relation to building applications (i.e. Building Integrated Photovoltaics, BIPV) but also in relation to any other renewable power application requiring the flexibility feature (e.g. PV car roofs in the Transport domain). The cross-fertilization between photonics, micro- and nano-electronics, advanced materials, nanotechnology and advanced manufacturing shall trigger, in this respect, higher efficiencies at reduced costs thanks to the optimization of materials consumption (including through the identification of alternatives for scarce chemical elements and the substitution of critical raw materials) and improvements at the manufacturing level. Another promising innovation field benefitting from the integration of several KETs could be constituted by **Concentrated Solar Power** (CSP) **collectors** (E.1.3) as well as **Concentrated Photovoltaics** (CPV) **for large scale electricity production** (E.1.2). While CPV is an emerging market that is expected to represent a sustainable market niche in the coming years, promising to provide cost-effective power generation at high levels of efficiency, being more technologically mature, the CSP sector is already growing, though slower than forecast some years ago. From a technological point of view, components of CSP collectors could be improved to operate at the high temperatures needed to significantly increase conversion efficiency thanks to the cross-cutting contribution of advanced materials, nanotechnology and advanced manufacturing, and cost could be reduced, as required by investors, by improved collector design combined with advanced optical materials with lower cost, higher performance and better durability also benefitting from the integration of advanced materials, nanotechnology and advanced manufacturing technologies. Also Concentrated Photovoltaics (CPV) could benefit from improved materials and components - e.g. optical systems, tracking systems, etc. - for enhanced reliability and stability. Moreover cost could be reduced thanks to optimization of material consumption as well as improvements at the manufacturing level. In this respect, the cross-fertilization between photonics, advanced materials and advanced manufacturing technologies is expected. **Solar Thermal Collector (STC) systems** (E.1.4) are expected to benefit from the integration between advanced materials and advanced manufacturing. STC find their major market in residential applications, but large installations are also increasing apace especially for commercial heating and cooling applications, which have shown a positive development, and very large systems, whose market is developing rapidly. Efficiency of STC for low temperature applications could be improved by higher performing surfaces, coatings and materials, while integrability could be enhanced by new designs as combined with advanced materials and advanced manufacturing. Moreover STC for medium/high temperature applications could benefit from high temperature-resistant materials as combined with advanced manufacturing technologies providing for lower cost production.

In the longer term, the cross-fertilization between KETs (i.e. advanced materials and advanced manufacturing especially) could benefit the automated production of **highly cost-efficient and reliable large wind turbines** (E.1.5), which clearly links with the innovation field focused on the upstream processes for the automated production of large composite structures reported in the framework of the Manufacturing and automation domain (see MA.1.4). With the offshore market being clearly on the crest of the wave, demand by the wind energy market for larger wind turbines is increasing. Advances in this field could be based on lightweight materials and designs for improved flow dynamics, structural integrity, and recyclability, which would include failure identification, condition monitoring and fault prediction capabilities, along with large and more flexible rotors with improved performance. Along with large wind turbines, reliable and cost-effective systems for their deployment, operation and maintenance, as fundamentally required by installers as well as operators operating in the relevant sector, should be developed. In this respect, since the largest market perspectives are expected in offshore technologies, **solutions for cost-effective substructure manufacturing and maintenance and for large scale system assembly, installation and decommissioning** (E.1.6) shall be developed by integrating advanced materials, nanotechnology, advanced manufacturing, and even micro- and nano-electronics to guarantee pervasive condition-monitoring approaches. These same solutions could also have application in semi-submerged power generation systems, such as tidal power or wave power plants, to name a few.

❖ **Advanced non-renewable energy solutions**

Despite the massive introduction of renewable energy to the energy landscape, a significant proportion of primary energy needs will need to be met by non-renewable energy in 2020 for energy security and economic reasons. Since most non-renewable energy sources rely on the combustion of fossil fuels, such as coal, petroleum, and natural gas, which are responsible for releasing significant volumes of carbon dioxide and other greenhouse gases to the atmosphere, there is however a need to improve the environmental performance of technologies for the generation of non-renewable energy.

Among advanced non-renewable energy solutions, those that could benefit the most from the cross-fertilization between Key Enabling Technologies according to the RO-cKETs study results are, in the shorter term, **high flexibility combined cycle gas turbine power generation systems** (E.2.4) whose flexibility is maximized along with efficiency. Gas turbines, increasingly in combined cycle applications with heat recovery steam generators converting waste heat into steam, and steam turbine generators using that steam for increased generation efficiency, will in fact continue to be the workhorses in the power generation industry. In this respect, the cross-fertilization between advanced manufacturing technologies and advanced materials especially oriented to address the important issue of durability, possibly also benefitting from the integration of nanotechnologies, in order to tackle problems such as creeping, cracking, thermal mechanical fatigue, corrosion, erosion, etc., is expected to provide incremental technological advancements in this field.

In a relatively longer time frame, a new generation of **coal-fired power plants** (E.2.2), based on clean coal technologies, might benefit from the cross-fertilization between Key Enabling Technologies in order to deliver solutions towards coal-based near-zero emission power production. Coal is expected to continue to be a dominant fuel in power generation, with the International Energy Agency (IEA) expecting that the use of coal will increase 43% from 2000 to 2020. Yet conventional coal power generation is a leading contributor to global greenhouse gas emissions as coal is the most carbon-intensive fuel. According to the RO-cKETs study results, the combination of advanced materials and nanotechnologies as well as advanced manufacturing will allow advances in various parts of clean coal power plants. As a particular element of clean coal technologies, carbon capture and sequestration technologies are expected to provide an effective solution for the reduction of carbon dioxide emissions globally, where there is a continuous and rising demand for energy world-wide. Moreover, driven by the need to find cost-effective solutions for the reduction of CO_2 emissions globally where there is a continuous and rising demand for energy world-wide, **carbon capture and storage technologies** (E.2.3), made up by post-combustion, pre-combustion, or oxy-fuel technologies, along with the development of a complete storage infrastructure, may benefit from the integration between advanced materials, nanotechnologies and advanced manufacturing technologies, which might help in extending the current portfolio of capture technologies on the one side and in enhancing handling and storage solutions on the other.

Another field that might benefit significantly from the cross-fertilization between Key Enabling Technologies in association, not only with non-renewable but also and very importantly with renewable energy generation, is energy storage. While storage of electricity will be highly relevant for achieving smart grids and therefore will be discussed within the framework of the next sub-section that is dedicated to smart grids, **thermal energy storage** (E.2.1) will be an interesting domain as well in terms of the integration of Key Enabling Technologies. Advanced heat storage, intended as the next generation heat storage solutions and systems for the storage of heat and cold towards reducing costs of actual systems and improving their ability to effectively and efficiently shift heat demand over days, weeks or seasons, is expected to benefit clearly from the cross-fertilization between advanced materials and advanced manufacturing, and possibly also from solutions in the nanotechnologies domain.

❖ **Solutions for the Smart Grid enforcement**

Smart grids are also expected to contribute fundamentally to achieving competitive, sustainable and secure energy. While helping to cope with the management of the increasing levels of renewable energy deployment within the European Union, they are also expected to contribute to developing a single energy market for Europe. Yet smart grids are not only expected to give benefits in terms of overall reduction of energy demand on a global scale; from a demand-side perspective, they are also expected to be advantageous in terms of savings over the conventional energy purchase for private as well as industrial end-users. Also seen from an energy market perspective, they are furthermore expected to provide for an easier integration of renewables within the existing energy distribution networks and with other energy generation systems and, last but not least, to increase electricity usage flexibility in order to cope with today’s lifestyles.

An important aspect in the enforcement of smart grids will be an increased use of electrical energy storage systems in the existing electricity distribution networks in order to resolve the mismatch issue between energy generation and demand. From a market point of view, demand for these systems is expected to rise due to the expected massive introduction of renewables on the one side and the consequent need for balancing energy as renewable energy generation causes an increase in fluctuations on the supply side. Within this framework, the cross-fertilization of Key Enabling Technologies could benefit the development of improved **voltage level-dependent energy storage facilities** (E.3.1) for the grid. These will consist of advanced electrical energy storage systems for the transmission, distribution and consumer grid, and may include bulk storage (at the grid level to maximize the use of distributed energy sources) and small size storage (for integration in the distribution network). In this respect, the integration between advanced materials and advanced manufacturing technologies along with micro- and nano-electronics and nanotechnologies are expected to provide benefit.

Other sub-systems taken into consideration for their relevance in terms of cross-cutting KETs contribution are **High Voltage AC-DC converters and High Voltage as well as Ultra High Voltage DC transformers for power grid applications** (E.3.2). Along with the increasing basic electrification of remote areas and the growing offshore as well as remote area power generation facilities installations, improved High

Voltage as well as Ultra High Voltage DC converters / transformers are needed to enable power transmission to occur to or from remote areas over long distances. These systems allow for the transmission of power over long distances and are also solutions for the interconnection of networks with different characteristics and frequencies. Furthermore, the combination of an ageing infrastructure, the rising use of renewables which need to be integrated into the existing grid, the rising demand for electricity, and the need to improve transmission as well as distribution efficiency including by minimizing losses, are translating into growth in the electric power transmission and distribution transformer market. Within this framework, in order to transmit electric power over long distances efficiently and reliably and distribute power to utilities while helping to reduce costs of operation and maintenance of energy transmission/distribution facilities, High Voltage AC-DC converters and High Voltage as well as Ultra High Voltage DC transformers will increasingly be deployed in the power grid. Within this framework, micro- and nano-electronics are expected to provide a fundamental contribution, combined with advanced manufacturing technologies as well as advanced materials.

Power system reliability is key to avoiding failures potentially resulting in blackouts that can have social and economic repercussions worth billions of Euro every year. Actually, the likelihood of blackouts has been increasing because of various physical and economic factors, and, as the portion of electricity in the total energy consumption continues to grow, the value of power system reliability is also increasing. In order to respond to the rising demand for electricity reliably, smart grids will develop towards intelligent digital systems capable of providing self-checking and self-healing thanks to an abundance of monitoring and sensing devices and of devices capable of providing adaptive and islanding protection, manual as well as automatic restoration, remote monitoring of equipment, predictive and condition-based maintenance, etc. They will moreover allow for bidirectional communication and huge information and data flow, highly benefitting for this of information and communication technologies. The combination of Key Enabling Technologies, and especially of micro- and nano-electronics, advanced materials and advanced manufacturing technologies, is expected to provide great advantage to this area. A particular sub-system of smart power grids identified by the RO-cKETs study to benefit from this KETs integration is **flexible AC power transmission/distribution systems based on high-speed power routing equipment and systems, allowing for self-healing grids** (E.3.3). A number of other specific components' examples could be cited within this framework, such as transformer stations, converter stations, measurement devices, links, and, last but not least, **power control and conversion electronics** (see E&C.2.3) as mentioned within the framework of the Electronics and communication systems domain.

At the very end of the power distribution chain, more **energy-efficient and smart household appliances** (E.3.4), such as auto-balancing or active appliances with built-in sensors (i.e. smart-grid ready), capable of communicating with the power grid thanks to being interoperable and internet-linked, are expected to benefit from the integration between micro- and nano-electronics and advanced manufacturing technologies in the first instance, but also possibly from advanced materials, nanotechnologies and photonics. As utilities increasingly deploy smart meters, smart household appliances (which use advanced control combined with intelligent power management strategies and networking technologies to optimize the load on the power distribution grid) will have an increasingly significant role to play within smart grids. Currently, there is already limited commercial availability of such appliances, which will however start to represent an increasing share of the total appliance market after 2015.

❖ **Embedded energy systems**

Pulled by the market of non-connected systems and devices, the market for embedded energy systems is expected to grow significantly. To increase usage flexibility of non-connected systems and devices, as required by the market, higher autonomy is needed from an energy point of view. The cross-fertilization between KETs could provide benefits in terms of increased power to weight ratio of small and miniaturized storage systems, thus providing for a larger supply availability of more reliable as well as small-sized/low-weight systems for the power supply of these non-connected systems and devices such as mobile, portable and consumer products as required by the specific application. While small-scale embedded energy systems are covered within the framework of the roadmap for cross-cutting KETs activities dedicated to electronics and communication systems (see E&C.3.2), within the framework of this roadmap dedicated to cross-cutting KETs activities in the Energy domain, focus is especially provided to fuel cell based systems, as these cannot be directly classified as electronic systems taken into consideration within the other domain.

The cross-fertilization between Key Enabling Technologies, with particular attention to advanced materials as combined with advanced manufacturing, as well as to micro- and nano-electronics and nanotechnologies, is expected to be especially relevant for the development of **fuel cell based systems for transport applications** (E.4.1) (see also innovation field 'Vehicle embedded power and heat systems', T.1.5, in the Transport and mobility domain, with which this innovation field is strictly related) in order to improve performance at both single component as well as at the system level. These can eventually be combined with efficient and reliable units for fuel processing of liquid fuels to hydrogen (reforming of for example gasoline, diesel and kerosene) for on board application in the Transport domain, which might also benefit from the cross-fertilization between KETs. Current transport applications of fuel cell technology include motive power for passenger cars, buses and other fuel cell electric vehicles (FCEV), specialty vehicles, material handling equipment (e.g. forklifts), and auxiliary power units (APUs) for off-road vehicles. Today, fuel cell technology based vehicles are considered to be in the demonstration stage, requiring to become more cost- competitive with conventional and advanced vehicle technologies in order to gain market share.

To a similar extent, the same combination of KETs, namely advanced materials, advanced manufacturing technologies, micro- and nano-electronics and nanotechnologies, is expected to contribute as well to the development of **fuel cell based systems for portable applications** (E.4.2), in whose domain they are similarly expected to provide for improved performance at both single component as well as system level towards fulfilling demand-side requirements such as miniaturization, compatibility, simplicity and cost-effectiveness including thanks to hybrid systems solutions capable of optimizing system efficiency, dynamics and start-up time.

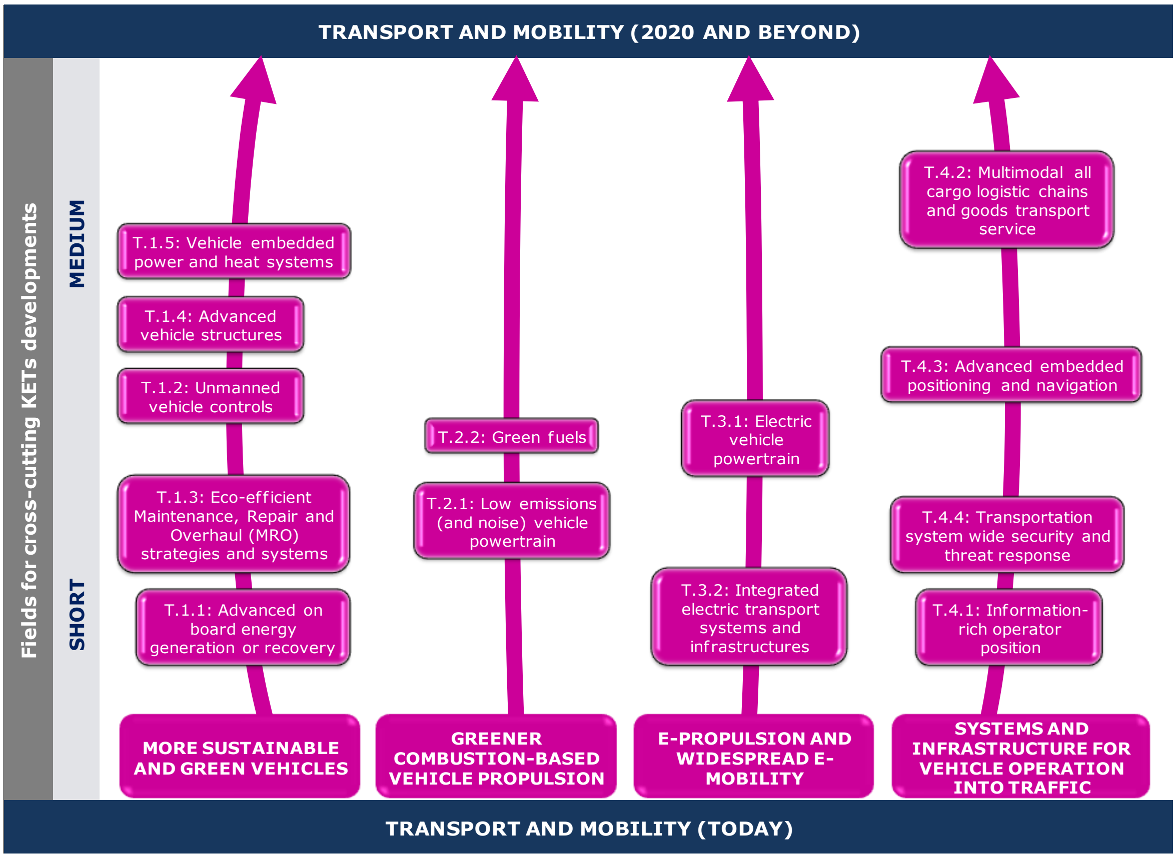
Along with fuel cell systems, **hydrogen storage systems** (E.4.3) need to be deployed in order to provide for fuelling of the fuel cells. Applications and markets for hydrogen storage technologies therefore strictly relate to the fuel cell technology applications and markets. The focus for hydrogen storage technologies' development is enabling the highest volume of hydrogen to be stored at the lowest weight while guaranteeing safety as well as a high number of charging and discharging cycles in the case of reversible hydrogen storage solutions (which are the focus especially in the transportation market segment). Within this framework, the combination of advanced manufacturing technologies, advanced materials and nanotechnologies is expected to contribute.

3.2.5. Potential areas of industrial interest relevant for cross-cutting KETs in the Transport and Mobility domain

Transport and mobility play a crucial role for both society and the economy as they significantly contribute to social welfare and economic development. This is even more evident in today's globalization context, in which economic development is fundamentally interconnected with the mobility of both people and freight, yet transport and mobility are important contributors to climate change. In order to tackle the smart, green and integrated transport societal challenge, the European Commission has set various transport-related strategies aimed at reducing greenhouse gas emissions of transport while improving mobility and the infrastructure system.

Within this overall framework, transport and storage activities, including postal and courier activities, accounted for around 1426 billion Euro of turnover in 2011, with this figure including the turnover of those companies whose main activity is the provision of transport (and transport-related) services. These two sectors employed together around 11.36 million workers in 2011[9]. Of this figure, around 55% of workers were employed in land transport (road, rail, inland waterways and pipelines), 2% in sea transport, 4% in air transport and 22% in warehousing and supporting and transport activities (such as cargo handling, storage and warehousing) and the remaining 17% in postal and courier activities[10]. Moreover, the manufacture of transport equipment such as motor vehicles, trailers and semi-trailers and other transport equipment, as classified within NACE codes C29 and C30 (NACE Rev. 2), accounted for around 1000 billion Euro of turnover and employed 2.9 million workers in 2011[11].

Within this framework, among the many potential innovations in this domain, which includes road, rail, marine and air transport as well as logistics, besides space, the integration between Key Enabling Technologies is deemed to be of highest benefit to innovation fields in the following sub-domains.



9 Eurostat, Annual enterprise statistics for special aggregates of activities (SBS)
10 European Union, EU transport in figures, Statistical Pocketbook 2013
11 Eurostat, Annual enterprise statistics for special aggregates of activities (SBS)

❖ **More sustainable and green vehicles**

More sustainable and green vehicles are expected to contribute to achieve both more environmentally sustainable and safer transport and mobility. Contributing to achieve this objective, the cross-fertilization between Key Enabling Technologies has been identified as being particularly relevant for the development of **advanced on board energy generation or recovery systems** (T.1.1), which play a key role in respect to today's new vehicle energy architectures aimed at increased energy efficiency responding to the market demand for more fuel-efficient vehicles as well as e-vehicles. They consist of systems and solutions for the generation or recovery of energy on board vehicles, from internal (motion, heat) as well as ambient sources (solar, wind, etc., see also innovation field 'Flexible solar cells (modules) enabling improved PV integrability', E.1.1, in the Energy domain) so as to improve the overall energy consumption of the vehicle, and power embedded systems, in whose regard the integration of micro- and nano-electronics, advanced materials, advanced manufacturing technologies, nanotechnologies and photonics is deemed to be important. In a similar vein, answering similar market requirements, **vehicle embedded power and heat systems** (T.1.5) (see also innovation fields 'Fuel cells-based systems for transport applications', E.4.1, within sub-domain 'Embedded energy systems' in the Energy domain, as well as 'Small-scale embedded energy systems', E&C.3.2, and 'High efficiency power control and conversion electronics', E&C.2.3, in the Electronics and communication systems domain, with which this innovation field is strictly related), involving more efficient embedded sub-systems, utilities and power components that require less energy provision and heat dissipation altogether, are moreover expected to benefit from the integration of micro- and nano-electronics, advanced materials, advanced manufacturing technologies, nanotechnologies and photonics in order to facilitate overall on-board energy management and make it possible to address the most demanding needs as electric propulsion or broadband communications. Answering the need to improve the environmental performance of vehicles, focussing in particular on the end of their service life, the cross-fertilization between advanced materials and advanced manufacturing is expected to contribute to the development of **advanced vehicle structures** (T.1.4) - as car chassis, aircraft airframes, ship hulls, trains or satellite platforms, etc. - **that are lightweight, crashworthy and have low wear/fatigue** (e.g. through single-piece or rivetless complex shapes). These may in addition be eventually functionalized, coated or otherwise treated for improved properties (see also innovation field CH.2.4 in the Chemical processes, chemicals, chemical products and materials domain, sub-domain 'Advanced functional materials'), and be produced at the same time with minimal use of materials and chemicals. **Maintenance, Repair and Overhaul** (MRO) **strategies and systems** (T.1.3) can help reducing the impacts of a vehicle being stopped for maintenance or repair, considering that maintenance costs usually account for a significant part of overall ownership costs, and ensure enhanced passenger and crew safety. Improving vehicle maintainability or maintenance processes can support a major progress in competitiveness of transport services besides reducing ownership costs, which constitutes a major advantage for both fleet operators as well as owners of private vehicles. MRO strategies, benefitting from the integration among advanced manufacturing technologies, advanced materials and micro- and nano-electronics for non-destructive testing, robotic maintenance or advanced retrofit methods, might contribute to the design of vehicles and systems for maintainability, including regular, condition-based, predictive and preventive maintenance to achieve a higher level of safety and reduced operation / ownership costs.

On the other side, higher safety can be achieved including thanks to the introduction of complete vehicle control chains – including environment data acquisition and processing, choice of reaction strategy and related actuation – which might enable high level capabilities for autonomous or remote controlled operations of all sorts of **unmanned vehicles** (T.1.2) in the longer term, including driverless trains, drones, cars, satellites, space probes, planetary exploration robots, or vehicles in which operators are assisted in the shorter term. Fully automated urban transports or space vehicles have actually been in operation for years, with positive impacts on operational costs, timeliness and safety. Further developments to apply vehicle control automation to vehicles evolving in more complex frameworks or under high responsibility conditions have the potential to bring similar progress. Amongst possible applications there are car driver assistance gradually moving to full automation capability, single pilot passenger air transport, autonomous robots operating in severe environments or sharing workspace with other machines and humans in factories or warehouses, etc. In this regard, the integration of micro- and nano-electronics, photonics, advanced manufacturing technologies, advanced materials and nanotechnologies is expected to play a relevant role.

❖ **Greener combustion-based vehicle propulsion**

In 2011, greenhouse gas emissions from transport amounted to 926 million tonnes of CO_2 equivalent, growing since 1990 by 19%. Over the 1990-2011 period, emissions from road transport and civil aviation grew by 21% and 17% respectively, while emissions from marine transport presented a 1% growth. Conversely, emissions from railway transportation fell by 46%[12].

Within this framework, the need for greener combustion-based vehicle propulsion becomes evident and this is also a domain in which the cross-fertilization between Key Enabling Technologies has been identified as being capable of providing added value. The integration between advanced materials, nanotechnologies, micro- and nano-electronics and advanced manufacturing technologies could in fact be advantageous to the development of **more advanced, low emissions (and noise) combustion powertrains** (T.2.1) taking into account flexible fuel feeding so as to reduce fuel consumption, thus responding to end-user requirements from vehicles' owners and operators who can thereby benefit from lower operational costs, as well as pollutant emissions, also benefitting the environment. These systems could take advantage of advanced engine architectures and control loops, powertrain subsidiary components, lubrication and power transmission, minimized vibration and noise energy losses, etc. On the other side, a major introduction of **alternative, more sustainable fuels** (T.2.2) in the fuel landscape, benefitting from the integration between industrial biotechnology, advanced manufacturing technologies as well as advanced materials, would be necessary along with the optimization of the combustion powertrains to take full advantage of greener fuel options. Strictly related with the innovation field focused on the upstream processes for the cost-efficient conversion of various biomass to biofuels (CH.3.1), reported in the framework of the Chemical processes, chemicals, chemical products and materials domain, a major adoption of greener fuels, pulled by forces such as increasing oil prices and consumer preference for more sustainable alternatives, would benefit the environment.

❖ **E-propulsion and wider e-mobility**

In order to contribute to greenhouse gas emission reduction from transport especially in urban environments, one of the trends to which cross-cutting KETs are deemed to be able to contribute, is represented by e-mobility. Except for trains and urban transport, where it is already widely applied, electric mobility is considered a mandatory enabler for Europe to meet its CO_2 reduction target. Even in sectors where it remains technically very exploratory, as in aeronautics and space, electric propulsion is being investigated. To the end of enhancing e-mobility solutions, combinations of Key Enabling Technologies are expected to contribute to the **adaptation of transport systems and infrastructures** (T.3.2), and especially road transport, which needs to be re-thought holistically to take into account a massive shift towards electric mobility, considering not only the electric vehicles, but also the charging infrastructure and related power grid management able to provide efficient services (such as relatively

[12] Eurostat Pocketbooks, Energy, transport and environment indicators, 2013

fast vehicle charging) whilst keeping resilient against use peaks typical of transport systems (daily peak times, holiday periods, etc.) and constraints of the power grid (use of renewables, pace of production ramp up, etc.) (see also sub-domain 'Smart grid enforcement' in the Energy domain as well as innovation field 'Solutions for adapting infrastructures to innovative transport means', CS.2.1, in the Construction domain). As a result of this trend, the market for electric vehicle charging stations is expected to grow rapidly from 7 250 charging stations in 2012 to over 3.1 million by 2019. Within this framework, a joint contribution from advanced manufacturing technologies, advanced materials, micro- and nano-electronics, nanotechnologies and photonics is expected. On the other side, advances in **electric vehicle powertrains** (T.3.1) would be beneficial in order to effectively respond to the increasing market demand for e-vehicles with enhanced performances. Sales of hybrid and electric vehicles are projected to grow steadily to reach 5.2 million units by 2020, or 7.3% of all passenger vehicles[13]. As this market develops, also the global market for automotive Lithium-ion batteries is estimated to increase from 3.3 billion Euro in 2014 to 16.4 billion Euro in 2020[14]. While many solutions already exist, though being at different levels of maturity depending on the category of vehicle (trams and trains, cars, ships, aircraft and even satellites with ion thrusters), electric propulsion is physically the most energy-efficient way of moving vehicles. Yet a high potential for optimization still exists. Around the electric vehicle powertrain, shared challenges appear on embedded energy storage and charging (see also innovation field 'Small scale embedded energy systems', E&C.3.2, in the Electronics and communication systems domain, as well as sub-domain 'Embedded energy systems' in the Energy domain), on-board power management (see also innovation field 'High efficiency power control and conversion electronics', E&C.2.3, in the Electronics and communication systems domain), use of rare materials (see also innovation field 'Metamaterials or novel chemistries for the substitution of rare elements and other critical raw materials', CH.1.2, in the Chemical processes, chemicals, chemical products and materials domain, sub-domain 'Competitive more sustainable alternatives to conventional materials') and all sorts of hybridization, and, last but not least, overall cost-effectiveness, to solve which combinations of advanced materials, micro- and nano-electronics, nanotechnologies and advanced manufacturing technologies are expected to contribute.

Setting up the bricks for electric mobility, including breaching the remaining barriers on the existence of a European industrial capability on the electric vehicle powertrain, is definitely one of the major axes of what a European industrial policy can be about.

- **Systems and infrastructure for vehicle operation into traffic**

Besides the many aspects faced above, transport also has implications on the health and safety of people. In order to enhance traffic management and possibly reduce transport-related accidents in Europe, infrastructures should be adapted to support enhanced capabilities, including new services, to which cross-cutting KETs could contribute significantly.

In a context where information capture (on-board vehicles, from the infrastructure or any other source) as well as multilateral communications (vehicle-to-vehicle, vehicle-to-infrastructure) are increased all over the transport chain, the provision of vehicle operators – such as pilots, drivers, sailors, traffic controllers, etc. – with full situational awareness and decision-making assistance is becoming fundamental. Taking stock of advanced data processing capabilities (see sub-domains 'Breakthrough enabling components and circuits' as well as 'Communication as the backbone of the Information Society' in the Electronics and communication systems domain), advanced ergonomics and optimal human-machine interfaces (see innovation field 'User-friendly

[13] J.D. Power & Associates, November 2010
[14] Japanese research firm B3, Bloomberg, www.bloomberg.com

human-machine interfaces', E&C.1.2, in the Electronics and communication systems domain), **information-rich operator position** (T.4.1), benefitting from the integration of micro- and nano-electronics, photonics, advanced materials and advanced manufacturing technologies, would be capable of supporting safer, more efficient, more automated and foolproof vehicle operations. Better operator assistance would be of energetic, environmental and economic interest and benefit, as it could participate in traffic regulation, propose alternative paths to busy axes, promote an eco-responsible way of driving, inform on temporary regulations due to climate events or pollution peaks, deliver warnings in case of excessive speed, etc. Actually, the opportunity of further developing vehicle-to-operator interfaces can be also regarded as a step forward toward a longer term autonomous vehicle operation. In a similar vein, the setting up of door-to-door, just-in-time and **highly resource efficient lean logistics systems, serviced with streamlined multimodal chains** (T.4.2) that take advantage of, thereby fulfilling end-user requirements for higher operational efficiency from logistics operators, integrated information-based facilitators, specialized vehicles (as cargo vessels or airships) and highly dependable automated cargo and baggage handling systems, even to, or from, remote areas of Europe and the world, might benefit from the cross-fertilization between micro- and nano-electronics, advanced materials, advanced manufacturing technologies, nanotechnologies and photonics.

In the medium term, **advanced embedded positioning and navigation systems** (T.4.3) might instead take advantage of the combination of Key Enabling Technologies such as micro- and nano-electronics, photonics and nanotechnologies, which might jointly contribute to the development of beacon-based[15], satellite-based or inertial systems, eventually coupled, able to deliver a highly precise and dependable positioning and navigation service, whatever the vehicle and operational conditions, cost-effectively and with low weight and cost-effective embedded systems. Benefitting from aerospace developments, navigation and positioning systems are in fact major enablers for advanced ground transportation services, including driver assistance, traffic management, jam avoidance or parking place detection, but also unmanned vehicle autonomous operations, stolen vehicle retrieval or even maybe upcoming capabilities such as collision avoidance.

Finally, the combination of Key Enabling Technologies is expected to provide added value to the development of **security systems under a holistic approach and with no breach all over vehicle operation and infrastructure** (T.4.4), as fundamentally required by transport chains, which may unfortunately be priority targets for political terrorism and possibly any other form of malevolent action. Ensuring the protection of transport systems is therefore a major contributor to the "Secure societies - protecting freedom and security of Europe and its citizens" societal challenge. Cross-cutting KETs developments might include, in this respect, highly reliable and efficient check points for persons and goods designed to take into account the human factor and manage all sources of information in security and privacy. This might also include the ability to support decision-making and respond to all sorts of threats, including those with non-lethal neutralization capabilities. In this respect, micro- and nano-electronics, nanotechnologies and photonics are expected to provide fundamental contribution, while advanced materials and advanced manufacturing technologies could also be key contributors.

3.2.6. Potential areas of industrial interest relevant for cross-cutting KETs in the Construction domain

Construction production for EU28 was valued at 1549 billion Euro in 2011 according to Eurostat data, generating a turnover of 1566 billion Euro and a value added of 501

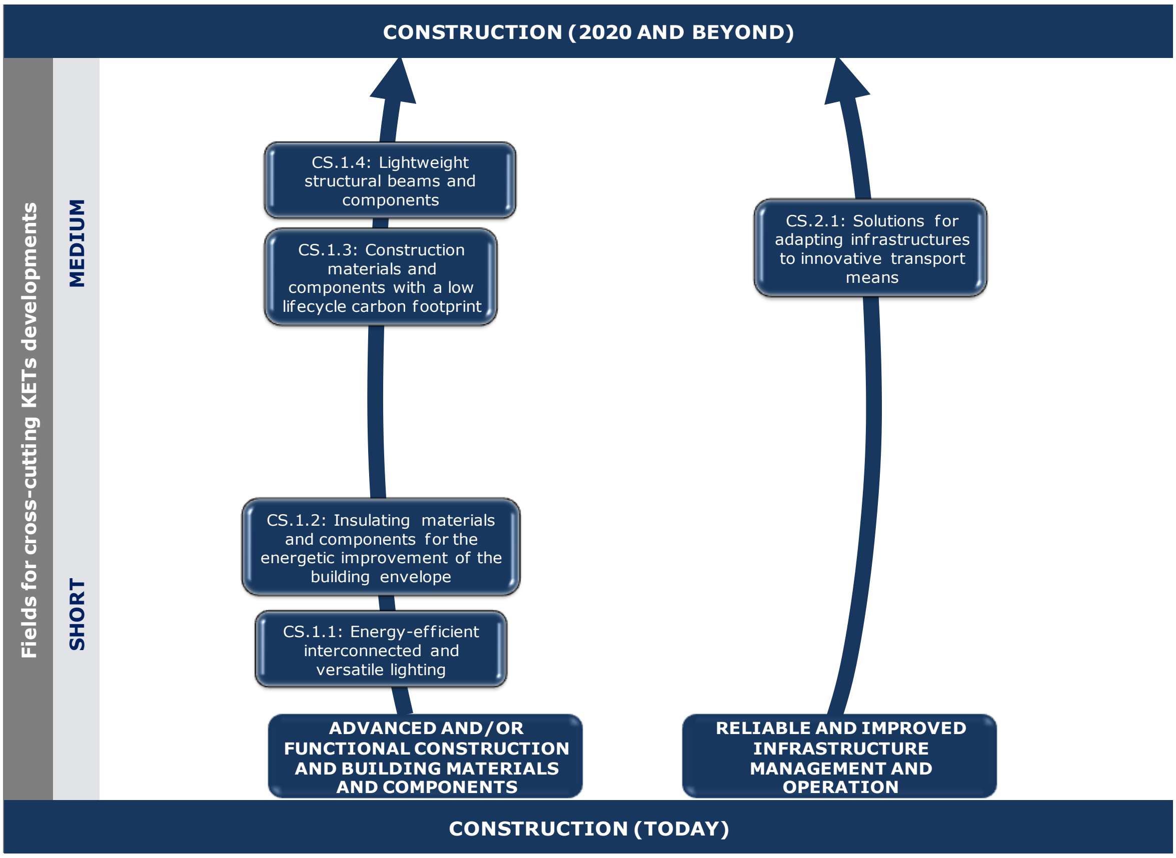
[15] Based on a guidance signal

billion Euro. The sector moreover employed 10.48 million workers[16] and was highly dominated by SMEs. Despite experiencing a significant decrease in the last few years since 2008 mainly resulted from the overall weak economic framework, according to Euroconstruct, a positive trend is foreseen for the next 4 years. According to Euroconstruct's outlook, in the course of the overall economic upswing, construction is expected to grow moderately by 0.9% in 2014, whereas a further more dynamic performance should follow in the period 2015-2016, given a stable economic framework. Euroconstruct also forecasts an expansion in volume in all sectors (i.e. housing, non-residential construction and civil engineering), though such expansion has to cope with the fact that the growth path starts from low volumes of the previous years[17].

Within this overall picture, driven by the need to perform more environmentally-friendly, the building and construction sector, which is a major consumer of both energy and resources, is moving toward the use of greener materials and methods. As environmental consciousness increases in the building and construction sector, environmentally-sustainable features are increasingly viewed by both buildings' and structures' owners and developers as a fundamental element, and attention to green building materials as well as to more sustainable construction methods is already considered a core competency, which is expected to grow in importance in the next future as the economy as a whole and the construction activity recover. The built environment and the infrastructure system needs at the same time to become increasingly secure thanks also to the introduction of more advanced infrastructure management and operation methods.

Within this framework, among the many potential innovations in construction methods, materials and components, the integration between Key Enabling Technologies is deemed to be of highest benefit to innovation fields in the following sub-domain within the Construction domain.

[16] Eurostat, Annual enterprise statistics for special aggregates of activities (SBS)
[17] Euroconstruct's outlook, Euroconstruct Conference, Prague, 2013



❖ Advanced and/or functional construction and building materials and components

Introducing new, more advanced and/or functional construction and building materials and components in the product portfolio of the building and construction industry will help making building and construction more resource as well as energy efficient, besides rendering this sector more precise and with greater risk avoidance. In the market of construction and building materials and components, lightweight structural beams and components, along with insulating materials and components for the energetic improvement of the building envelope, energy-efficient interconnected and versatile lighting, and construction materials and components with low lifecycle carbon footprint have been identified of being capable of benefitting the most from the cross-fertilization between KETs.

In the short term, within the buildings market, the development of **energy-efficient interconnected and versatile lighting** (CS.1.1) can bring, together with the adoption of innovative insulating materials and components for the building envelope, a consistent energetic improvement for the building thoughout its use phase. Markets in these domains are largely driven by European legislation to boost energy savings in buildings. Significant growth is being driven in the European energy efficient lighting market primarily by EU legislation to phase out incandescent lamps and other inefficient lighting technologies. As a result of the large push by Europe to adopt energy efficient lighting (among other home appliances) (see also innovation field 'Energy-efficient and smart household appliances', E.3.4, in the Energy domain), in order to boost energy savings, the European energy-efficient lighting market is reported to have earned revenues of 0.8 billion Euro in 2011 and estimates this to reach 1.4 billion Euro in 2018. While compact fluorescent lamps are currently the major product segment, the LED segment is expected to grow rapidly as the technology improves and prices fall. In regard to new lighting solutions, the integration between advanced manufacturing, advanced materials, micro- and nano-electronics, nanotechnologies and photonics could bring to cost-effective production of improved lighting equipment that is interoperable and adaptable – in colour, hue, intensity, etc. – and that could encourage the design of low consumption highly comfortable and customizable lighting solutions.

As a result of this strategy, all EU28 countries are required to use energy more efficiently at all stages of the energy chain – from the transformation of energy and its distribution to its final consumption. The new Energy Efficiency Directive will particularly help removing barriers and overcoming market failures that impede efficiency in the supply and use of energy and provides for the establishment of indicative national energy efficiency targets for 2020. The Directive on the Energy Performance of Buildings, moreover, which imposes certain energy efficiency standards on buildings, including lighting products, will also play an important part in achieving the objective to enhance insulation of buildings. As regards **insulating materials and components for the building envelope** (CS.1.2), the insulation market is actually a mature market, with a large number of technologies available. However, due to the highly competitive nature of this market, innovation is expected to push for highly energy-efficient technologies tackling especially the retrofit segment. With this respect, the integration between advanced manufacturing, advanced materials and nanotechnologies is particularly expected to provide benefit.

With a greater focus on civil construction, the development of **lightweight structural beams and components** (CS.1.4), benefitting from the cross-fertilization between advanced manufacturing and advanced materials and from nanotechnologies to a certain extent, can instead lead to huge reductions in the weight of a structure, besides easing construction towards higher performance works, which is an essential requirement for the construction sector. The ability to use composite structures to design lightweight, prefabricated modules can bring about significant cost savings to constructors. Pre-fabricated lightweight structural beams and components can be easily transported to the job site and be readily installed in a portion of the time needed for conventional construction, also providing cost benefits to infrastructure operators as regards maintenance.

As environmental consciousness increases in the building and construction sector, green building standards and certifications are also gaining in importance as a consequence. There are several award programmes for certifying green buildings in Europe, the four most common which have gained importance being the LEED, BREEAM, DGNB, and HQE. Among these programmes, mainly certifying the energy performance of buildings, some (e.g. LEED) also award for the use of green building materials and the sustainable use of resources. In order to respond to the increasing demand for green building materials and preference toward a more sustainable use of resources in the construction sector, in the medium term, the cross-fertilization among KETs, with particular focus on advanced manufacturing technologies, advanced materials and nanotechnologies, could deliver **construction materials and components with reduced lifecycle carbon footprint** (CS.1.3), such as green concrete or bricks, concrete or bricks using recycled materials, etc., which could lead to the production of construction materials and components/elements (including prefabricated modules) subject to lower greenhouse gas emissions as well as energy and resource consumption.

All these items will benefit from the interaction among KETs and will contribute to creating a built environment that is accessible and usable for all, at the same time cutting down on CO_2 emissions of the construction sector and improving resource efficiency.

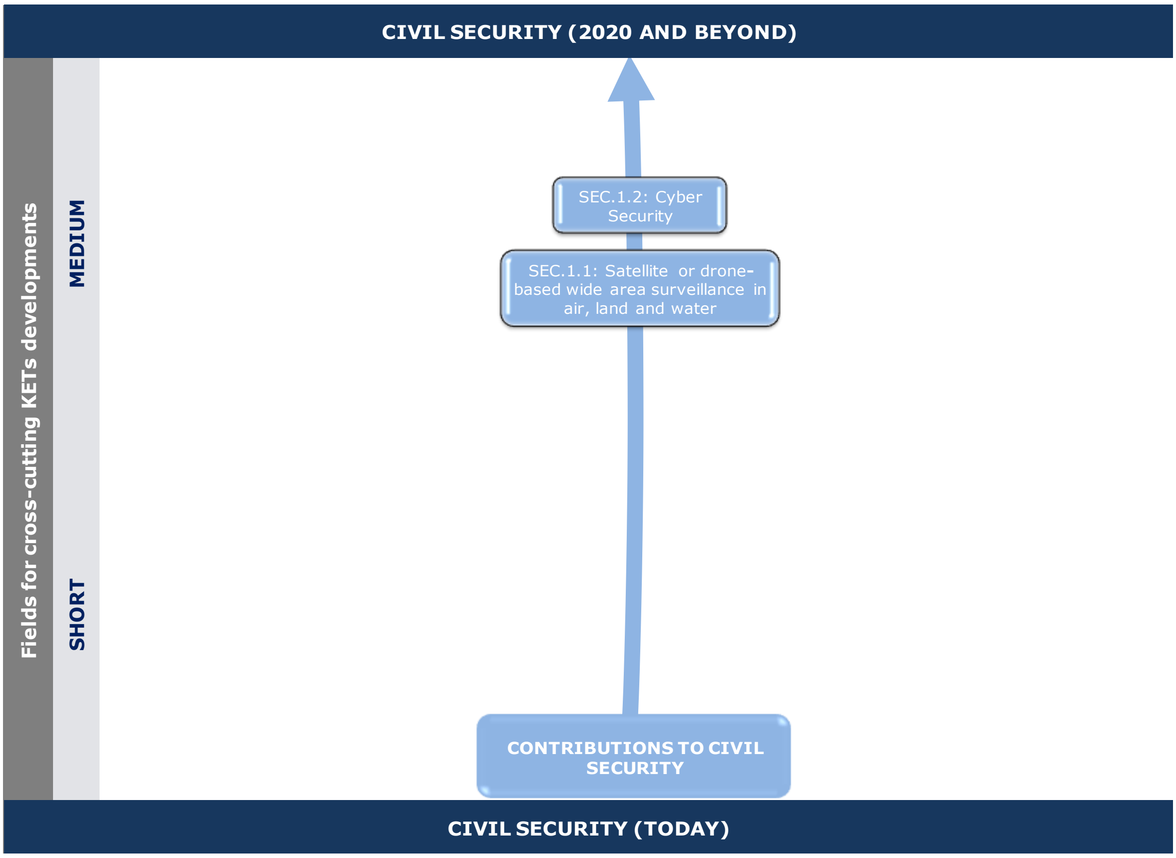
❖ **Reliable and improved infrastructure management and operation**

For the construction industry, it is also of utmost importance to reduce impacts and nuisances related to infrastructure construction, upgrade and/or maintenance and operation. In this respect, the cross-fertilization between KETs, and especially between advanced materials and micro- and nano-electronics, is expected to provide the greatest benefit to **solutions for adapting infrastructures to innovative transport means** (CS.2.1), such as solutions to make urban road and railroad infrastructures able to support operation of new transport modes, a fundamental requirement for, for example, the increasing introduction of e-mobility in Europe. The challenge here is to facilitate the adaptation of existing and new infrastructure to alternative transport modes that use new energy sources in the medium term, an innovation field which is also strictly linked with innovation field 'Integrated electric transport systems and infrastructures', T.3.2, in the Transport and mobility domain, sub-domain 'E-propulsion and wider e-mobility'.

3.2.7. Potential areas of industrial interest relevant for cross-cutting KETs in the Civil Security domain

Among several other measures, technology can also contribute to protecting the freedom and security of Europe and its citizens, within the realm of, for example, (critical) infrastructures and perimeters monitoring or for effective crisis and emergency management.

Within this framework, among the many potential innovations in civil security technologies, the integration between Key Enabling Technologies is deemed to be of highest benefit to innovation fields in the following sub-domain within the Security domain.



❖ **Contributions to civil security**

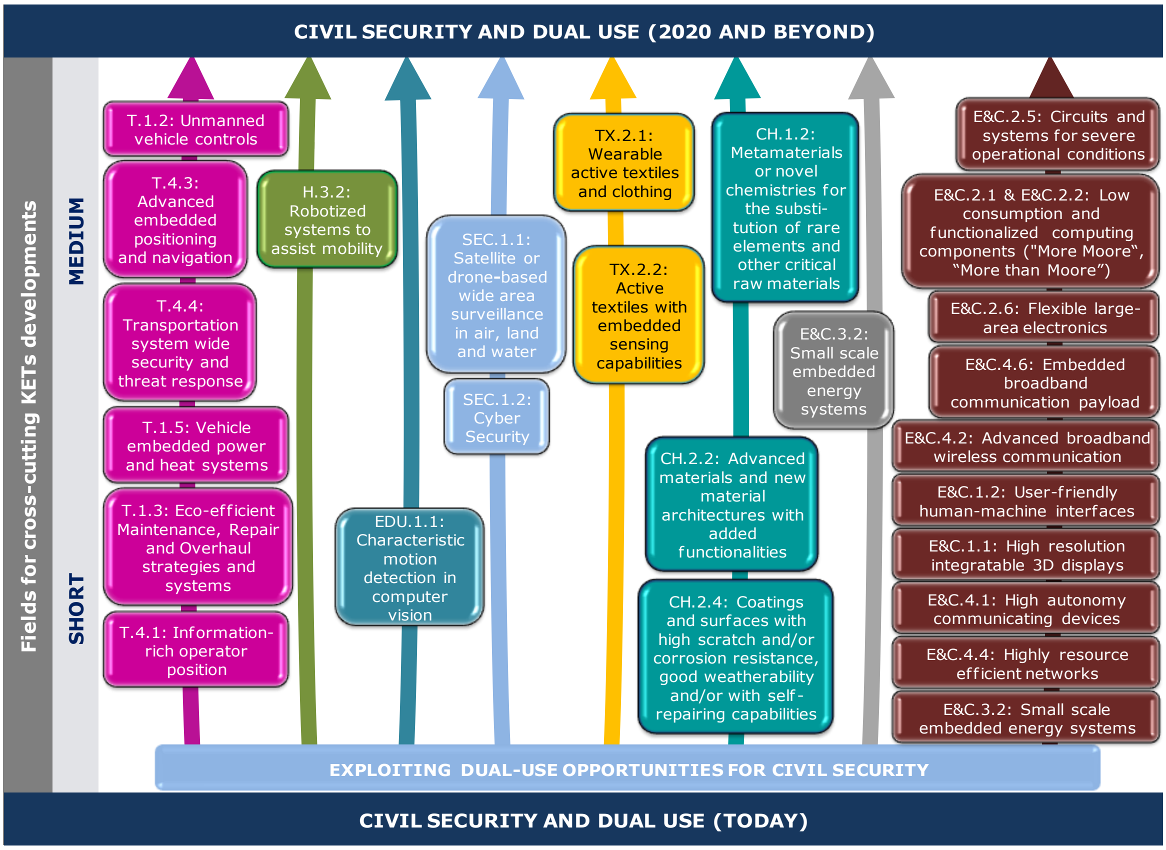
In order to ensure security of European citizens, a particular innovation field in which the integration between KETs is expected to provide a high contribution is represented by **satellite-based systems, multi-robot systems and drones for monitoring and surveillance in air, land and water environments** (SEC.1.1) aimed at border security or critical infrastructures and perimeter monitoring, which is a field expected to be fully developed in the mid-term and to strongly benefit from developments in the military domain in terms of dual use. The development of drones, which will need significant cross-fertilization between KETs, particularly of micro- and nano-electronics, nanotechnologies and photonics, will benefit from an increased resolution and observation range of onboard observation sensors and sensing systems, enhanced communicative interaction (see also innovation field 'High autonomy communicating devices', E&C.4.1, in the Electronics and communication systems domain) of robotic systems to other systems (including other robotic systems) and strengthened networked robotic architectures, allowing improved cognitive and self-configuring software architectures and dynamic models of physical, social and ecological environments. This innovation area is also linked to improved user interfaces benefitting from enhanced human-machine interaction (two-sided) that has already been addressed in the Electronics and communication systems domain (see innovation field 'User-friendly human-machine interfaces', E&C.1.2, and sub-domain 'Improved Human Machine Interaction and interfaces' as a whole). Further miniaturization and integration of actuators, sensors, control systems, and other physical manipulators with improved efficiency of energy systems, including power management, and enhanced efficiency of locomotion will be addressed to obtain such new features. The implementation of these features will also include further development of low weight power sources, enhanced robot control sytems, including self-learning, self-calibrating, fault tolerant, and improved image recognition sensor systems, including environment assessment (objects, human emotions/behaviour, environments, etc.) (see also innovation field 'Characteristic (such as human) motion detection in computer vision', EDU.1.1, addressed in the Training, education and edutainment domain) as well as innovative integrated sensor systems, including multi-sensors and high quality (bio, neuro, physical, environmental, chemical, motion, positioning, etc.). The electronic-related components will have to find adequate mechanical support thus new lightweight, high-strength materials and advanced integrated mechatronic systems will be necessary to enhance the drones' applications. Other innovative concepts include distributed intelligence and improved navigation through mapping and localization (e.g. 3D, cooperative mapping, enhanced GPS or the Galileo system in the future, autonomous). As clearly evident from the interaction of the above mentioned systems, the expected cross-KETs contribution will be particularly strong in this topic for advanced manufacturing technolgies and advanced materials, micro- and nano-electronics, nanotechnologies and photonics.

Also in the medium term, tools and techniques for **cyber security** (SEC.1.2), including wireless security, cloud security and privacy, and autonomic network defence, are going to be more and more crucial to guarantee security of people and operators' and citizens' privacy, especially in relation to the ever increasing convergence and smartification also fundamentally taken into account within the framework of the roadmap dedicated to the Electronics and communication systems domain (see particularly sub-domain 'Communication as the backbone of the Information Society'). Additionally within this framework, further integration of secure spectra sharing techniques and secure operating systems for commercial handsets will be investigated. Advanced approaches to providing security and privacy for the growing enterprise cloud computing market, new tools and techniques to secure virtual machines and proactive network defences that can autonomously implement protective measures against identified attacks are at the basis of privacy and citizens' security, involving strong cross-KET contibution, particularly by micro- and nano-electronics, nanotechnology and photonics.

- **Exploitation of dual use opportunities**

Whilst already described within the framework of the specific domains to which these innovation fields pertain, besides benefitting from the cross-fertilization of Key Enabling Technologies, some innovation fields comprised in this roadmap for cross-cutting KETs activities might also have a dual-use potential, thus they could also be of a high interest to defence and security industries. The following roadmap view depicts the specific innovation fields that could exploit dual-use opportunities. A colour code as well as a label are used in order to locate these innovation fields within the framework of the specific domain to which they pertain.

Actually, within Horizon 2020, the areas of 'Leadership in Enabling and Industrial Technologies', including 'Key Enabling Technologies', and 'Secure Societies' (societal challenge), offer prospects of technological advances that can trigger innovation not only for civil applications, but which also have a dual-use potential. While the research and innovation activities carried out under Horizon 2020 will have an exclusive focus on civil applications, the Commission will evaluate how the results in these areas could benefit also defence and security industrial capabilities. The Commission also intends to explore synergies in the development of dual-use applications with a clear security dimension or other dual-use technologies (COM(2013)542 final). Also the implementation roadmap 'Towards a more competitive and efficient defence and security sector' highlights the identification of a number of innovation fields and applications to which cross-cutting KETs contribute, including a range of civil sectors that are of high interest to the defence and security industries, indicating a clear potential for defence to engage in a broader innovation and technology context (COM(2014)387 final).

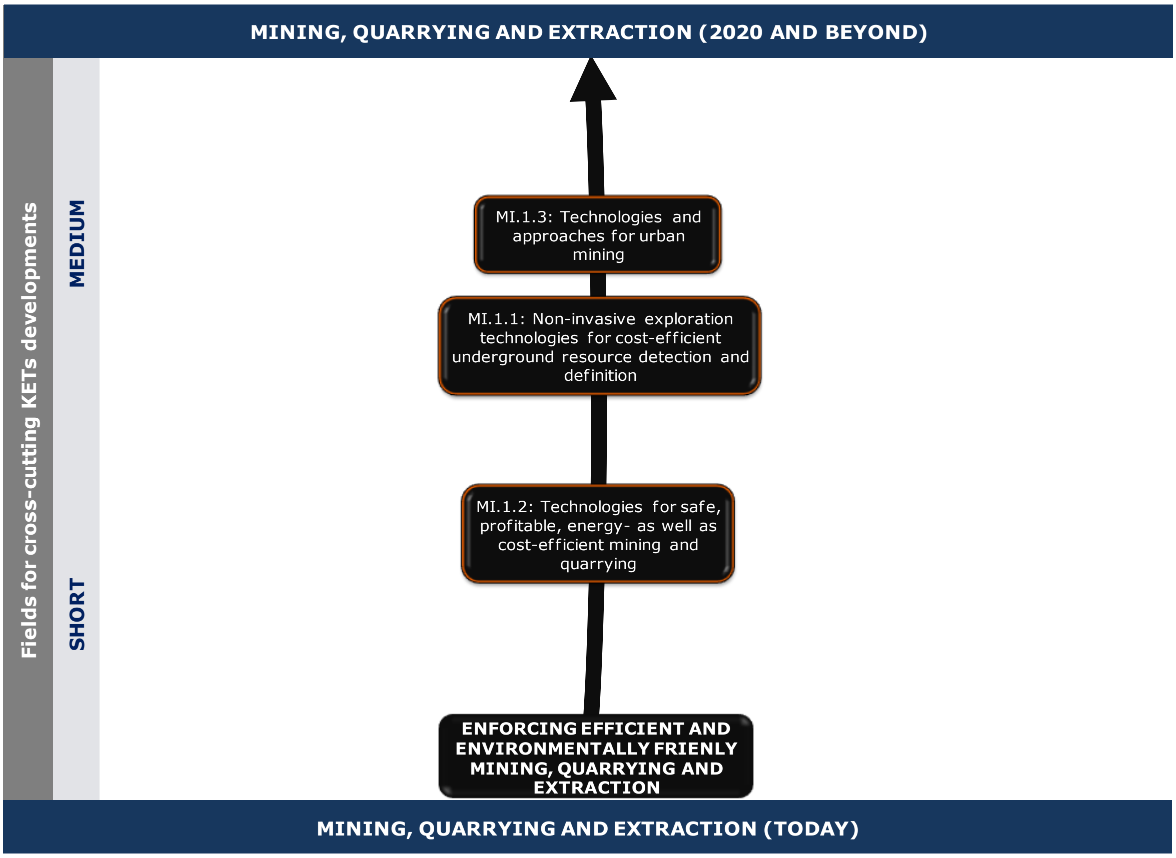


3.2.8. *Potential areas of industrial interest relevant for cross-cutting KETs in the Mining, Quarrying and Extraction domain*

The European mining, quarrying and extraction industry has a long tradition and an important role in addressing the secure supply of both raw materials and various types of mineral and fossil resources for Europe. In 2011, the sector's turnover in EU28 amounted to 252 billion Euro and the industry counted 19 700 enterprises and 605 000 employees[18]. Despite a decrease in the mining and extraction activity for energy producing resources, according to Eurostat data, the index of production for mining and quarrying of non-energy producing resources has been rising since 1997.

[18] Eurostat, Annual enterprise statistics for special aggregates of activities (SBS)

Consumption of aggregates as well as of industrial minerals and metals has actually grown rapidly over the past decade in Europe. Europe is rich in natural resources and the extraction and supply of aggregates and minerals continue to play a crucial role in the European economy. Aggregates (such as crushed rock, sand and gravel) are widely used as construction materials, while minerals are utilized for industrial purposes (e.g. metals, lime, kaolin, silica sand, talc) in the production of steel, cars, computers, medicines, human and animal foodstuffs and fertilizers, to name a few key applications. Today, Europe is almost self-sufficient in producing many of the industrial minerals and aggregates required by downstream industrial activities. However, it is at the same time a significant net importer of most metals and metal ores[19]. Within this framework, this industry is currently also facing the need to shift from maximizing value by increasing production to maximising returns from existing operations from increased productivity and efficiencies. Important drivers in this domain are the need to reduce field operating costs while ensuring safety and decreasing environmental impacts. All these aspects require a major emphasis on research, development and innovation and the latter could benefit substantially from the cross-fertilization between KETs, especially in the following innovation fields.



❖ **Enforcing efficient and environmentally friendly mining, quarrying and extraction**

In the mining, quarrying and extraction sectors, there is a strong need to reduce field operating costs while ensuring safety and decreasing environmental impact, at the same time enhancing the productivity of mining, quarrying and other extractive activities. The cross-fertilization between Key Enabling Technologies can be of particular help in this respect for advances in non-invasive exploration technologies for cost-efficient underground resource detection and definition as well as for enhancing technologies for safe, profitable, energy- as well as cost-efficient mining and quarrying. In the short term, improvements to the latter set of technologies and

[19] http://www.euromines.org/mining-in-europe

processes will ensure **safe** as well as **profitable mining, quarrying or extraction** (MI.1.2), with a focus on demand-side requirements such as risk mitigation, cost reduction, productivity enhancement, energy efficiency, and environmental impact reduction: in this specific innovation field the combination of all KETs (excluding industrial biotechnology) is expected to be highly significant. Indeed this combination could lead to technological improvements in underground ventilation to decrease energy costs while ensuring the highest level of safety and also to technological improvements aimed at increasing energy efficiency in rock fragmentation as well as comminution (i.e. blasting, crushing, milling), excavation (e.g. by mechanical cutting, high-pressure water, microwaves, etc.), hauling and transportation.

In the medium term, the overall requirement for enabling more efficient and sustainable resources utilization, coping with societal challenge 'Climate action, environment, resource efficiency and raw materials', could be addressed by advances in non-invasive exploration technologies, among others. Exploration technologies could benefit from the cross-fertilization between advanced manufacturing, advanced materials, micro- and nano-electronics, nanotechnologies and photonics, in order to deliver more advanced solutions capable to answer the sector's industrial requirement for more cost-efficient and environment-friendly exploration aimed at the detection and definition of underground resources (i.e. oil, gas, mineral, as well as water resources). KETs might contribute to relevant improvements of **non-destructive exploration approaches to detect underground resources** (MI.1.1), including ground penetrating radars, 3D and 4D seismic prospecting, hyperspectral imaging, and other geophysical technologies that make excavating not necessary and to an upgrading of sensing while sampling techniques, such as Measuring While Drilling (MWD).

Moreover, **technologies and approaches for urban mining** (MI.1.3) might strongly benefit especially from the interaction among advanced manufacturing technologies and advanced materials, which could contribute to the implementation of efficient and sustainable recovery operations (including logistics) for secondary raw materials and also in the setting up of effective collection of obsolete and discarded equipment and assuring environmentally sound dismantling practices (see also innovation field 'Use of waste as a resource enabled by advanced sorting, separation and treatment technologies', EV.1.5, in the Environment domain). Thanks to legislation, Europe is currently a world leader in urban mining. The EU's WEEE Directive requires all Member States to recover 45 tonnes of e-waste for every 100 tonnes of e-goods sold by 2016, with the recovery target increasing to 65% of sales by 2019 or 85% of all waste generated. Hence, strong growth is expeted in the future in this domain, while market momentum is maintained by a fast growth in e-waste volumes.

3.2.9. Potential areas of industrial interest relevant for cross-cutting KETs in the Environment domain

Over the past decades, the European Union has put in place a broad range of environmental legislative measures, which have efficiently contributed to reduce air, water and soil pollution significantly. However, as of today many challenges persist and these must be tackled together in a structured manner in order to prevent climate change and its related dangerous consequences, thus protecting, conserving and enhancing the EU's natural capital, turning the EU into a resource-efficient, green, and competitive low-carbon economy and safeguarding EU's citizens from environment-related pressures and risks to health and wellbeing[20].

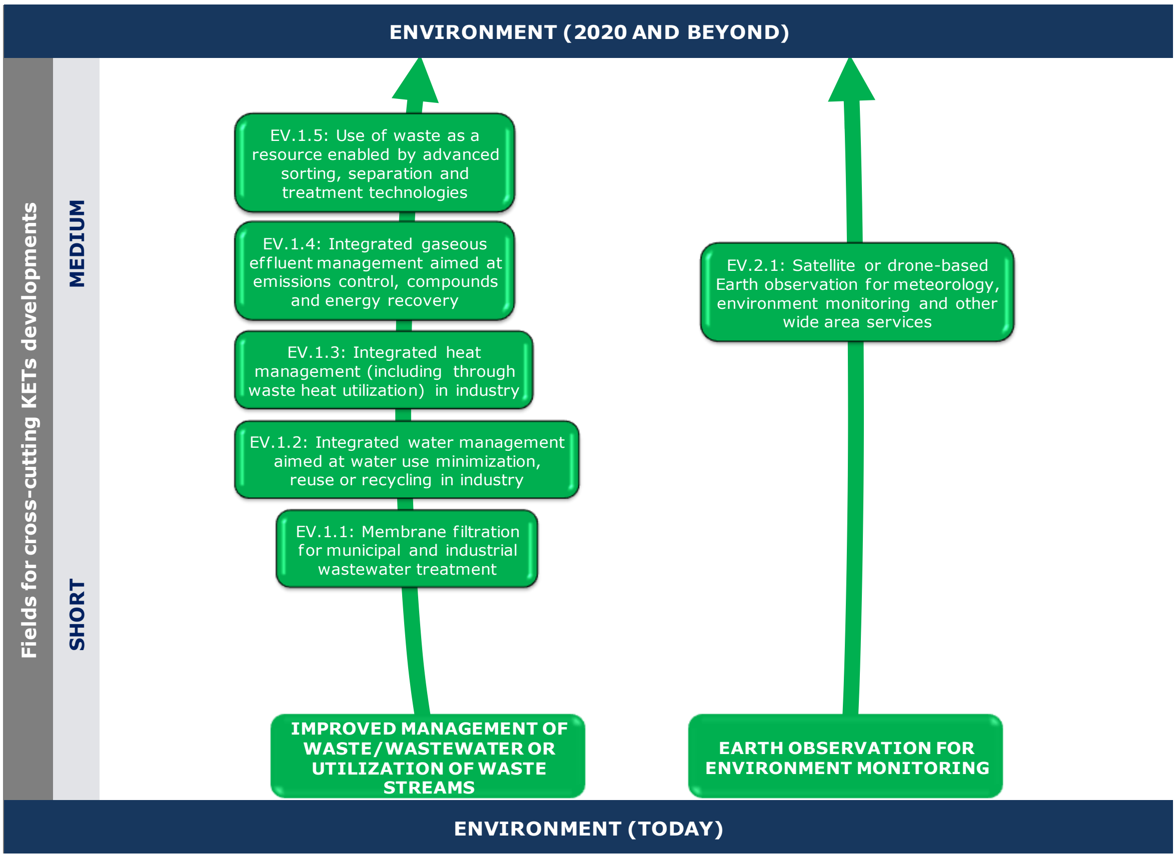
As regards the sector, environment-related activities such as water supply, sewerage, waste management and remediation activities comprised within NACE (Rev. 2) code E,

---

[20] 7th Environment Action Programme (EAP)

generated a turnover of 240 billion Euro in 2011 and employed 1.36 million workers in over 70 800 enterprises[21].

Within this framework, among the many potential innovations in the environment domain, the integration between Key Enabling Technologies is deemed to be of highest benefit to innovation fields in the following sub-domains.



❖ Improved management of waste/wastewater or utilization of waste streams

Within the Environment domain, the cross-fertilization between KETs is expected to contribute significantly to improving technologies aimed at reaching a better management of waste and wastewater and a higher level of control over emissions in general.

In the short term, promising innovation fields that could benefit from the cross-fertilization between KETs are integrated heat management (including waste heat utilization and industrial symbiosis) together with integrated water management aimed at water use minimization, reuse or recycling, both of them applied at industry level. The demand for waste heat recovery approaches in industry is expected to increase with the growing requirement for energy efficiency and rising environmental concerns regarding industrial waste heat emissions. Waste heat recovery is actually being increasingly regarded by industry as offering energy savings thanks to effective utilization of the waste heat potential as a solution to concerns over increasing energy prices. As in the case of industrial wastewater treatment, market drivers are dominated by the implementation of stricter regulations that are stimulating especially water-intensive industries in the take up of cost-effective **integrated water and wastewater treatment solutions aimed at water use minimization and water reuse or recycling** (EV.1.2). This expanding practice exploits solutions for the reuse

[21] Eurostat, Annual enterprise statistics for special aggregates of activities (SBS)

or recycle of process water possibly in a closed-loop inside a factory or on a broader perimeter among different factories and/or solutions for optimizing water-energy coupling aimed at water cooling in order to recover the heat that is available in the water. While it is expected that advanced **integrated heat management approaches** (EV.1.3) could benefit from the cross-fertilization between advanced manufacturig and advanced materials (see also innovation field 'Energy-efficient factories', MA.2.1, in the Manufacturing and automation domain), the contribution of industrial biotechnology blended with advanced manufacturing, advanced materials and nanotechnologies could facilitate the development of more advanced industrial as well as urban wastewater treatment approaches benefitting, for example, from improved technologies such **membrane filtration** (EV.1.1), reverse osmosis, and others, which can bring superior product water quality, reduced footprint at plant level and reduced energy consumption.

To a similar extent, integrated **gaseous effluent management** (EV.1.4) could benefit from the integration between KETs in the medium term to achieve a higher level of emissions control associated with energy and even compounds recovery. Drivers for gaseous effluents management and emissions control technologies are dominated by increasingly strict regulation in sectors where gaseous emissions are among the major issues, being mainly power generation, industrial processing, transport in its various forms (land, marine, air) and space heating. The specific requirement for reducing air polluting emissions represents hence the most significant driver for the European end-of-pipe emissions control equipment market. End-of-pipe emissions control equipment is installed in order to comply with legislative requirements, thus avoiding penalties. This innovation field could potentially benefit from the integration of all KETs; in particular advanced materials and nanotechnologies could be applied to develop advanced filters and adsorbers or improve catalysis, while advanced manufacturing as associated with advanced materials and nanotechnologies could be exploited to develop plasma post-treatment and other ways for oven and furnace top gas recycling and dust emission control.

Moreover, in the medium term, an **increased use of waste as a resource** (EV.1.5) could be enabled by the integration of KETs for the development of more advanced sorting, separation and treatment technologies that are able to sort and separate waste (including municipal waste) more effectively into the various recoverable waste fractions in a more efficient manner and treat them accordingly toward effective recovery, thus empowering the circular economy, including through effective industrial symbiosis approaches. Waste sorting, separation as well as treatment technologies, is already widely applied in industrial practice, although the potential for improvement through the implementation of more advanced solutions is high. One of the key features of companies leading the market is the ability to sort the increasingly diverse range of materials coming through, and deal with them appropriately. Among technologies, one should mention sensors, a diverse range of which (based on for example optical, X-ray, electromagnetic, conductive, thermal technologies) allows the recognition of the various materials within waste streams, as combined with effective separation methods (based on for example grasping, ejection using compressed air, etc.), as well as treatment options to allow the efective recovery of waste (through both reuse and recycling). As an example, Waste Electrical and Electronic Equipment (WEEE) is currently considered to be one of the fastest growing waste streams in the EU, growing at 3-5% per year. WEEE contains diverse substances that pose considerable environmental and health risks if treated inadequately. On the other hand, the recycling of WEEE offers substantial opportunities in terms of making secondary raw materials available on the market. EU legislation promoting the collection and recycling of such equipment (Directive 2002/96/EC on WEEE) has been in force since February 2003. The legislation provides for the creation of collection schemes where consumers return their used waste equipment free of charge (see also innovation fiels 'Technologies and approaches for urban mining', MI.1.3, in the Mining, Quarrying and Extraction domain). Yet, separation still largely relies on manual work, which also hinders appropriate treatment to be put in place.

❖ **Earth observation for environment monitoring**

Earth observation from space can provide for more continuous and consistent information about the environment, as compared to observations at ground level alone, which are often fragmented and periodic. However, satellite data alone are not sufficient and the real value of Earth observation lies in its combination with in-situ monitoring and simulations to provide powerful imaging, reporting and forecasting functions. In Europe, Earth observation is already producing a wealth of data that is being used in applications such as mapping urban sprawl, tracking oil spills at sea and measuring concentrations of harmful air pollutants, with implications for sustainable development, marine conservation and human health. Earth observation can inform decisions in environmental policy making at local, regional and pan-European levels[22]. From a market point of view, the exploitation of **satellite-based Earth observation** (EV.2.1) is expected to grow significantly in the future.

Within this framework, in the short term, the development of satellite- and also drone-based Earth observation systems for meteorology, environment monitoring and other wide area services (which also links with innovation field 'Satellite- or drone-based wide area surveillance in air, land and water', SEC.1.1, addressed in the Civil security domain) is expected to be reinforced through the cross-fertilization between advanced manufacturing technologies, advanced materials, nanotechnologies and photonics. The integration between those KETs will be pivotal to increasing resolution and observation range of on-board Earth observation sensors and sensing systems, and optimising data chains, from generation to processing, compression, storage and transmission, so as to reduce resource use and increase security and dependability.

3.2.10. Potential areas of industrial interest relevant for cross-cutting KETs in the Health and Healthcare domain

The European health and healthcare sector plays a crucial role in contributing to the overall health and well-being of society. Within this framework, there are broadly comprised the pharmaceutical industry, the medical technologies industry and the healthcare industry.

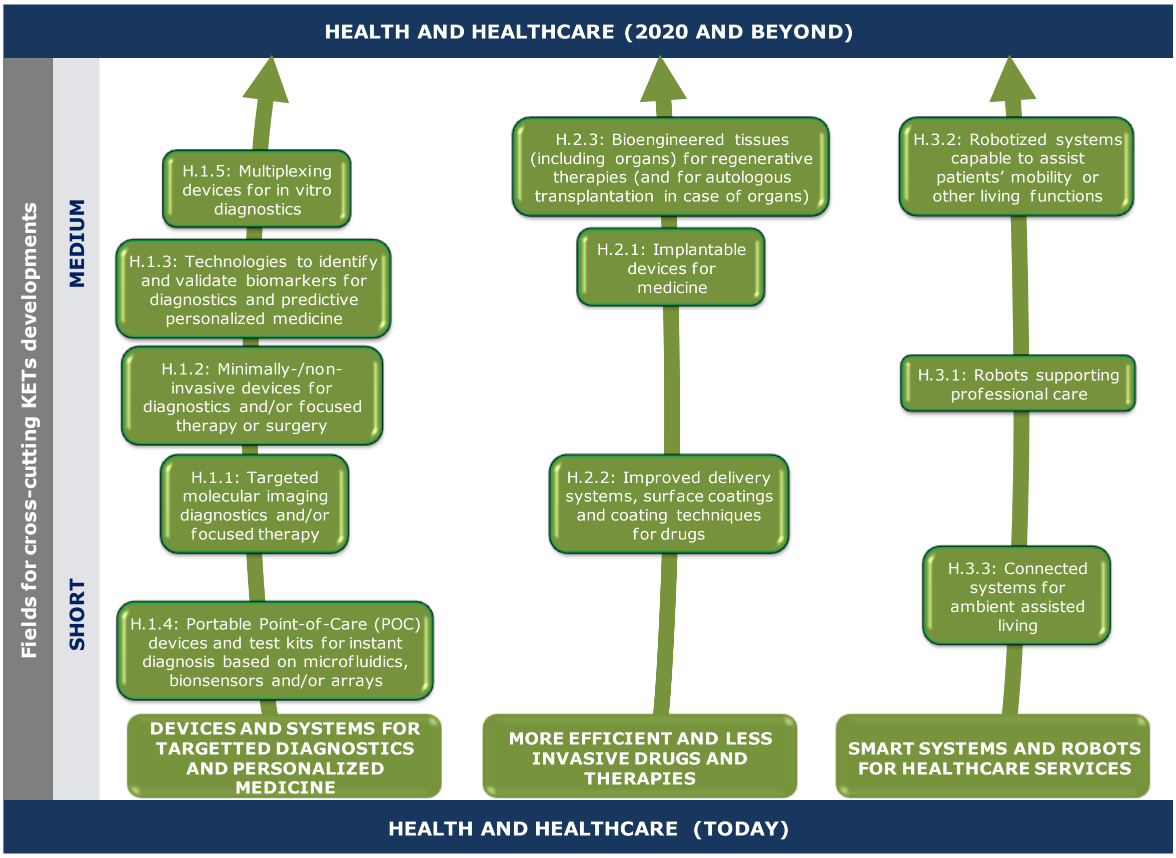
The pharmaceutical industry occupies an important position in the European economy, with a production value, in 2013, of 217.5 billion Euro and employment representing over 690 000 jobs[23]. In terms of industry structure, it is composed of a relatively small group of big pharmaceutical companies representing a very significant share of the annual European turnover and a large number of small and medium sized enterprises. Market demand in this sector is driven by a complex interrelationship between patients, doctors, hospitals and the health system as a whole[24].

The European medical technologies industry, covering a vast variety of products such as medical devices, in vitro diagnostics, medical imaging equipment and e-health solutions, moreover employed over 575 000 people in 2012. More than 25 000 individual medical technology companies populated this industry in Europe in 2012, about 95% of which are small and medium sized enterprises, the majority of which employ fewer than 50 people. The European market was estimated at roughly 100 billion Euro, representing, with a share of 30%, the second largest market after the market in the US (40%)[25].

---

[22] Science for Environment Policy Future Brief: Earth Observation's Potential for the EU Environment, Report produced for the European Commission DG Environment, February 2013
[23] EFPIA, The Pharmaceutical Industry in Figures, Key Data 2014, http://www.efpia.eu
[24] ECORYS, Competitiveness of the EU Market and Industry for Pharmaceuticals, Volume II: Markets, Innovation & Regulation, Final report, for the European Commission, DG Enterprise and Industry, December 2009
[25] MedTech Europe, The European Medical Technology Industry in Figures, 2013

Within this framework, among the many potential innovations in the health and healthcare domain, the integration between Key Enabling Technologies is deemed to be of highest benefit to innovation fields in the following sub-domains.



- **Devices and systems for targeted diagnostics and personalized medicine**

In the area of devices and systems for targeted diagnostics and personalized medicine, the cross-fetilization between KETs is deemed to be particularly interesting for the development, in the short term, of **minimally or non-invasive endoscopic instrumentation and devices** (H.1.2) for in vivo medical diagnostics/imaging, eventually combined with focused therapy or surgery (this might comprise, as an example, endoscopic instruments eventually integrating multiple functionalities such as imaging guided surgery), addressing demand-side requirements such as improved quality (increased sensitivity and speed) of diagnostics approaches, early detection of diseases, increased safety for patients and, last but not least, decreased patient pain during medical, diagnostic and treatment activities. In this regard, the combined contribution of advanced materials, micro- and nano-electronics, nanotechnologies, photonics, and advanced manufacturing technologies is deemed to be beneficial to miniaturization for achieving lower invasiveness and surface functionalization of the instruments and devices to increase biocompatibility.

Also in the short term, addressing the market need for improved rapid, safe and cheap diagnostics, cross-cutting KETs might be instrumental for the development of **portable Point-of-Care (POC) devices** (H.1.4) and test kits for instant diagnoses based on microfluidics, bio-sensors and/or arrays. These might comprise portable and miniaturized devices or easy kits for diagnosis or treatment monitoring for personal use, being capable of data collection and possibly of communication with the medical doctor (see also innovation field 'Connected systems for ambient assisted living', H.3.3, in this same domain, sub-domain 'Smart systems and robots for healthcare services'). Also in this case, developments would require a high level of trans-disciplinarity, which is reflected by the expected combined contribution of all the six

KETs, namely advanced materials, biotechnology, micro- and nano-electronics, nanotechnologies, photonics and advanced manufacturing technologies. On a similar note, multi-parameter measuring devices allowing for fast, accurate, easy medical laboratories analyses need to be developed to allow for the design and development of integrated multifunctional devices with a broad range of applications for improving in vitro diagnostics and develop **reliable, cheap, fast and multiplexed highly sensitive detectors** (H.1.5) providing high content results from a single sample. The global multiplexed diagnostics market has increased the volume and quality of diagnostic procedures phenomenally by reducing the turnaround time and analyzing multiple analytes in a single cycle and thereby resulting in rapid adoption of such techniques[26]. This aspect also clearly involves integration among all six KETs.

In the medium term, developments related to technologies for the **identification and validation of more accurate and informative biomarkers** (H.1.3) for diagnostics might benefit from the cross-fertilization between, particularly, advanced materials, industrial biotechnology, nanotechnologies, advanced manufacturing, and micro- and nano-electronics as well as photonics to a lesser extent. Such predictive biomarkers will favour the early detection of diseases, thus improving health and quality of life. The medium-term expected development of **targeted molecular imaging techniques** (H.1.1) eventually combined with focussed therapy (theranostics) will moreover enable higher efficiency and more biocompatible targeted molecular imaging for in-vivo diagnostics eventually combined with focussed therapy. The increase in the ageing population and incidences of various chronic diseases are driving the demand of molecular diagnostics world over, thus the global molecular diagnostics market is witnessing a period of growth. Targeted molecular imaging techniques will also benefit from the cross-fertilization between all KETs, with particular focus on advanced materials and nanotechnologies, expected to contribute to improving tracers' or agents' efficiency and biocompatibility thanks to the incorporation of active nano-particles.

❖ **More efficient and less invasive drugs and therapies**

Another domain in which the cross-fertilization between Key Enabling Technologies is expected to contribute significantly is to achieve more efficient and less invasive drugs and therapies. The market for drug delivery systems, which include several product types (among which oral, parenteral, inhalation, implantable, transdermal) will continue to grow at a high rate along with an increasingly ageing population in Europe. Today's drug delivery technologies enable the incorporation of drug molecules into new delivery systems, thus providing numerous therapeutic and commercial advantages. Today, drugs formulation is more challenging in terms of the development of improved delivery systems than in terms of formulation itself. Fast disintegrating or dissolving tablets, which are tablets that dissolve or disintegrate in the mouth in the absence of additional water upon introduction into the mouth, for easier administration of active pharmaceutical ingredients responding to today's lifestyles, are a clear example thereof, having received ever-increasing demand during the last decade so that the field has become a rapidly growing area in the pharmaceutical industry[27]. Within this framework, one area in which the combination of KETs could be beneficial in the short term is the development of **improved delivery systems, surface coatings and coating techniques for drugs** (H.2.2), which could be achieved through optimized formulation research. Such a topic directly involves advanced materials and advanced manufacturing techniques as well as nanotechnology and industrial biotechnology.

[26] Multiplexed Diagnostics Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013-2019
[27] V. Parkash et al., Opportunity in drug delivery system, Journal of Advanced Pharmaceutical Technology and Research, 2011 October-December; 2(4): 223–235

In the medium term, the cross-fertilization between KETs could benefit the development of **implantable devices for assisting vital functions or controlled drug delivery** (H.2.1), such as for example heart assisting devices, devices for drugs on demand delivery, pain therapy and management. This ambitious goal may be reached by implementing actual miniaturization for lower invasiveness, surface functionalization and 'biologicalization' of the implants to increase their biocompatibility. Also the development of nano- or micro-scale devices for drug delivery, as micropumps, could support this goal, thus contributing to the development of targeted treatment of diseases, assistance to living functions and, more generally, to individualized and personalized health care. The cross-fertilization between KETs is also strong in this topic, particularly involving advanced materials, nanotechnology and micro- and nano-electronics, besides advanced manufacturing.

Also the expected medium-term development of **bioengineered tissues** (including organs) **for regenerative therapies** (H.2.3) (and for autologous transplantation in case of organs), which would allow the introduction into the market of alternative therapeutic approaches with minimized risks for patients, is deemed to be interesting in respect to the cross-fertilization between KETs. This field, which might include research on biocompatible materials, Extracellular Matrix Analogs (EMAs) and polimeric structures to be used as scaffolds for effective tissue regeneration, is a significant cross-KETs topic, involving particularly advanced materials and advanced manufacturing, as well as nanotechnology and industrial biotechnology.

❖ **Smart systems and robots for healthcare services**

As regards improvements in the healthcare system, advanced robotic systems may have a high impact and are thus receiving great attention and interest. Robotics applied to healthcare is in fact an emerging field, which is expected to grow especially in the face of an ageing population and the subsequent need for high quality care. Within this framework, one of the innovation fields expected to leverage the cross-fertilization between KETs in the medium term is **improved robots supporting professional care** (H.3.1) capable of supporting healthcare workers both within hospitals and at patients' homes in monitoring and care activities. These might comprise, for example robotized aids for nurses, robotized patient monitoring systems, automated medicine delivery systems, and systems for other robotized physical tasks in care provision. This development might benefit from medium-term developments in the expansion of robotic platform technologies to enhance standardization and cooperation, from the creation of open design and simulation systems to jointly develop new robotic systems and by the enhancment of communicative interaction of robotic systems to other systems, including other robotic systems. The growth of networked robotic architectures and the creation of open source software architectures, supported by improved cognitive and self-configuring software architectures will have a significant impact on the improvement of dynamic models of physical, social and ecological environments validating sensor and motion performance. The enhancement of user interfaces to improve human-machine interaction and real-time dynamic models for robotic structures will strongly benefit from the upgrading in robustness of robotic architectures by redundancy in hardware, also aided by advances in software and design. Advances in hardware might benefit particularly from the cross-fertilization between advanced materials, micro- and nano-electronics and advanced manufacturing technologies, which might be capable of enhancing specific capabilities, like grasp, motion and distributed planning for robotic systems, interactive and intelligent planning, programming and scheduling.

The same combination of KETs might be instrumental in the development of **passive robotized systems (including intelligent prostheses) capable of assisting patients' mobility or other living functions** (H.3.2) (e.g. exoskeletons for disabled patients) in the medium term. Increasing the autonomy of people with disabilities (including of people having experienced stroke or amputations) through robot-assisted mobility and advanced prostheses has the potential of facilitating these people's mobility besides their social development as a consequence, as well as reducing the burden of caring for such populations in both inpatient and outpatient settings. While techniques for task-specific assistance exist, they are largely focused on satisfying short term goals (e.g. rehabilitation treatment and locomotion training). For lifelong disabled users, however, fewer opportunities exist, despite the market of robot-assistive mobility is gaining much attraction as robotic and bionic systems evolve[28]. Further miniaturization and integration of actuators, sensors, control systems, etc., and a higher efficiency of energy systems, including power management (see also sub-domain 'Breakthrough enabling components and circuits', in the Electronics and communication systems domain) and enhanced locomotion is going to be necessary. New light-weight, high-strength materials (see also innovation fields 'High-strength/low-weight fibre-reinforced polymer composite materials', CH.2.1, as well as 'Advanced materials and new material architectures with added functionalities', CH.2.2, in the Chemical processes, chemicals, chemical products and materials domain) and advanced integrated mechatronic systems will contribute significantly to this field.

Another important innovation field in the healthcare domain, which might benefit from the integration of KETs, is represented by **connected home systems for e-health** (H.3.3), which will comprise integrated solutions for various home care support applications enabling health and disease monitoring as well as assisted living (e.g. assistance for disabilities and/or chronic diseases, rehabilitation monitoring, personalized fitness or nutrition assistance, etc.). While society ages, connected systems for ambient assisted living are gaining much attention. Being strictly related to domotic systems but offering in addition advanced functionalities and connectivity, these systems offer the opportunity especially to elderly people to remain autonomous for longer, while being assisted remotely from their relatives (with solutions expected to gain attraction in the shorter term), or from their medical doctor (in the longer run). This trend is benefitting much from new technologies in mobile electronics devices as well as the smartification of the environment where we live (see sub-domains 'Smart and user-centric consumer electronics' as well as 'Communication as the backbone of the Information Society' within the Electronics and Communication Systems domain). This field is also able to benefit significantly from the cross-cutting interaction of KETs, and most of all from the combination of micro- and nano-electronics with advanced manufacturing and advanced materials e.g. for the development of wearable wireless communicating devices with low weight, ergonomic and high autonomy sensing and monitoring capabilities (see also innovation field 'Wearable active textiles and clothing for improved human performance aimed at human safety and protection', TX.2.1, in the Textiles domain).

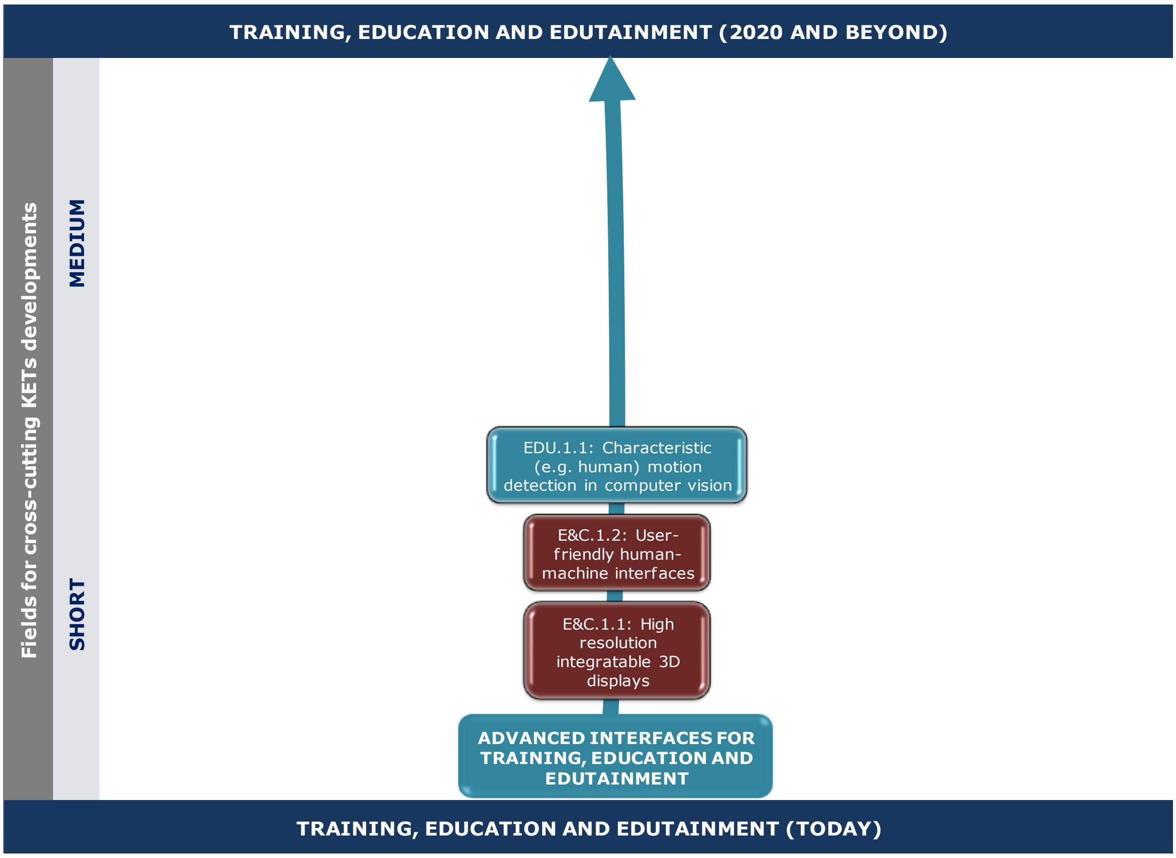
3.2.11. Potential areas of industrial interest relevant for cross-cutting KETs in the Training, Education and Edutainment domain

Training, education and edutainment are increasingly moving toward contactless interactive approaches that leverage the human body's experiencing and senses and provide for various real-time virtual experiences. In this framework, the societal need for more inclusive, innovative and reflective societies can be addressed, among other measures, by offering highly realistic simulation and virtual reality capabilities to amateurs as well as professional categories that are subject to delicate/risky operations (e.g. pilot training, chemical plant maintenance, etc.) for which highly realistic and reliable professional training is crucial.

Within this framework, the integration between Key Enabling Technologies is deemed to be of highest benefit to innovation fields in the following sub-domain within the training, education and edutainment domain.

---

[28] Y. Demiris and T. Carlson, Lifelong robot-assisted mobility: Models, Tools, and Challenges, In Proc. of IET Assisted Living Conference, London, March 2009



❖ **Advanced interfaces for training, education and edutainment**

In the market addressed above, the capability of creating advanced interfaces for training, education and entertainment scopes is fundamental. The contribution of cross-cutting KETs in this respect can be particularly relevant for the development of efficient **motion detection** (e.g. human motion) **in computer vision** (EDU.1.1) characterized by real-time performance, insensitivity to background clutter and movement, and a modular design that can be generalized to other types of motion aimed at various higher-level applications (including automatic motion capture for film and television, human-computer interaction, robotics, industrial machine vision, navigation, events detection, surveillance, etc.). These kinds of applications, which are expected to be feasible in the short term, are not only useful for realizing innovative education and entertainment approaches for students, but also for realizing reliable professional training modules offering highly realistic simulation and virtual reality environments in order to achieve highest operational efficiency along with improved working conditions and safety. Such applications are expected to involve primarily micro- and nano-electronics, advanced manufacturing technologies and photonics.

3.2.12. Potential areas of industrial interest relevant for cross-cutting KETs in the Textiles domain

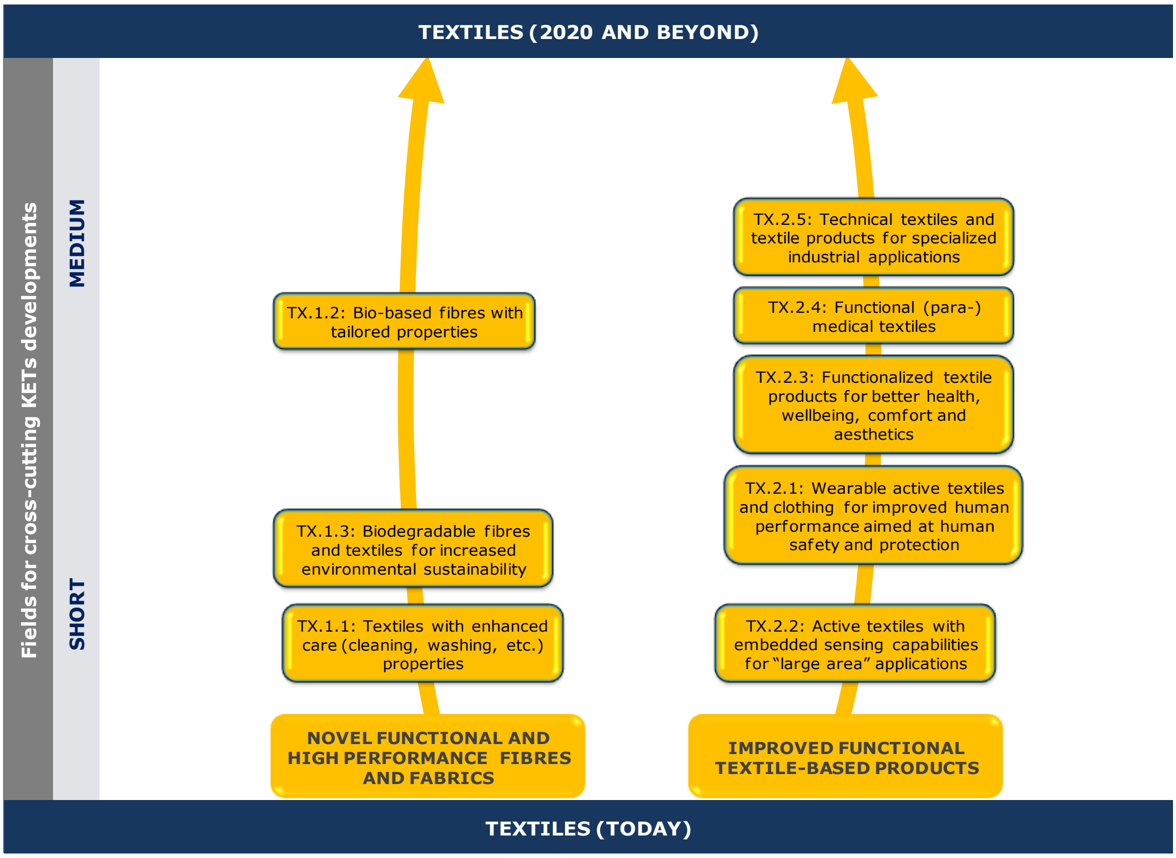
According to Euratex, the European apparel and textile confederation's statistics, as well as estimates[29], in 2013 the textile and clothing industry realized a turnover of 166 billion Euro and counted 1.7 million employees in more than 173 000 companies, the largest proportion of which SMEs with fewer than 50 employees. Actually, the size of the industry declined substantially between 2000 and 2010[30]: turnover declined by

[29] The EU-28 Textile and Clothing Industry in the year 2013, Euratex, http://euratex.eu
[30] In-depth assessment of the situation of the T&C sector in the EU and prospects, Task 7: Synthesis report for the European textile and clothing sector, Final Report ENTR/2010/16, prepared for European Commission, Enterprise and Industry DG, December 2012

25%, employment by 50% and the number of companies by 27%. Yet, in 2010 there were some signs of recovery. Driven by these facts and by the need to restructure, the textiles and clothing industry is experiencing a period of deep change in the supply chain, in the end markets and in its business models. Among others, this industry is particuarly experiencing a change from providing commodities to providing specialty products, in whose regard the cross-fertilization between KETs can find a relevant role.

In terms of sub-sectors, while clothing and interior textiles make up the most important part of the European textile and clothing industry, technical textiles have become an increasingly vital part. The sub-sector of technical textiles is probably the most dynamic, accounting for an increasing share in production, with estimates suggesting that technical textiles account today for 33 to 36% of Europe's textile and clothing turnover. Different from the core of the textile and clothing industry, the technical textiles segment is organized in rather large companies, with a high level of organization and the necessary skills to compete worldwide.

Within this framework, among the many potential innovations in textiles technologies, the integration between Key Enabling Technologies is deemed to be of highest benefit to innovation fields in the following sub-domain within the textiles domain.



❖ **Novel functional and high performance fibres and fabrics**

In its shift from providing commodities to providing specialty products targeting higher added value, the textiles industry has, over several years, started to apply high-tech processes, fibres, filaments, and fabrics in production. Within this framework, one of the earliest functional products introduced to the market by the textile industry are textiles with anti-stain properties imparted thanks to surface treatments (e.g. plasma treatment) and coatings. Yet, the industry is still developing enhanced surface treatments and coatings to provide effective anti-stain and anti-dust as well as **other properties to the textile so to facilitate care** (TX.1.1) (cleaning, washing, etc.) in order to respond to short-term market needs calling for increased products' usage flexibility, which is especially the case in the home textiles market segment, in order to cope with today's lifestyles. The cross-fertilization between KETs in this respect might involve advanced manufacturing systems, advanced materials, industrial biotechnology and nanotechnology, together being capable to aid in the development of new formulations for coatings and in the application of advanced surface treatments and coatings, including making use of e.g. plasma or enzymatic processes, to fibres and fabrics.

Other fields of innovation in which the cross-fertilization between KETs could provide benefit, with particular focus on advanced manufacturing systems, advanced materials, industrial biotechnology and nanotechnologies to some extent, are represented by bio-based fibres as well as biodegradable fibres and textiles for increased environmental sustainability. **Bio-based fibres with tailored properties** (TX.1.2) intended for biomedical and various other technical applications can help decrease dependency on chemical production from oil by shifting the feedstock base towards alternative feedstocks and improving environmental performance of products. Indeed various bio-based fibres have long been used for fibre manufacture. Fibre manufacture from natural, bio-based resources do not only rely on physical transformations (such as in the case of cotton or wool fibres) but on chemical conversion processes (a clear example is Rayon, which is a synthetic fibre obtained thanks to chemical conversions from purified cellulose). Today, new bio-based chemicals, obtained thanks to biorefinery approaches, can be used to manufacture polymeric materials that, depending on their characteristics, can be spun into fibre for use in textiles (see also innovation field 'Bio-based fine as well as specialty chemicals, bio-polymers and other bio-based derivatives', CH.1.1, in the Chemical processes, chemicals, chemical products and materials domain). **Biodegradable fibres and textiles** (TX.1.3) could benefit as well from the cross-fertilization between advanced manufacturing systems, advanced materials, industrial biotechnology and nanotechnologies in the short term in order to provide for increased environmental sustainability with the highest benefits in the markets of disposable products such as sanitary napkins, as well as medical products, disposable filters, agricultural products (e.g. mulch covers), etc., in relation to which biodegradability and compostability are appreciated properties by the market and consumers.

❖ **Improved, functional textile-based products**

The textile industry and related markets are also moving toward final products with highly functional, purpose-targeted properties at the same time. Among others, the textile industry is experiencing a change from providing commodities to providing specialty products by applying high-tech processes, fibres, filaments, fabrics and functionalized final products. Especially in sport and workwear, end-users demand textile products and (protective) clothing with a broad range of functionalities. Within this framework, the application of technical finishes, as well as multilayer coatings and lamination are areas of substantial innovation. Textiles with antimicrobial properties have been one of the earliest functional products introduced to the market segment of sport and workwear by the textile industry. Yet only a few possibilities have been explored and commercialized to date. A new generation of finishes based on nanotechnology (e.g. the lotus effect) is also at the level of market introduction. Biotechnology-based functionalities provided e.g. by enzymes or plant extracts are also being researched and developed. Alternative, more sustainable finishing processes based on digital technology, plasma or supercritical CO_2 are being explored and tested. This is hence another domain in which cross-cutting KETs might provide relevant contribution. In the short term, particularly, the integration between KETs is expected to provide contribution to the development of improved **functionalized textile-based products for better health**, **wellbeing**, **comfort and aesthetics** (TX.2.3), which will benefit from advances in surface functionalization methods and processes for the production of fibres and textiles, thus involving directly aspects of advanced manufacturing and advanced materials along with nanotechnologies and industrial biotechnology. The same combination of KETs will also benefit the development of **functional (para-) medical textiles** (TX.2.4) and textile-based products (e.g. bandages) with built in functionalities to be used for targeted drug release or controllable biomedical properties, especially in tissue scaffolds and intelligent textile implants (see also innovation field 'Implantable devices for medicine', H.2.1, in the Health and healthcare domain). Medical textiles are actually one of the faster growing sectors of the global technical textiles industry. The global market for medical textiles becomes increasingly relevant every year and its importance is expected to increase even more in the future.

Also in the short term, but aimed at **specialized industrial applications**, there will be **technical textiles and textile-based products with improved functionalities and performance** (TX.2.5), e.g. textile-based filters with high filtration efficiencies (see also related innovation fields 'Integrated water management aimed at water use minimization, reuse or recycling in industry', EV.1.2, and 'Integrated gaseous effluents management aimed at emissions control, compounds and energy recovery', EV.1.4, in the Chemical processes, chemicals, chemical products and materials domain), lightweight, non-flammable and scratch resistant technical textiles for application e.g. in the automotive industry (see also innovation field 'Advanced vehicle structures, T.1.4, in the Transport and mobility domain), including for seats and in-vehicle garments, textile reinforcements for use in fibre reinforced composites manufacturing making composites stronger (see also innovation field 'High-strength/low-weight fibre-reinforced polymer composite materials', CH.2.1, in the Chemical processes, chemicals, chemical products and materials domain), and many more. This is definitely another area in which cross-cutting KETs, and specifically advanced materials, advanced manufacturing and nanotechnologies, are expected to provide a contribution.

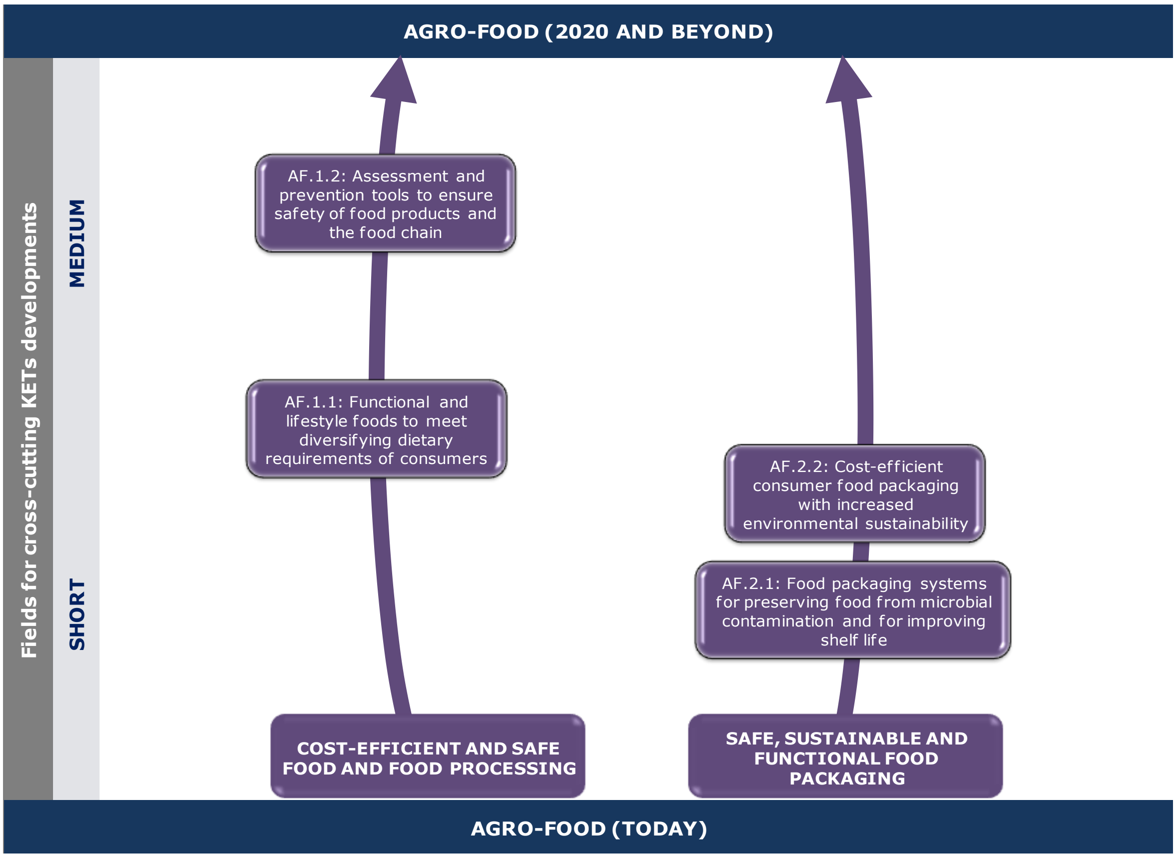
In the medium term, the cross-fertilization among KETs is expected to benefit instead from the development of **wearable textiles and clothing capable of measuring and communicating human living functions** (TX.2.1) (including through integrating sensors, flexible screens, embedded energy storage or harvesting devices) **and/or reacting autonomously to changing activities or conditions of the wearer** in order to optimise the wearer's comfort and safety at every moment. Reaching such a goal will enable improved human performance, guaranteeing higher human safety and protection, with particular relevance for workers required to operate in harsh environments or people required to be monitored for healthcare purposes (see also related innovation field 'Connected systems for ambient assisted living', H.3.3, in the Health and healthcare domain). Products will rely on the integration of smart textile materials and built-in electronics in order to achieve intelligent and functional textiles and clothing capable of measuring parameters and reacting autonomously to critically changing conditions of the wearer. Today, smart textiles have been already introduced in fashion, while efforts for introducing smart textiles in other wearable textiles applications, such as healthcare and workwear, are still dominating research and innovation activities, so far slowed down by a limited availability of integratable electronic components and circuits, which could guarantee adequate performances at the low weight that is required for such applications, a situation which is however changing today thanks to advances in electronics (e.g. in flexible screens or other flexible electronic components and circuits, miniaturized components including embeddable energy storage or harvesting devices as well as sensors and actuators, etc., see sub-domains 'Improved Human Machine Interaction and interfaces' as well as 'Breakthrough enabling components and circuits' in the Electronics and communication systems domain) as well as in manufacturing (e.g. in processes for printing circuits, etc., see innovation field 'Tools and equipment for manufacturing of high performance flexible structures, MA.1.9, in the Manufacturing and automation domain). This innovation field is influenced by all KETs, particularly benefitting from advanced materials, micro- and nano-electronics, nanotechnologies and, finally, advanced manufacturing. Also in the medium term, other types of **active and intelligent textiles for 'large area' applications** (TX.2.2) are expected to benefit significantly from cross-KETs innovations; these might include textile products capable of reacting autonomously or actively to the changing conditions of their surrounding environment (such as geotextiles with built-in sensing functionalities capable of monitoring slopes or other changing conditions of the environment in which they are integrated) for environmental protection and environmental, climate-related risks mitigation or as well for other large area applications. This case can also be highly trans-disciplinary, involving advanced materials and advanced manufacturing, besides micro- and nano-electronics and photonics.

3.2.13. Potential areas of industrial interest relevant for cross-cutting KETs in the Agro-food domain

The food and beverages sector is one of the largest and most important manufacturing sectors in Europe, accounting for 1023 billion Euro of turnover and 206 billion Euro of value added[31]. Within this framework, in 2010, 99.1% of the companies were small and medium sized enterprises, representing 48.7% of the industry's turnover and 48% of the value added, accounting for 63% of the industry's employment of over 4 million workers[32].

Responding to societal challenges, especially regarding food security and sustainability of related activities (including agriculture, animal breeding, etc.), the trends in this sector are affected by the fundamental need for assuring food safety combined with the need for reducing the environmental footprint of agricultural and breeding activities, as well as food production.

Within this framework, among the many potential innovations in the agro-food domain, the integration between Key Enabling Technologies is deemed to be of highest benefit to innovation fields in the following sub-domains.



[31] Eurostat, Annual enterprise statistics for special aggregates of activities (SBS)
[32] FoodDrinkEurope calculation based on Eurostat 2009 (SBS), www.fooddrinkeurope.eu

❖ **Cost-efficient and safe food and food processing**

Food contamination, resulting from contaminated input food materials, inadequate treatment/processing of food during production, improper handling of food throughout the logistics chain to consumption, etc., can be responsible for serious foodborne illness. In order to diminish the risk of biological contamination, chemical hazards (procured e.g. by toxins), the introduction of undesirable components (e.g. allergens) or fake components (e.g. fake meat) in food products, including all along the food chain, improved solutions aimed at a cost-efficient and safer food processing as well as handling will need to include **new and enhanced assessment and prevention tools to ensure safety of food products and the food chain** (AF.1.2). These may include solutions aimed at the traceability of foodstuff and at the identification of potentially risky events along the food chain. Approaches may refer to stable isotope labelling of foodstuff, sensing and monitoring systems for the real-time in-line process control in food processing, labels and tags allowing the tracing of abnormal events experienced by food products during handling throughout the logistics chain, etc. The development of more advanced approaches and tools will improve food chain management (thereby also importantly contributing to decreasing food waste) and food safety, thus addressing refinement and improvement of (quantitative) risk assessment procedures foreseen by current legislation, norms and standards. Such solutions are expected to imply a high level of cross-fertilization between KETs, particularly among industrial biotechnology, advanced materials and nanotechnologies, as well as advanced manufacturing technologies and micro- and nano-electronics.

The food industry is also currently facing an increasing market demand **for functional and lifestyle foods responding to diversifying dietary requirements** (AF.1.1) from consumers of different ages, lifestyles and health conditions. This means combining several functionalities in one food product, such as particular textures, high nutritional quality, and ease of use in case of savoury foods, having the capability to improve health, well-being and longevity. The medium-term development of food structures with physiological beneficial impact and the modulation of nutrients' composition in food will for example allow improving effects of diet/dietary constituents in delaying/preventing the decline of cognitive functions in the ageing human population, thus also significantly contributing to the societal challenge of health, demographic change and wellbeing. This segment is highly dependent on advanced manufacturing, advanced materials, industrial biotechnology and nanotechnology, which may help in introducing more desirable traits in food by altering the food's structure or nutrients content (e.g. thanks to the tailored addition of components such as antioxidants at defined nano-scale quantities through the use of nano-emulsions, nano-composites, etc.).

❖ **Safe, sustainable and functional food packaging**

Packaged, frozen, and ready-to-eat food has recently witnessed a significant increase in demand. As a result, the packaging industry has been focusing on the development of solutions that can provide for maximum food safety while maintaining nutritional values as well as flavour, taste and colour, unaltered, at competitive prices.

Some important innovation areas that are reachable within a short-term timeframe, highly significant in terms of the cross-fertilization between KETs, include **advanced and intelligent food packaging systems for preserving food from microbial contamination and for improving shelf life** (AF.2.1). Long food chains and storage times call for intelligent/communicative or functionalized packaging materials and/or coatings that can improve food safety (e.g. through alerts regarding risky events occurring during distribution and/or storage) and reduce the need for cold chain use, including, for example, by enabling in-package food processing, while simultaneously helping in reducing food waste. The development of active food packaging materials (e.g. packages modified by the entrapment of biomolecules or useful microorganisms), of multi-functional food packaging materials and coatings (e.g. packages coated or modified by the entrapment of (nano-)particles) and of smart intelligent/communicative packaging solutions is at the basis of future research that will strengthen EU's position in this sector, clearly displaying contributions from advanced materials and manufacturing systems, from industrial biotechnology, nanotechnology and micro- and nano-electronics to some extent.

At the same time, the increase of consumers' food packaging or single use containers for food, which generates vast amounts of waste, calls for improved solutions enabling more efficient reduction, recycling and/or reuse. Therefore new solutions, reachable within the short term, are also needed in this regard, including **more sustainable packaging** (AF.2.2) aimed at packaging waste minimization as well as packaging items aimed at more effective material recycling or item reuse. Increasingly sustainable packaging will have to include recyclable (including biodegradable/compostable) as well as reusable packaging items along with the enhancement of the infrastructure and/or logistics supporting the recycling and/or reuse practices. Also in this case a high level of cross-fertilization between KETs is expected, particularly involving advanced manufacturing and advanced materials, industrial biotechnology, nanotechnology as well as micro- and nano-electronics that might be especially relevant for logistics-related aspects in order to trace packaging/containers (e.g. through the use of labels and tags and related scanning devices and portals).

ANNEX: INDIVIDUAL FICHES DESCRIBING THE POTENTIAL AREAS OF INDUSTRIAL INTEREST RELEVANT FOR CROSS-CUTTING KETs

The roadmap for cross-cutting KETs activities presented in the main roadmap document identifies the potential innovation fields of industrial interest relevant for cross-cutting KETs developments. The roadmap has been developed starting from actual market needs and industrial challenges in a broad range of industrial sectors relevant for the European economy. The roadmapping activity has focused on exploring potential innovation areas in terms of products, processes or services with respect to which the cross-fertilization between KETs could provide an added value, taking into account the main market drivers for each of those innovation areas as well as the societal and economic context in which they are located. Taking the demand side as a starting point, cross-cutting KETs activities will in general include activities closer to market and applications. The study focused on identifying potential innovation areas of industrial interest implying Technology Readiness Levels of between 4 and 8.

In this Annex, each innovation field relevant for cross-cutting KETs activities is described by means of a dedicated fiche.

How to read the Fiches describing the potential areas of industrial interest relevant for cross-cutting KETs

Innovation fields are first of all grouped within cross-sectoral domains and moreover classified within sub-domains. For each innovation field relevant for cross-cutting KETs activities, a dedicated fiche describes the relevant information retrieved throughout the study for the specific innovation field.

I. Demand-side requirements and challenges

For each sub-domain, the demand-side requirements stemming from specific societal challenges that the specific group of innovation fields addresses are described. One activity in this study has been an analysis of the relevance of each innovation field towards the grand societal challenges burdening today's society. Moreover, if relevant for a whole group of innovation fields identified under the umbrella of a specific sub-domain, then the demand-side requirements stemming from specific market needs that the specific group of innovation fields addresses are also described. On the contrary, if specific only to one innovation field (rather than to a whole set of innovation fields), demand-side requirements stemming from specific market needs are described with reference to the specific innovation field and hence they are introduced within its dedicated fiche.

Sub-domain (self-explanatory short description)
Demand-side requirements (stemming from Societal Challenges) addressed: • Demand-side requirement 1 • Demand-side requirement 2 • ... ... **Demand-side requirements (stemming from market needs) addressed:** • Demand-side requirement 1 (if relevant for a whole set of innovation fields) • Demand-side requirement 2 (if relevant for a whole set of innovation fields) • ... ...

The dedicated fiches provide firstly a self-explanatory short description of the innovation field, as well as an extended description providing additional details and explanation ('Scope'). Subsequently, demand-side requirements stemming from specific market needs are described, if referred to the innovation field (rather than to a whole set of innovation fields, as reported above). Moreover, technical/industrial challenges (mainly resulting from gaps in technological capacities) specific to the innovation field are reported. Both the demand-side requirements stemming from the market needs and the technical/industrial challenges are the result of the extensive analysis carried out in order to map potential innovation areas along with their associated market needs and industrial challenges, thanks to a thorough screening of Strategic Research (and Innovation) Agendas and Strategic Roadmaps developed by European Technology Platforms and other European initiatives (such as Joint Technology Initiatives or Undertakings) as well as from other available acknowledged sources of information with European relevance (e.g. market studies, foresight studies, sector analyses, etc.). The initial desk analysis to gather preliminary information was subsequently complemented by further input from more than 80 representatives of key industrial players, collected through interviews and workshops.

Innovation field (self-explaining short description)

Scope:

- Extended description of the innovation field

Demand-side requirements (stemming from market needs) addressed:

- Demand-side requirement 1 (if relevant for a specific innovation field only)
- Demand-side requirement 2 (if relevant for a specific innovation field only)
- ... ...

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Technical/industrial challenge 1
- Technical/industrial challenge 2
- ... ...

II. Contribution by cross-cutting KETs

Afterwards information is provided about the contribution that cross-cutting Key Enabling Technologies could have with respect to the innovation field. This information is the combined result of three main actions, namely a Europe-wide survey involving KETs experts, an extensive patent scenario analysis, and deskwork combined with evaluation and harmonization by the project team experts. On the one side, a survey that extensively involved high level experts in Key Enabling Technologies and that was aimed at matching the identified innovation fields with the technological offering to be provided by the cross-fertilization between KETs was established. This part of the analysis leveraged views of 272 experts in all the six KETs, mobilized via a dedicated Europe-wide online-based survey. Technology experts were called to identify which KETs could contribute to each innovation field and moreover to assess whether the integration of the potentially contributing KETs beyond their mere combination could constitute an additional success factor for the achievement of highly innovative products, processes or services. On the other side, an extensive patent scenario analysis aimed at examining the KETs-related patenting activity in relation to each innovation field was carried out. A KETs-related patent database was exploited for the purpose, which had been obtained by having identified and extrapolated from patent databases only those patents dealing with KETs thanks to search strings delineating each of the six KETs. Activities were furthermore complemented by extensive deskwork.

Specifically as regards the survey, the questionnaire had been designed in such a way to allow KETs experts to choose one or more specific domains within which to assess related innovation fields. The system hence gave respondents a list of innovation fields that were either directly classified within the chosen domain(s) or cross-sectorally linked to such domain(s). Each innovation field had been in fact redundantly classified within more than one domain in order to increase its opportunity to be reached through different paths regardless of the initial choice of the domain, if relevant for more than one domain. Accordingly, each innovation field could be assessed by a variable number of KETs experts. Notably, the result of this survey is not intended to be statistically relevant, but rather to be a source of input along the same line as an expert consultation process. It should be noted that, according to profiling, more than 90% of the respondents had an expertise of longer than 5 years. Throughout the questionnaire, KETs experts were specifically asked to assess how important each of the six KETs was in relation to a specified innovation field (with possible multiple choice among fundamental, important, marginal, not needed) and, in case at least two KETs had been selected as being at least important or fundamental, the respondent was asked to assess to which extent those technologies interrelate and interact beyond their mere combination so to provide novel technological opportunities (i.e. the cross-cutting KETs relevance was assessed). A multiple choice was again possible among the categories: rather strong interaction, rather low interaction, mere combination without interaction. Since it was a fundamental requirement to identify cross-cutting KETs opportunities, only innovation fields for which a rather strong interaction had been indicated were selected as relevant and further considered throughout the next assessment steps.

This information was combined with the result of the KETs-related patent scenario analysis and particularly cross-checked against the indication of the patent distribution by KETs and related combinations of KETs. This particular piece of information provides indication of how many patents identified in relation to a specific innovation field refer to any of the six KETs and, as a part of this number, how many refer to specific combinations of KETs as indicated in the right column of the table provided in the relevant section of the fiche ‘Results of patent scenario analysis’.

As a result of this process, the contribution by cross-cutting Key Enabling Technologies toward each innovation field is indicated in the fiches through a list of the relevant KETs and a description of how they can contribute. Moreover, a histogram provides an indication of the related shares in terms of experts’ answers (with a focus on the two answers pointing to either the fundamental or important role of each KET, besides which the total share referring to the two combined answers is also indicated).

Contribution by cross-cutting Key Enabling Technologies (EXAMPLE):

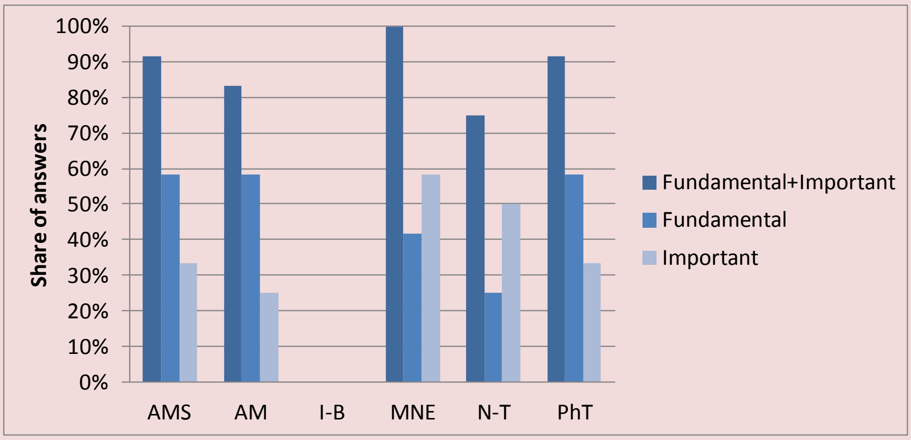
In respect to this Innovation Field, the integration of KETs could contribute to the development of enhanced displays offering more realistic and immersive 3D video reproduction, including energy-efficient and wearable displays, also supported by new methods and tools for immersive sound reproduction and adequate video processing hardware. Exploration of the use of flexible materials, thin film glass and organic electronics to develop flexible/wearable displays can also be an opportunity. To this aim, the combination of KETs experts’ opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with fundamental contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Photonics (PhT)

and important contribution by:

- Micro- and Nano-Electronics (MNE)

- Nanotechnologies (N-T)



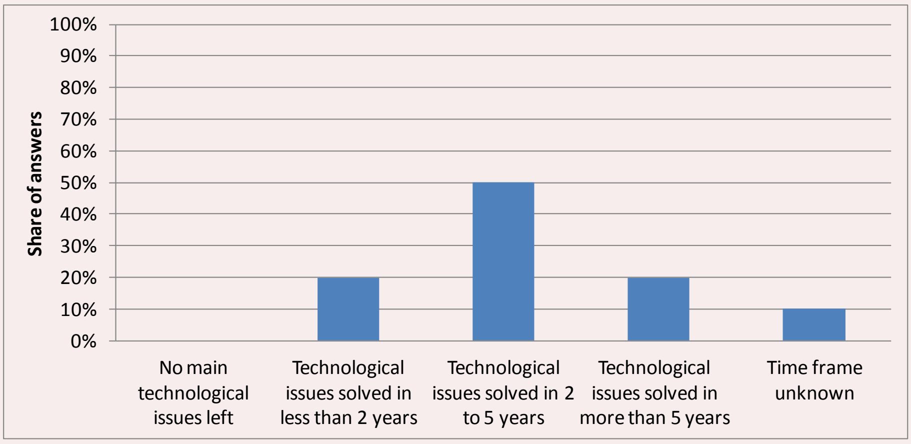
III. Timing

KETs experts had been additionally asked to provide their opinion about how long it would take to solve the main technological issues holding back the achievement of cross-cutting KETs based products within a specific innovation field. Answers had to be chosen among the following options: no main technological issues left, less than 2 years, from 2 years to 5 years, from 5 to 10 years, more than 10 years. This allowed the grouping of innovation fields into two main blocks, namely innovation fields with short-term priority relevance (if the answer 'from 2 years to 5 years' was selected) and innovation fields with medium-term priority relevance (if the answers 'from 5 to 10 years' or 'more than 10 years' were selected), despite the fact that many of the innovation fields could be considered as being subject to continuous, incremental improvement as they are associated with well-established market needs driving the development of new products, processes, goods, and services as soon as new enabling technologies or technological solutions become available. On the other side, innovation fields for which 'no main technological issues left' was indicated were considered state-of-the-art, whereas for innovation fields for which 'less than 2 years' were indicated were considered as already planned within commercial plans of industrial organizations and thus out of the scope of pre-commercial development.

Also this set of information was combined with the result of the KETs-related patent scenario analysis, as well as with deskwork. Within respect to the patent scenario analysis, the shape of the patenting activity's trend curve as well as the relative share of industrial and academic applicants in relation to a specific innovation field were used as indicators to provide useful information about the maturity of developments in a given framework, in the assumption that a growing trend curve would normally point out to an evolving, thus not yet mature technological scenario (as opposed to a stable or even descending trend curve pointing out to technological maturity or even obsolescence) according to the typical S-shaped curve describing technology life cycles, and that the presence of academic applicants would normally point to research activities, highlighting lower technological maturity, going on in a given framework (as opposed to a high share of industrial applicants pointing to innovation activities and a higher technological maturity).

Timing for implementation (EXAMPLE):

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back to the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back to the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

IV. Market / industrial potential

Activities were then aimed at assessing the identified innovation fields in terms of market impact and opportunity toward industrial growth and job creation. This assessment involved two main actions as well as desk analysis. A second Europe-wide online-based survey allowed industrial experts' opinions to be obtained with regard to market demand aspects. The survey leveraged opinions from 285 industry experts. Moreover, also for this part of the analysis, patent-based indicators were exploited in order to provide information about Europe's positioning in terms of KETs-related patenting activity in relation to each innovation field. Furthermore, extensive desk analysis activity allowed the assessment of potential markets and related drivers.

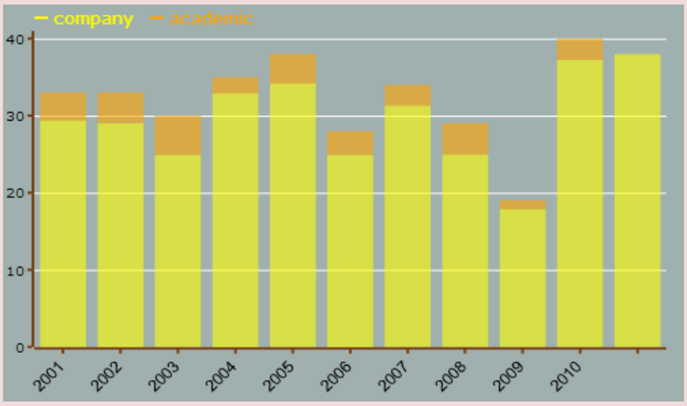
As regards the industry representatives' survey, the questionnaire had been designed in such a way to allow industry experts to start the process by selecting a specific domain as well as sub-domain in line with their markets and business activities. The system thus provided respondents with a list of the innovation fields that were either directly classified within the chosen domain as well as sub-domain or cross-sectorally linked to such domain as well as sub-domain, within which to select a maximum number of 3 innovation fields of strategic relevance or interest for their company to assess in major details whilst remaining strictly anonymous. Considering that the purpose of this survey was to characterize industrial interest toward the identified innovation fields, this filter logic was already intended to identify interesting innovation fields to industrial organizations so to gain relevant aggregated information about their strategic relevance for industry in Europe. A set of questions followed, which were aimed at gathering qualitative information about R&D activity and industry plans in relation to each of the selected innovation fields. The gathered information was complemented by extensive deskwork aimed at retrieving, whenever possible, information about potential market size and specific market drivers for each innovation field.

These pieces of information were once again combined with the result of the KETs-related patent scenario analysis. The use of patent-based indicators has intrinsic limitations, but can anyway be a powerful aid in qualitative assessments. Patent-based indicators, such as particularly patent distribution by applicant organization, geographical zone, and patent distribution by geographical zone of priority protection were used to provide information about Europe's relative industrial strength (in the assumption that European applicant organizations contribute to industrial strength in Europe) and market relevance (in the assumption that filing for a patent is used as a way for applicants to protect themselves in a specific geographical market) in relation to a specific innovation field, respectively.

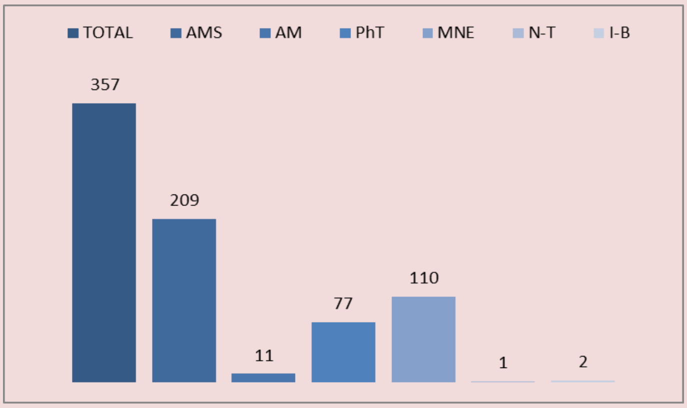
Additional information according to results of assessment:

➢ *Impact assessment:*
- Market drivers, market size, etc. (whenever specific information could be gathered through desk analysis)

➢ *Results of patent scenario analysis:*
- Indication of the number of exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Indication of the shape of the trend curve (number of patents per year)
- Indication of the relative share between industrial and academic applicants (EXAMPLE):



- Patents by KET(s) (EXAMPLE):

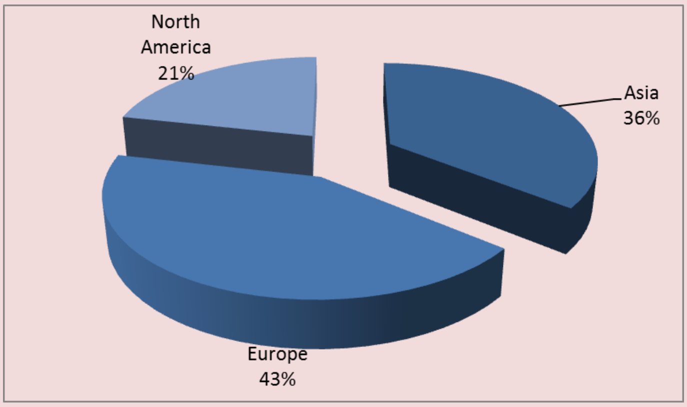


- Patents by KET(s) and relevant combinations of KETs (EXAMPLE):

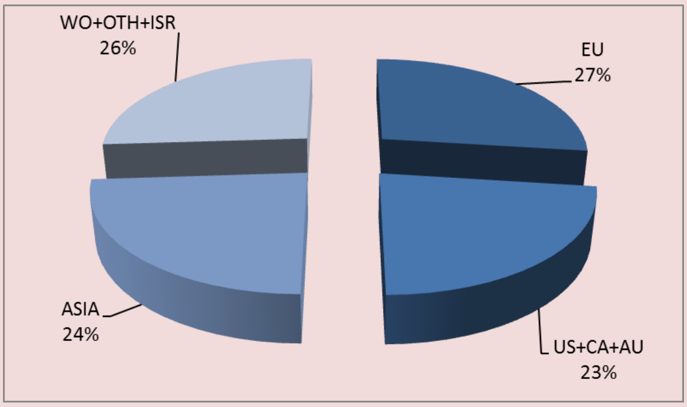
KET(s)	*Number of patents*
AM	11
AM / MNE	1
AM / PhT	1
AMS	209
AMS / MNE	15
AMS / MNE / PhT	2

AMS / PhT	5
IBT	2
MNE	110
MNE / N-T	1
MNE / PhT	32
N-T	1
PhT	77

- Patents distribution by (Applicant) organization geographical zone (EXAMPLE):



- Patent distribution by geographical zone of priority protection (EXAMPLE):



POTENTIAL AREAS OF INDUSTRIAL INTEREST RELEVANT FOR CROSS-CUTTING KETS IN THE ELECTRONICS AND COMMUNICATION SYSTEMS DOMAIN

Sub-domain: Improved Human-Machine interaction and interfaces

Demand-side requirements (stemming from Societal Challenges) addressed:

- "Inclusive societies" need an efficient interaction between all sorts of systems and humans whatever their technical and communication abilities, including bridging the age and disability gap with regards to digital technologies
- "Innovative and reflective societies" are supported by machines and systems designed to enable human users to take best advantage of technologies' potential and leave room to individual and collective creativity
- "Health and wellbeing", "secure, clean and efficient energy", "smart, green and integrated transport", various environment and resource management and surveillance systems or advanced production chains are served with expert systems that enable trained operators to raise their overall awareness, take very reactively the good decision and make sure it is efficiently and safely implemented, which calls for expert systems' operator-friendly interfaces
- Protecting security of Europe and its citizens without hampering freedom requires that many systems in interaction with humans are able to undertake seamless identification of users and operators

Demand-side requirements (stemming from market needs) addressed:

- With many technologies becoming causes of fears, misunderstanding and exclusions, offering a more natural way to interact with and within information-rich environments is a condition for sustained societal trust in technological progress, thus a condition for "smartification" of our environment
- Many recent successful innovations as smart phones or tablets have been based on smooth, ergonomic and personalized interfacing, improving overall user experience of technology services. This is a long-term trend in all sorts of markets and "mass-customization" starts with human-machine interfaces
- The human factor remains a significant source of accidents and inefficiencies in complex systems, calling for ever-improving training of operators but also for better decision-making assistance, vigilance monitoring and various forms of personal assistance. Well-designed interfaces will deliver high value services at a low human attention cost
- New interfaces create standards that then require wide deployments and ubiquitous applications, including on specifically constrained environments as embedded in vehicles, in remote areas, on nomadic devices, etc. Advanced systems need advanced interfaces whatever their operational constraints (shock resistance, electro-magnetic aspects, weight, power management, etc.)

E&C.1.1: High resolution integratable 3D displays

Scope:

To develop displays offering realistic and immersive three-dimensional (3D) video reproduction, supported by energy-efficient, flexible/wearable and easily integrated technologies, supported by methods of immersive sound reproduction as well as file formats and adequate video processing hardware.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of displays to offer realistic and immersive three-dimensional (3D) video reproduction, including energy-efficient and wearable displays, and new methods of immersive sound reproduction
- Development of new tools to classify metadata as well as new "modelling formats": file formats for the audio, three-dimensional (3D) video and data that are the active constituents of services, plus the metadata that describes them and allows them to be

processed
- Exploration of opportunities from flexible materials, thin film glass and organic electronics, to develop flexible/wearable displays

Contribution by cross-cutting Key Enabling Technologies:

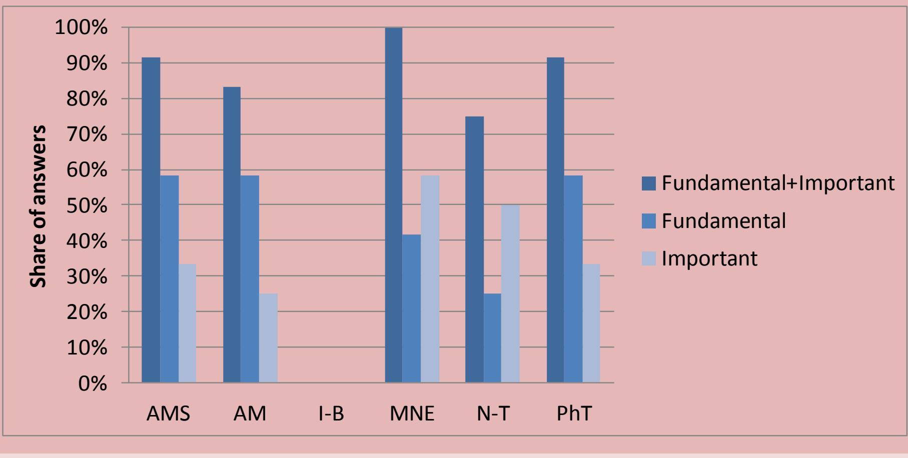
In respect to this Innovation Field, the integration of KETs could contribute to the development of solutions such as enhanced displays offering more realistic and immersive three-dimensional (3D) video reproduction, including energy-efficient and wearable displays possibly based on flexible materials, tools for immersive sound reproduction and video processing hardware, etc.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with fundamental contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Photonics (PhT)

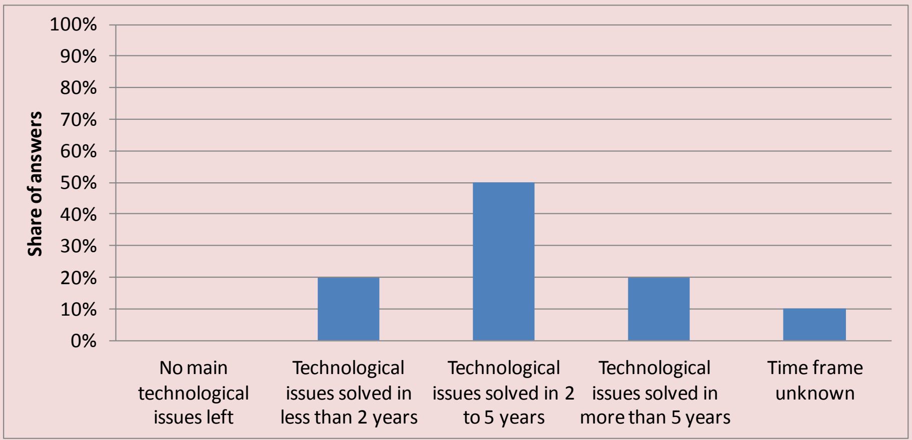
and important contribution by:

- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:

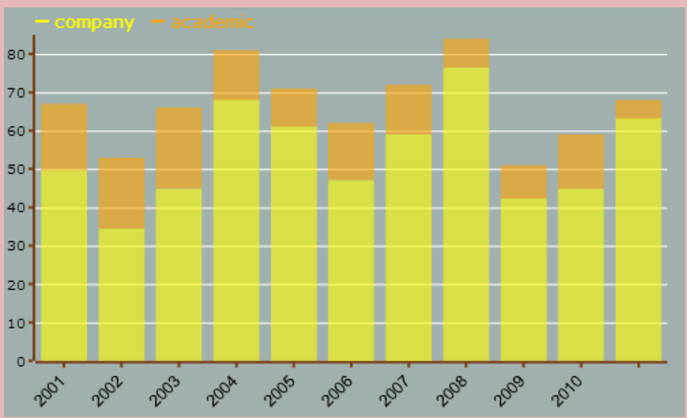


Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

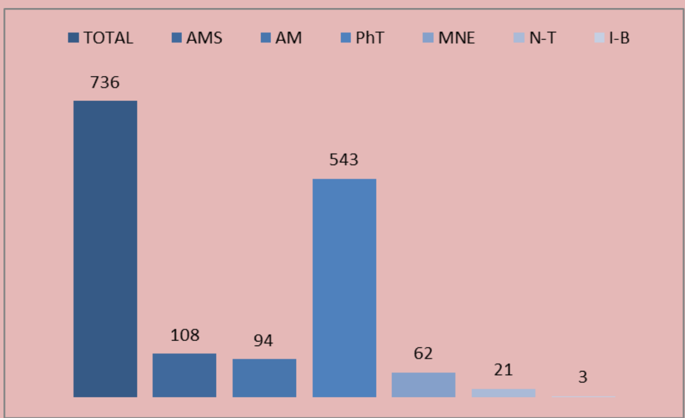
Additional information according to results of assessment:

- ***Impact assessment:***
  - Novel three-dimensional (3D) display technology is aimed at offering viewers a truly immersive experience, with main market impacts expected in entertainment businesses, including cinema and television, videogames, all sorts of individual or social games.
  - Education and training is next market opportunity, either for "edutainment" / "serious games" – taking advantage of the attractiveness of the immersion effect to best capture the participant's attention – or for highly demanding professional training (pilots and other vehicle operators, surgeons, sportsmen, etc.) – using high definition ultra-realistic three-dimensional (3D) visualization to offer a near-real-life professional situation simulation.
  - Much other usage of such technology is expected to rise when satisfying technology is made available in the market, including mission preparation (e.g. surgical, space, military, rescue or complex building and manufacturing missions), commercial displays (typically for architects and urbanist projects), industrial design, visual arts, videoconferences, science, etc.
  - Considering all these potential applications, advanced three-dimensional (3D) displays have a large potential for creating not only direct but also many indirect activities and jobs.
  - Three-dimensional (3D) dimensional display technology crossed an important threshold in the past two years, with explosive growth expected in the commercial sector and, increasingly, a feature of military simulations. Such displays provide the viewer with depth perception, and thus an illusion of reality that cannot be achieved with a conventional bi-dimensional (2D) display. Such technology is already used for battleship simulations, thus the knowledge in this sector could be transferred into civilian applications with potential uses for wide ranges of markets.

- ***Results of patents scenario analysis:***
  - 736 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Quite stable trend curve (number of patents per year), with a decreasing share of academic applicants, highlighting progress towards industrial maturity:



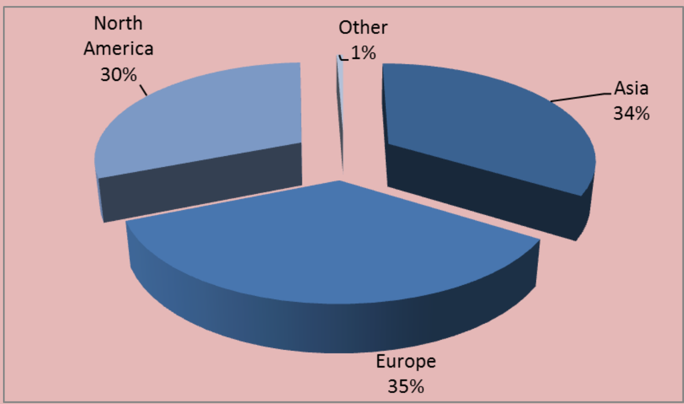
  - Patents by KET(s):



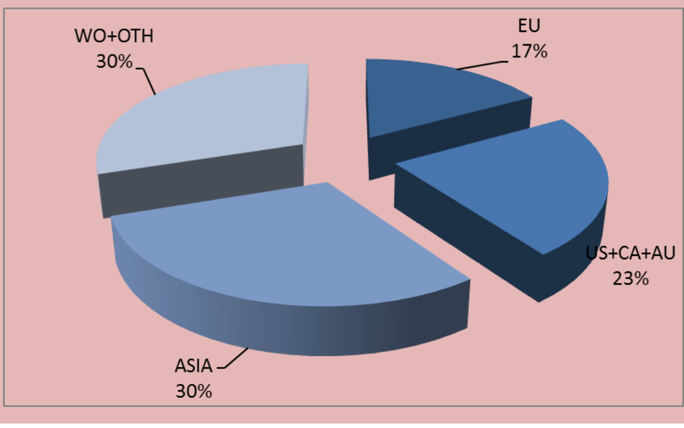
  - Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	94
AM / MNE	2
AM / MNE / N-T	1
AM / MNE / PhT	1
AM / N-T	6
AM / N-T / PhT	3
AM / PhT	34
AMS	108
AMS / MNE	1
AMS / N-T	2
AMS / N-T / PhT	1
AMS / PhT	11
IBT	3
MNE	62
MNE / N-T	2
MNE / PhT	36
N-T	21
N-T / PhT	7
PhT	543

- Patent distribution by (Applicant) organization geographical zone:
- Japanese companies are dominating the top 30 patent applicants list, but the top patent applicants are Phillips, Bayer and a noticeable Luxemburgish SME named Seereal



- Patent distribution by geographical zone of priority protection:



E&C.1.2: User-friendly human-machine interfaces

Scope:

To enable easy human-machine interactions and interfaces that increase user-friendliness through e.g. real-time human language technologies, multimodal interfaces mimicking human communication skills, safe natural proximity and hands-free interaction and up to virtual reality for high complexity systems.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of tools for content creation and manipulation (content capture: sensors for human senses; content manipulations: 3D authoring tools; oralization tools)
- Development of human language recognition technologies (spoken and written) to provide language transparency in real-time to allow all citizens to become e-included in the information society
- Development of multimodal user interfaces with the environment aiming at mimicking human communication skills that use several modes of communication ("hands-free computer interfaces")
- Development of technology for "virtual reality": interactive technology for communication, business and entertainment applications
- Increase of the usability of highly complex Information Technology (IT) systems though more intuitive interfaces
- Development of solutions for enabling ubiquitous deployment of electronics, as large area sensors and actuators, so as to optimize opportunities for human interactions with machines, including with flexible printed electronics
- Development of the specific protection systems to support human-machine proximity and cooperation, as with collaborative robotics in manufacturing

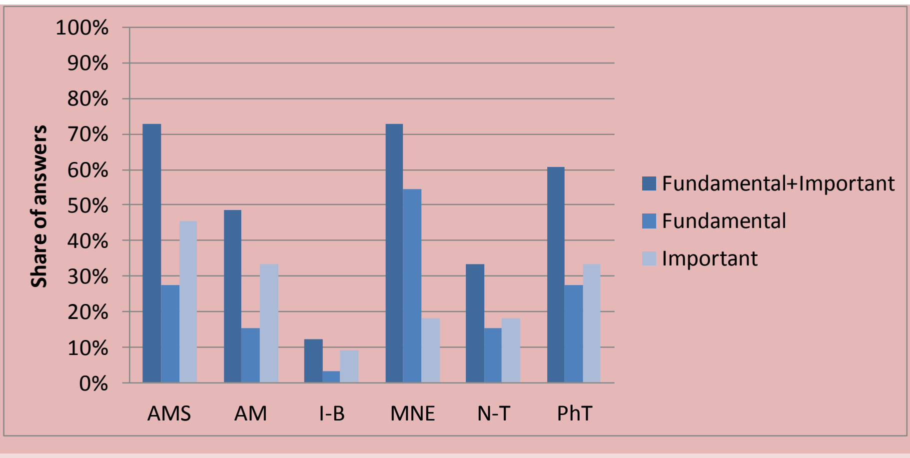
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced as well as user-friendly/intuitive human-machine interfaces based on devices able to capture signals, sensors to mimic human senses, instruments for content manipulation and other technologies that can be integrated for the development of multimodal user interfaces, capable to mimic human communication skills through several modes of communication.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

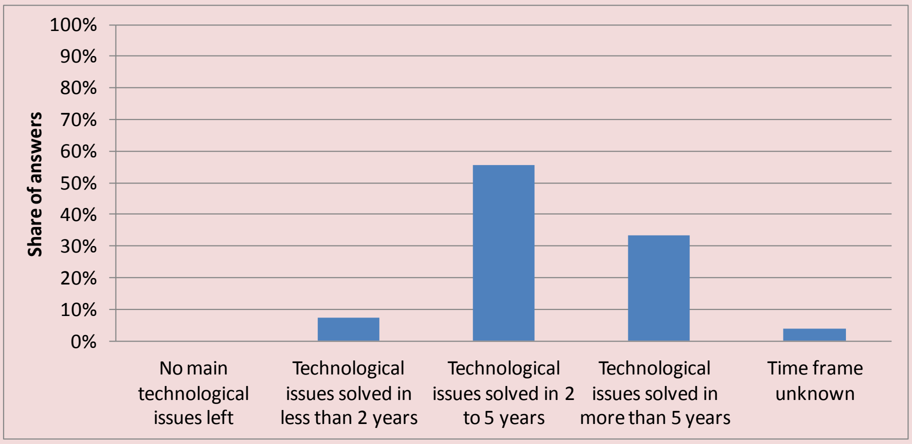
- Micro- and Nano-Electronics (MNE)
- Advanced Manufacturing Systems (AMS)
- Photonics (PhT)
- Advanced Materials (AM)

To a lesser extent Nanotechnologies (N-T) and Industrial Biotechnologies (I-B)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also longer periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

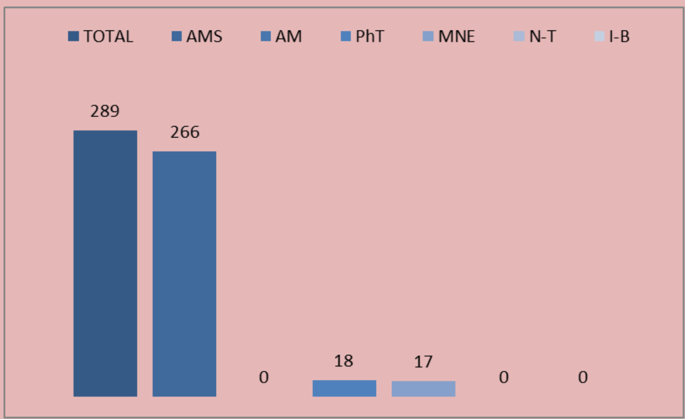
- Improved interaction systems between machines and humans are levers for breaching barriers towards the adoption and deployment of many technologies, including robots, enhanced reality, multi-service converged equipment, connective devices, etc.
- One of the aspects of that better interaction is the reduction of the burden of tasks bringing no or little added value to the end user. The ability of machines to identify people, "understand" human behaviour and react consequently – e.g. automated connectivity or sleep/active mode switch – is one of the levers for making "smart" technologies less intrusive and more acceptable. This is particularly important to reduce the digital divide with little e-skilled population as ageing or disabled people.
- Another aspect is enabling machine operators to take better advantage of technical potentialities by providing the operator with just the right information at the right time and in the right format, supporting efficient and sound decision-making and operational decisions. This is particularly crucial where safety is involved, as in vehicle cockpits or for precision surgery. Solutions integrating KETs into cross-cutting combinations will benefit from multi-sources sensing capabilities, supporting multi-criteria data pre-analysis by the machine, allowing best analysis and reaction to human behaviour.
- "Natural" interaction with machines, e.g. based on language or ordinary body movements, also enable to stimulate individual and collective creativity.

- Ergonomics and human machine interfaces are getting more and more important roles in a technology successfully meeting its markets, and can be major non-price competitiveness factors for Made in Europe technology products.
- Wearable computers with advanced human-machine interfaces were introduced by the American Army already in 1989. This was a small computer that was meant to assist soldiers at the battlefield. Since then the concept has grown into the current Land Warrior program and proposal for future systems. The advanced development in this sector make it a clear dual use technology that can be applied into the civilian sector.

➢ ***Results of patents scenario analysis:***

- 289 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Increasing again trend curve (number of patents per year) after some years of decrease
- Highest share of industrial applicants:

- Patents by KET(s):

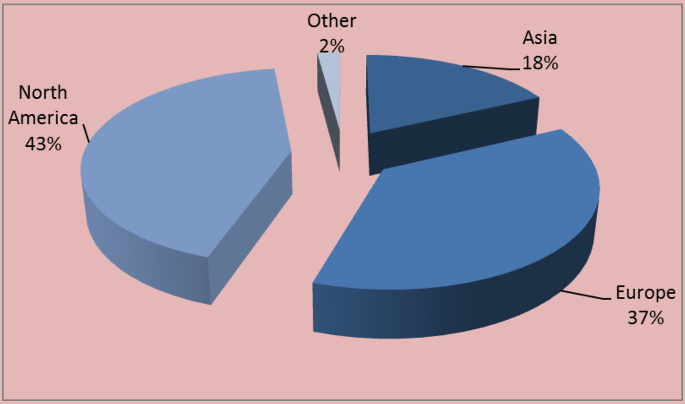


- Patents by KET(s) and relevant combinations of KETs:

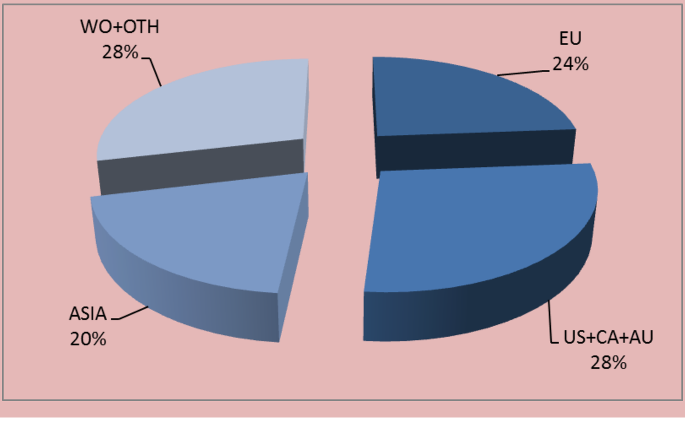
KET(s)	*Number of patents*
AMS	266
AMS / MNE	4
AMS / MNE / PhT	1
AMS / PhT	2
MNE	17
MNE / PhT	7
PhT	18

- Patent distribution by (Applicant) organization geographical zone:
- Many European companies in the top applicants (from Netherlands, Switzerland, Germany, Finland, France), also many Japanese and US, and players coming from a wide variety of sectors: computer industry (Toshiba, Sony, Nec, Intel, Motorola, etc.), transport systems (Siemens, Honeywell, Rockwell, Valeo, Honda, Daimler, GE), electronics (Philips, Matsushita, Qualcomm, Thomson CSF, Movea), energy (ABB,

Siemens), software (SAP, Microsoft), etc.



- Patent distribution by geographical zone of priority protection:



Sub-domain: Breakthrough enabling components and circuits

Demand-side requirements (stemming from Societal Challenges) addressed:

- "Innovative and reflective societies" and a competitive European economy need breakthrough innovations, smart capabilities or high performance, a large part of which will be made possible by improved or even radically new electronics components and circuits
- Energy and material resources efficiency are demanding much from electronic components, be it direct energy consumption reduction, advanced power management, low use of critical materials, recyclability, miniaturization, etc.
- Large areas monitoring – as for agriculture, forestry, marine resources, water resources, pollution monitoring, homeland security, etc. – require "smartification" of the environment, e.g. with high autonomy ubiquitous low cost sensing and communication capabilities, serviced by new components, circuits and architectures
- High value systems for energy, transport, health care as well as some industrial, space or military applications need components and circuits for highly demanding applications, severe vibration or temperature environments, high computing power, specific reliabilities, real time operations, miniaturization, upgrade/retrofit,etc.
- Electronic components being a basic bricks for all high added-value systems, maintaining an electronics industry in Europe is a critical matter of strategic non-dependence

Demand-side requirements (stemming from market needs) addressed:

- Electronics industry is a highly competitive market integrated into global value chains, with short cycles and requiring large investments. Keeping caught-up with Moore's law (computing power doubles every two years) as well as with new trends (non-computing capabilities grouped under the "More-than-Moore" concept) is a survival issue for the European electronics industry facing huge global competition
- With electronic and telecommunication systems getting more and more complex,

developing circuits and components dedicated to a specific application is a key for competitiveness of entire industries. Industrial eco-systems in consumer or professional electronics require strong interactions with the components and circuits link
- Setting up the "Internet of Things", "Cloud computing" or "Big data" services are major requirements from many industries and services in Europe. It requires developments in components as well as from upper technical layers
- Cost is a key and all components design and production has to integrate competitive production aspects from the earliest phase

E&C.2.1: Low consumption high computing power components ("More Moore")

Scope:

To develop affordable and sustainable high computing power low consumption components and circuits, basically "more Moore" (e.g. based on Complementary Metal-Oxide Semiconductor (CMOS) and Silicon technology), for further miniaturization, higher performance, increased energy efficiency and better heat management of computing systems, supported by a shift to renewable, abundant and non-toxic materials and more cost effective production processes and higher transistor density, such as extreme ultra-violet (UV) photolithography and increased size of semiconductor wafers.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

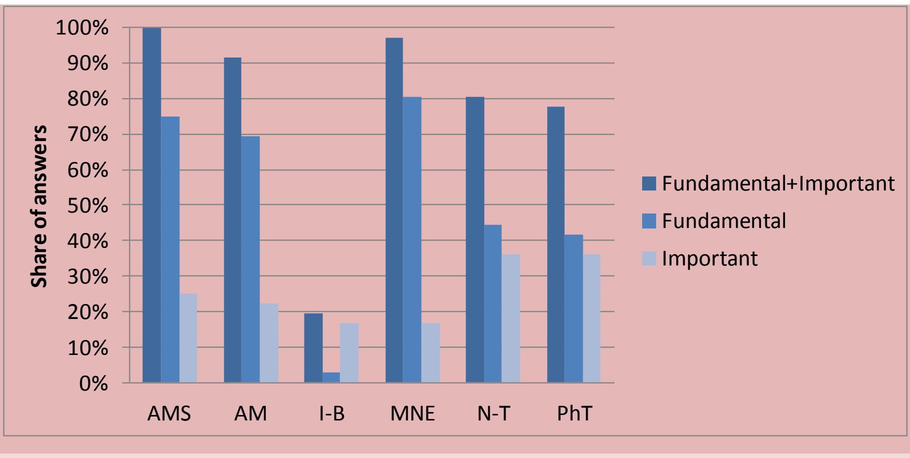
- Continue following Moore's law on developing processes for very small size semi-conductor engraving, so as to further miniaturize electronics (i.e. put more transistors per surface unit)
- Increase of the number of chips per wafer to reduce cost
- Increase of energy efficiency and energy management of computing systems
- Improvement of thermal management of components and circuits, including active thermal management of integrated systems, usage of waste heat and highly effective cooling solutions
- Development of intelligent high-performance hardware for simulation purposes
- Preparation to shift to renewable materials and implementation of recycling by design (include life cycle of products and materials into "product planning")
- Increase of performance of embedded computing
- Ensure affordable production of optimized for application chipsets and modules for communication infrastructure (typically low volumes), connection stations and cells (low to medium volumes, set top boxes (medium volumes) and handsets (high volumes)

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced, affordable and sustainable high computing power, low consumption components and circuits, thanks to very small size semi-conductor engraving , increase of the chips density, thermal management improvements, as well as the use of renewable materials and recycling by design approaches.

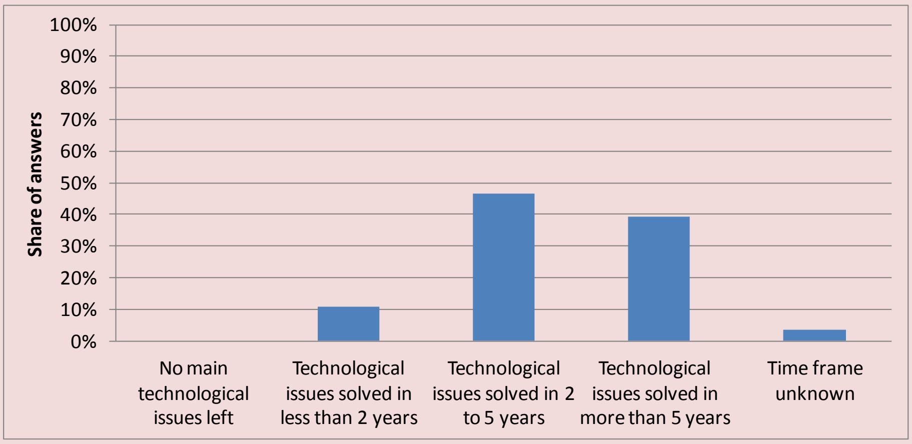
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Micro- and Nano-Electronics (MNE)
- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also longer periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - In the highly competitive environment of the electronic components industry, developing high added-value "more Moore" products and their advanced production lines at the cross-roads between different KETs is mandatory for guaranteeing that an electronics industry remains viable in Europe, with impacts on European economic and strategic non-dependence and security, as well as on European capability to develop and produce products and systems with advanced, innovative and ground breaking capabilities.
  - Keeping in line with Moore's law means continuing to increase the available computing power, which is important not only for enabling new services but also for just continuing delivering today's services within an environment where running data volumes are continuously increasing. Future internet and all future communication networks, big data services, advanced modelling and simulation capabilities, large integrated information-based services, all these will need increased computing power and "more Moore" components.
  - The defence sector has in the past years strongly contributed to the development of advanced products. The knowledge, technology and services developed may strongly contribute in improving the civilian sector applications by transferring the know-how into the market.
- ***Results of patents scenario analysis:***
  - Many different KETs-related technologies apply to this Innovation Field, but too few of

them highlight the final application or target functionalities, so that the RO-cKETs study patent analysis approach is not suitable to delivering significant results in this field.

E&C.2.2: Functionalized cost-effective components ("More than Moore")

Scope:

To develop components and circuits going beyond Complementary Metal-Oxide Semiconductor (CMOS) technologies ("more than Moore") to deliver powerful low cost and/or functionalized computing, sensing and actuation solutions, building on the functionalization of the semi-conductor substrate to enrich the non-digital capabilities of the circuits, manage their growing complexity, enable alternative computer architectures (e.g. self-organizing, reconfigurable, defect- and fault tolerant architectures) or high performance solutions for radiofrequency, sensing and control/actuation microsystems, making all these potentially integratable/coupleable with Complementary Metal-Oxide Semiconductor (CMOS) ("system on chip").

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

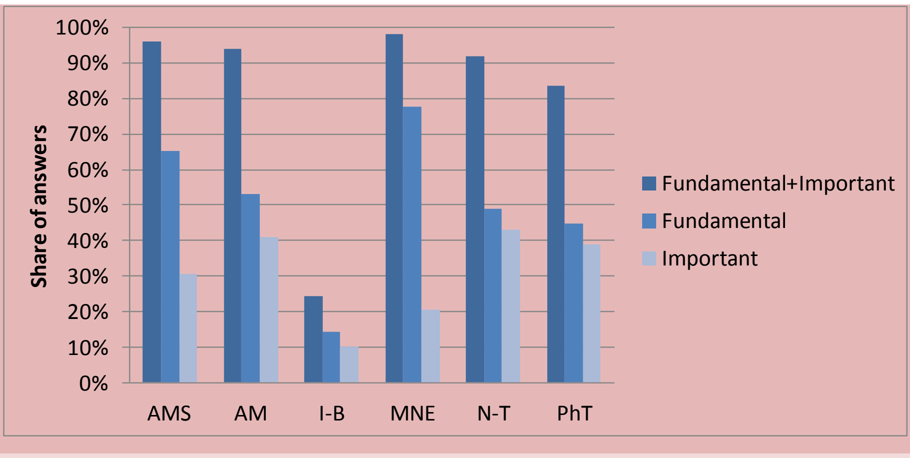
- Development of bottom-up nano-electronics beyond Complementary Metal-Oxide Semiconductor (CMOS)
- Development of alternative computer architectures, as self-organizing and reconfigurable or defect- and fault-tolerant architectures, and related hardware technologies
- Combination of functional substrate materials to improve components' functionalities
- Application of novel known and unknown functional materials for better products (e.g. biobased plastics, graphene)
- Find deployments and applications of advanced materials
- Recycling by design (include life cycle of products and materials into "product planning")
- Further miniaturization of electronics
- Integration/coupling of novel "More than Moore" designs to Complementary Metal-Oxide Semiconductor (CMOS) (system on a chip), packaging and organic electronics (less powerful but lower cost)
- Development of autonomous computing: adaptive, self-configuring, optimizing and repairing systems

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced components and circuits going beyond Complementary Metal-Oxide Semiconductor (CMOS) technologies ("more than Moore"), building on the functionalization of the semi-conductor substrate, alternative computer architectures, the combination of functional substrate materials, miniaturization, packaging and organic electronics, renewable materials and recycling by design approaches.

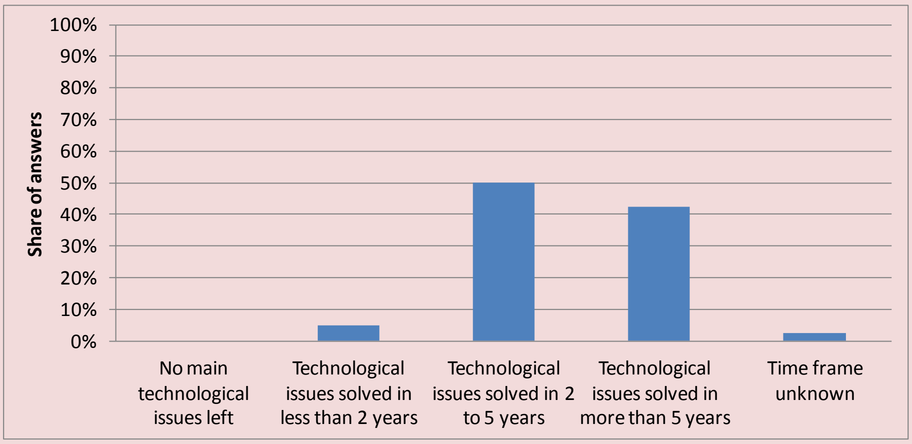
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also longer periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - In the highly competitive environment of the electronic components industry, developing high added-value "more than Moore" products and their advanced production lines at the cross-roads between different KETs is mandatory for guaranteeing that an electronics industry remains viable in Europe, with impacts on European economic and strategic non-dependence and security, but also on European capability to develop and produce products and systems with advanced, innovative and ground breaking capabilities.
  - Beyond conventional digital semiconductor technologies and applications, "more-than-Moore" integrated components and circuits offer the opportunity to convert non-digital as well as non-electronic information – such as mechanical, thermal, acoustic, chemical, optical and biomedical functions – to digital data and vice-versa. This, eventually converged and integrated with advanced digital electronics, allows them to deliver high value functionalities and support breakthrough innovation in wireless communication, power grids, lighting, biomedicine, energy scavenging, imaging, micro-nano sensing, micro-nano actuation, etc. This innovation field is a basic component of many other fields highlighted in the present report.
  - In 2012, just the MEMS-NEMS (Micro and Nano-Electro Mechanical Systems) market reached about 9 billion Euro, with a regular 10-15% annual growth. Up to 56 production fabs are dedicated to Micro-Electro Mechanical Systems (MEMS) in the EMEA (Europe,

Middle-East and Africa) area, the two biggest global players – ST Microelectronics and Robert Bosch GmbH – are European, and even though there is a fierce competition in particular from Asian countries, these "more than Moore" components represent a major volume of activity and jobs in Europe, with a large growth potential (Source: Yole 2012 and 2013).

- Many of the technologies in this field have already been studied and developed by the defence industry for applications in both defence and civilian areas, for example in aerospace. However, a stronger development can be expected in the near future coming also from the potential dual use applications deriving from the know-how developed to be transferred into civilian markets.

➢ ***Results of patents scenario analysis:***

- Many different KET related technologies apply to this innovation field, but too few of them highlight the final application or target functionalities, so that the ROcKETs study patent analysis approach is not adapted to delivering results making sense in this field.

E&C.2.3: High efficiency power control and conversion electronics

Scope:

To develop efficient, effective, reliable and sustainable solid-state fast dynamics power electronics for the control and conversion of electric power, mainly for power grid or transport applications.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

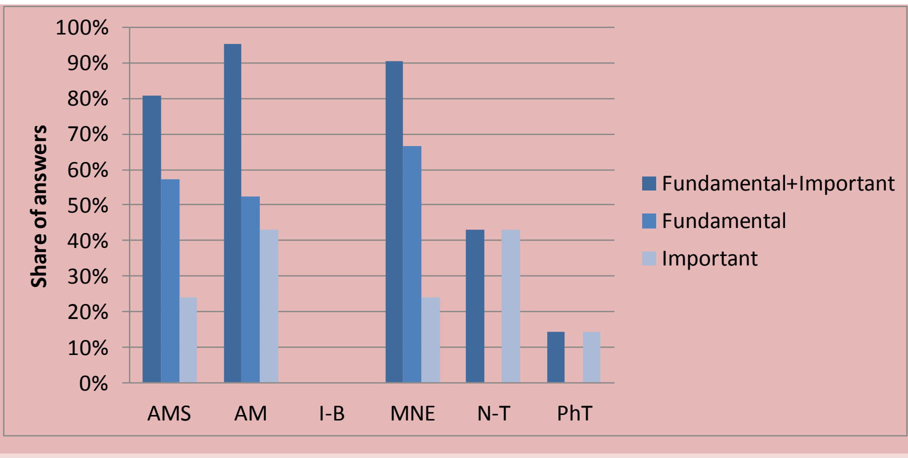
- Development of efficient solid state power electronics for power conversion into energy systems as batteries, fuel cells, photovoltaic and overall grid systems
- Adaptation of remote power supply/storage to specific requirements of application (e.g. very long lifetime without recharging)
- Development of mobile energy storage systems

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more efficient solid state power electronics for power conversion into energy systems as batteries, fuel cells, photovoltaic and grid systems, contributing to the adaptation of remote power supply/storage to specific application requirements.

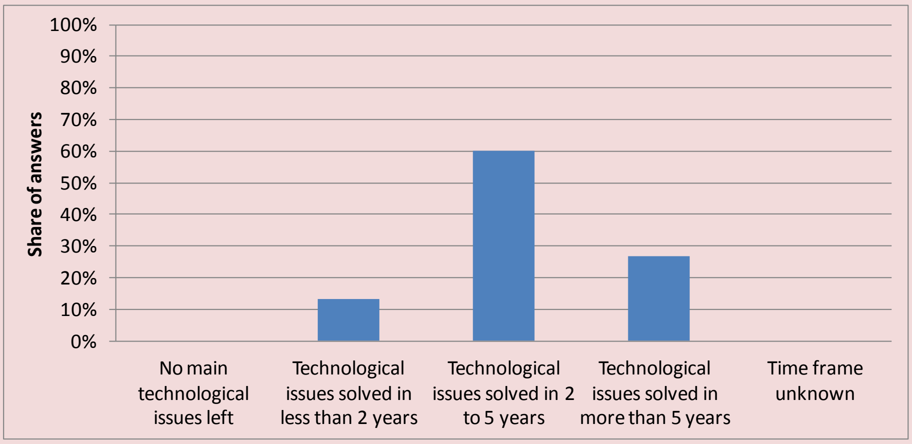
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Advanced Materials (AM)
- Advanced Manufacturing Systems (AMS)
- To a lesser extent a possibly important but not fundamental contribution from Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:

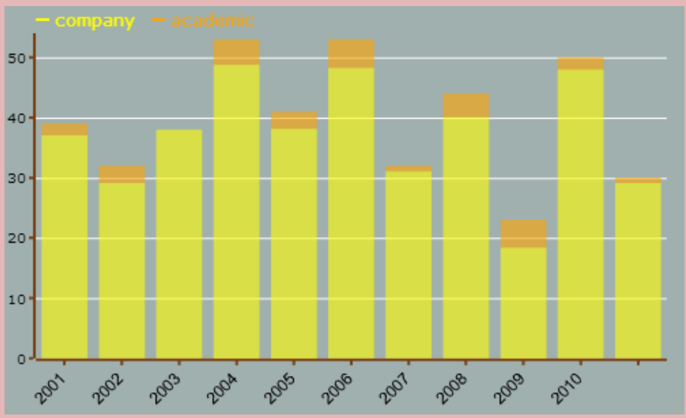


Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

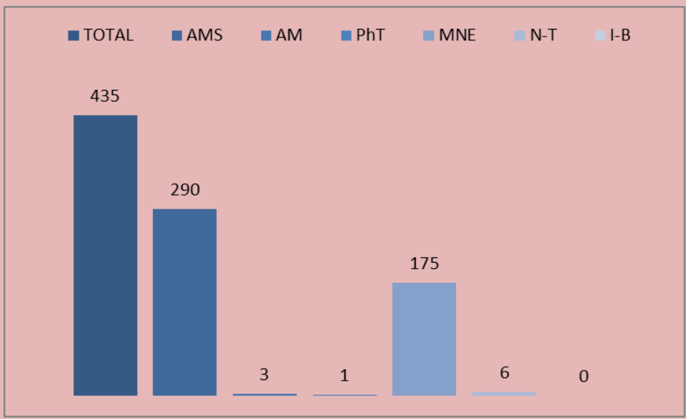
Additional information according to results of assessment:

- ***Impact assessment:***
  - Digital power control and conversion is at the heart of many nowadays energy challenges, namely e-mobility, energy efficiency in transport or manufacturing, power generation, transport and management into smart grids, autonomous systems and more specific aspects as for some space and science issues. Compared to previous analogue power technologies, these digital solutions allow reducing the number of discrete components and overall footprint of the subsystem, increasing power density, monitoring and optimizing power levels and system requirements whilst in operation and speeding up product time to market. Smart meters, on board vehicle advanced power management or the energy-efficient factory all need advanced power electronics to deliver their results.
  - The total global market for digital power components is forecast to quadruple to about 11.5 billion Euro from 2012 to 2017 (IMS Research 2012, quoted in Power Electronics Europe Jan/Feb 2013). With good positions in transport and energy, the two biggest application markets for power electronics, Europe has the potential for grasping major market shares from that growth.
- ***Results of patents scenario analysis:***
  - 435 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Quite stable trend curve (number of patents per year), possibly slightly decreasing

- Highest share of industrial applicants:



- Patents by KET(s):

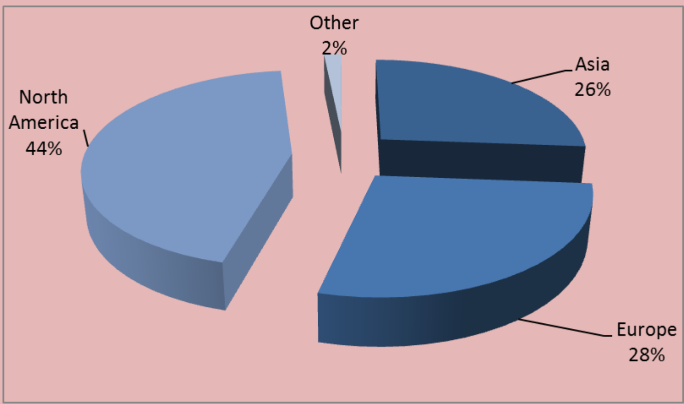


- Patents by KET(s) and relevant combinations of KETs:

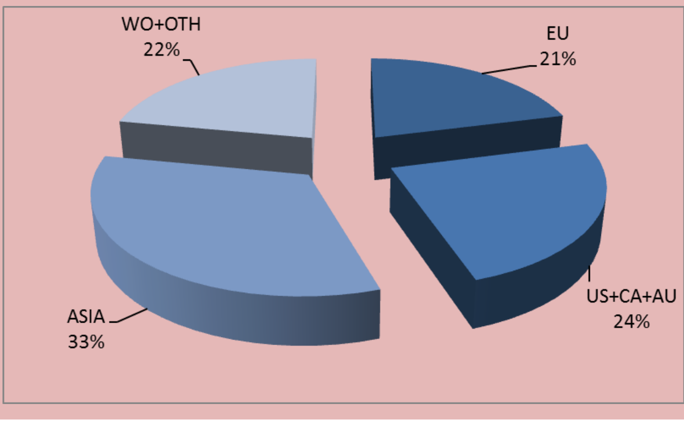
KET(s)	*Number of patents*
AM	3
AM / MNE	1
AM / MNE / N-T	1
AM / MNE / N-T / PhT	1
AM / MNE / PhT	1
AM / N-T	2
AM / N-T / PhT	1
AM / PhT	1
AMS	290
AMS / AM	3
AMS / AM / MNE	1
AMS / AM / MNE / N-T	1
AMS / AM / MNE / N-T / PhT	1
AMS / AM / MNE / PhT	1
AMS / AM / N-T	2
AMS / AM / N-T / PhT	1
AMS / AM / PhT	1
AMS / MNE	46
AMS / MNE / N-T	1
AMS / MNE / N-T / PhT	1
AMS / MNE / PhT	7
AMS / N-T	2
AMS / N-T / PhT	1

AMS / PhT	13
MNE	175
MNE / N-T	1
MNE / N-T / PhT	1
MNE / PhT	44
N-T	6
N-T / PhT	1
PhT	62

- Patent distribution by (Applicant) organization geographical zone:
- Japanese and US industries are dominating the top applicants list, but European companies as Philips, Semikron, ST Microelectronics, Siemens, Robert Bosch, Nokia, NXP or Infineon maintain significant positions



- Patent distribution by geographical zone of priority protection:



E&C.2.4: Lightweight vehicle embedded circuits and systems

Scope:

To develop electronic components and circuits adapted to (and qualified for) the specific constraints of vehicle embedded systems: lightweight and energy efficient, modular (as much as possible) and easily upgraded/retrofitted, resistant/resilient to vibrations and other operational constraints (dynamics, temperature, etc.), long campaign life and fit for architectures offering the best operational safety.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Increase of the usability of standard "off the shelf" components in embedded systems, including through virtualizing demanding processes / relying on external system intelligence
- Support of incremental and modular evolution of the systems, taking into account life

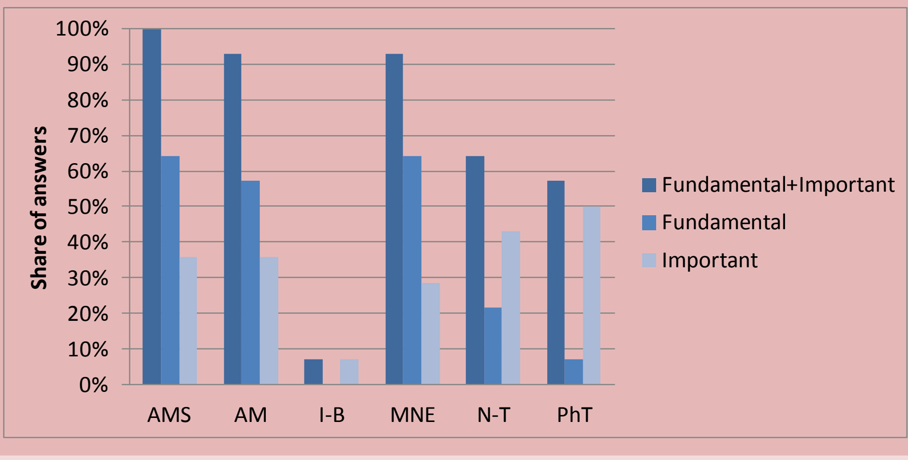
expectancy, obsolescence and upgrade of the components
- Development of safe and secure broadband wireless communications between subsystems
- Development of new integrated open, distributed and performing architectures (including through optic fibre networks)
- Reduction of weight and energy consumption of displays and other human machine interfaces
- Reduction of embedded electronics power consumption
- Reduction of embedded electronics weight through miniaturization and packaging improvement, facing issues on reliability, radiation shielding and heat dissipation

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced electronic components and circuits adapted and qualified for vehicle embedded systems, through miniaturization, exploitation of wireless communications, energy efficiency, incremental and modular evolution; systems have to take into account life expectancy, obsolescence and need for upgrade of the components, resistance / resilience to vibrations, dynamics, temperature and safety.

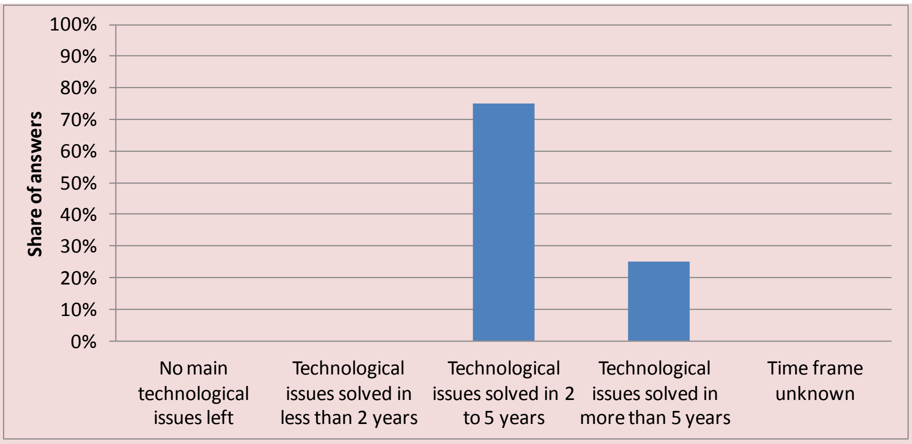
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Micro- and Nano-Electronics (MNE)
- Advanced Materials (AM)
- Nanotechnologies (N-T) and Photonics (PhT), with a less fundamental input



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:

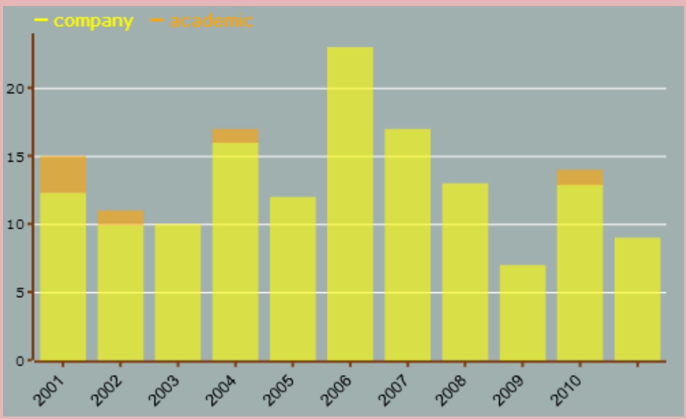


Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

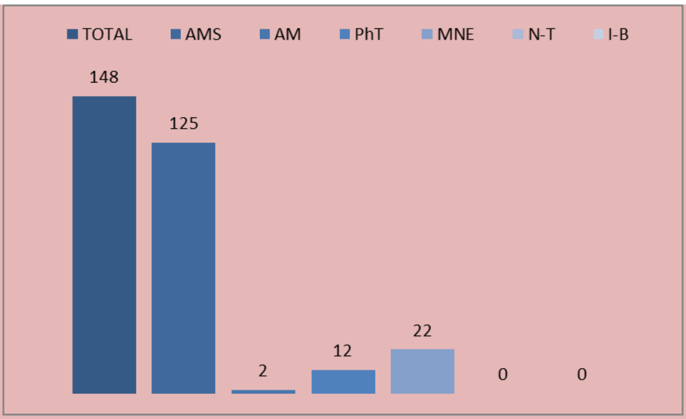
Additional information according to results of assessment:

- ***Impact assessment:***
  - Avionics typically represents only a few % of the total aircraft flying mass and is even lower in other types of vehicles. Nevertheless, with more and more electric systems on board, up to "full electric" including propulsion, that share of total vehicle weight is deemed to increase. Since flying weight is always direct energy consumption, minimizing the weight of embedded electronics is a matter of cost and environment efficiency (and of vehicle autonomy and range as well).
  - There is also a safety aspect to consider, since vehicle embedded circuits have to successfully face, whatever the conditions, specific constraints as vibration and vehicle dynamics, electromagnetic radiations from other vehicle circuits or passenger and crew personal devices in the enclosed Faraday cage of vehicle's structures, temperature changes, dust, etc. Increased safety levels typically means increasing protection from packaging, which has a direct weight cost. Working out lower weight components, circuits and architectures will reduce the pressure on the weight versus safety balance.
  - Europe is in a leading position in transport electronics and there is a direct beneficial cross-fertilization effect in supporting consolidated eco-system links between the European electronics and transport industries.
  - Last but not least, working out low weight electronics means working out materials, increase overall resource efficiency, including or critical resources, and provide opportunities for better recyclability.

- ***Results of patents scenario analysis:***
  - 148 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Quite stable trend curve (number of patents per year), had a peak around 2006
  - Highest almost exclusive share of industrial applicants:



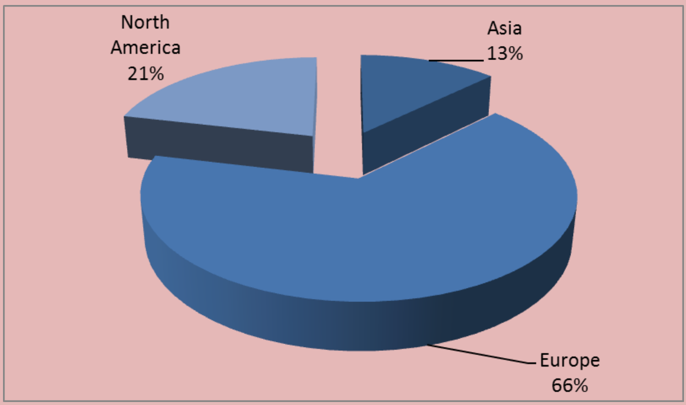
  - Patents by KET(s):



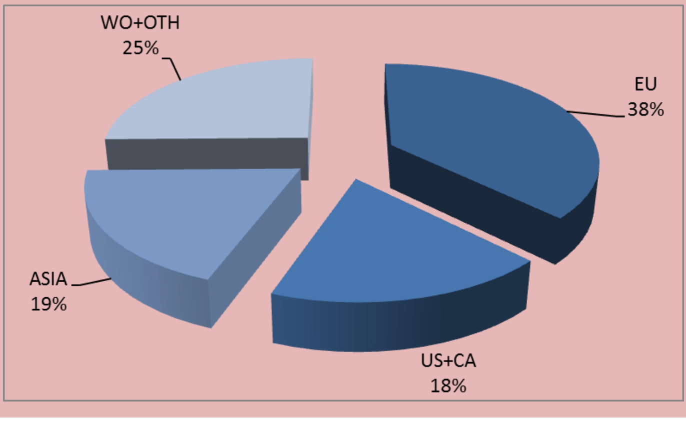
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	2
AMS	125
AMS / AM	1
AMS / MNE	4
AMS / PhT	3
MNE	22
MNE / PhT	5
PhT	12

- Patent distribution by (Applicant) organization geographical zone:
- German players, mainly from the automotive industry, dominate patent application in this field.



- Patent distribution by geographical zone of priority protection:



E&C.2.5: Circuits and systems for severe operational conditions

Scope:

To develop dedicated circuits and systems for severe environmental conditions of operation, as much as possible from adaptation of standard high performance electronic, electric and eletro-mechanical (EEE) components to extreme operational conditions (extreme temperatures, out of atmosphere radiations, space launch acceleration and vibrations, nuclear environment, etc).

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

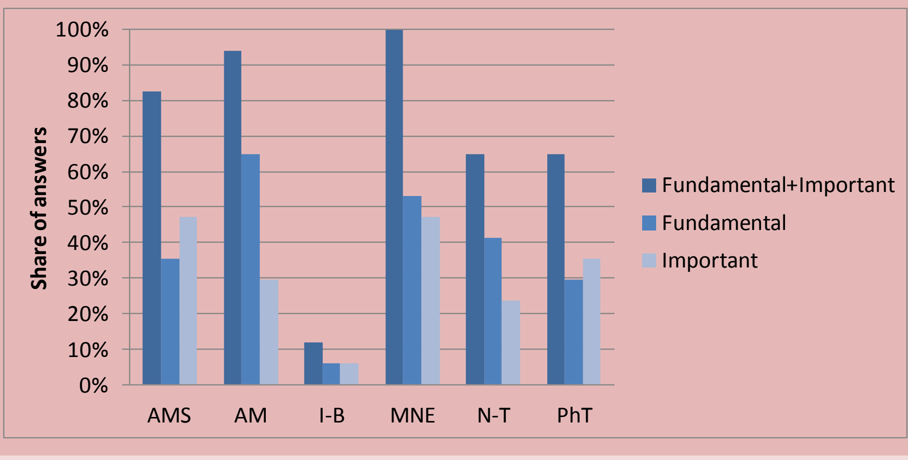
- Development, qualification and supply chain certification for radiation hardened components for mixed analogue, digital and RF applications, active or passive
- Development of robust, low and very low noise, linear and low power RF components and devices
- Qualification of an European source for space qualified high performance digital processing capabilities
- Qualification of European sources for high pin count hermetic and non-hermetic electronics packaging
- Development of high voltage / power components capable for high constraints applications
- Enable use of standard commercial off-the-shelf (COTS) components even into most demanding systems

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced dedicated circuits and systems for severe environmental conditions of operation, like radiation hardened components for mixed analogue, digital and active or passive radio-frequency (RF) applications, linear and low power radio-frequency (RF) components and devices, high voltage/power components, etc.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

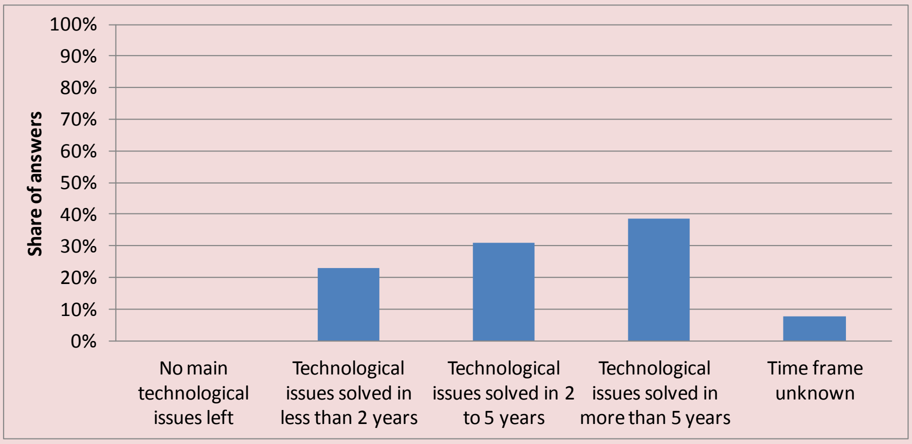
- Micro- and Nano-Electronics (MNE)
- Advanced Materials (AM)
- Advanced Manufacturing Systems (AMS)
- Nanotechnologies (N-T)
- Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more

than 5 years, yet significant consensus by experts indicates also shorter periods being necessary:

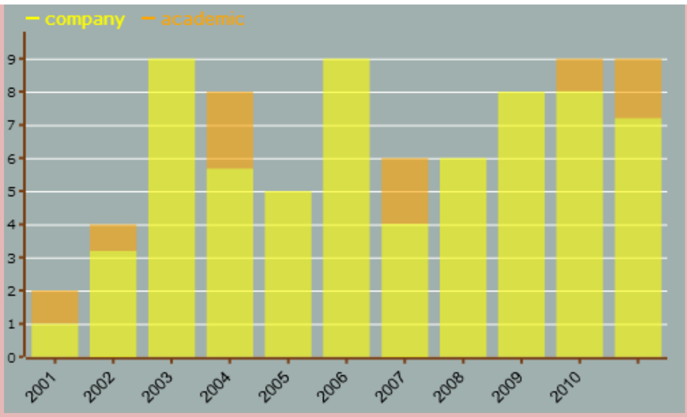


Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field and on the specific environment constraints to be faced as well as considering the rather longer lead times for these technologies requiring reliability demonstrations, the provision of support in the short to medium term should be taken into consideration within this framework.

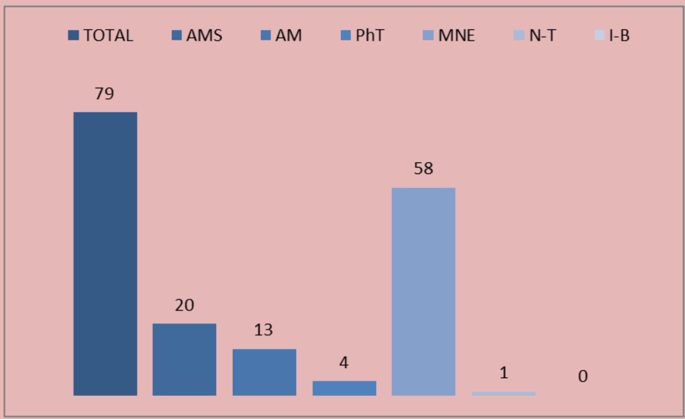
Additional information according to results of assessment:

- ***Impact assessment:***
  - Usual electronics are designed for operating under ordinary conditions of temperature, pressure, vibration, dust, ionizing radiations, humidity, etc. Circuits and systems for operations in harsh environments – including space, underground, underwater, nuclear, deserts, etc. – have to face fiercer operational conditions. Meanwhile, these operations in harsh environments often allow less fault-tolerance, so that requirements on all conditions reliability are higher than for usual components. Circuits and systems especially developed to face severe operational conditions while delivering high levels of performance are therefore mandatory for many applications in scientific research, offshore or underground resource exploration and exploitation, rescue missions, space and/or military activities, dismantling, decommissioning and decontamination of nuclear or otherwise polluted facilities, and eventually some industrial or energetic routine operations.
  - Among these applications, EEE (Electronic, Electrical and Electro-mechanical) components are especially crucial for space activities. With public budget crunches and commercial space reaching the industrial and standardized age, costly development of highly specific and costly fault-proof components and systems is becoming a significant issue. Attempts to use more standard, even directly off-the-shelf, radiation hardened components is a steady trend. Facing same constraints, military or scientific applications will be more and more looking to the same direction.
  - Meanwhile, costs in the electronics sector make it difficult to maintain production capabilities for low volumes of very specific components. The sector is facing concentration phenomena, but Europe has to make sure that it remains non-dependent for these critical components and hardened electronics based on advanced manufactured multi-KET components is a way of guaranteeing such capability.

- ***Results of patents scenario analysis:***
  - 79 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Increasing trend curve (number of patents per year)
  - Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants, most probably standing for new technologies having been patented in the corresponding periods:



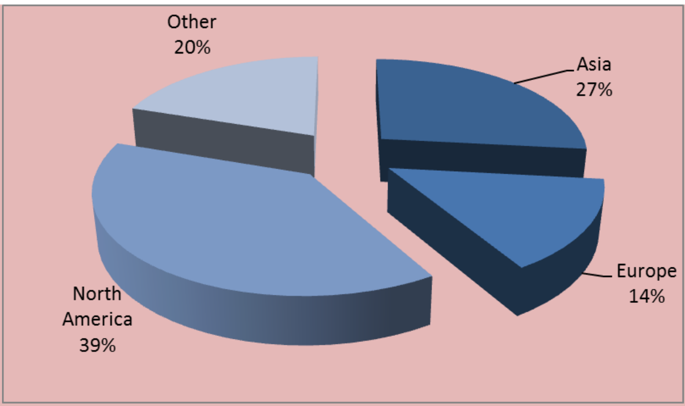
- Patents by KET(s):



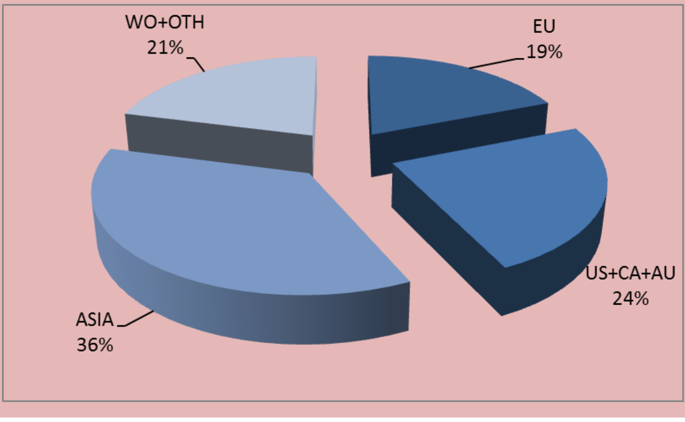
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	13
AM / MNE	10
AMS	20
AMS / AM	2
AMS / MNE	5
AMS / MNE / PhT	1
AMS / PhT	1
MNE	58
MNE / N-T	1
MNE / PhT	3
N-T	1
PhT	4

- Patent distribution by (Applicant) organization geographical zone:
- Patent application is very little concentrated, with the biggest applicants (Honeywell and Murata) having only 6 patents each in the period



- Patent distribution by geographical zone of priority protection:



E&C.2.6: Flexible large-area electronics

Scope:

To develop semi-conductive inks, substrate treatments and related manufacturing processes enabling printed and thin film electronics, eventually organic, for lesser performance but lower costs of circuits (compared to silicon electronics), and for developing large scale and flexible integration of smart capabilities into textiles/wearable products, packaging, buildings, lighting, etc.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

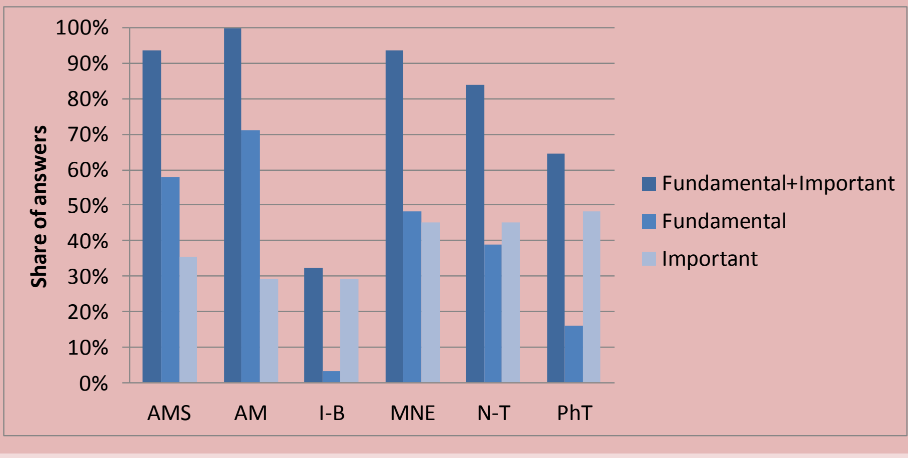
- Improvement of printed electronics for ubiquitous and flexible electronics (packaging, disposable electronic patches, "wearable electronics" incorporated on textile or cosmetics, chip cards, biometry, etc.), in particular for supporting smartification of all sorts of objects in the Internet of Things
- Improvement of conductive inks formulation and substrate treatment to reduce cost and adapt properties to final product requirements, in particular in terms of resistance to temperature or humidity
- Take advantage of organic electronics potential to develop low cost low computing power components, potentially including multiple functionalities on same circuits (luminescence, transparency, energy storage or generation, embedded memory, sensing, traceability, etc.)
- Development of high flexibility production processes (roll to roll, serigraphy, ink jet, etc.) for highly cost efficient large area printed electronics
- Development of small scale high energy density storage systems, as micro-batteries or small fuel cells, that are suitable for mobility-portability and/or autonomous applications

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the improvement of printed electronics for highly cost efficient large-area electronics applications thanks to the improvement of conductive inks formulation and substrate treatments. Requirements focus on resistance to temperature and humidity, multiple functionalities (e.g. luminescence, energy storage or generation, embedded memory, sensing, traceability, etc.), along with high flexibility and capacity production processes.

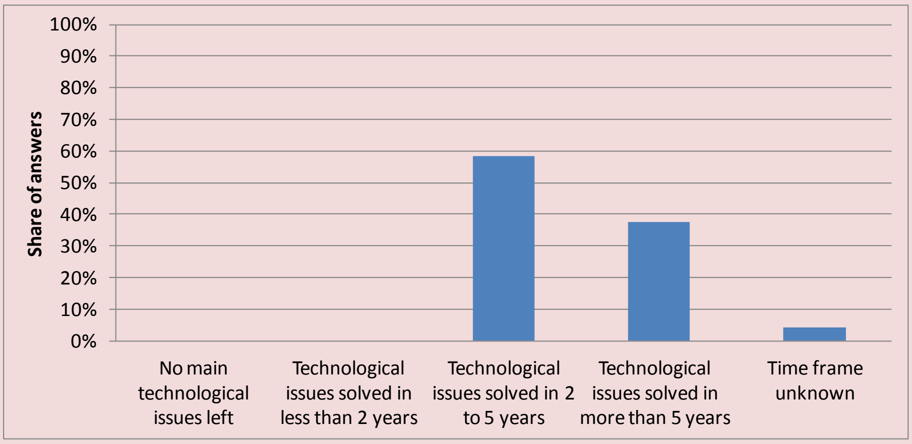
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Materials (AM)
- Advanced Manufacturing Systems (AMS)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- A less fundamental input from Photonics (PhT)



Timing for implementation:

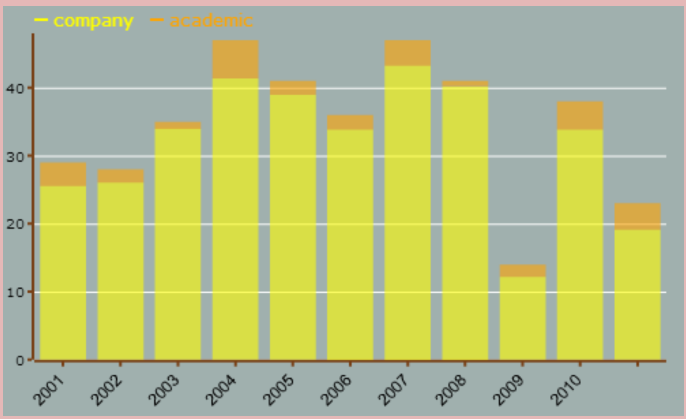
According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also longer periods being necessary:



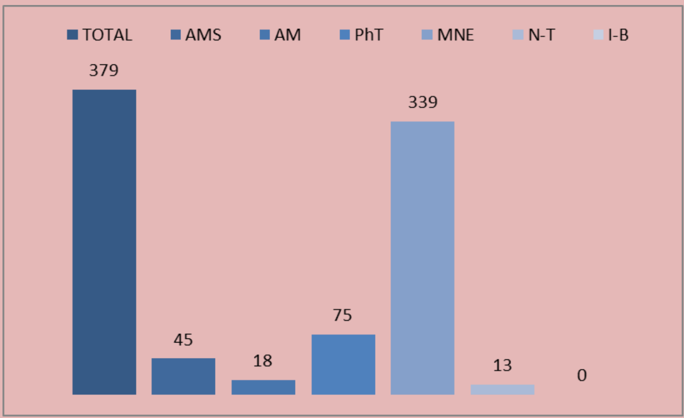
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Printed electronics allows producing low performance but low cost solutions for implementing smart capabilities into traditionally passive materials, such as building surfaces (wall papers, windows, etc.), papers or textiles. As such, it is a direct contributor to the "Smartification" of our everyday environment, to the "Internet of Things", "Smart Cities" and all forms of information enrichment of our environment.
  - A major application concerns energy efficient buildings, with opportunities on thin film photovoltaic, lighting, ambient conditions or materials aging monitoring. Others are in "intelligent" products packaging, i.e. in the agro-food sector, heating textiles, e-newspapers, advertisement, etc. All these are still emerging or even still-to-be-born markets but the lights and screens from printed organic Light-Emittign Diodes (LED) are in particular expected to grow from a few tens of million dollars in 2012 to several billion from 2015.
  - An important impact of the printed electronics sector is the opportunity to offer growth relays to the paper and printing industries, in difficulties in Europe in the recent years but still employing 850 000 persons in Europe and generating more 100 billion Euro annual turnover (source: EC DG Enterprise and Industry website).
  - Many opportunities for suppliers of the mentioned technologies can derive from the transfer of the technologies and know-how from the military and defence sector into civilian applications.
- ***Results of patents scenario analysis:***
  - 379 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Quite stable trend curve (number of patents per year) with a strong downturn in 2009, since in recovery
  - Highest share of industrial applicants:



  - Patents by KET(s):

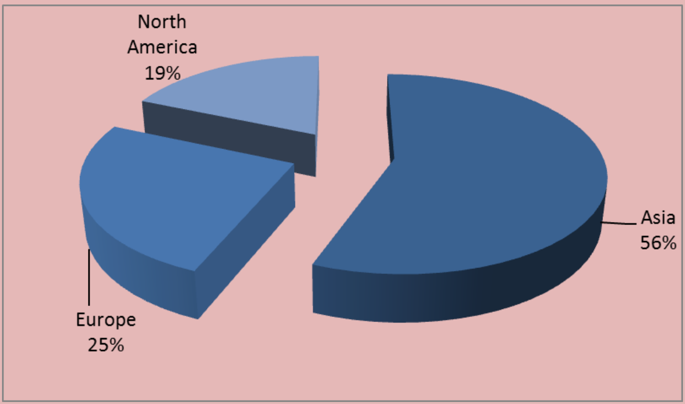


  - Patents by KET(s) and relevant combinations of KETs:

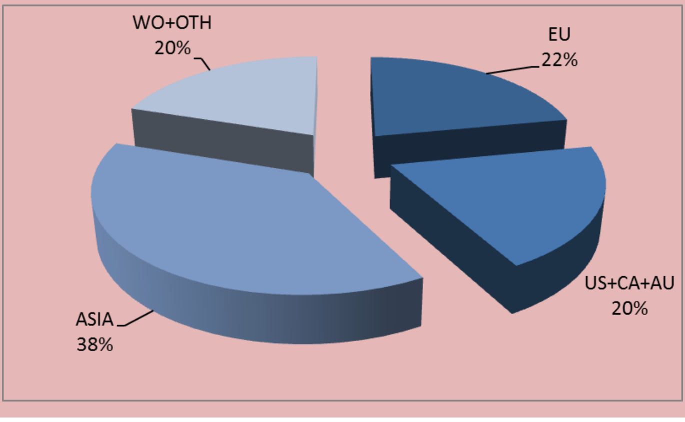
KET(s)	*Number of patents*
AM	18

AM / MNE	11
AM / MNE / N-T	7
AM / MNE / N-T / PhT	1
AM / MNE / PhT	2
AM / N-T	8
AM / N-T / PhT	1
AM / PhT	3
AMS	45
AMS / AM	1
AMS / MNE	16
AMS / MNE / PhT	5
AMS / PhT	7
MNE	339
MNE / N-T	10
MNE / N-T / PhT	2
MNE / PhT	69
N-T	13
N-T / PhT	2
PhT	75

- Patent distribution by (Applicant) organization geographical zone:
- Asian players, mainly Japanese, are dominant. However European players like Philips, Siemens, Infineon, Polyic, Alcatel, Epcos, CEA or NXP are still in the race



- Patent distribution by geographical zone of priority protection:



Sub-domain: Smart and user-centric consumer electronics

Demand-side requirements (stemming from Societal Challenges) addressed:

- "Inclusive, innovative and reflective societies" and a competitive European economy need breakthrough innovations, smart capabilities, personalized services and high performance systems to be made available to consumers and citizens
- Twentieth century consumer society produces huge wastes of energy and resources. Waste Electrical and Electronic Equipment Directive (WEEE), the European Community directive 2002/96/EC, highlights the specific role to be played by the consumer electronics industry in building up a sustainable model
- Individual behaviour changes can have a dramatic impact on environment and climate impact; they have to be supported with life-easing technological solutions. Smartification and convergence of consumer electronics have a role to play in a better organization of society consumptions
- Protecting citizens security and freedom requires personal data and personal equipment and systems to be protected against misuses and malevolent actions

Demand-side requirements (stemming from market needs) addressed:

- Consumer electronics markets deliver a wide variety of services to European customers, including for entertainment, education, sports, well-being, lifestyle, communication, home services, connected mobility, etc. These markets experience rapid shifts based on evolution of the needs or on product-based new opportunities that create their own markets. Open innovation driven by the use is requested to quickly identify and support fast-adoption technologies
- Context-aware, personalized and convergent capabilities embedded into seamless experiences and serving smart services are necessary for citizens to go on with buying new products and services without being stuck in a growing complexity
- Guaranteeing a sufficient level of trust, privacy and security is mandatory for supporting a sustainable acceptance of Information-based services

E&C.3.1: Convergence and smartification of consumer electronics

Scope:

To develop high usability and multi-functional consumer lifestyle products (e.g. washing machine, television), supported by high degrees of connectivity and convergence of all home/consumer equipment and devices, so as to support advanced consumer services as more automation of house-keeping, assisted-living, etc.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- "Smartification" (novel information-based functions) of classic devices through connectivity and automation
- Development of multi-function devices, converge devices by means of functionality (e.g. MP3 players become more and more obsolete due to the emergence of smart-phones that allow for extensive music consumption, include smart phone functionality in TVs, etc.)
- Increase of connectivity of multi-media devices
- Development of robots as smart household helpers
- Development of services taking advantage of the novel smart functions

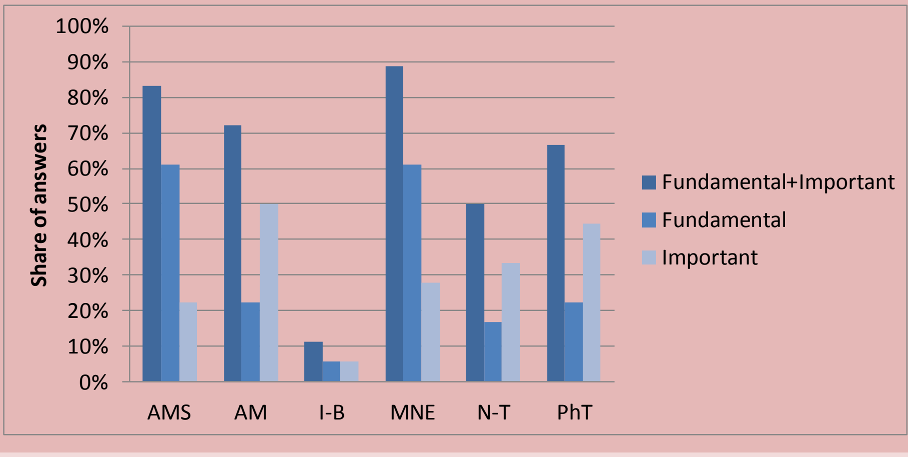
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to achieving higher levels of "smartification" of classic devices and systems through increased connectivity and automation, thanks to the integration of novel functions supported by appropriate miniaturized and embedded hardware components.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

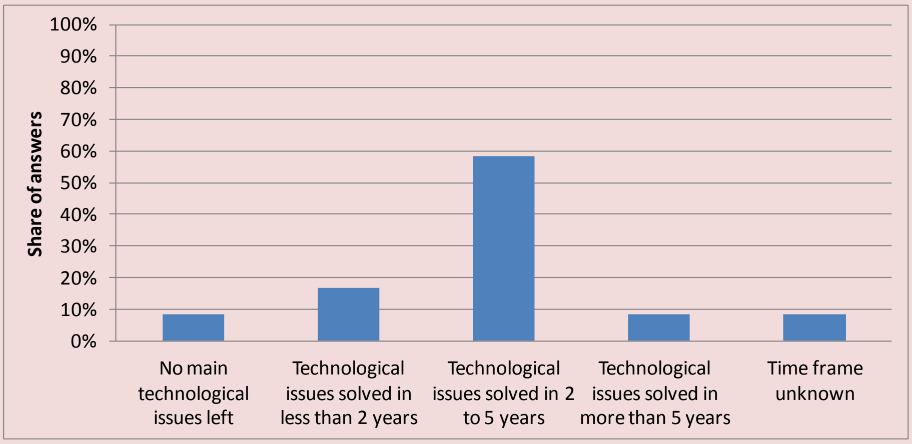
- Micro- and Nano-Electronics (MNE)

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM), Nanotechnologies (N-T) and Photonics (PhT), with an important but less fundamental contribution



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

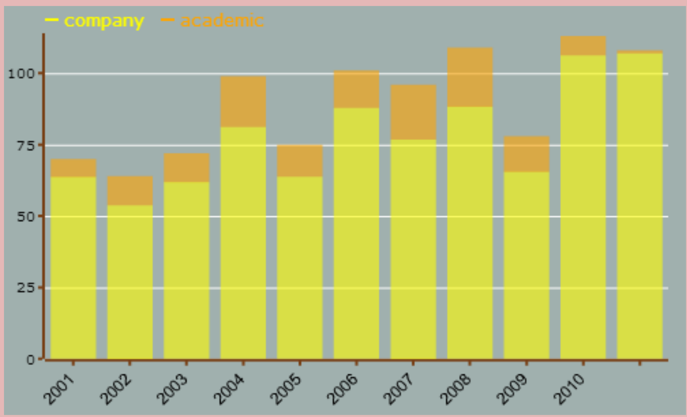
Additional information according to results of assessment:

➢ ***Impact assessment:***

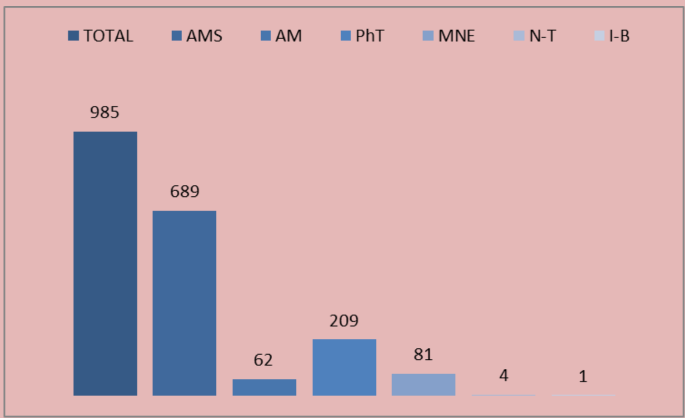
- Consumer electronics gather consumer devices and home equipment used for entertainment, home care, communication, office works, education, personal care and wellbeing. Organizing their convergence and smartification will improve delivered services whilst delivering social, environmental and economic benefits.
- New services will support more creative and innovative usage of electronic devices and provide better services with the help of more personalization, planning and decision-making assistance, remote controls and nomadic usage capability, more user-friendly interfaces and attractive designs. Massive market growth can be supported by such new functionalities, if security and privacy is ensured so that trust between citizens and industry is maintained.
- Western Europe has lost a large part of its industrial capabilities in such innovation field, but in some cases to the advantage of Eastern and Central Europe and with relevant players remaining in Europe with know-how in designing high added-value consumer electronics.
- Social, environmental and economic benefits are expected from KET-based convergence and smartification, through better context-aware energy usage and management (e.g.

home equipment able to start when energy is abundant and cheap and stop when it is not, easier interfaces enabling better inclusion of elderly or disabled persons, personalized healthcare support, waste reduction assistance (e.g. with the smart fridge), etc.

- ***Results of patents scenario analysis:***
  - 985 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Increasing trend curve (number of patents per year), with a decreasing share of academics (sign of technology reaching industrial maturity)



  - Little concentration of patent applications (top 10 applicants represent only 7 to 22% of annual applications, depending of the years). Except Sharp and Sanyo (Japan), top applicants are either US or European, balanced between the two regions.
  - Patents by KET(s):

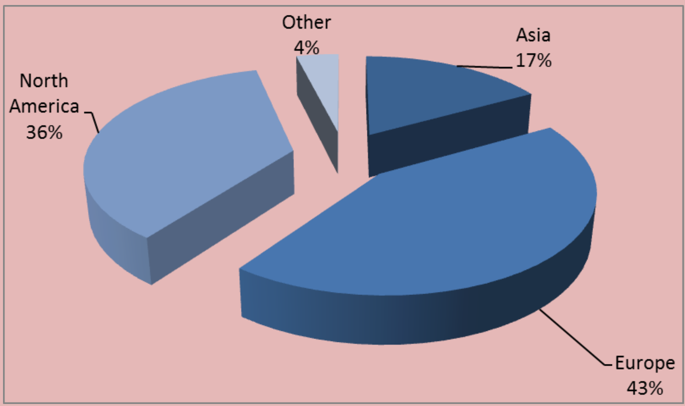


  - Patents by KET(s) and relevant combinations of KETs:

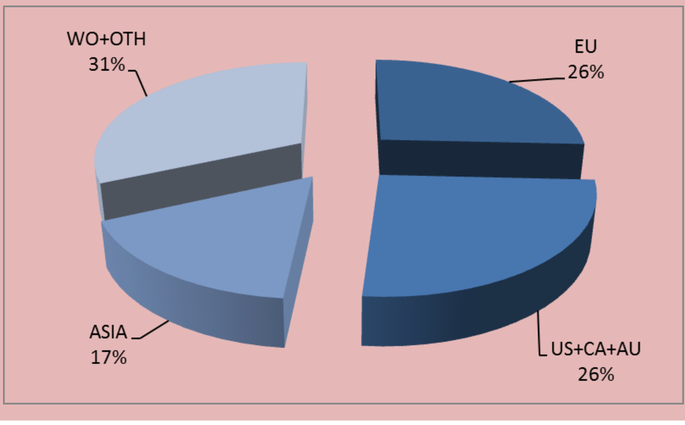
KET(s)	*Number of patents*
AM	62
AM / MNE	1
AM / MNE / PhT	1
AM / N-T	2
AM / PhT	5
AMS	689
AMS / AM	6
AMS / MNE	16
AMS / MNE / PhT	2
AMS / PhT	10
IBT	1
MNE	81
MNE / N-T	1
MNE / PhT	22

N-T	4
N-T / PhT	1
PhT	209

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



E&C.3.2: Small scale embedded energy systems

Scope:

To develop power systems and solutions, such as battery or fuel cell systems, for supplying mobile and autonomous devices with embedded energy in an operational, safe, cost-effective, user-friendly and long-lasting format.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of small scale high energy density storage systems, such as micro-batteries or small fuel cells, that are suitable for mobility-portability and/or autonomous applications
- Ensure production is cost-effectively feasible on the large scale, i.e. materials used are available in sufficient quantities at a reasonable cost (in particular critical materials are replaced by synthetic equivalent) and processes are cost-effective
- Ensure operations are safe in all operating conditions (temperature, humidity, vibrations), resilient to manipulations and chocks, including in terms of connectivity
- Package the energy systems so as to be easy to plug and charge
- Development of solutions, e.g. printed batteries, for very small power storage, particularly for very small autonomous devices as distributed sensors, eventually coupled with energy harvesting solutions
- Development of high scalability and modularity systems through improved encapsulation of small capacities
- Ensure long-enough campaign life of energy storage systems, and/or monitor system

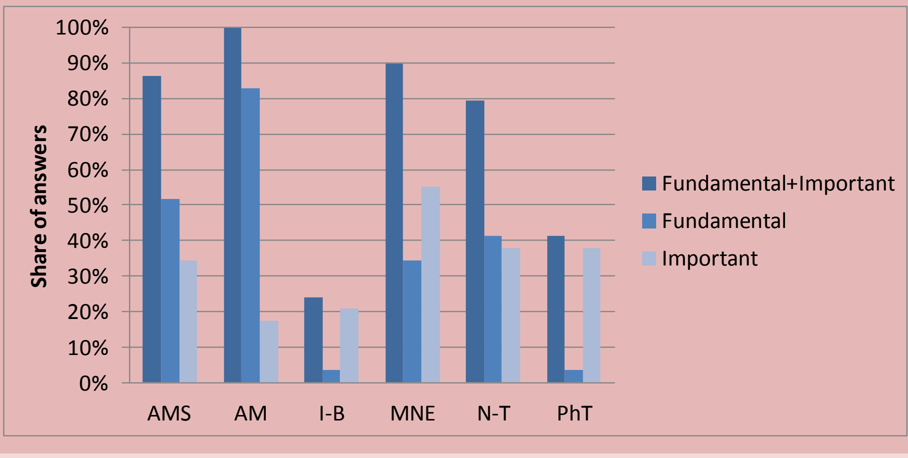
ageing with embedded sensing and interpretation capability

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of small-scale, high energy density storage systems, such as micro-batteries (also printed ones) or small fuel cells, suitable for mobility-portability and/or autonomous applications, ensuring cost-effectiveness, reduced dependency on critical materials, safety in operating conditions, long life cycle, scalability and modularity.

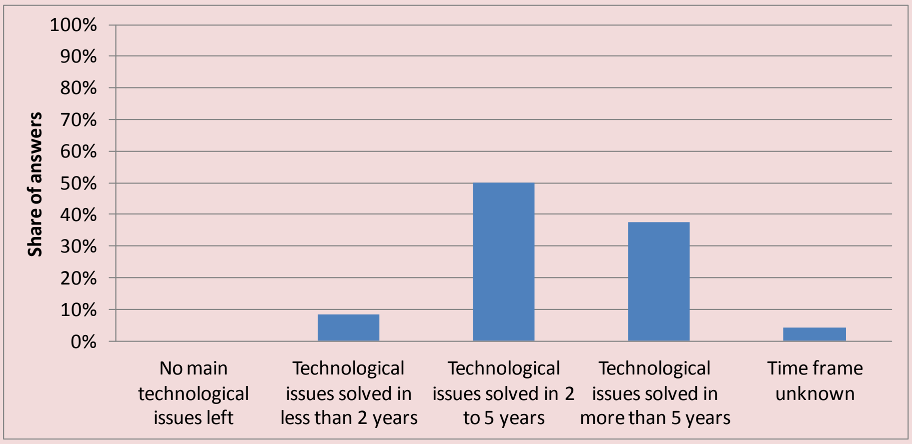
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Materials (AM)
- Advanced Manufacturing Systems (AMS)
- Nanotechnologies (N-T)
- Micro- and Nano-Electronics (MNE) and Photonics (PhT), less fundamentally



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also longer periods being necessary:

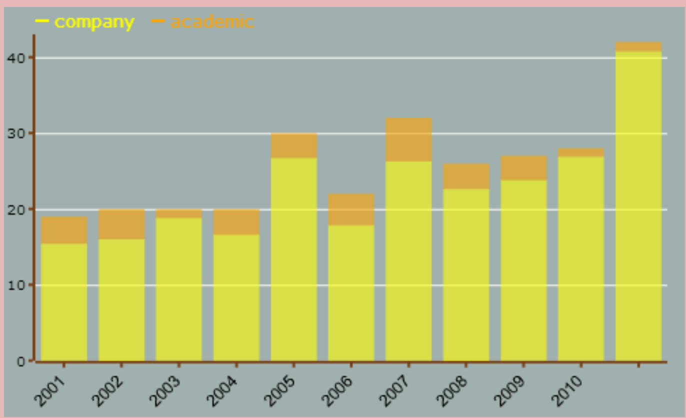


Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

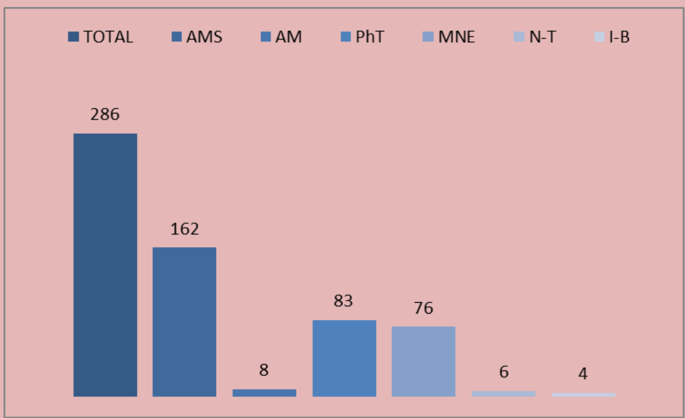
Additional information according to results of assessment:

- ***Impact assessment:***
  - Considering the evolutions of mobility and nomadic uses, energy systems embedded in any sort of devices are becoming a critical point. Lithium-ion batteries have played a major role in the development of the mobile phone market and they continue being a best seller, highly demanding needs on power or autonomy require alternatives in battery technologies, other sorts of energy storage (as fuel cells), energy scavenging (as energy captured from motion or micro-solar PV) and their combination into integrated energy systems to be driven to market deployment.
  - Developing more diverse sets of nomadic energy systems will also help relieving pressure on critical raw materials, especially considering that new technologies are developed taking into account the recyclability requirement.
  - Small scale embedded energy systems have been developed in the defence sector. This background can be applied to the civilian market by using already developed technologies and consolidated know-how.

- ***Results of patents scenario analysis:***
  - 286 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Increasing trend curve (number of patents per year)



  - Patents by KET(s):

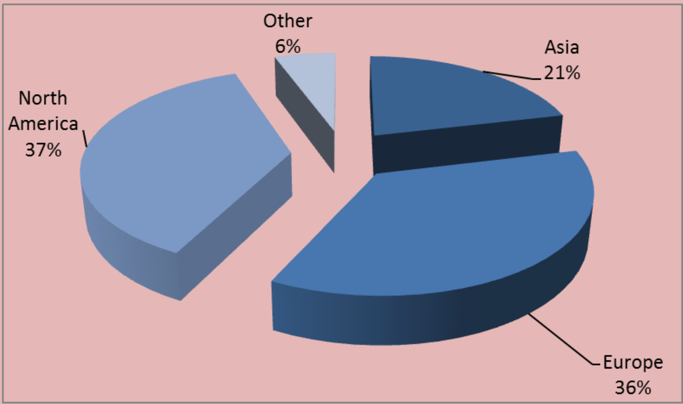


  - Patents by KET(s) and relevant combinations of KETs:

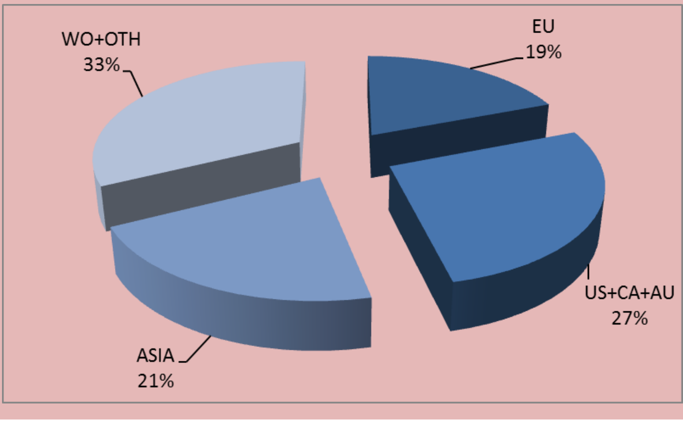
KET(s)	*Number of patents*
AM	8
AM / MNE	1
AM / MNE / N-T	1
AM / N-T	3
AMS	162
AMS / MNE	2
AMS / MNE / PhT	1
AMS / PhT	2

IBT	4
MNE	76
MNE / N-T	1
MNE / PhT	45
N-T	6
N-T / PhT	1
PhT	83

- Patent distribution by (Applicant) organization geographical zone:
- Patent application is very little concentrated, with the biggest applicants (Philips and Honeywell) having only applied 6 patent families each in the period



- Patent distribution by geographical zone of priority protection:



Sub-domain: Communication as the backbone of the Information Society

Demand-side requirements (stemming from Societal Challenges) addressed:

- Inclusive society is also about closing the digital divide (according to the Digital Agenda for Europe (DAE), 78% of EU citizens use the internet at least once a week, 20% never used the internet, and 62% of the EU has 30Mbps broadband, but only 18% of rural areas). Skills or network deployment are to be supported, but technological developments are required in broadband wireless communications, very high broadband wireline communications, networks interfacing and systems autonomous connectivity, user-friendliness
- With ubiquitous digitalization, cyber-security and protection of the communications is a crucial contributor to a safe EU secure and free society
- Improved transport and energy services, as well as all sorts of system monitoring services (environment monitoring, homeland surveillance, industrial supply chains, etc.) all rely on ever-growing flows of digital information, increasing the need for reliable high throughput communication networks

- Information and communication technologies consume around 2% of global energy consumption, and this is the sector with the fastest growth over past and probably upcoming years. Increasing energy efficiency in Information and Communication Technology (ICT) is crucial

Demand-side requirements (stemming from market needs) addressed:

- Volumes of data exchanges have been continuing growth in the recent years, while European telecommunication operators have been experiencing a drop. These operators expect improved communication networks to provide them with capabilities for new services and constitute important growth and profitability relays
- Normalization is a very important driver or barrier for telecom-related industrial activities. Being at the top-front of innovation in low layer telecoms often provides a direct competitive advantage
- Concern is growing in society about electromagnetic waves. In the meanwhile, the radiofrequency spectrum is a limited resource more and more intensively exploited. Optimizing wireless networks for minimizing resource use and possible health impacts is getting more and more important

E&C.4.1: High autonomy communicating devices

Scope:

To develop cost-effective and all-size embedded sensors with high connectivity for the Internet of Things, or for airborne or satellite-based Earth / environment observation, with embedded sensor systems and observation/detection instrument chains or autonomous sensors / devices making use of remote power supply/storage and/or micro energy harvesting.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of embedded sensor systems and instrument chains, including miniaturized high stability and reliability systems with accurate pointing for large and/or active optical observation systems
- Miniaturization of communicating modules and devices embedded systems, possibly including sensors and human interface systems, so as to reduce overall size (down to “smart dust”), weight and power consumption of devices
- Development of smart meters with high connectivity for real time operation control
- Adaptation of remote power supply/storage to specific requirements of application (e.g. very long lifetime without recharging, wireless power, etc.)
- Combination of very low embedded system energy consumption, unlimited cycle zero power leakage energy storage and embedded energy harvesting capability (off-grid power supplies using environmental or parasitic power sources) to enable long and very long device autonomy
- “Smartification” (novel smart functions) of classic devices through automated connectivity
- Increase of energy storage capabilities of handsets (batteries), combined with optimized handset systems' and architecture power consumption (including advanced sleep/active switch and context-dependent system adaptation), and possibly energy harvesting
- Increase of resolution and observation range of satellite-based/airborne Earth observation detectors (including sub-mm optical observation, infra-red (IR) & ulta-violet (UV) spectrometry, radar systems, sub-mm radiometry, X-ray detection, fine interferometry, humidity detector, complementary metal-oxide semiconductor (CMOS) imagers, magnetometers, etc.)
- Minimization of noise on detectors, including with high efficiency zero vibration cryo-coolers, and develop systems to detect and control residual errors
- Increase of performance of embedded computing and enable smartification/data optimization of collected information
- Creation of open networks of embedded systems
- Enable context-dependent scalability of device activity, including dynamic adaptation of emission power to real communication environment, context-based sleep/active cycles and automated low power cost connectivity
- Development of stable, reliable and high power lidar instruments for environment

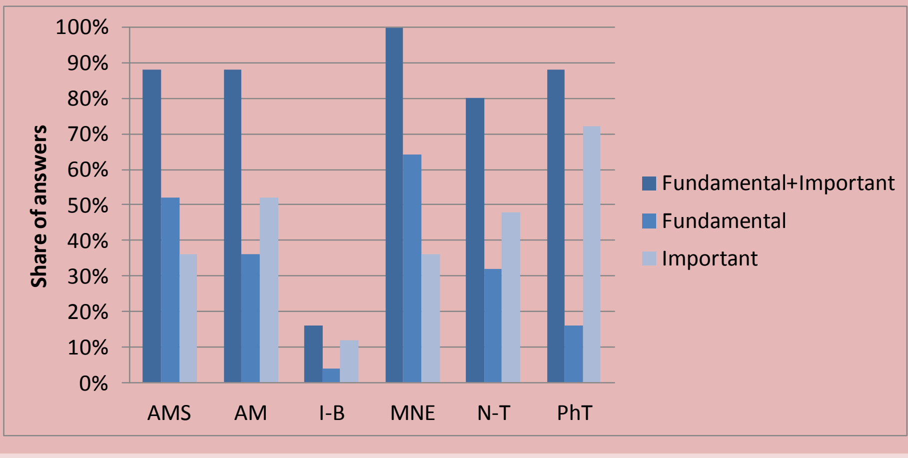
observation, including wind measurements or pollution monitoring

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of cost-effective and all-size embedded sensors with high connectivity, including autonomous sensors/devices making use of remote power supply/storage and/or micro-energy harvesting, building on miniaturization of communicating modules and devices embedded systems. The integration of KETs could moreover contribute to minimizing noise on detectors.

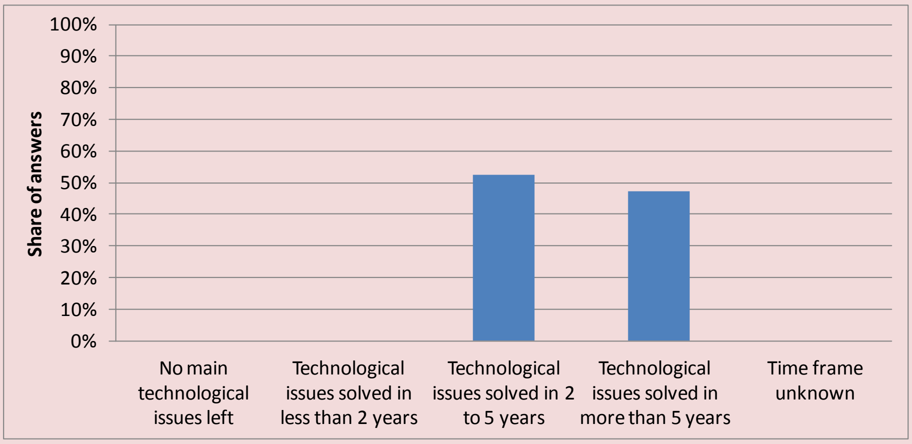
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Photonics (PhT)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also longer periods being necessary:

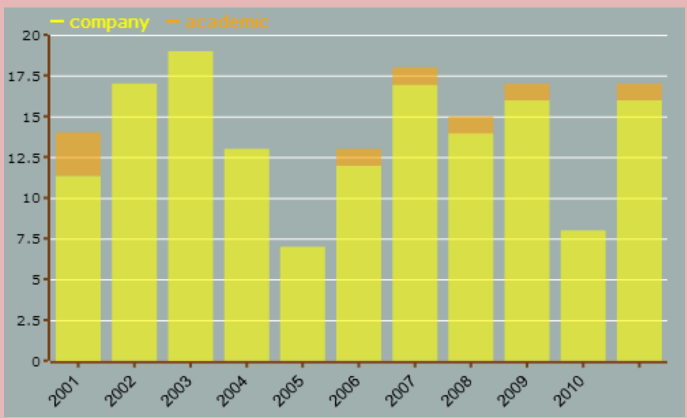


Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

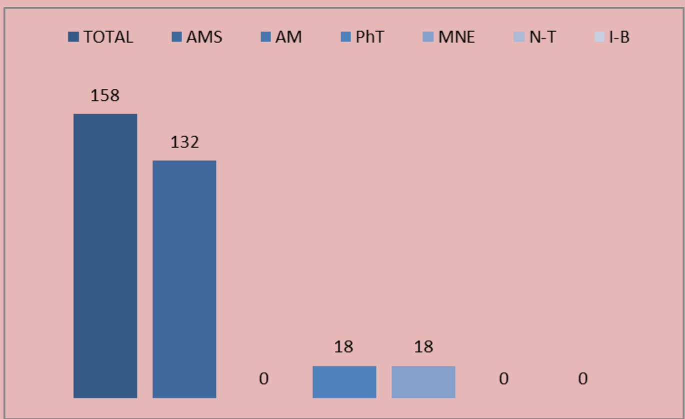
Additional information according to results of assessment:

- ***Impact assessment:***
  - Communicating devices, in particular but not limited to sensors, are direct contributors to the "Smartification" of our everyday environment. Converged with the capability for autonomous operation – energy storage and management, minimal consumption, energy harvesting or simply passive communicability – they are enablers to the "Internet of Things", advanced production and supply chains, "Smart Cities" and all forms of wide spread information enrichment of our environment. They contribute to efficient management of distributed resources, cargo or baggage management, area surveillance for unauthorized intrusion detection and identification or environment protection, infrastructure, buildings or vehicles health monitoring, tourist information, etc.
  - A specific case of these autonomous communicating devices, based on passive and near-field radio-frequency identification (RFID) and data exchange, is the RFID set of technologies, including tags, readers and software/services for RFID cards, labels, fobs and all other form factors. In 2014, the total global radio-frequency identification (RFID) market was worth 7 billion Euro, up from 6 billion Euro in 2013 and 5.4 billion Euro in 2012, forecast to rise to 23.2 billion Euro in 2024 (source: IDTechEx 2014). With the help of active communicability, other solutions in this field are expected to open even bigger market opportunities.
  - Sensing or monitoring system which may include a vehicle or vehicles (submarine, water surface, land, air, space) which is operated autonomously (or capable of being operated autonomously) has been developed for defence sector. Thus the contribution of this technology to civilian applications can be really significant in the near future.

- ***Results of patents scenario analysis:***
  - 158 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Quite stable trend curve (number of patents per year)
  - Highest almost exclusive share of industrial applicants:



  - Patents by KET(s):

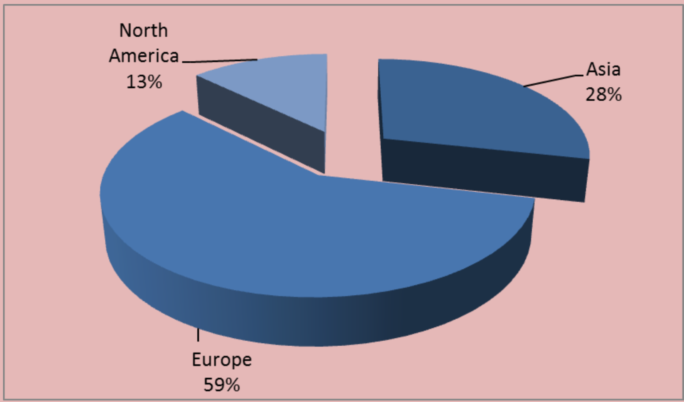


  - Patents by KET(s) and relevant combinations of KETs:

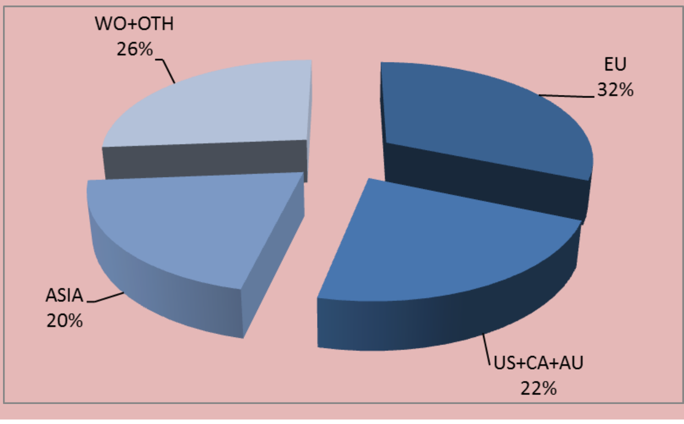
KET(s)	*Number of patents*

AMS	132
AMS / MNE	1
AMS / PhT	1
MNE	18
MNE / PhT	8
PhT	18

- Patent distribution by (Applicant) organization geographical zone:
- Strong position of the European applicants on this field, 14 out of the 19 top applicants are European (9 German) and Siemens alone applied 18 patent families in the period (11% of the global total)



- Patent distribution by geographical zone of priority protection:



E&C.4.2: Advanced broadband wireless communication

Scope:

To develop radio-frequency technologies for seamless, high-performance (broadband), reliable, interoperable, efficient and secure wireless communication, including cognitive radio and new radio technologies to make better use of the limited radio spectrum and advanced wireless networks with increased bandwidth and energy efficiency and multiple communication chips in single platforms such as radio-frequency micro electro-mechanical systems (RF-MEMS) or Antennas and radio-frequency (RF) parts for next generation wireless networks.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Combination of all relevant solutions to make a better use of limited radio spectrum
- Ensure a tight-integration of network deployment
- Development of very high bandwidth small directive antenna
- Development of broadband integrated wireless network architectures taking advantage of network diversity, including direct peer-to-peer communications, mesh networking, cross-layer design, cognitive networking, etc.

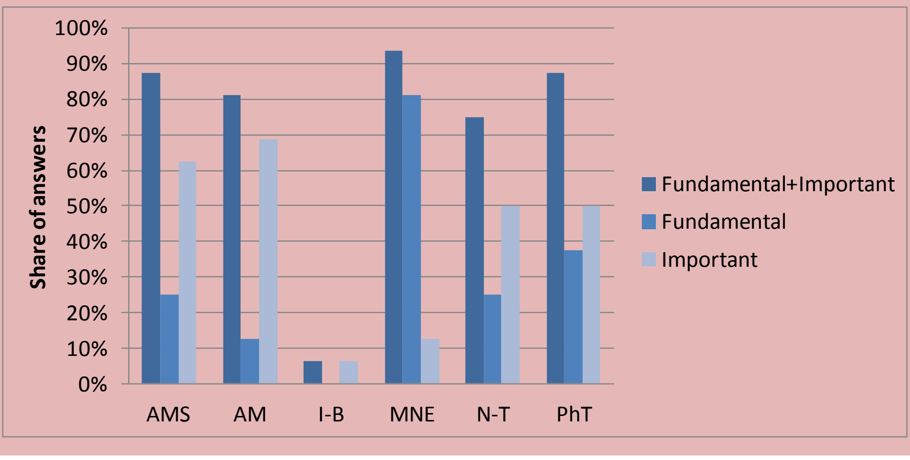
- Integration of multiple communication chips into single platforms to support multiple network connection (cellular 3G/4G, wireless local area network (WLAN), near-field and other short range communication, wireline with Ethernet or optic fibre connection)
- Firmware over the air capability for remote control of software components in wireless networks management
- Development of very high frequency short distance directional communication means, including cost effective stations and low power related processing capabilities
- Leverage sensitivity of spectrum scanning sensor, including through collaborative sensing between different sensors
- Improvement of theoretical characterization and physical layer realization for cognitive radio networks, with sense-and-avoid techniques (as machine learning and/or artificial intelligence) to learn on unused frequency bands at a given time, optimize spectrum use from wireless communications and develop the concepts for related platforms
- Use of adaptive waveform to dynamically reconfigure and match instantaneous spectral availability with transmission parameters (freq. band, transmitted power, modulation schemes, etc.) of the radio platform
- Development of terminals and infrastructure for innovative (incl. cognitive) radio solutions (analogue front-ends and digital platforms, antennas and antenna interfaces), including through the integration of radio-frequency micro electro-mechanical systems (RF-MEMS) and of joint combination of sensing, localization and identification for context aware and ultra-low power communication, pro-active context sensitive systems
- Development of open hardware radio platform integrating software configurable elements, i.e. virtualizing middleware, to support re-configurability
- Broadcast spectral traffic digital information for neighbouring nodes, using multiple antenna systems or high frequency selectivity forms of signal (as multi-carrier modulations) for avoiding harmful interferences
- Development of high computational capability low power communication chipsets and modules for RF front end, signal processing, digital processing and handset or other devices accessories (imagers, memories, embedded sensors, localization devices)

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced broadband wireless communication, building on radio-frequency technologies for seamless, high-performance, reliable, interoperable, efficient and secure wireless communication and advanced wireless networks with increased bandwidth and energy efficiency. This may be achieved e.g. by high bandwidth directive antennas, multiple communication chips, and short distance directional communication means.

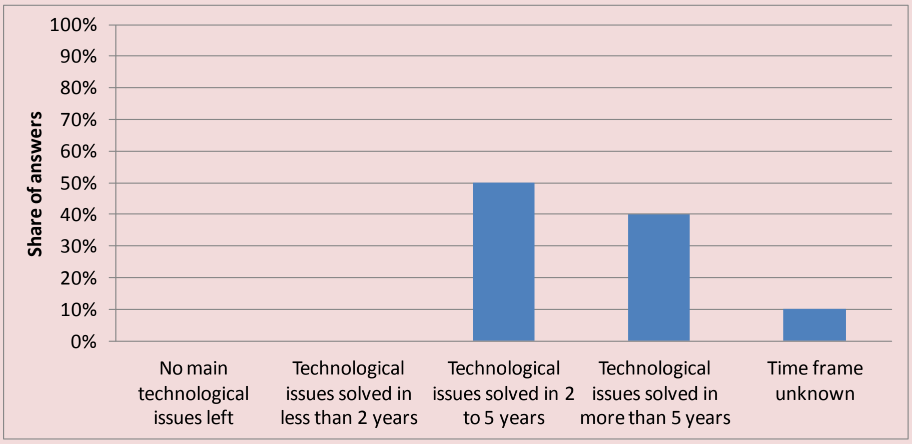
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Photonics (PhT)
- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also longer periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

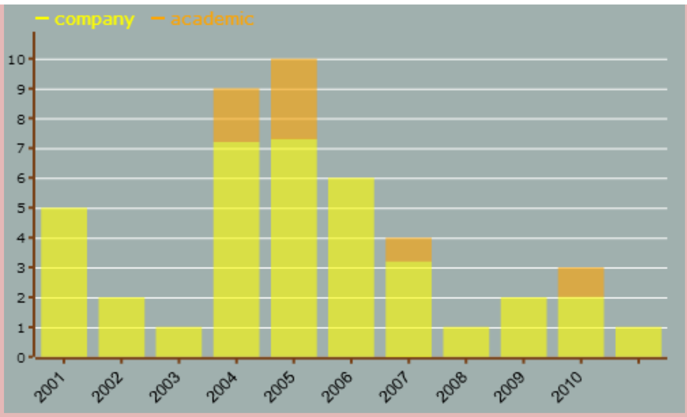
Additional information according to results of assessment:

➢ ***Impact assessment:***

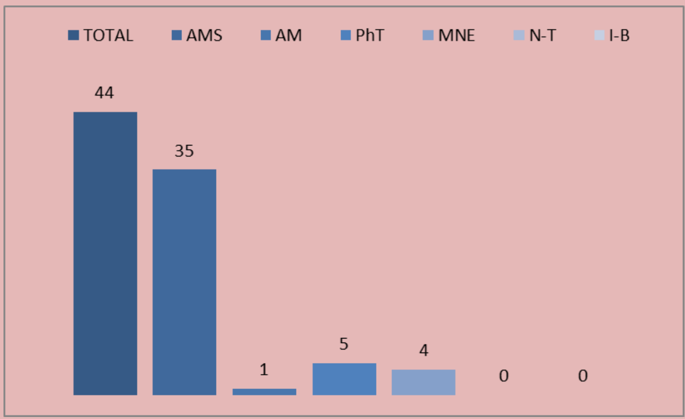
- The quality of service offered by wireless communications has been experiencing continuous improvement, in particular in terms of bit rate (bps) theoretically and practically offered to users. This has been commercially translated into generations of technologies: historical analogue cellular systems, 2nd generation or 2G with first digital cellular, 3G with combining voice and data and allowing mobile internet access and now being deployed 4G with high speed and more flexible connections. 5th generation, 5G, does not exist yet but the term is used to identify future ultra-broadband wireless communication that could support massive cloud computing and the ubiquitous communicating devices of the Internet of Things deployment around 2020. Rather than real generation effects, many technological steps will enable progress – higher data throughputs, automated connectivity, full interoperability between different sorts of protocols, etc. – many of them relying on KET based hardware developments.
- Increasing bit rates will allow new services based on "big data", cloud computing, the acceleration in deploying communicating devices, etc. A very wide range of applications will derive from this, from entertainment and social games to smart power grids, smart homes and cities, driverless transports, and many unforeseen services. Related markets are in € billions, and direct industrial impacts are enormous since the whole wireless network infrastructure has to be adapted to the communication protocols in usage. A large part of the industrial capability has been lost by Europe but innovation based on hardware, i.e. KETs, is seen by the telecom sector experts as the main chance of reconquering market shares taken in particular by Chinese players.
- Possible health impacts, as well as cyber-security measures and privacy protection have to be considered. All these aspects may benefit from defence applications already in use that can be transferred into the civilian domain.

➢ ***Results of patents scenario analysis:***

- 44 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Since 2004-2006, on a decreasing and very low trend curve (number of patents per year)



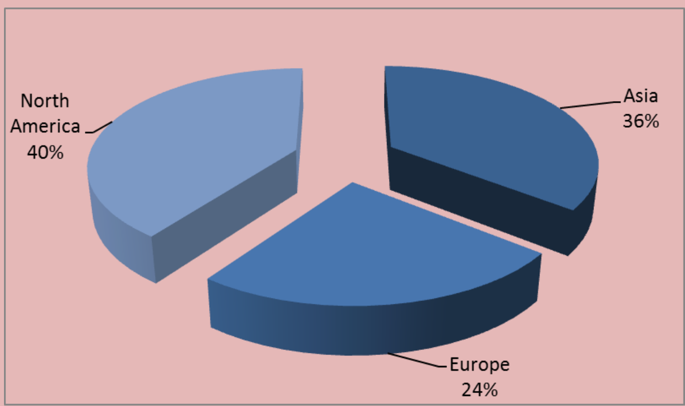
- Patents by KET(s):



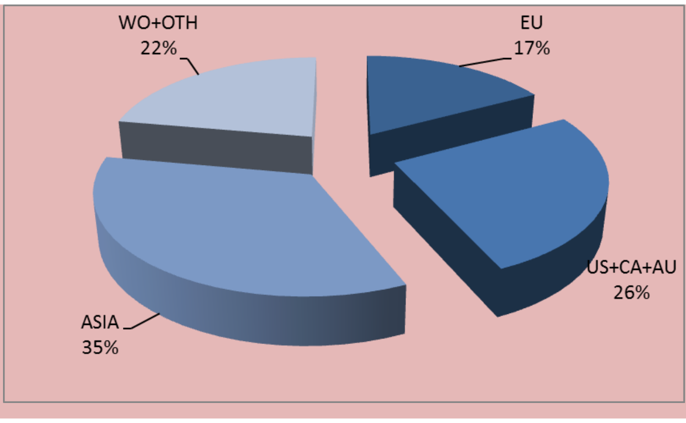
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	1
AM / PhT	1
AMS	35
MNE	4
PhT	5

- Patent distribution by (Applicant) organization geographical zone:
- Samsung (South Korea) is the dominant applicant in this field, with 9 patent families in the period (20% of the total)



- Patent distribution by geographical zone of priority protection:



E&C.4.3: High bandwidth optical networks

Scope:

To develop advanced network infrastructures with ultrahigh bandwidth, mainly based on an optical backbone and taking advantage of solutions as radio over fibre or other seamless network technologies.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

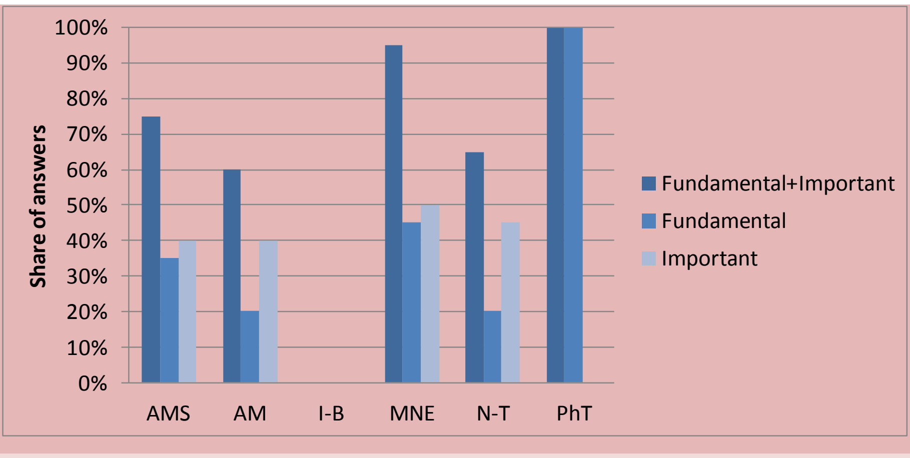
- Development of optical network switching for hybrid traffic
- Implementation of radio-over-fibre access points, for wireless networks to rely on high bandwidth optic fibre networks while minimizing the need for heavy data processing and allowing more virtualization in the network
- Development of new seamless network technologies for ultra-high bandwidth
- Setup of large core diameter plastic fibre to ease large deployment of optic fibre (mainly for home usage)
- Development of optical routing back panels and very high rate signal processing capabilities for bottleneck avoidance in optical networks
- Replacement of traditional bus backbones by full-fibre backbones

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced network infrastructures with ultra-high bandwidth, mainly based on an optical backbone and radio-over-fibre or other seamless network technologies, high bandwidth optical network switching for hybrid traffic, radio-over-fibre access points, optical routing back panels, replacement of traditional bus backbones by full-fibre backbones, etc.

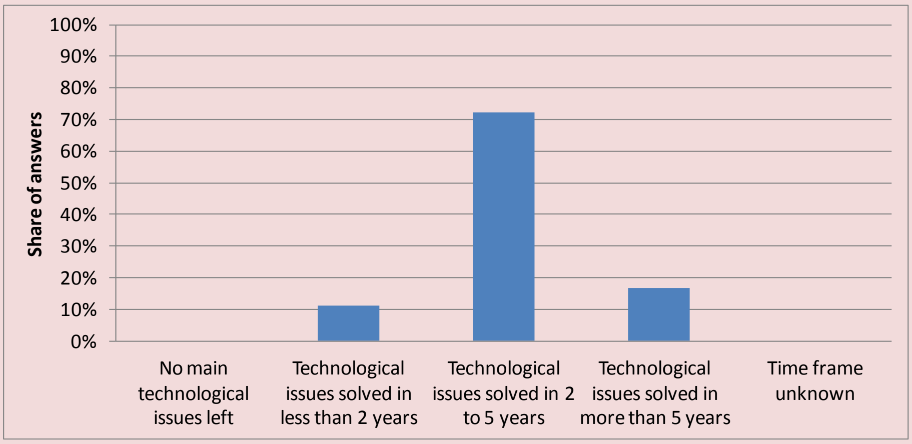
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Photonics (PhT)
- Micro- and Nano-Electronics (MNE)
- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:

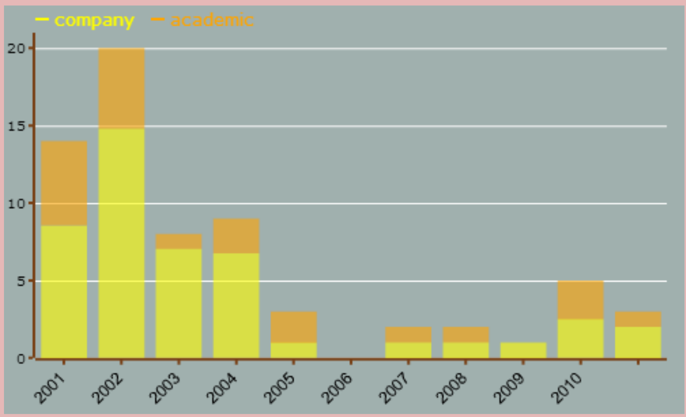


Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

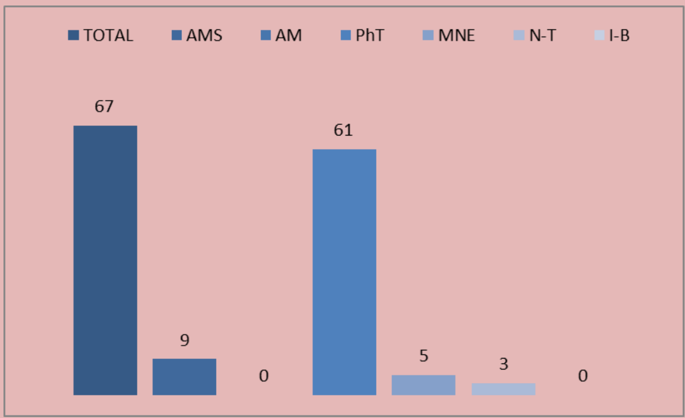
Additional information according to results of assessment:

- ***Impact assessment:***
  - A large share of front end communications are endorsed by wireless networks, but long distance and high volume data communications have to – and will continue – rely on wire/fibre-based networks. As the data rates are increasing, these networks face increasing bandwidth demand and wire/fibre availability is diminishing. To support Pillar IV of the Digital Agenda for Europe – Fast and ultra-fast Internet access, objective of 30 Mbps download capability all over Europe and 50% of European households subscribed at >100 Mbps services – and thus go on with increasing data volumes and enabling the development of bandwidth intensive applications – like HD video streaming, cloud computing, machine to machine communications, data mining , e-Health, etc. – network operators have to move towards more and full optical networks, able to provide high performance and quality of service at reduced costs.
  - Optical networks are already being deployed in dense urban or "bit-intensive" areas, down to final users in the cases of "Fibre-to-the-home" (FFTH) or "Fibre-to-the-building" deployments, but further KET-enabled systems deployment is necessary for large-scale systematic implementation and bottleneck avoidance which will bring additional benefits. As stated in the EU Digital Agenda, "*a 10% increase in broadband penetration brings up the GDP by 1-1.5%*".
- ***Results of patents scenario analysis:***
  - 67 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field

- Since early 2000 years, annual applications in the field remain at a relatively low level, with a significant share of academic applicants:



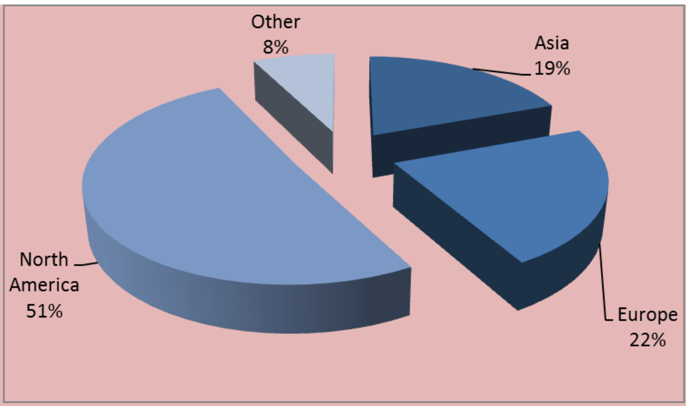
- Patents by KET(s):



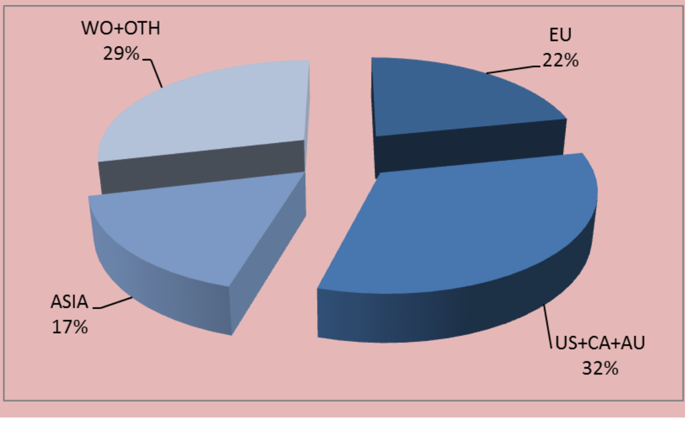
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AMS	9
AMS / PhT	3
MNE	5
MNE / N-T	2
MNE / N-T / PhT	2
MNE / PhT	5
N-T	3
N-T / PhT	3
PhT	61

- Patent distribution by (Applicant) organization geographical zone:
- Patent application is not particularly concentrated, with the biggest applicant (Samsung) having applied only 3 patent families in the period



- Patent distribution by geographical zone of priority protection:



E&C.4.4: Highly resource efficient networks

Scope:

To develop resource efficient networks and infrastructures with a low use of energy (i.e. limited heat dissipation), spectrum and processing power, including through concepts such as multi-hop mesh solutions, multi-criteria routing and cognitive/self-organization, context based sleep/active cycles, low power infrastructure chipsets and modules and a special effort on developing distributed cloud computing and data centre eco-efficiency.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of intelligent management of energy (power and dissipated heat) all over network systems
- Development of multi-hop mesh solutions, multi-criteria routing and cognitive/self-organization capabilities for reducing energy consumption from the terminals to the base stations and access points
- Development of low power infrastructure chipsets and modules, including for very high frequency / performance communication
- Development of distributed cloud computing supporting a dynamic scalability of computing centralization in the network, depending on the application, terminal capability and context
- Allow network low layers management based on "ordinary" software
- Better management of interferences to increase use of best-scale cells in wireless networks and / or allow dynamic scaling of emissions
- Emit only minimum necessary level of power, depending on actual network conditions, so as to optimize energy consumption, minimize interferences and reduce potential impact on human health
- Increase of the use of context-based sleep/active cycles
- Increase of data management eco-efficiency, including in data-centres
- Development of modelling tools and related techniques to optimize resources

management when deploying wireless networks

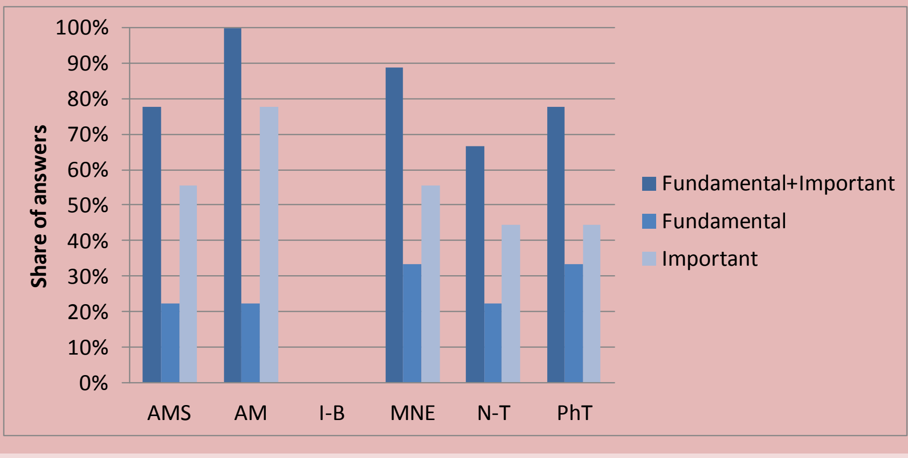
- Integration of a mediation bus between services and network/transport layer, so as to integrate more functionalities in the information transportation service
- Management of aggregated interference in multiuser patterns, including for guaranteeing quality of service and network security
- Development of very efficient cost effective small size device front end power modules

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of resource efficient networks and infrastructures with a low use of energy (i.e. limited heat dissipation), including through concepts such as multi-hop mesh solutions, multi-criteria routing and cognitive/self-organization capabilities, context conscious sleep/active cycles, low power infrastructure chipsets and modules.

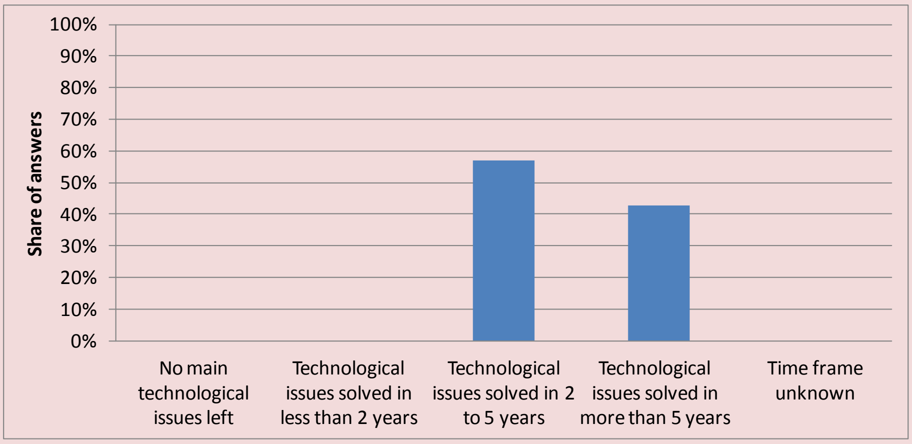
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Advanced Materials (AM)
- Advanced Manufacturing Systems (AMS)
- Photonics (PhT)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also longer periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the

achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

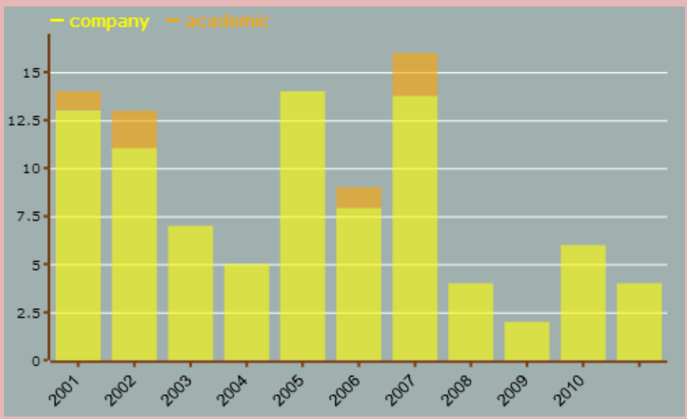
Additional information according to results of assessment:

➢ ***Impact assessment:***

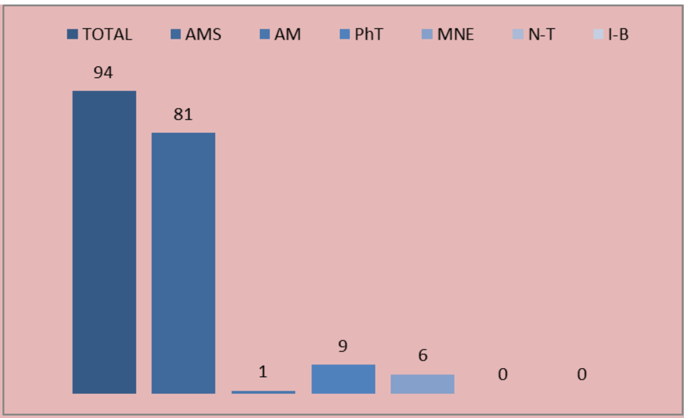
- Nowadays Information and Communication Technology (ICT) energy consumption represents around 2% of global energy consumption, and ICT accounted for 3.9% of total worldwide electricity consumption in 2007, 4.6% in 2012 (source: "Overview of ICT energy consumption" FP7 project). Without significant progress in this innovation field, the energy/carbon footprint of the ICT sector would double on the period.
- Taking into account the global bit transfer increase, it is however the quickest growing contributor to human energy consumptions. Moreover, current communication networks and technologies have been designed without paying much attention to the energy cost, long considered insignificant. According to the Green Touch ICT stakeholders consortium, there are technical opportunities for huge energy efficiency improvements (in watt per processed bit), up to a factor 1000 for mobile communications, 450 for wireline communications, 60 for core networks. Taking into account the relative weight of mobile, wireline and core networks, traffic evolutions and realistic (yet ambitious) technological achievements, net energy consumption from telecom networks could be reduced by 90% from 2010 to 2020 (source: Green touch Green Meter Research Study 2013).
- Reducing energy consumption of communication networks is not only a matter of environment footprint, it serves also networks operators energy bill reduction.
- The Defence sector has traditionally worked on efficient networks and has, in the last years, increased its research in this field towards a safer and faster approach to communication systems. All this know-how and consolidated knowledge is potentially applicable on civilian applications for improved performances and broader autonomous and intelligent communication systems.

➢ ***Results of patents scenario analysis:***

- 94 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Decreasing trend curve (number of patents per year)
- Highest almost exclusive share of industrial applicants:



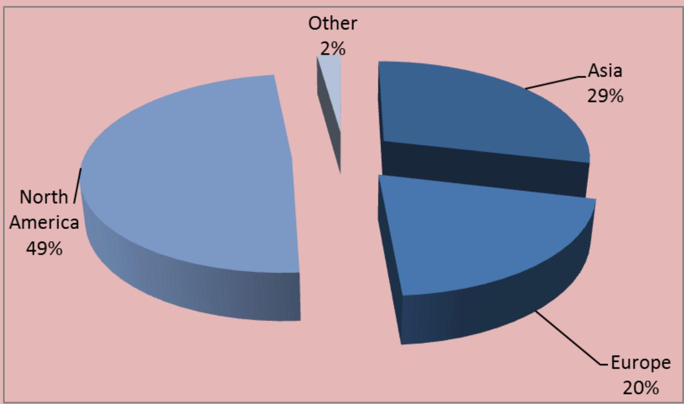
- Patents by KET(s):



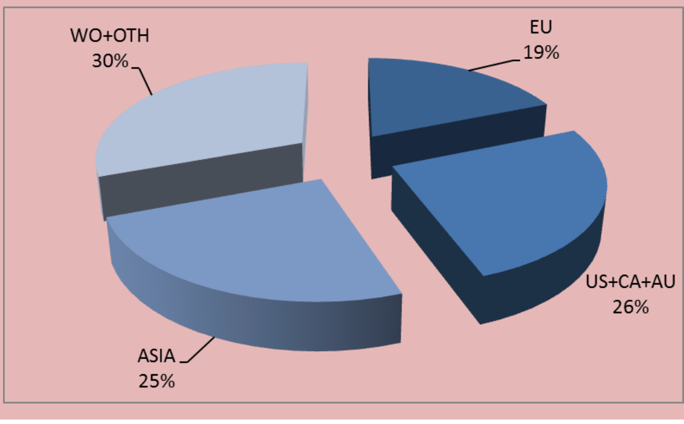
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	1
AMS	81
AMS / PhT	2
MNE	6
MNE / PhT	1
PhT	9

- Patent distribution by (Applicant) organization geographical zone:
- US industries have a good position in list of top applicants, but innovation is little concentrated in this field and the 17 biggest players have only applied 2 to 5 patent families in the period (8 for 1st applicant, the South Korean LG)



- Patent distribution by geographical zone of priority protection:



E&C.4.5: Improved mobile phones and connected mobile devices

Scope:

To develop mobile devices that go beyond current devices as smart phones with improved functionalities, convergence with other devices (supported by virtualization and cloud computing), higher connectivity (through universal systems), weight reduction, more autonomy (with increased energy efficiency, better batteries or micro energy harvesting), long campaign life and damage resistance and recycling by design.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of off-grid power supplies, micro-energy harvesters using environmental or parasitic power sources, or even wireless power
- Increase of energy storage capabilities of handsets (batteries), combined with optimized handset systems' and architecture power consumption (including advanced sleep/active switch and context-dependent system adaptation), and possibly energy harvesting
- Development of cloud computing and virtual devices to reduce the need to spend handset energy on complex computing operations and limiting the need for complete integrated devices, only interface keeping really necessary, the rest being virtual and in the cloud
- Development of novel materials for better design ("look&feel") with better properties (e.g. more wear resistant, lightweight), possibly functional materials delivering new capabilities
- Design of devices for recycling, including with planning overall life cycle of products and materials
- Improvement of human-machine-cooperation with including "psychology" of humans for parts of consumer electronics and with supporting devices getting "social"
- Development of usable, scalable and built-in security, trust, dependability and privacy for mobile communications, including with high-performing cryptographic methods
- Allow fast and flexible customization (smaller series, personalization, customization of products)
- Development of highly efficient radio frequency front-end modules, including antennas (active, directional, designed with better understanding indoor propagation, etc.)
- Development of low power embedded chipsets, modules (including power modules) and/or embedded computation mechanism
- Always chose most efficient connection link (for energy and service), based on multiple network and context-awareness capabilities (positioning, incl. indoor, user authentication and profiling, embedded sensors, etc.) and/or dynamically adapt emission power
- Integration of more and more embedded sensing capabilities (imagers, accelerometry, gyrometry, measurement of pressure, magnetic field, hygrometry, etc.) to allow more situational awareness, whilst minimizing volume, weight, energy consumption and cost
- Adaptation of system interface to user's environment, device or skills, using context data and available data and relying on universal systems (e.g. Universal Serial Bus (USB): data transfer and power supply)
- Development of automated connectivity, supporting terminal roaming and intercell handover with multiple network connection capability, to make ubiquitous network access feasible and invisible to the end user

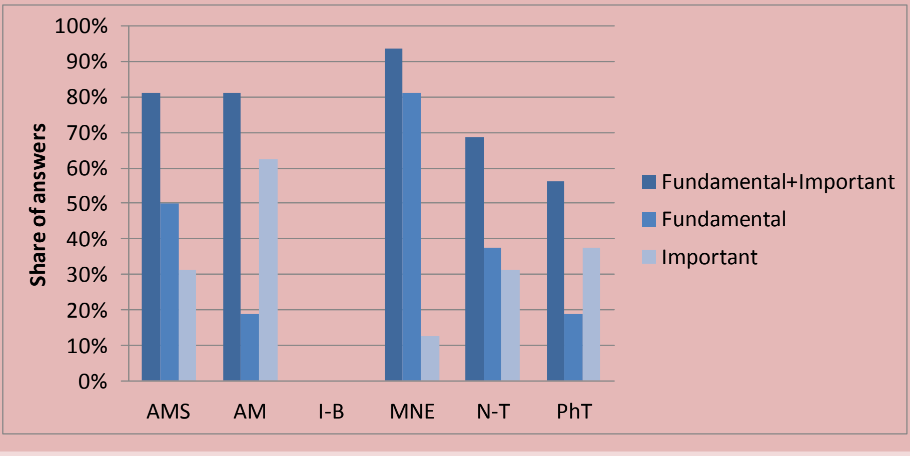
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development and integration of enhanced off-grid power supplies, micro-energy harvesters using environmental or parasitic power sources, or even wireless power, increased energy storage capabilities, improved human-machine cooperation, enhanced built-in security, trust, dependability and privacy during mobile communications, including thanks to cryptographic methods, highly efficient radio-frequency front-end modules, low power embedded chipsets, sensing capabilities, novel materials for better design and functionalities.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

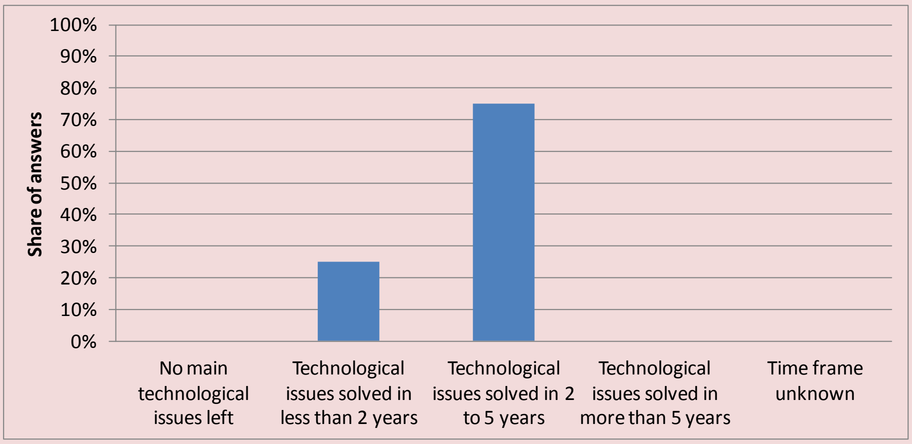
- Micro- and Nano-Electronics (MNE)

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- To a lesser extent Nanotechnologies (N-T) and Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

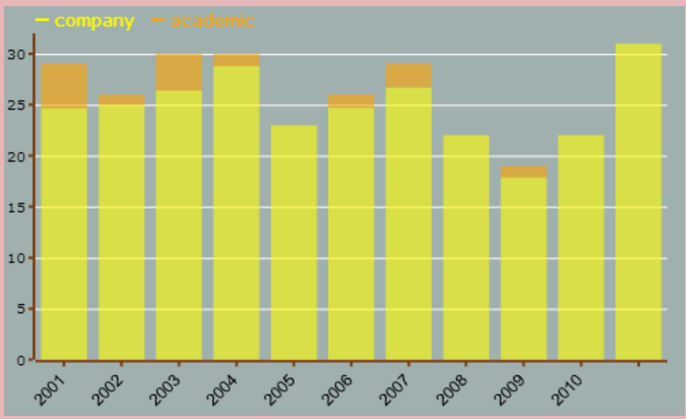
➢ ***Impact assessment:***

- Mobile communication is a marker of a dynamic, communicative, mobile, innovative society. Future mobile phones will have to enable broadband seamless connectivity everywhere, supporting ubiquitous access to high performance online or "in the cloud" services, offering increased autonomy, all sorts of sensing capability including biometric identification enabling secured banking services, precise geolocation and high usability personal assistance and guidance, whatever the environment and at affordable costs. They will also have to be designed for recyclability and minimal or zero health impact.
- At the end of 2012, the penetration rate of mobile communication services was 123.3%, versus 91.7% at end 2005. 1.8 billion mobile phones were sold in the world in 2013, including more than 1 billion smart phones, 120 million just in Europe. Since September 2013 and the buyout of Nokia mobile terminals division by the American Microsoft, there is no longer a large European mobile phone integrator. Yet, mobile phones are complex systems and many components and subsystems are still delivered by European manufacturers. The success encountered by companies selling their own mobile phone brands as Wiko, NGM, Mobistel or Jolla, even though not necessarily assembled in Europe, also highlights the real consumer interest for the "made in Europe" in this field.

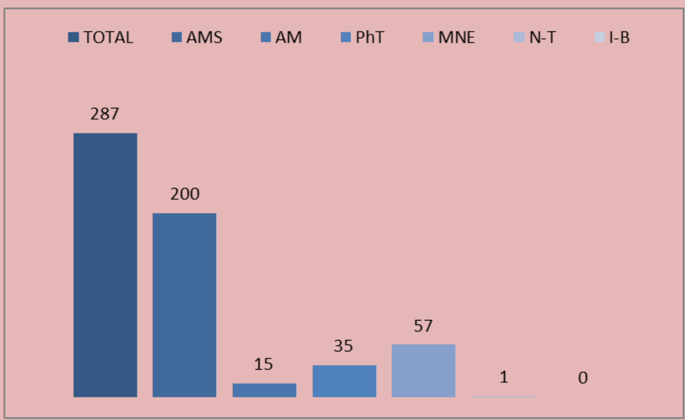
- A major issue in the mobile communicating devices industry is the need for critical materials as coltan, indium or various rare earths, often extracted in unstable regions and/or under poor environmental conditions. To prevent and reduce international risks and dependencies, future mobile phones and connected mobile devices will use less of these resources, or from secondary (recycled) source, or rely on substitutes.

➢ ***Results of patents scenario analysis:***

- 287 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Quite stable trend curve (number of patents per year), recovering from a slight downturn in 2008-2009
- Highest share of industrial applicants especially in the most recent part of the period:



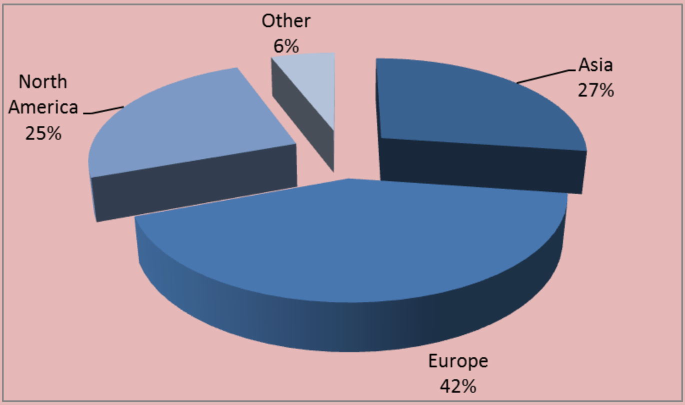
- Patents by KET(s):



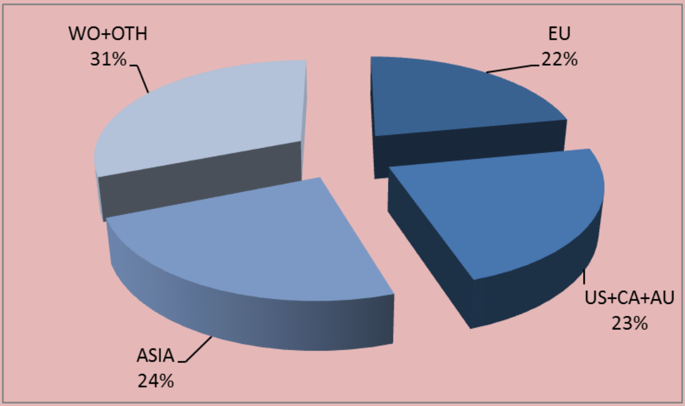
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	15
AM / MNE	1
AM / MNE / PhT	1
AM / PhT	3
AMS	200
AMS / AM	1
AMS / MNE	3
AMS / MNE / PhT	2
AMS / PhT	2
IBT	1
MNE	57
MNE / PhT	15
N-T	1
PhT	35

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



- Patent application with regard to this field is little concentrated and the 38 top applicants have only applied 111 patent families in the period. Out of these 111 families from top applicants, 42 are from Japanese players, the rest being split between US and European players, plus a few South Korean (6), Chinese (2) or Canadian (2).

E&C.4.6: Embedded broadband communication payload

Scope:

To develop transponder systems enabling embedded communication payloads of satellites, airships or any flying or otherwise moving platforms to provide a broadband communication service at a reasonable cost, with a limited energy consumption (and heat dissipation) and including with all protection systems for preventing unwanted spoofing and jamming of other systems.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Increase of transponders data processing rates whilst keeping energy consumption under control
- Development of payload capability for broadband communication (C to Ku and Ka bands), including through increased operational flexibility and reconfigurability
- Enable higher onboard processing power with increasing onboard available energy and improving embedded power and thermal management (including with deployable radiators or cryogenic cooling)
- Power and cost optimized satellite platform
- Development of high performance frequency filters for optimal dimensioning of the transmitter and receiver systems, including supra-conductivity filtering
- Development of building blocks for high performance low cost antennas as large focal length reflectors and their reliable deployment and actuation mechanisms, multi-beam feeds, multi-spot reflect arrays, reconfigurable beam forming antennas or classical

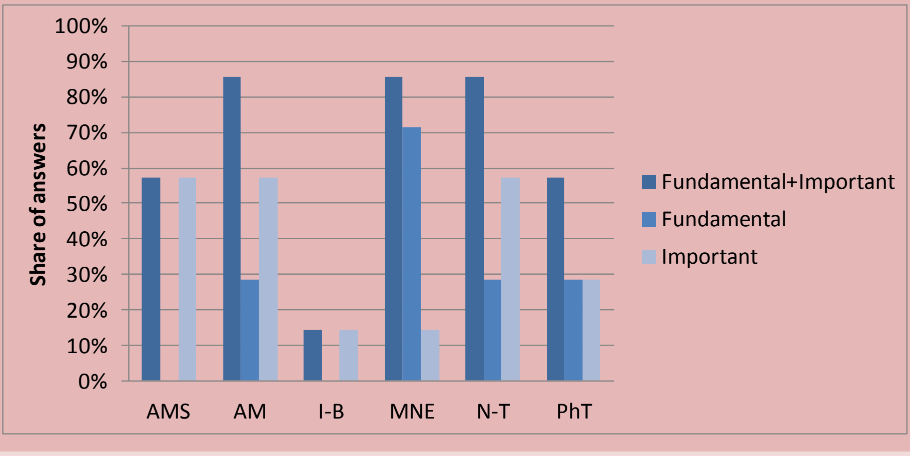
Q/V/UHF band antenna manufactured in a repeatable way

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of solutions such as more advanced transponder systems, including thanks to increasing transponders data processing rates enabling higher on-board processing power whilst increasing on-board available energy and improving embedded power and thermal management, the development of high performance frequency filters, and the development of payload capability for broadband communication (C to Ku and Ka bands).

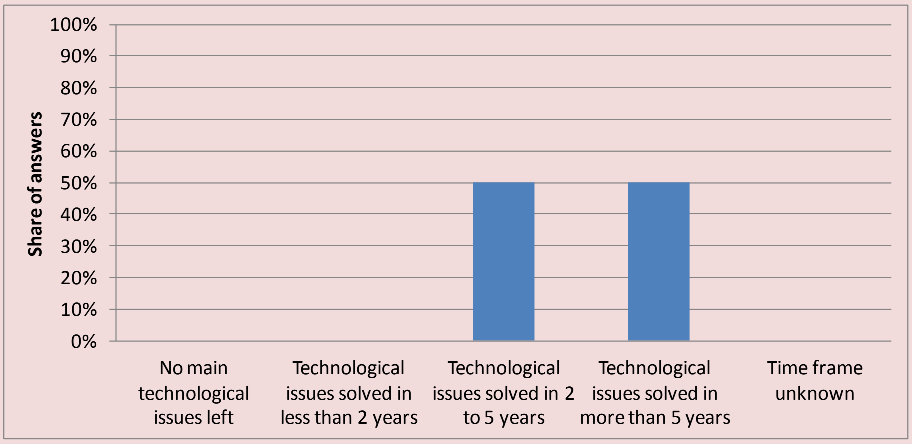
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Photonics (PhT)
- Advanced Manufacturing Systems (AMS)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years or more than 5 years:

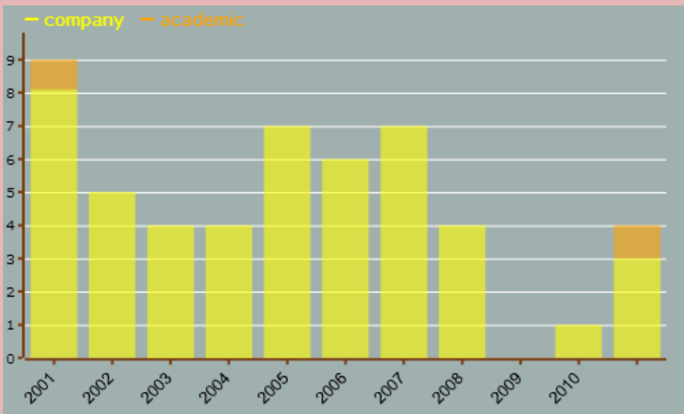


Hence, considering that advanced telecom payloads are expected to be particularly requested for the medium term period, but with already opportunities on the short term, the provision of support in the short to medium term should be taken into consideration within this framework.

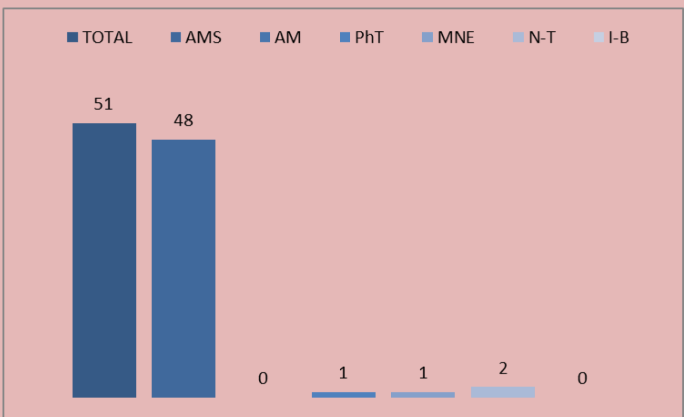
Additional information according to results of assessment:

- ***Impact assessment:***
  - Satellite-based or airborne wide coverage telecommunication means will support quickly deployable additional communication means, supporting continuity and accessibility of the mobile communication service in specific situations as natural disasters, industrial accidents, exceptional crowd concentration as for sports or cultural events, exceptional use of communication needs (e.g. the typically New Year's Eve SMS flooding) or even warfare contexts. The availability of such additional capability, when and where needed, will allow tailoring normal communication networks without unnecessary margins, saving costs and energy.
  - The Digital Agenda for Europe objective of 100% territory covered with 30 Mbps capability needs broadband capability even with very low density and hardly accessible areas, guaranteeing universal access to broadband Internet but also creating opportunities for new services as telemedicine or e-education. Embedded communication systems will be part of the answer.
  - Telecom satellites also offer alternatives to intercontinental / long-distance communications. Most of these systems had a specifically defence application. However, in the last few years and in the near future it is expected that more transfers from the defence to the civilian sector can be achieved, building on consolidated know-how.
  - As regards industrial impacts, European space industry is suffering on one side the reduction of institutional commands due to public budget restrictions, on the other side growing competition on a stagnant market from industries from America and emerging countries. KET-based innovation supporting more competitive telecom payloads is one of the directions for boosting the market and retrieving market shares and profitability.

- ***Results of patents scenario analysis:***
  - 51 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Decreasing trend curve (number of patents per year) in recent years, with slight downturn in 2009
  - Highest share of industrial applicants:



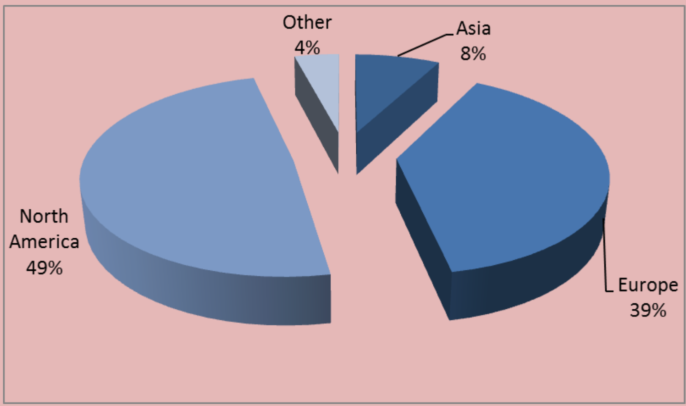
  - Patents by KET(s):



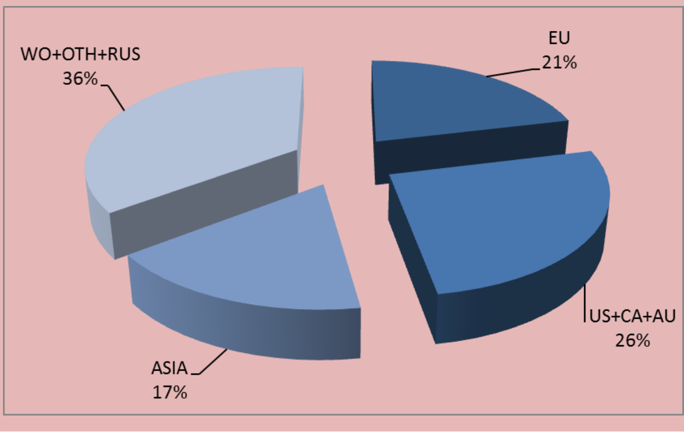
  - Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AMS	48
AMS / MNE	1
MNE	1
N-T	2
PhT	1

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



E&C.4.7: Dependable communication platforms and IT infrastructures

Scope:

To build secure and dependable communication platforms and Information Technology (IT) infrastructures and services, relying on cryptography, authentication, authorization and accounting methods, deperimeterized firewalling, pro-active STDP (security, trust, dependability and privacy) solutions, physical hardening, etc.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Provision of services and their content securely between all users by high-performing cryptographic methods, including low cost low power highly secure hardware-based cryptographic protection of networks ("cryptographic key") and systems for payment and micropayment
- Replacement of network securing by platform securing, so as to ensure deperimeterized architecture firewalling (protection against attacks) and antivirusing (against malicious code)
- Development of methods for authentication, authorization and accounting (AAA) while tackling privacy issues
- Mutual authentication of user device and the network based on identity management,

including terminal biometrics

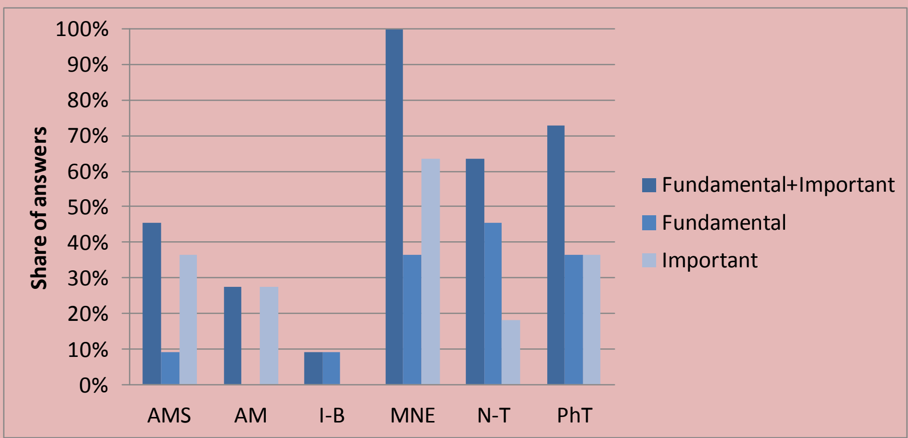
- Development of technology to offer appropriate and fair protection to those who wish to retain a degree of control over content they have created or acquired (including the right to remuneration) when it is distributed over heterogeneous networks
- Development of industrial strength methods, metrics and tools for security assurance, forensics and vulnerability discovery
- Development of alternative self-organizing and reconfigurable and/or defect- and fault tolerant architectures and related hardware technologies
- Limitation of intrusion possibilities using near field communication (incl. Radio-frequency identification, RFID), device-to-device communication, secure protocols and low power consumption self-node's integrity validity check
- Setup of proactive network surveillance capabilities to detect and track malicious users of (mainly wireless) networks, and trigger counter intrusion or self-healing measures, including STDP solutions (security, trust, dependability and privacy)
- Support of network management software controlled by European players and/or open source
- Guarantee sufficient supply of rare raw materials, especially rare earths, or develop synthetic equivalent
- Ensure trustworthy record, storage, transfer and usage of personal data, so as to prevent new types of attacks, privacy breaching or technology-induced safety risks
- Development of hardened components, including memories
- Increase of modularity, scalability and interoperability of data server modules

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of secure and dependable communication platforms and IT infrastructures and services, relying on hardware-based cryptographic protection, authentication, authorization and accounting, limitation of intrusion, device-to-device communication, self-organizing and reconfigurable, defect and fault tolerant architectures.

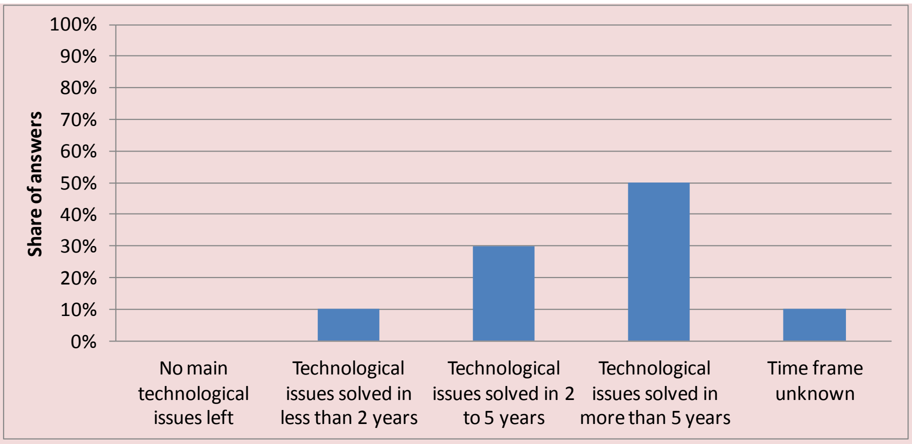
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Photonics (PhT)
- Nanotechnologies (N-T)
- To a lesser extent, Advanced Manufacturing Systems (AMS)



Timing for implementation:

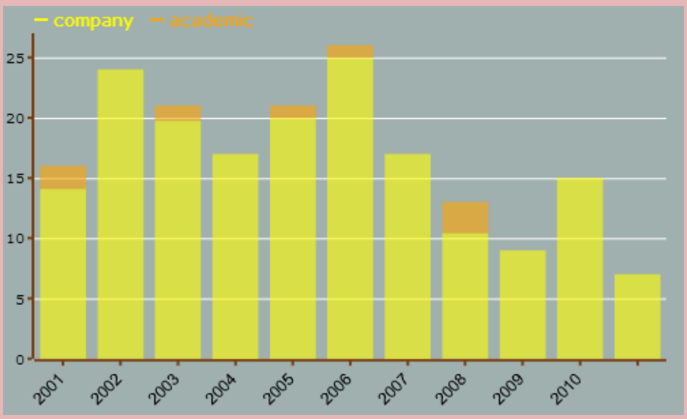
According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:



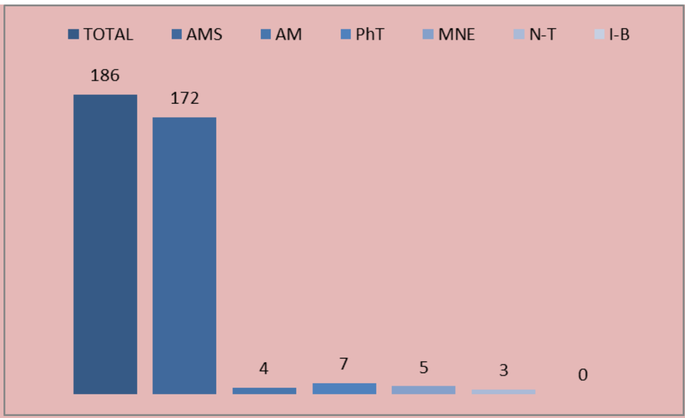
Cyber-security and infrastructure dependability are supported by technology developments but also heavily dependent on non-technical aspects taking time for assembling altogether. Hence, the provision of support in the medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
    - As information-based services take deeper roots into European societies, ensuring reliability and high quality and continuity in the communication services gets more and more crucial. Dependable communication platforms and IT infrastructures are mandatory links for supporting end-to-end communication chain resistance and resilience, protecting citizens' privacy, ensure society's trust in the communication backbone of the inclusive, innovative and reflexive information society.
    - Secure communications will enable fulfilling the Digital Agenda for Europe objectives for citizens to use eGovernment services, as well as supporting the deployment of e-Health/telemedicine, protecting online sales/purchase and e-banking services against malevolent actions and intrusions, ensuring reinforced European protection against unfriendly economic or political intelligence or even cyber war attacks.
    - The European telecommunication systems' industry faces a fierce competition from international competitors, and technological advance in dependability technologies is one of the axes which can comfort its competitiveness.
- ***Results of patents scenario analysis:***
    - 186 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
    - Slightly decreasing trend curve (number of patents per year)
    - Highest share of industrial applicants:



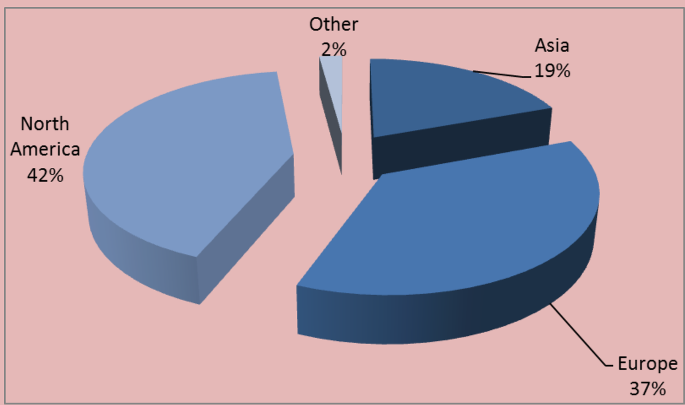
- Patents by KET(s):



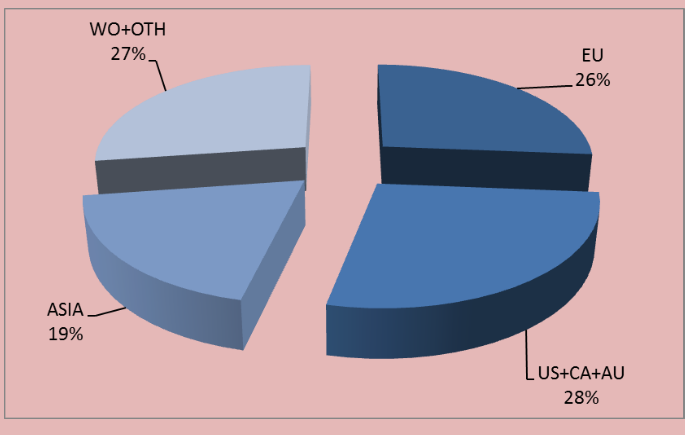
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	4
AM / MNE	1
AM / N-T	1
AMS	172
AMS / AM	1
AMS / PhT	2
MNE	5
N-T	3
PhT	7

- Patent distribution by (Applicant) organization geographical zone:



- The top applicant positions are shared between European, Japanese and American companies
- Patent distribution by geographical zone of priority protection:



Potential areas of industrial interest relevant for cross-cutting KETs in the Chemical Processes, Chemicals, Chemical Products and Materials domain

Sub-domain: Competitive more sustainable alternatives to conventional materials

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "climate action, resource efficiency and raw materials" challenge, indirectly also contributing to address challenges such as "smart, green and integrated transport" and "secure, clean and efficient energy"

CH.1.1: Bio-based fine as well as specialty chemicals, bio-polymers and other bio-based derivatives

Scope:

Bio-based fine and specialty chemicals, bio-polymers, bio-lubricants, and other bio-based materials as well as derivatives produced starting from renewable resources, which may either be biodegradable/compostable or have properties that render them suitable for durable applications.

Demand-side requirements (stemming from market needs) addressed:

- Provide for the replacement of fossil resources, thereby addressing security of supply for key market sectors

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

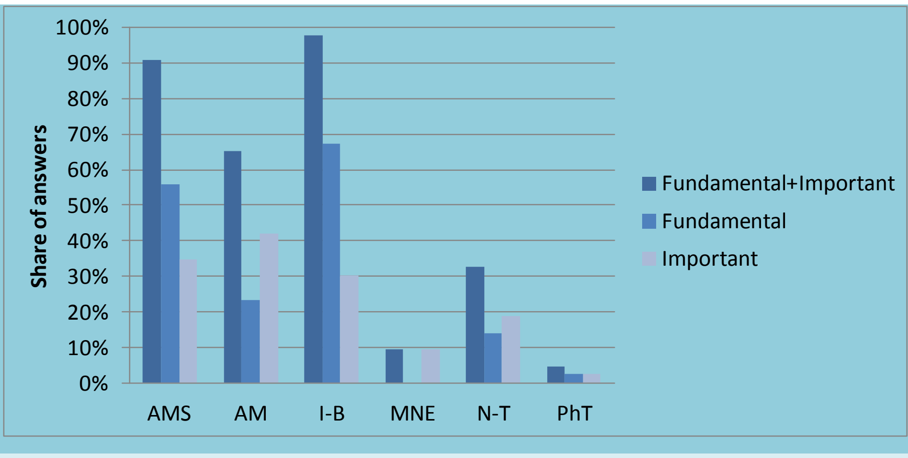
- Development of innovative formulations for biodegradable and compostable products aimed at widening the application potential of bio-based derivatives in non-durable goods
- Modification (e.g. by alloying and fortification with impact modifiers, reinforcing fillers, nano-additives, etc.) to overcome most bio-polymers' inherent brittleness, low heat resistance, and processability limitations so as to widen their application potential particularly in durable goods

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the further development of innovative formulations for bio-based fine as well as specialty chemicals, bio-polymers and other bio-based derivatives aimed at widening the application potential of bio-based products. The integration of KETs could for instance contribute to the development of innovative formulations for bio-based materials to be applied in durable goods (besides in non-durable goods), especially by the modification (e.g. by alloying and fortification with impact modifiers, reinforcing fillers, nano-additives, etc.) to overcome most bio-polymers' inherent brittleness, low heat resistance, and processability limitations.

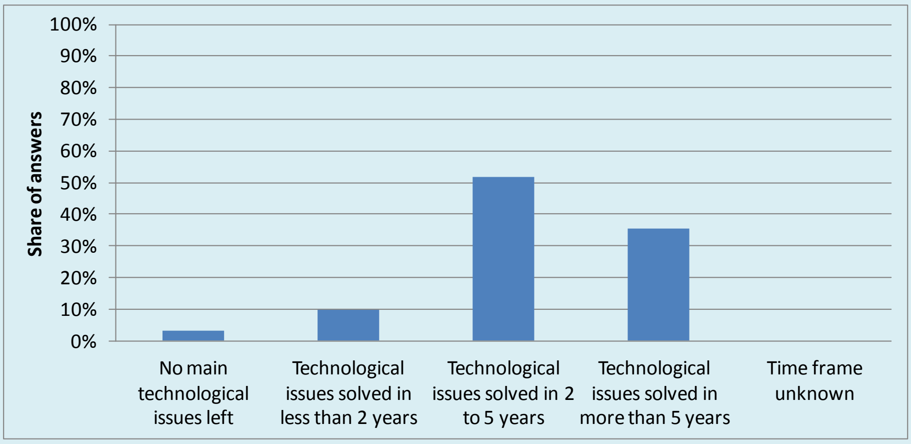
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Industrial Biotechnology (I-B)
- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:



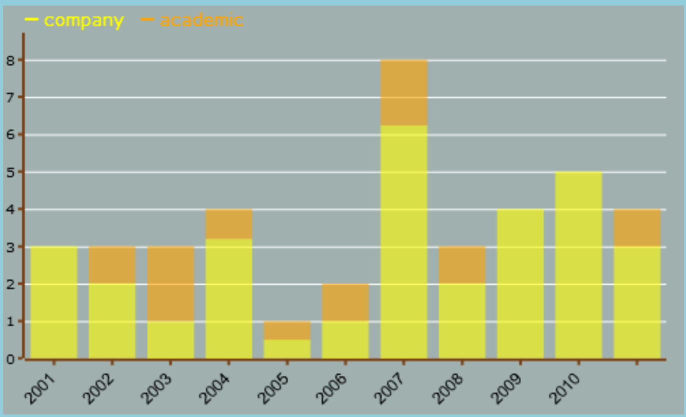
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

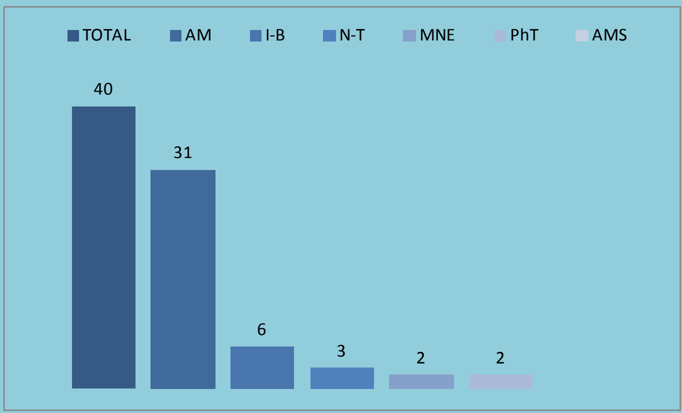
- ***Impact assessment:***
  - Several forces, including high oil prices, consumer preference, corporate commitment, and government mandates and support, are driving development in the area of bio-based chemicals and materials. As a result, the bio-based industry has reached a tipping point, with production expected to double in the upcoming years. Current developments (which include several investments being made in pilot production facilities) let assume that especially the bio-based chemicals sector will likely have a strong expansion in the next future. Platform chemicals obtained from renewable resources are expected to grow substantially over the next five years. This will open up perspectives for new applications for bio-based products including fine as well as specialty chemicals, bio-polymers and other bio-based derivatives and will also generate a strong boost for the cost effective production of biofuels within a biorefinery context (Source: International Energy Agency (IEA) Bioenergy, Bio-based Chemicals, Value Added Products from biorefineries, 2012).
  - As stated within COM(2012) 60 final, the bioeconomy sectors in Europe are worth 2 trillion Euro in annual turnover and account for more than 22 million jobs and approximately 9% of the workforce. However, in order to remain competitive and maintain jobs in the light of major societal challenges and rising markets, the European bioeconomy sectors need to innovate and further diversify. Within this framework, it is estimated that direct funding for research and innovation associated to the Bioeconomy

Strategy under Horizon 2020 could generate about 130 000 jobs and 45 billion Euro in value added in bioeconomy sectors by 2025. Further growth is expected from other – direct and indirect – public and private investments in all parts of the bioeconomy (Source: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions titled 'Innovating for Sustainable Growth: A Bioeconomy for Europe' (COM(2012) 60 final)).

- ***Results of patents scenario analysis:***
  - 40 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Almost stable trend curve (number of patents per year) with a generally low patenting activity per year
  - Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants, most probably standing for new technologies having been patented in the corresponding periods:



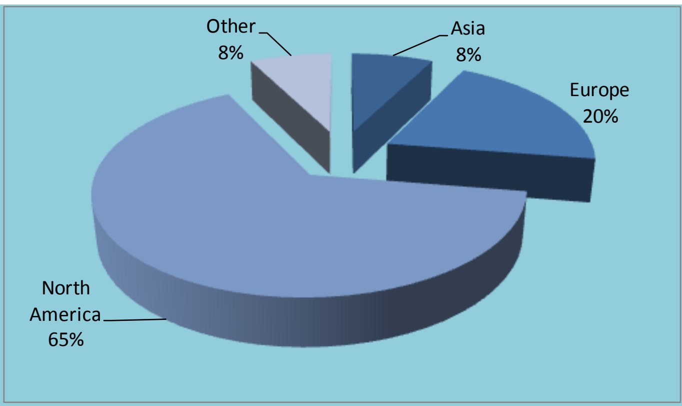
  - Patents by KET(s):



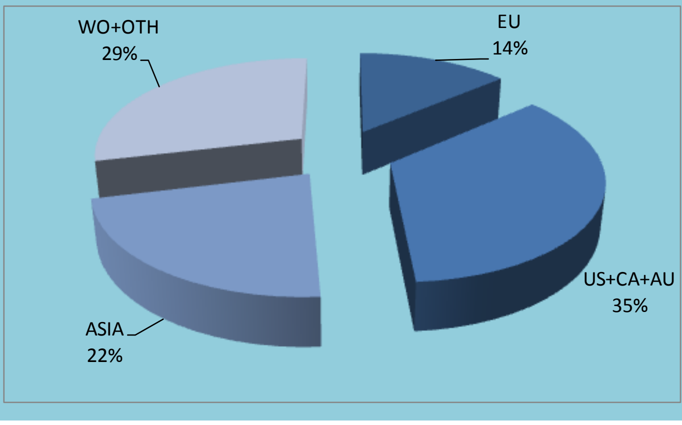
  - Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	31
AM / IBT	1
AM / N-T	1
IBT	6
MNE	2
MNE / PhT	1
N-T	3
N-T / PhT	1
PhT	2

  - Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



CH.1.2: Metamaterials or novel chemistries for the substitution of rare elements and other critical raw materials

Scope:

Metamaterials or novel chemistries to be applied as safe and cost-effective equivalents to rare and toxic adjuvants to various productions, or minimal use of them, with application e.g. in catalysts without precious metals (especially without Platinum), permanent magnets and battery electrodes without rare earths, replacement of Indium tin oxide (ITO) where thin transparent oxides are needed as in screens and displays, etc.

Demand-side requirements (stemming from market needs) addressed:

- Provide for the substitution of rare elements and other critical raw materials, thereby addressing security of supply for key market sectors

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of innovative material structures and chemistries
- Replacement of Cadmium (used for example in obtaining the red colour in glass) or Boron (used for example within the boro-silicate glass used in pharmaceutical containers), with performing non-toxic and low cost equivalents
- Characterization of toxicity as well as risks for purchase difficulties of all key adjuvants (Mercury, Arsenic, Boron, etc.)
- Development of synthetic materials with equivalent properties to replace toxic or rare materials for application e.g. in catalysts without precious metals (especially without Platinum), permanent magnets and battery electrodes without rare earths, for the replacement of Indium tin oxide (ITO) where thin transparent oxides are needed as in screens and displays, etc.
- Development of alternative solutions allowing to use necessary adjuvants just where needed, including only as a surface coating if not needed inside the material (e.g. anti-

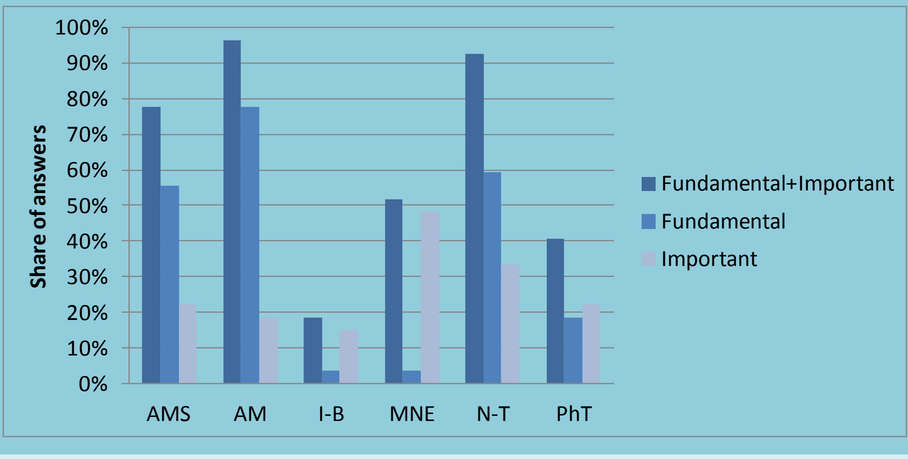
bacterial adjuvants)

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of innovative material structures and chemistries allowing to replace rare or toxic substances with performing non-toxic and low cost equivalents, thanks to the development of synthetic materials with equivalent properties. The integration of KETs could moreover contribute to developing alternative solutions allowing to use necessary adjuvants just where needed, including only as a surface coating if not needed inside the material (e.g. anti-bacterial adjuvants).

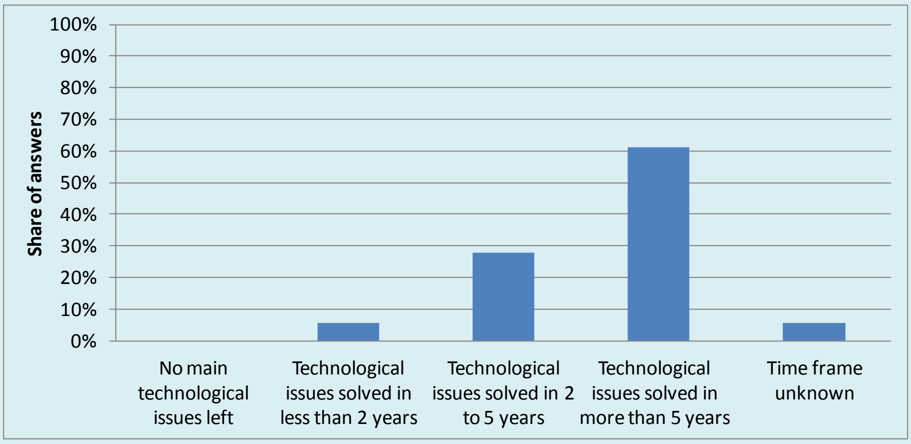
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Advanced Manufacturing Systems (AMS)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:

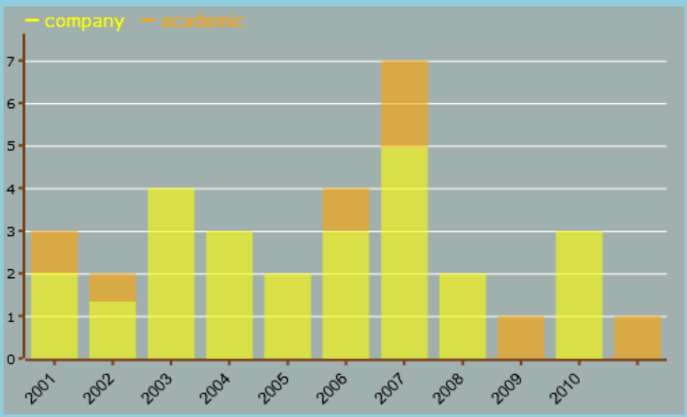


Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

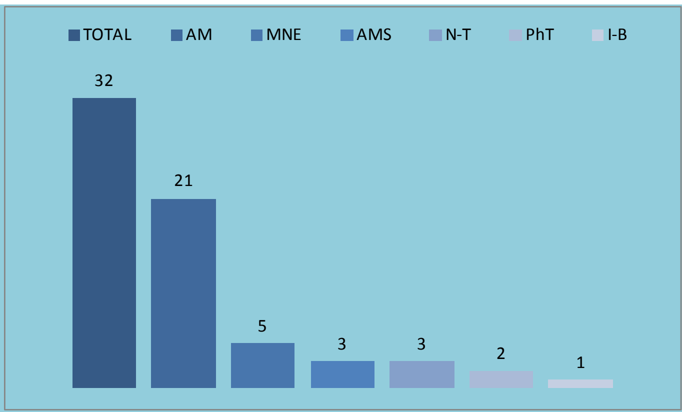
Additional information according to results of assessment:

- ***Impact assessment:***
  - Rare earth elements and other critical raw materials are essential to industrial production and thus to many key market sectors. They are involved in wind turbines, solar cells, electric vehicles, energy efficient lighting, many other electric and electronic devices, catalysts for chemical production, just to name a few. Wind turbines are among the most rapidly growing sources of electricity generation in Europe and elsewhere. Solar photovoltaic cells are steadily declining in cost, which will result in their even more widespread application within the coming decade. Electric vehicles, meanwhile, offer a means to move away from imported oil for transport towards a more sustainable energy mix and their adoption is also expected to grow significantly. Compact fluorescent and Light-Emitting Diode (LED) lighting allow to greatly reduce electricity consumption. Modern electric and electronic devices and technologies pervade most aspects of society. Catalysts are widely applied in the chemical industry for the production of a large variety of intermediates as well as end products. These and other options can contain smaller (but vital) to larger amounts of critical raw materials, thus leading to high quantities of materials being used in a highly distributed form; quantities which are expected to grow along with their respective end markets.
  - Production of some of these rare earth elements and other critical raw materials is concentrated in very small world portions (production of many of these materials is predominantly from outside Europe; in many cases it is dominated by a single country or region and thus affected by conflicts over access as well as geopolitical and trade issues), which lets assume that supplies might become tight and costs prohibitive as markets grow. If this would occur, there would be serious impacts in key market sectors as a consequence of the restricted supply of these materials.
  - Metamaterials have been widely studied for applications in the aerospace and defence sector, particularly referring to innovative antenna systems. Such developing knowledge can find its alternative applications in civil markets, strengthening its possibility to be commercialised in the medium-term.
  - Sources: European Commission, Critical raw materials for the EU, Report of the Ad-hoc Working Group on defining critical raw materials, June 2010; Materials Security Special Interest Group of Technology Strategy Board Network, Innovation Opportunities and Material Security, 2012

- ***Results of patents scenario analysis:***
  - 32 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Unstable trend curve (number of patents per year) with a generally low patenting activity per year
  - Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants, most probably standing for new technologies having been patented in the corresponding periods:



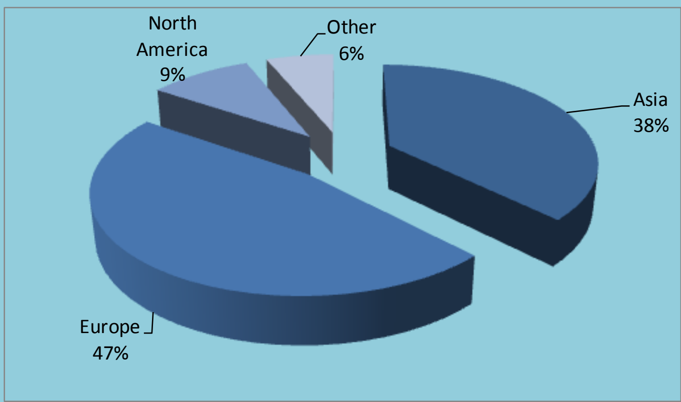
  - Patents by KET(s):



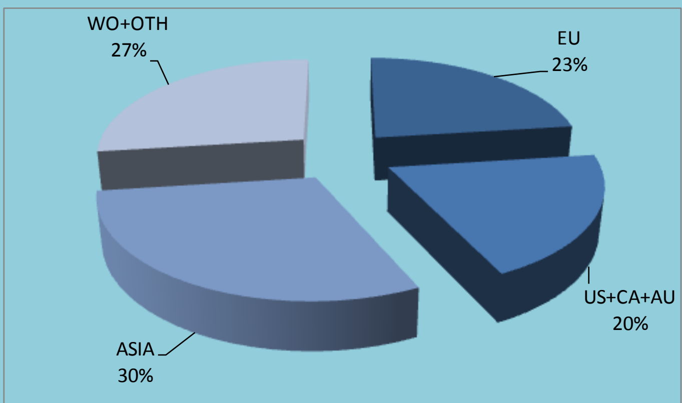
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	21
AM / N-T	1
AM / PhT	1
AMS	3
IBT	1
MNE	5
MNE / PhT	1
N-T	3
PhT	2

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



Sub-domain: Advanced functional materials

Demand-side requirements (stemming from Societal Challenges) addressed:

- Indirectly tackle challenges such as "climate action, resource efficiency and raw materials", "smart, green and integrated transport" and "secure, clean and efficient energy" thanks to contributing higher performing materials for various applications that are key to the achievement of the aforementioned challenges

Demand-side requirements (stemming from market needs) addressed:

- Production of high performing materials with improved functionalities

CH.2.1: High-strength / low-weight fibre-reinforced polymer composite materials

Scope:

Fibre-reinforced polymer composite materials with superior strength and lower weight for application in transport applications (to reduce fuel consumption while guaranteeing strength), civil engineering (to provide for steel substitution in structures requiring strength combined with lightweightness or low maintenance), sports equipment, etc.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

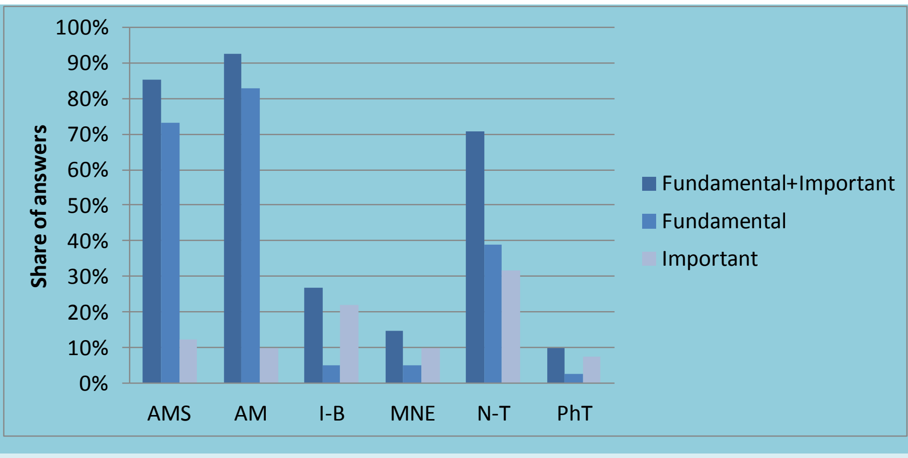
- Rational design, tailoring of properties, adaptation of design procedures as well as processing techniques towards automatized production of fibre-reinforced polymer composite materials
- Lifetime prediction for fibre-reinforced polymer composite materials
- Development and incorporation of stiffer and more rigid fibres into matrix materials (such as metals or plastics) to make a stiff but lightweight composite material with anisotropic properties

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced, high-strength/ low-weight fibre-reinforced polymer composite materials by tailoring their properties, thanks to the adaptation of processing techniques as well as procedures towards automated production and the development of stiffer and more rigid fibres for their subsequent incorporation into matrix materials (such as metals or plastics) to make the composite material stiffer but lightweight and with anisotropic properties.

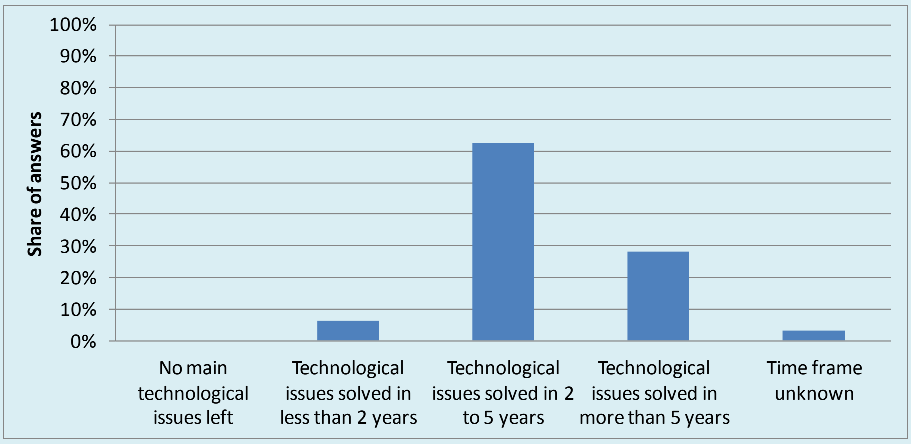
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet minor consensus indicates also greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

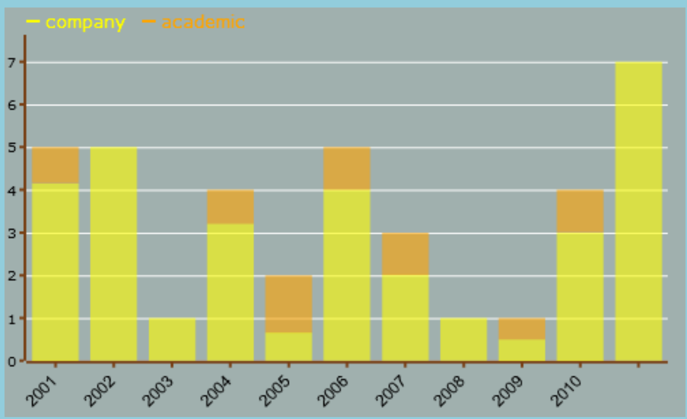
- ***Impact assessment:***
  - Fibre-reinforced polymer composite materials offer a number of advantages over some of the traditional materials they can replace. Such advantages mainly comprehend high structural efficiency (meaning strength-to-weight ratio) and corrosion resistance to a wide range of chemicals. As a result, the range of applications of these materials has increased exponentially in the last thirty years.
  - Fibre-reinforced polymer composite materials find today their application mainly in the space, aeronautics, marine/naval, automotive, industrial equipment, energy equipment (mainly wind turbines), electrical equipment, and general consumer commodities' sectors (mainly sports equipment). Although fibre-reinforced polymer composites were initially developed for cost-insensitive military and aerospace applications, improvements in manufacturing techniques and the development of lower-cost fibres have opened them up to the highly price-conscious sectors such as the structural and civil engineering sectors, their market relevance being therefore strictly related to the respective market sectors in which they find application.
  - Fibre-reinforced polymer composite materials are normally applied in order to provide high strength as combined with low weight. This, in relation to transport applications, can lead to savings in fuel consumption with consequent advantageous emissions reduction. They are moreover applied for their corrosion resistance, thus providing longer useful life to components. Last but not least, they can provide tailor-made properties to components, thus enabling optimal design as combined with lower

material usage as well as waste generation. Within this framework, they can indirectly contribute to tackle challenges such as "climate action, resource efficiency and raw materials", "smart, green and integrated transport" and "secure, clean and efficient energy".

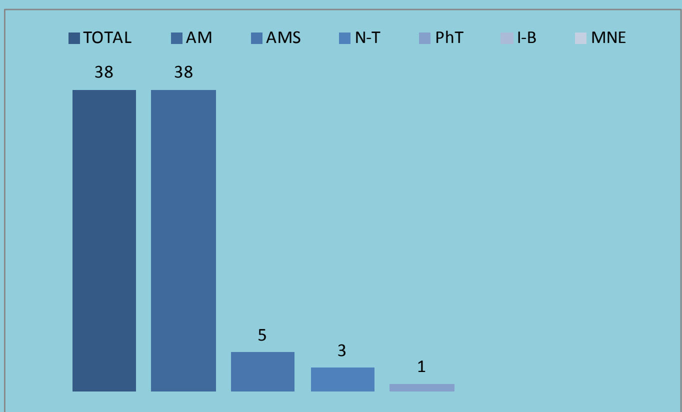
- Production of fibre-reinforced polymer composite materials is expected to grow annually of 6% in terms of value and 5% in terms of volumes, with thermoplastic matrix composites witnessing faster growth (8%/year) than thermo-hardening composites. In terms of volumes, composites remain largely dominated (85%) by fibreglass, despite the large increase in carbon fibres and natural fibres, with the global fibreglass reinforced plastic composites market being estimated to grow at a compound annual growth rate (CAGR) of 7.4% from 2014 to 2019 to reach a value of 35 billion Euro.
- Composites manufacturers in Europe stand at circa 10 000 companies and involve a total of about 100 000 employees, with the majority of these companies being SMEs.
- In light of the economic difficulties in Western Europe (Spain for instance) and the growth of regions such as Asia and the BRIC counties, in general terms, countries which export are faring much better than others. In 2012, largest growth was witnessed in Germany, the UK and Eastern Europe. In Benelux, production moved from 42 ktons in 2011 to 43 ktons in 2012. A certain decline was instead observed in Scandinavia mainly due to difficulties in shipping construction (which constitutes about 2/3 of production of composites in Finland). Outsourcing production to India and the ordering of composites in China (for wind turbine blades for instance) are affecting European countries.
- Sources: +Composites, Composites: materials of the future, Part 2: Market and market developments, 2012; Reportlinker.com, March 2014

➢ ***Results of patents scenario analysis:***

- 38 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Almost stable trend curve (number of patents per year) with a generally low patenting activity per year
- Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants, most probably standing for new technologies having been patented in the corresponding periods:



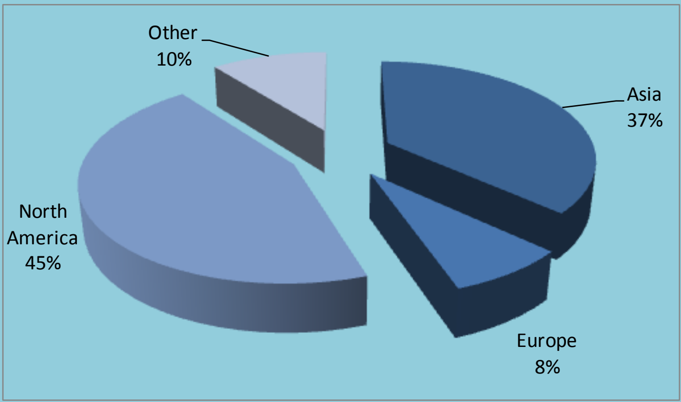
- Patents by KET(s):



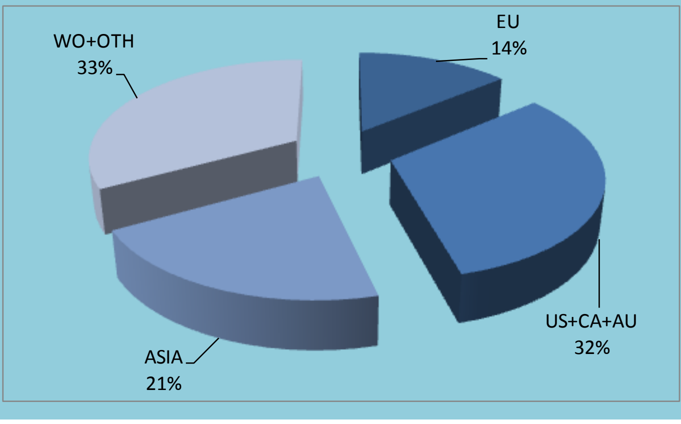
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	38
AM / N-T	3
AM / PhT	1
AMS	5
AMS / AM	5
N-T	3
PhT	1

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



CH.2.2: Advanced materials and new material architectures with added functionalities

Scope:

To develop advanced, mainly structural, materials with added functionalities, such as for sensing or self-repair, and new material architectures incorporating novel fibres, nanomaterials, etc., capable to provide added functionalities especially to large structures.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of bio-inspired approaches to effect self-healing, which can be described as mechanical, thermal or chemically induced damage that is autonomously repaired by materials already contained within the structure
- Manufacture and incorporation of micrometric hollow fibres or capsules capable to release a repair agent (e.g. a resin) within both composite laminates and sandwich structures
- Incorporation of e.g. magnetic materials or structures within composite components to provide e.g. magnetic sensing functions

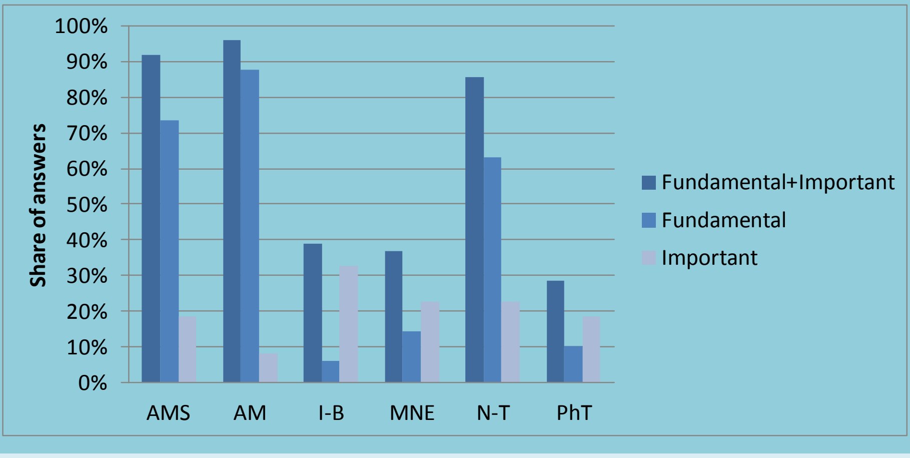
- Development and incorporation of stiffer and more rigid fibres into matrix materials (such as metals or plastics) to make a stiff but lightweight composite material with anisotropic properties

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced materials and new material architectures with added functionalities, thanks to e.g. the development of bio-inspired approaches to effect self-healing, the manufacture and incorporation of micrometric hollow fibres or capsules capable to release a repair agent within both composite laminates and sandwich structures, the incorporation of materials or structures, within composite components, to provide sensing functions, or other approaches capable to add ad-hoc functionalities to materials.

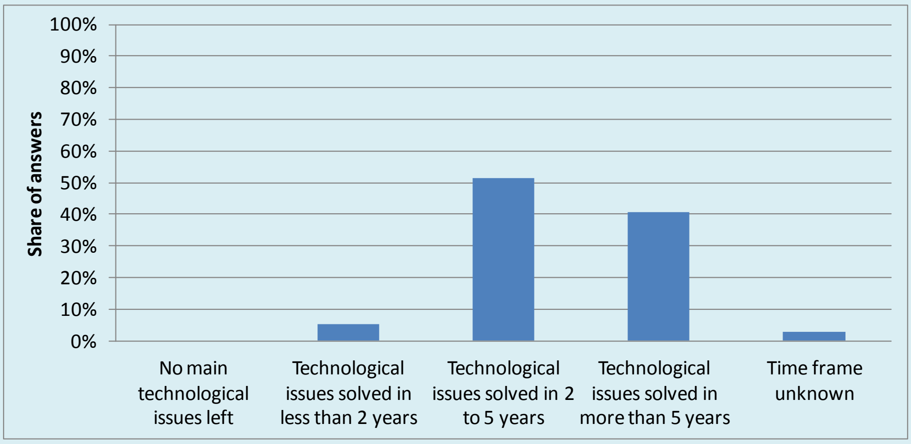
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:



Depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, according to the authors' view, the provision of support in the short to medium term should be taken into consideration within this framework.

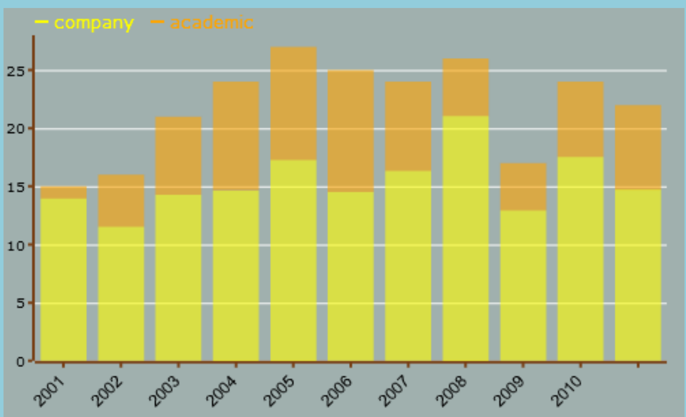
Additional information according to results of assessment:

➢ ***Impact assessment:***

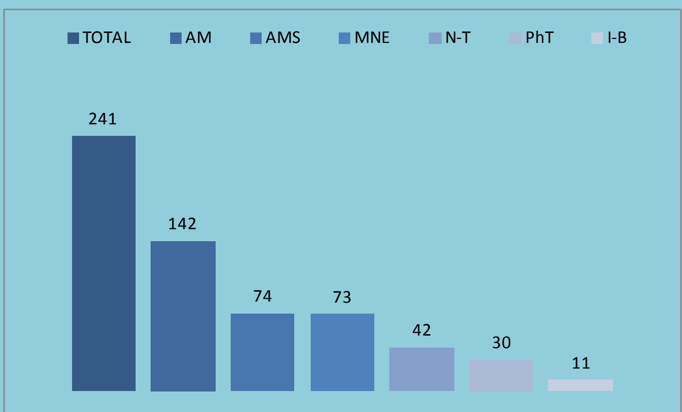
- Advanced structural materials or new material architectures with added functionalities may include materials such as metals and alloys (ferrous and non-ferrous), ceramics, polymers, semiconductors, and composites, which are engineered thanks to knowledge-intensive processing methods or the incorporation of e.g. novel fibres, nanomaterials, etc., in order to achieve added functionalities and 'unique' material properties.
- Differently from more conventional materials as well as conventional composite materials, these materials find their application in niche markets in which the added functionality represents a competitive advantage over conventional materials.
- Added functionalities can provide, for example, for sensing or self-repair and can be achieved thanks to new material architectures incorporating novel fibres, nanomaterials, etc.
- These materials are generally engineered in such a way to optimally respond to customers' requirements meaning that they are tailored to customers' specifications.
- Also defence applications and equipment often make use of lighter and stronger materials, for example, on military aircraft, rockets, ground vehicles and munitions. Advanced materials are also used to improve the performance of reduced radar visibility, coatings for jet engine performance, and armour for military vehicles. For some of these applications, especially regarding aircraft structures, there are strong ties with civilian developments and applications. Therefore this area is particularly linked to dual use applications.

➢ ***Results of patents scenario analysis:***

- 241 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Almost stable trend curve (number of patents per year)
- High participation of academic applicants in the patenting activity standing for technologies being still in the evolving phase:



- Patents by KET(s):

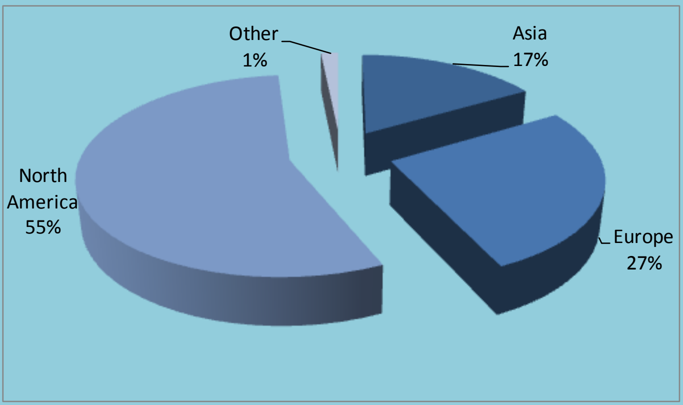


- Patents by KET(s) and relevant combinations of KETs:

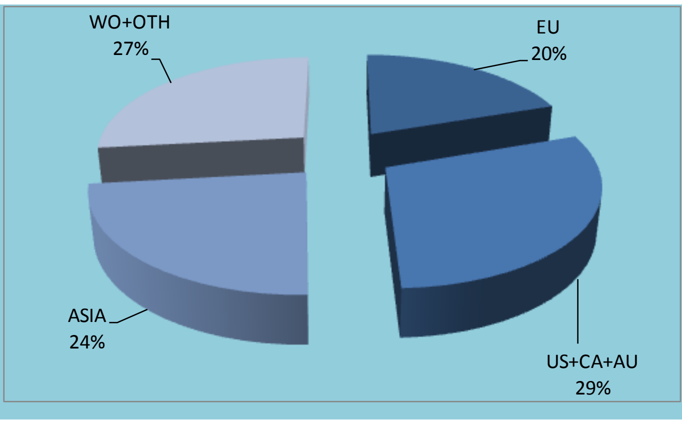
KET(s)	*Number of patents*
AM	142

AM / IBT	6
AM / IBT / MNE	3
AM / IBT / MNE / N-T	1
AM / IBT / N-T	2
AM / MNE	36
AM / MNE / N-T	11
AM / MNE / N-T / PhT	1
AM / MNE / PhT	7
AM / N-T	29
AM / N-T / PhT	2
AM / PhT	11
AMS	74
AMS / AM	15
AMS / AM / MNE	6
AMS / AM / MNE / N-T	1
AMS / AM / N-T	2
AMS / AM / PhT	1
AMS / IBT	1
AMS / MNE	17
AMS / MNE / N-T	3
AMS / MNE / PhT	2
AMS / N-T	5
AMS / PhT	9
IBT	11
IBT / MNE	3
IBT / MNE / N-T	1
IBT / N-T	3
MNE	73
MNE / N-T	18
MNE / N-T / PhT	1
MNE / PhT	13
N-T	42
N-T / PhT	3
PhT	30

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



CH.2.3: Ceramics, intermetallics, alloys, superalloys and metal/ceramic-based composite materials for high-performance applications

Scope:

Lower cost, lower density, high-strength, high-temperature or corrosion-resistant ceramics, intermetallics, alloys, supealloys as well as metal-matrix, ceramic-matrix or metal-ceramic composites for high-performance applications mainly in the fields of energy and transport.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

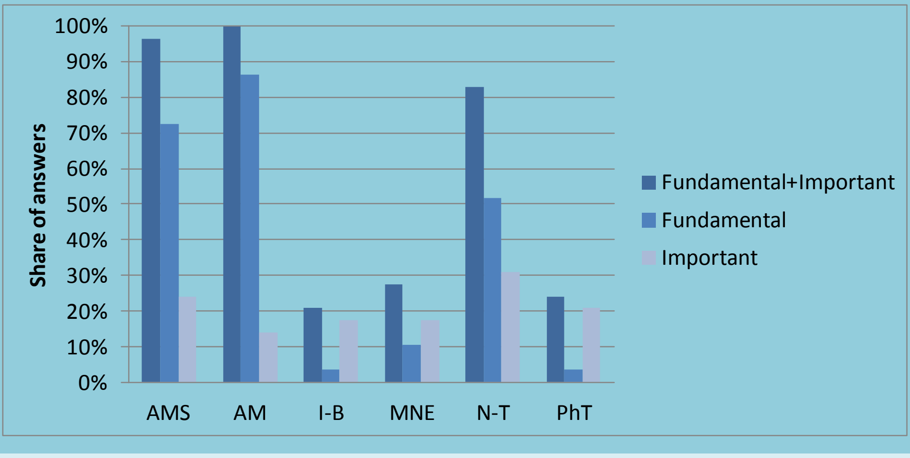
- Development of more efficient and economic production technologies, also including secondary production based on (e.g. steel) scrap recycling
- Development of novel materials for energy applications addressing the important issues of durability, efficiency and cost of energy systems
- Increase of the steam data, i.e. pressure and temperature, of power plants through developments in new materials (austenitic alloys, ferritic alloys, FeCrAl alloys, ceramics) tackling problems such as creeping, cracking, Thermal Mechanical Fatigue (TMF), corrosion, erosion
- Development of materials for application in acid gas compression and other highly corrosive operations
- Development of steel-based materials for energy applications addressing the issues of durability, energy efficiency and overall costs of power generation
- Development of steel or aluminium-based lightweight crashworthy, low wear eco-designed materials for vehicle structural parts
- Development of steel-based very thick materials with high Young modulus (e.g. as steel matrix composites with ceramic compounds)
- Implementation of high precision near shape casting and other rolling and finishing capabilities to produce optimal metal-based products and semi-products (blooms, billets or slabs) that reduce manufacturing operations, costs and material waste in later manufacturing operations
- Development of one-piece / net-to-shape / molecular connection / advanced welding techniques for complex steel structure shapes (to limit joints, scraps and machining)
- Development of low density resistant, reinforced, resilient (against fatigue, incidents, attacks, etc.), shock absorbing and/or even self-healing / self-repairing alloys
- Development of solutions alternative to zinc coating (galvanization) for anti-corrosion treatment of new steels containing easily oxidized elements
- For new steels likely to be welded (most of them), demonstration of the reliability of the welds under critical conditions
- Implementation of very narrow control of metallurgical process parameters enabling a wide range of properties as high temperature usage, high strength at more or less constant deformability, high deformability at more or less constant strength

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of ceramics, intermetallics, alloys, superalloys and metal/ceramic-based composite materials for high-performance applications, thanks to the development of novel materials addressing the important issues of durability, efficiency and cost of final applications, , along with more efficient and economic production technologies, also including secondary production based on scrap recycling or the implementation of high precision near shape casting and other processing and finishing capabilities to produce optimal products and semi-products that reduce manufacturing operations, costs and material waste in later manufacturing operations.

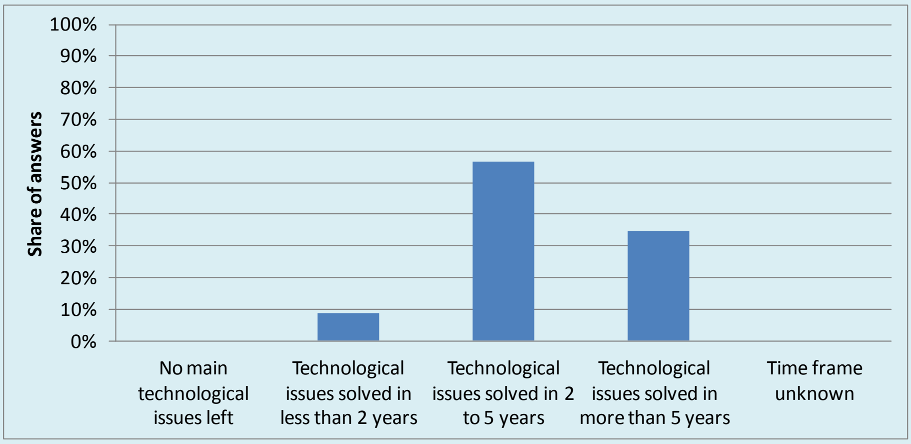
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

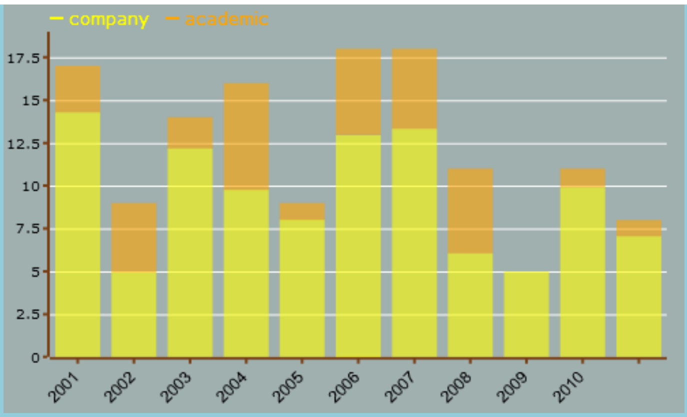
According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:



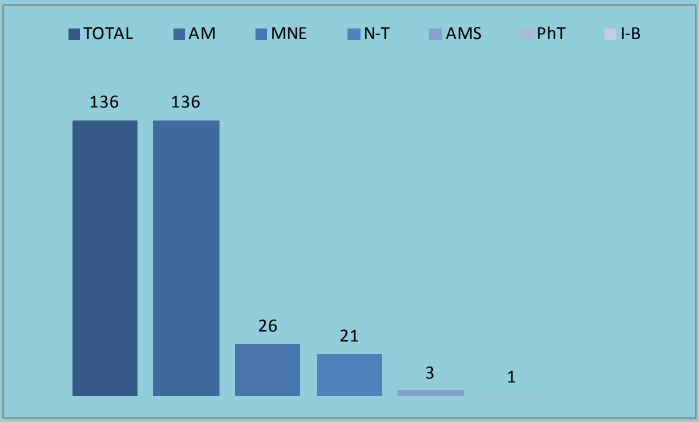
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Ceramics, intermetallics, alloys, superalloys, and metal/ceramic-based composite materials are mainly developed and applied for high-performance engineering applications mainly in the fields of energy and transport.
  - Materials developed at the first instance for gas turbine and other engine-related high temperature components (e.g. valves, nozzles, etc.) had high temperature tensile strength as the prime requirement. This requirement however quickly changed as operating temperatures rose. Stress rupture life and then creep properties became important. Subsequently, low cycle fatigue life became another important parameter. As a result, advances in the field of materials have contributed much to achieving gas turbines as well as engines with higher power ratings and efficiency levels, allowing also the introduction of important improvements at the design level over the years.
  - Gas turbines are widely utilized in aircraft engines as well as for stationary applications importantly for power generation. Moreover, other engine parts such as jet engine blades, compressor wheels for turbo chargers, valves, pistons, and other high temperature components are widely utilized either in aircraft or in other engines. Advances in gas turbine as well as engine materials have always played a prime role; the higher the capability of the materials to withstand elevated temperature service, the higher the turbine or engine efficiency because materials with high elevated-temperature-strength-to-weight ratio help in weight reduction.
  - Air transport is a major industry, also having important impacts onto wider economic, political, and social systems. The global civil air transport market has grown significantly since its inception around the 1950s. Today, while globalization and internationalization increase, the mobility and personal interchanges that air transport facilitates also increase, letting forecast a steady growth rate of 4-5% per year up to 2030. As a result, new aircrafts are being produced either to replace aircraft retirements or in excess in order to be parked for future replacements. Taking a view to 2031, it has been forecast by Rolls-Royce (2012) that the global aircraft market will require 149 000 engines to be delivered, worth around 720 billion Euro (Sources: European Union, Increasing the sustainability of air transport, 2013; Rolls-Royce, Market outlook, 2012).
  - In terms of stationary power generation, gas turbines, increasingly in combined cycle applications with heat recovery steam generators converting waste heat into steam, and steam turbine generators using that steam for increased generation efficiency, will continue to be the workhorses in the power generation industry. In evaluating the market for gas turbine electrical power generation over the next decade, many factors lead to the conclusion that annual growth will most likely exceed 2.5-3.0% worldwide in order to keep up with demand (Sources: The Market for Gas Turbine Electrical Power Generation, Special Focused Market Segment Analysis by Forecast International, 2011).
  - Europe is home to important manufactures of both aircraft engines (e.g. Rolls-Royce among others) as well as turbines for stationary power generation (e.g. Siemens among others). Besides having positive impact on aircraft engines as well as gas and steam turbines manufacturers, the aforementioned forecasts will have consequent positive impacts onto European manufacturers of high-performance engineering materials and components.
- ***Results of patents scenario analysis:***
  - 136 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Unstable trend curve (number of patents per year) with descending trend in most recent years
  - Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants, most probably standing for new technologies having been patented in the corresponding periods, yet low patenting activity of the latter type of applicants in most recent years:



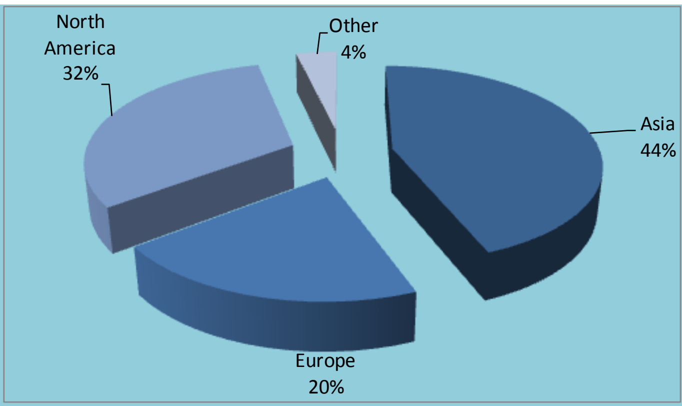
- Patents by KET(s):



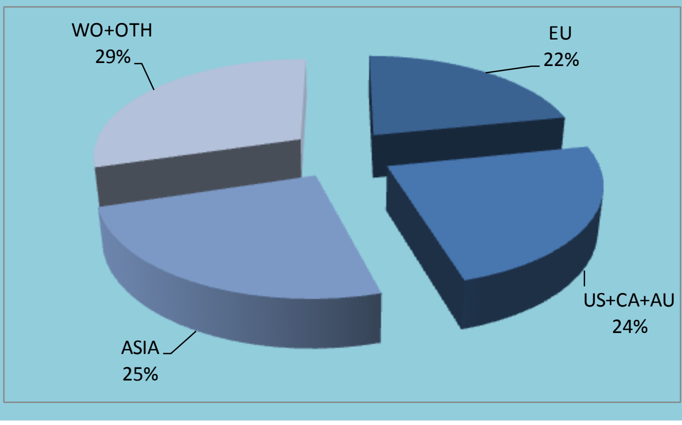
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	136
AM / MNE	26
AM / MNE / N-T	5
AM / MNE / PhT	1
AM / N-T	21
AM / PhT	1
AMS	3
AMS / AM	3
AMS / AM / MNE	1
AMS / MNE	1
MNE	26
MNE / N-T	5
MNE / PhT	1
N-T	21
PhT	1

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



CH.2.4: Coatings and surfaces with high scratch and/or corrosion resistance, good weatherability and/or with self-repairing capabilities

Scope:

Long-lasting coatings and surfaces with high scratch and/or corrosion resistance, good weatherability as well as coatings and surfaces with self-healing, self-repairing or self-replicating properties.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Understanding and prediction of the relationships among chemistry, microstructure and material properties/ performance
- Control of functional properties and performance through synthesis and processing
- Lifetime prediction

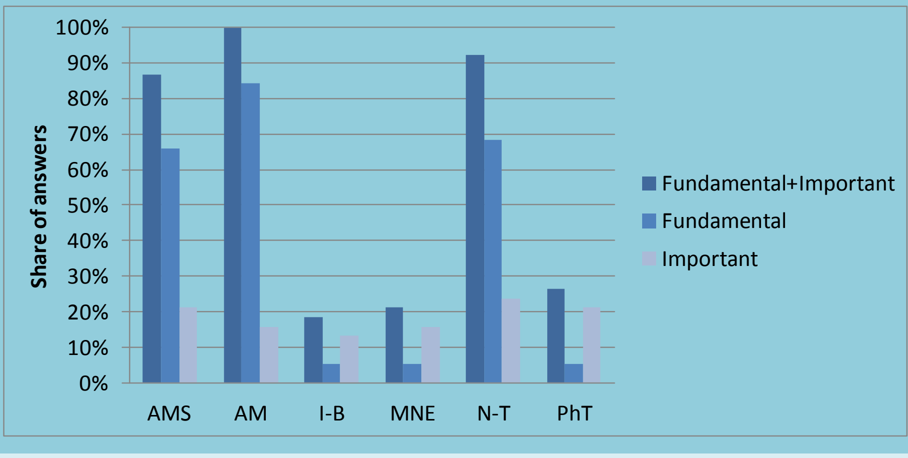
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced, long-lasting coatings and surfaces with high scratch and/or corrosion resistance, good weatherability and/or with self-repairing capabilities, thanks to adjusting chemistry, microstructure and material properties/performance and the precise control of their functional properties and performance through specialized synthesis and processing.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

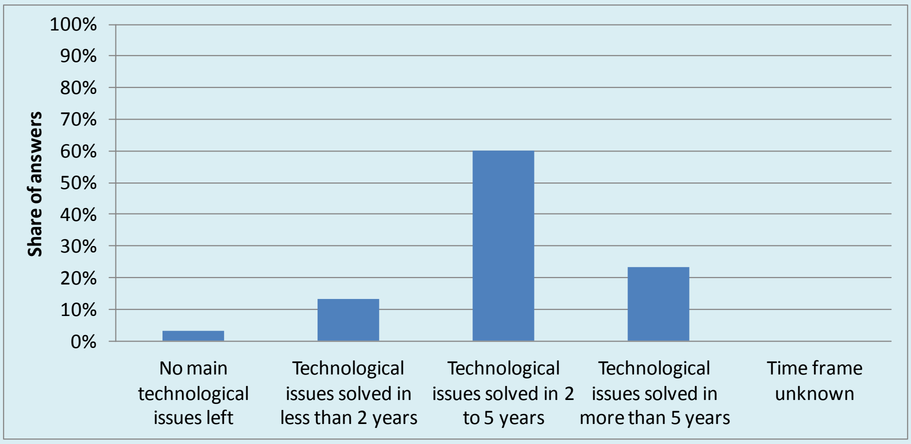
- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)

- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

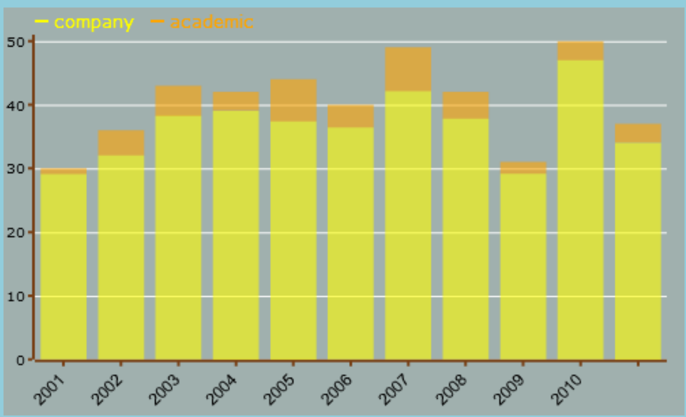
- Along with paints and finishes, protective coatings are widely used in many industrial sectors (transport, construction and other various industrial applications). Coats for the various applications must maintain their properties over long periods in the face of degradation caused by damage or environmental exposure.
- Exterior clearcoats and topcoats, the outermost coatings used for various applications importantly in the transport sector, including in aircrafts and vehicles, must maintain properties such as smoothness of surface finish (for aircrafts) and clarity and gloss (for vehicles), though they may be subject to damage caused by numerous elements, including environmental fallout; exposure to ultraviolet radiation from sunlight; exposure to high relative humidity at high temperature; and defects made by impact from small, hard objects resulting in chipping. Yet they can be formulated to minimise scratches and environmental exposure degradation.
- While environmental regulations are driving the shift to low Volatile Organic Compound (VOC) products such as waterborne or powder coatings, the market demand for advanced paints and coatings technology is increasing. As a result, advanced coating solutions are being developed and provided by paints and coatings companies to vehicle and aircraft manufacturers. Within this framework, Europe is the base for important international paints and coatings producing companies such as Akzonobel,

Arkema, BASF, Bayer, Clariant, Solvay, to name a few (Source: ResearchandMarkets, Automotive Paints Market by Coat Type, Technology, Texture Type, Vehicle Type & Geography - Global Trends & Forecast to 2018, September 2013).

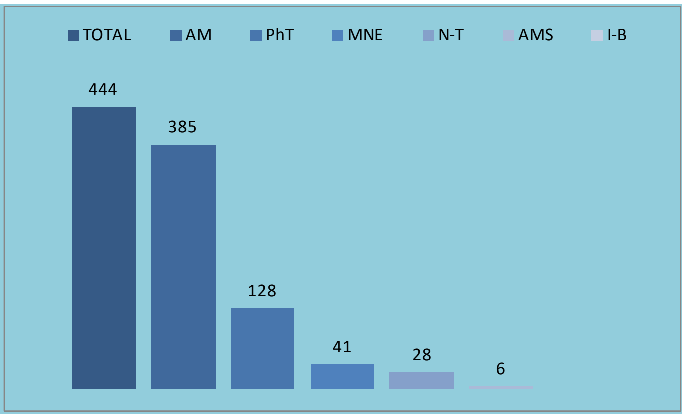
- Global demand for vehicles is increasing, specifically for passenger cars and light commercial vehicles, and global vehicle production reached 84.1 million units in 2012. Analogously, global demand for aircrafts is increasing. Due to the increase in vehicle as well as aircraft production, paints and coatings consumption also increased in 2012. The global market for paints and coatings is also expected to grow at a promising rate in the next years. Within this framework, while Europe constituted the largest paints and coatings market as well as producer in 2007, it then left its position to the Asia-Pacific region, despite maintaining high volumes in terms of both market and production (Source: ResearchandMarkets, Automotive Paints Market by Coat Type, Technology, Texture Type, Vehicle Type & Geography - Global Trends & Forecast to 2018, September 2013).
- Also in the construction industry paints, finishes and coatings find important applications. In this case, they require good weatherability, impermeability, and, in case of steelworks, most importantly corrosion resistance.
- The European construction paints and coatings market size was worth 10 billion Euro in 2011. Market size increased by 1.9% in 2011 over 2010, after recording two consecutive years of decline in 2009 and 2010. Europe also recorded an increase in demand by 2.1% in 2011 over 2010 despite registering a decline in volume in the previous year, which can be attributed to the significant reduction of construction activities across all European countries due to the global economic slowdown. The market recovery in 2011 came about due to the positive growth in market size of paints and coatings across all European countries except Spain and the UK. In 2011, Poland recorded the highest annual growth of paints and coatings market size in Europe (6.8%). The high growth in Poland is due to the country's persistent housing deficit which encouraged residential construction. The other European countries recorded negative growth rates in the market size, with the UK declining the most (Source: Timetric, Global Construction Paints and Coatings - Market Opportunities and Business Environment, Analyses and Forecasts to 2016, December 2011).
- The aerospace and defence sector have widely implemented advanced coatings to exploit materials performance. This is also due to the fact that the requirements typically needed in the defence sector are much more challenging than in other fields, as for example the need for lightweight, thermal stability, high melting point, high thermal conductivity, oxidation resistance, complex shapes. This shows that the potential for dual use applications is very high, particularly from the aerospace & defence to other civilian sectors.

➢ ***Results of patents scenario analysis:***

- 444 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Stable trend curve (number of patents per year)
- Highest share of industrial applicants:



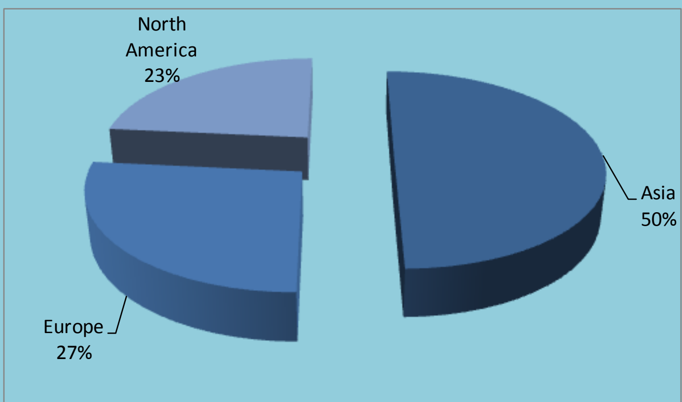
- Patents by KET(s):



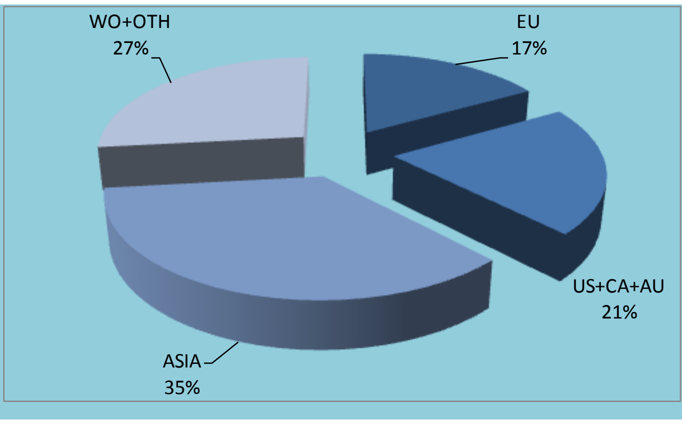
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	385
AM / MNE	21
AM / MNE / N-T	3
AM / MNE / N-T / PhT	1
AM / MNE / PhT	12
AM / N-T	24
AM / N-T / PhT	4
AM / PhT	84
AMS	6
AMS / AM	1
AMS / AM / PhT	1
AMS / MNE	2
AMS / MNE / PhT	1
AMS / PhT	2
MNE	41
MNE / N-T	4
MNE / N-T / PhT	2
MNE / PhT	23
N-T	28
N-T / PhT	5
PhT	128

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



CH.2.5: Coatings and surfaces with anti-fouling or self-cleaning properties

Scope:

Coatings and surfaces with anti-fouling or self-cleaning properties able to recognise and inhibit e.g. bio-fouling agents, pollutants, corrosion agents, etc.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

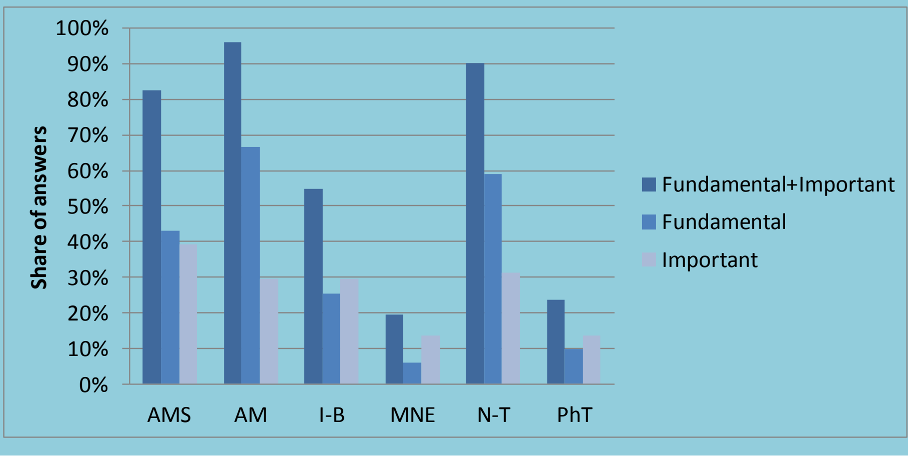
- Understanding and prediction of the relationships among chemistry, microstructure and material properties/ performance
- Control of functional properties and performance through synthesis and processing

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced coatings and surfaces with anti-fouling or self-cleaning properties, thanks to adjusting chemistry, microstructure and material properties/ performance and the precise control of their functional properties and performance through specialized synthesis and processing.

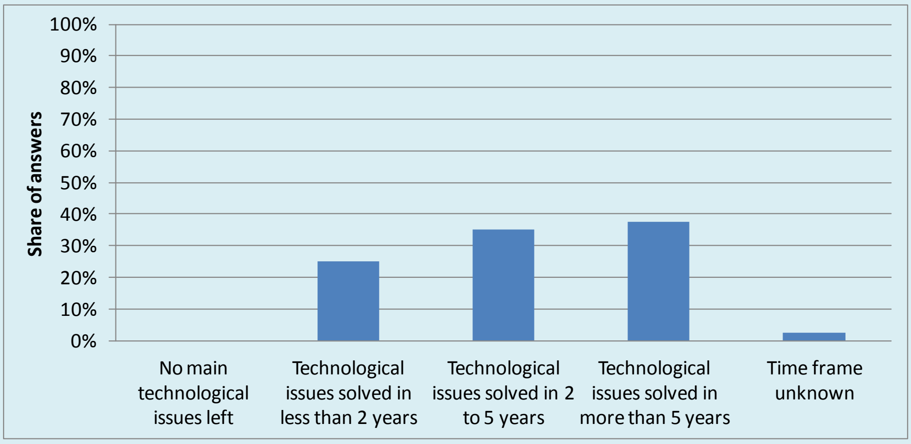
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus by experts indicates also shorter periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

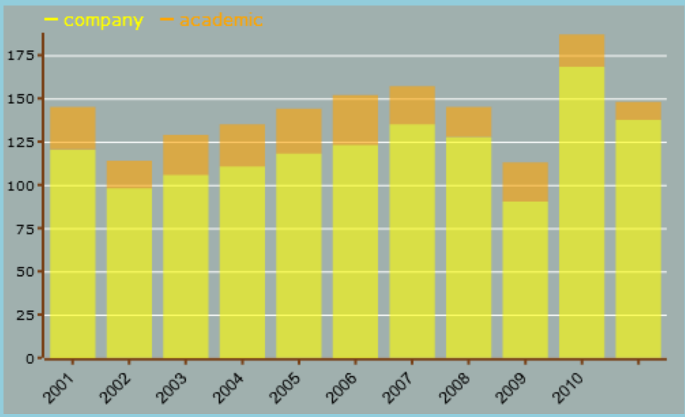
Additional information according to results of assessment:

➢ ***Impact assessment:***

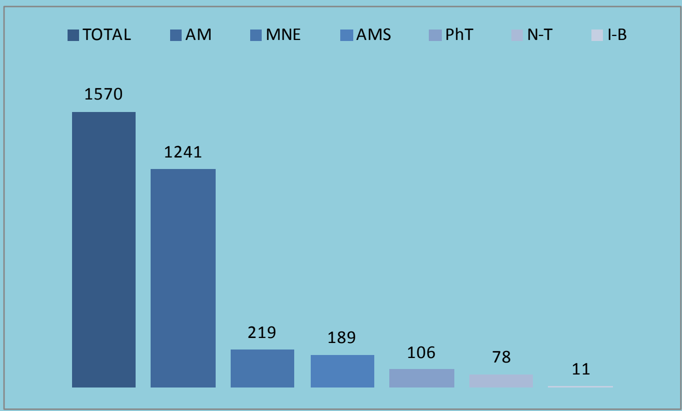
- Anti-microbial coatings were the majorly consumed coatings among self-cleaning, anti-bacterial, and anti-fouling coatings in 2012. Anti-fouling and easy-to-clean coatings were the second largest consumed coatings in the market. They are expected to grow on account of their increasing usage in end-uses such as industrial engineering, marine, food manufacturing, automotive and energy among others. Anti-fingerprint coatings are also expected to grow quickly due to rising demand from the electronics, medical and healthcare sectors. Moreover, there is significant demand of this type of coatings from the building and construction industry as they inhibit microbial growth, mildew and algae formation. Self-cleaning, anti-bacterial, and anti-fouling coatings are also widely used in food manufacturing, packaging, textiles and water treatment among others.
- The demand for anti-fouling coatings has been largely driven by the marine industry. Although ship newbuilding continues to decline, the market for marine coatings benefitted from an increase in ship repair and maintenance, thus growing steadily in 2012. The global market is also expected to continue to grow at around 4% globally, with Asia continuing to grow and both Europe and the US flattening down. Marine coatings manufacturers are especially focusing their efforts on developing anti-fouling coatings that will decrease maintenance costs and increase vessel efficiency with the driver being an increased awareness of the importance of hull and anti-fouling performance with regards to influence on vessel efficiency. In this regard, significant savings in fuel consumption and carbon dioxide emissions can be achieved. The global marine coatings market is highly consolidated since the top 4 players, among them the European multinational AkzoNobel, contribute nearly 80% of the total production (Sources: Coatings World, The Marine Coatings Market, August 2013; Transparency Market Research, Marine Coatings Market - Global Industry Analysis, Size, Share, Trends, Analysis, Growth and Forecast, 2012-2018).
- Besides the more consolidated markets for, especially, anti-fouling marine coatings, high market potentials for, especially, self-cleaning coatings are expected in the energy and the construction sectors. In the energy sector, self-cleaning coatings could be successfully applied to glass as well as mirror surfaces used in photovoltaics (PVs), concentrated photovoltaics (CPVs) and concentrated solar power systems (CSPs) in order to reduce maintenance costs whilst maintaining conversion efficiencies high. Moreover, self-cleaning coatings added with multiple components could improve service life and impart corrosion or abrasion resistance to wind turbines used mainly in deserts and offshore locations facing air borne sand-related damage. In the construction sector,

coats and paints capable to repel dirt and pollution could be successfully applied in order to reduce maintenance costs of buildings, including historic ones.

- ***Results of patents scenario analysis:***
  - 1570 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Stable trend curve (number of patents per year)
  - Highest share of industrial applicants:



  - Patents by KET(s):

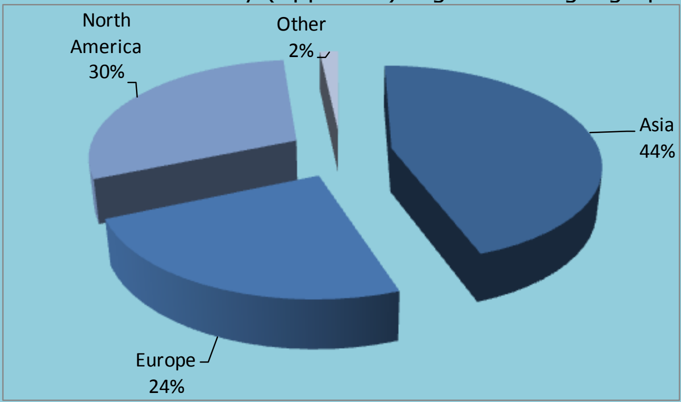


  - Patents by KET(s) and relevant combinations of KETs:

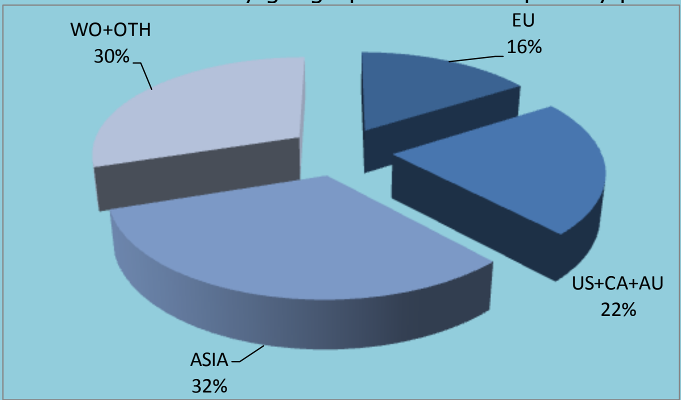
KET(s)	*Number of patents*
AM	1241
AM / IBT	3
AM / IBT / N-T	1
AM / MNE	67
AM / MNE / N-T	7
AM / MNE / N-T / PhT	2
AM / MNE / PhT	12
AM / N-T	59
AM / N-T / PhT	3
AM / PhT	42
AMS	189
AMS / AM	52
AMS / AM / MNE	3
AMS / AM / N-T	1
AMS / AM / PhT	1
AMS / MNE	18
AMS / N-T	1
AMS / PhT	1

IBT	11
IBT / MNE	1
IBT / N-T	1
MNE	219
MNE / N-T	10
MNE / N-T / PhT	5
MNE / PhT	43
N-T	78
N-T / PhT	7
PhT	106

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



CH.2.6: High mechanical, chemical and optical properties thin glass for low weight, high performance applications

Scope:

Cost-effective, high mechanical, chemical and optical properties thin glass layers for low weight, high performance applications, such as to improve or replace costly coatings and surface treatments whilst maintaining mechanical and chemical properties (purity, anti-reflectiveness, spectral behaviour, anti-fog, anti-dust, etc.).

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of cost-effective glass production processes that enable to improve or replace costly coatings and surface treatments whilst maintaining mechanical and chemical properties (purity, anti-reflectiveness, spectral behaviour, anti-fog, anti-dust,etc.)
- Development of high strength flat glass enabling large panels including for high insulating properties vacuum glass surfaces

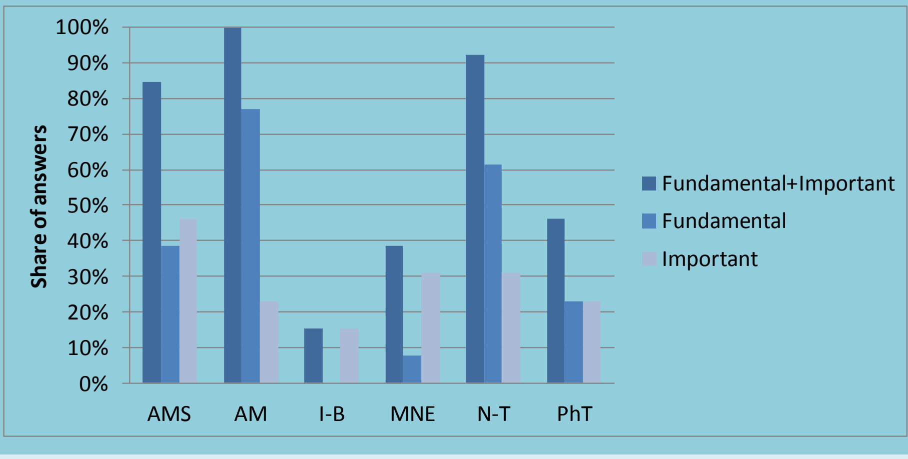
- Development of solutions that stabilize the production process so as to minimize thickness variations and allow a reduction of design margins
- Development of energy efficient thermal toughening of very thin glass layers, eventually through employing liquid or a gas/liquid phase as a cooling medium
- Development of chemical high throughput hardening processes to produce scratch and shock resistant ultra-thin glass for sensitive screens (tablet-like)

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the further development of high mechanical, chemical and optical properties thin glass for low weight, high performance applications, including thanks to the development of cost-effective thin glass production processes that enable to improve or replace costly coatings and surface treatments, including the development of chemical high throughput hardening processes to produce scratch and shock-resistant ultra-thin glass for sensitive screens (tablet-like).

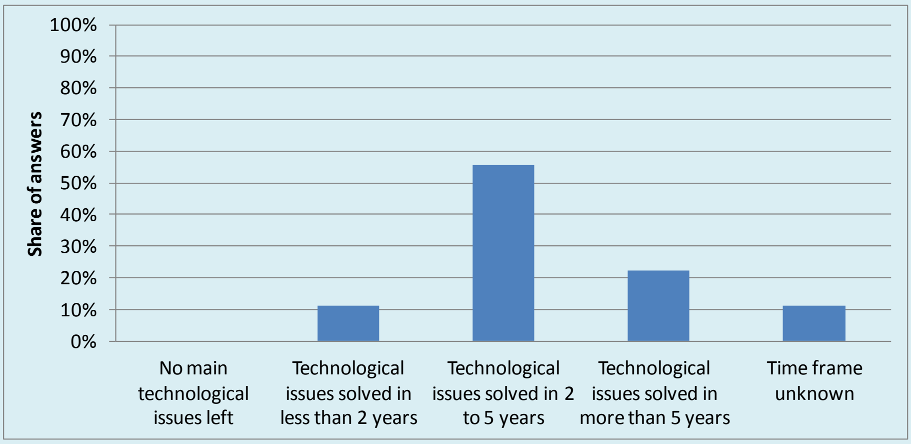
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

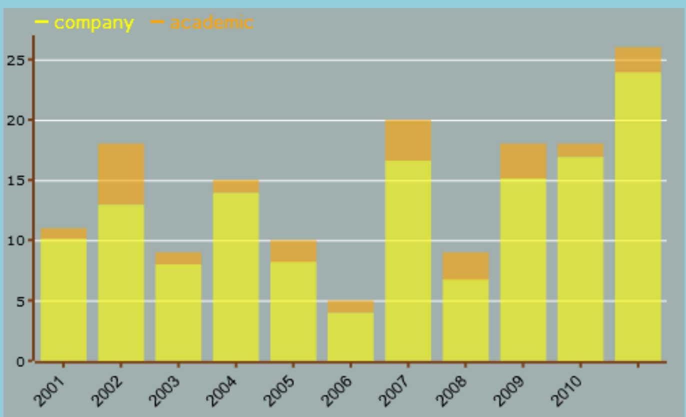
Additional information according to results of assessment:

➢ ***Impact assessment:***

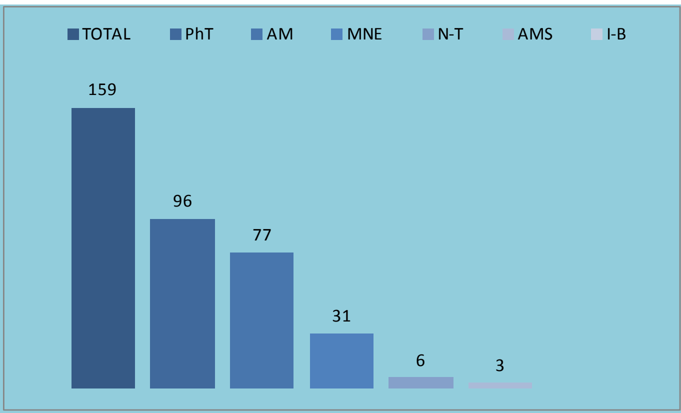
- The global glass industry generates about 55 billion Euro in annual revenue, dominated by the building construction market. Top exporters include Belgium, China, France, Germany, Japan, and the US. World demand for flat glass is forecast to rise of 7.1% per year through 2016 so that the global market value of fabricated flat glass is forecast to reach 67 billion in 2016. The Asia/Pacific region, which accounted for 60% of global flat glass demand (on a square metre basis) in 2011, will continue to post the fastest gains through 2016. The global market for flat glass in 2009 was approximately 52 million tonnes, representing a value at the level of primary manufacture of around 22 billion Euro. This market has historically been growing in volume terms at 4-5% a year.
- Fabricated flat glass demand will also benefit from rapid growth in sales of energy efficient products such as solar control, insulation, and low-E glass. Moreover, the solar energy market, which was hurt by recent global economic weaknesses, will take off once again. It should be noted, however, that demand for flat glass used in solar energy applications totalled just around 120 million square metres in 2011, so being a niche market with respect to the greater construction market.
- Thin glass classifying as special glass has instead a high added-value linked to its intense technological content. This sector regroups a large range of products such as lighting glass, glass tubes, laboratory glassware, glass ceramics, heat resistant glass, optical and ophthalmic glass, extra thin glass for the electronics industry (e.g. Liquid-crystal display (LCD) panels, photovoltaics (PVs)) and radiation protection glasses. Special glass only micrometers in thickness can be manufactured as a continuous ribbon and then be rolled up at Schott, Germany. Although thin glass is already available on the market, Schott claims to be the first manufacturer capable of producing it in a thickness of only 25 microns. Ultra-thin glass will open up a number of applications. This extremely thin and flexible glass can replace materials that offer flexibility and are durable, yet cannot offer the outstanding physical and chemical properties of glass, such as plastics, for instance, which in contrast to glass are not gas-tight and therefore do not offer enough protection for electronic components from environmental influences. Special glass, on the other hand, stands up to high temperatures and offers long-term stability, is durable, highly resistant to chemicals, and resists diffusion. Furthermore, it also protects against UV radiation.
- (Sources: Glass Market Intelligence Report, Ispy publishing Industry Survey, Market Intelligence and Forecasts Series, 2013; www.schott.com).

➢ ***Results of patents scenario analysis:***

- 159 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Overall, slowly increasing trend curve (number of patents per year)
- Highest share of industrial applicants:



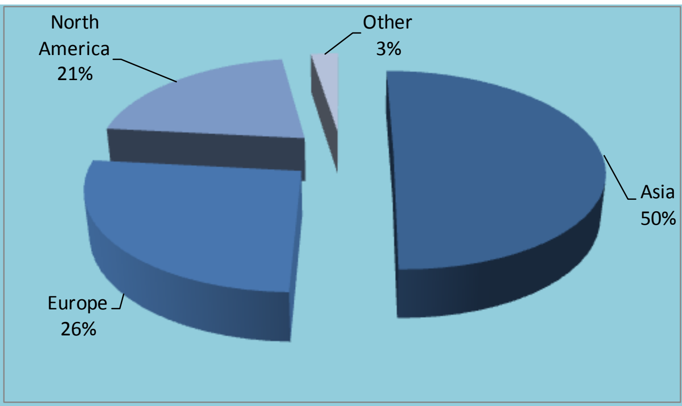
- Patents by KET(s):



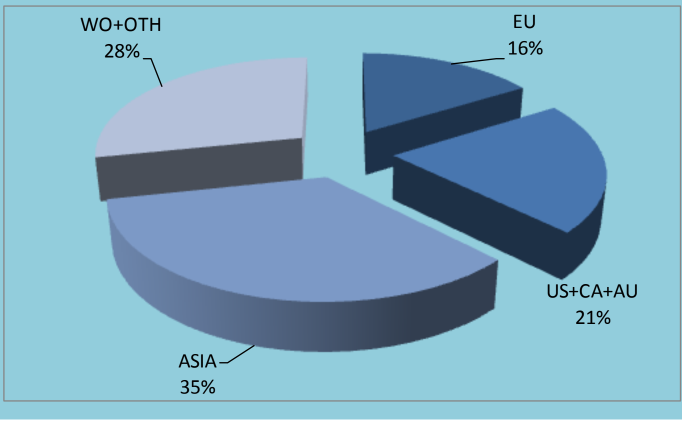
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	77
AM / MNE	6
AM / MNE / N-T	1
AM / MNE / N-T / PhT	1
AM / MNE / PhT	3
AM / N-T	5
AM / N-T / PhT	3
AM / PhT	23
AMS	3
AMS / AM	2
AMS / AM / MNE	1
AMS / AM / MNE / N-T	1
AMS / AM / MNE / N-T / PhT	1
AMS / AM / MNE / PhT	1
AMS / AM / N-T	1
AMS / AM / N-T / PhT	1
AMS / AM / PhT	1
AMS / MNE	1
AMS / MNE / N-T	1
AMS / MNE / N-T / PhT	1
AMS / MNE / PhT	1
AMS / N-T	1
AMS / N-T / PhT	1
AMS / PhT	2
MNE	31
MNE / N-T	1
MNE / N-T / PhT	1
MNE / PhT	20
N-T	6
N-T / PhT	3
PhT	96

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



Sub-domain: Efficient processing of materials and chemicals

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "climate action, resource efficiency and raw materials" challenge, indirectly also contributing to address challenges such as "smart, green and integrated transport" and "secure, clean and efficient energy"

CH.3.1: Processes for the cost-efficient conversion of various biomass to biofuels

Scope:

Bio-chemical and thermo-chemical conversion processes for the cost-efficient conversion of biomass (e.g. agro-biomass, organic waste, forestry and aquatic biomass) to biofuels.

Demand-side requirements (stemming from market needs) addressed:

- Reduce dependency on hydrocarbon-based propulsion, subject to a long term price increase tendency, and related operational costs
- Enable short term transport greening without waiting for full scale mature and financeable revolutionary propulsion means, allowing to make best use of retrofit and improvement capabilities of existing fleets of vehicles and vehicle production capabilities
- Support the transition from our current fossil fuel-based industries to bio-based industries

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of availability-cost curves for different sources of biomass (energy crops, forestry and agriculture residues, wastes) and geographical locations

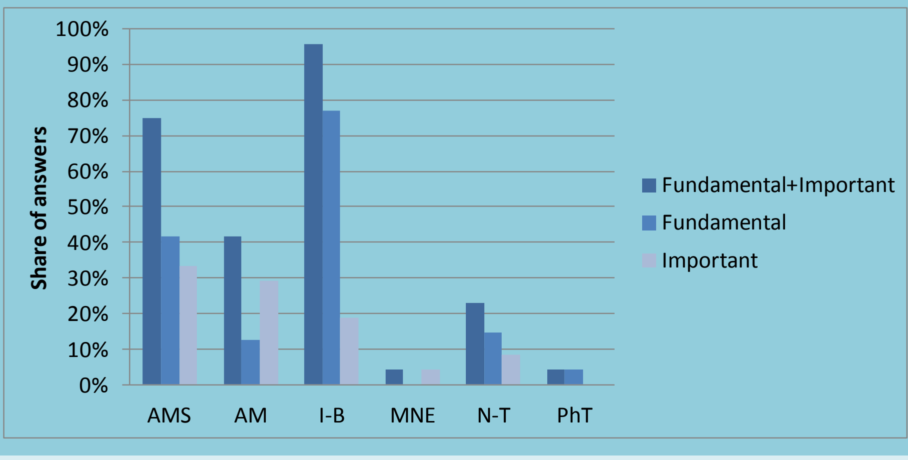
- Development of efficient biomass logistic systems (harvesting/collection/storage) for different conversion concepts at different scales
- Development of integrated biorefinery concepts making full use of a variety of biomass feedstocks to obtain diverse high-value bio-products
- Improvement of current conversion processes to their full potential (feedstocks for biorefinery) for higher GHG reduction, increased flexibility for different raw materials and lower cost
- Development and demonstration of advanced cost-efficient high quality solid and liquid biomass fuels from agro-biomass, organic waste, forestry and aquatic biomass
- Identification of a simple, coherent and global certification system to assure environmental sustainability of biofuel production chains
- Establishment of conditions for compatibility of biofuels and biofuel blends with existing logistics, as well as existing and new powertrains
- Development of a biological route / process based on lipase enzymes for the production of biodiesel

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced bio-chemical and thermo-chemical conversion processes for the cost-efficient conversion of various types of biomass to biofuels, which are characterized by high performance, stability and selectivity, thanks to the integration, into the industrial production within integrated biorefineries, of novel bio, chemical and catalytic processes allowing for the introduction of novel, improved synthetic routes for production.

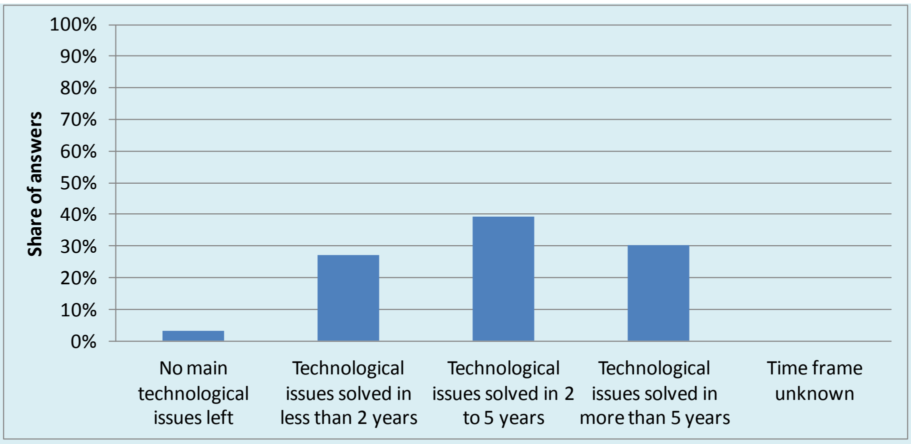
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Industrial Biotechnology (I-B)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also both shorter as well as greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

- Global biofuel development and production continues at a strong pace from the past years. Several European companies are producing biodiesel at commercial scale and cellulosic ethanol at either commercial or large demonstration scale, yet reductions in biofuel production costs must still occur thanks to optimization in conversion processes and feedstock exploitation (especially waste biomass or algae), while more advanced biofuels are being developed. The Spanish headquartered Abengoa has for instance recently completed a demonstration unit in Spain for ethanol production from Municipal Solid Waste, while Beta Renewables, a joint venture between Chemtex and TPG, has begun shipping ethanol fuel produced from wheat straw from its Italian facility in June 2013. Clariant produces ethanol from agricultural residues, running both a pilot and a demonstration facility in Germany, and has an annual capacity of 1 000 tons of ethanol/year. Inbicon/DONG, headquartered in Denmark, currently operates a large-scale pilot plant in Denmark and has formed several strategic partnerships to develop new projects in Denmark, China, and North America.
- Despite there has been a tense relationship over the past decade between oil companies and the biofuels industry, oil companies are currently slowly becoming major investors in biofuel production, as global policy moves towards assigning costs to carbon emissions. In Europe, for instance, Shell (The Netherlands) has entered a joint venture with the Brazilian energy company Cosan, which is called Raízen, while Eni (Italy) is in the process of converting a traditional refinery to a biorefinery close to Venice, in partnership with UOP. The plant will begin producing green diesel in 2014 and be fully operational by 2015. The Norwegian company Statoil provides ethanol at 1 300 stations in six countries (Norway, Sweden, Denmark, Lithuania, Latvia and Poland), while they are investing R&D efforts in investigating the potential of algae as a feedstock for production.
- Drop-in renewable hydrocarbons, which may be blended directly into standard gasoline, diesel, or jet fuel are also being developed.
- Sources: Environmental Entrepreneurs (E2), Advanced Biofuel Market Report 2013, Capacity through 2016, 2013

➢ ***Results of patents scenario analysis:***

- 5 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- No significant patent-related indicators can be reported in this field

CH.3.2: Processes for the cost-efficient conversion of various biomass to basic chemicals and intermediates

Scope:

Bio-chemical and thermo-chemical processes for the cost-efficient conversion of biomass (e.g.

agro-biomass, organic waste, forestry, etc.) to basic chemicals and intermediates, characterized by high performance, stability and selectivity (through integration of bio, chemical and catalytic processes), paying special attention to cope with the natural variability in the quality of biomass-derived raw materials.

Demand-side requirements (stemming from market needs) addressed:

- Reduce dependency on hydrocarbon-based chemicals as well as materials production, subject to a long term price increase tendency, and related operational costs
- Decrease dependency of chemical production from oil by shifting the feedstock base towards alternative feedstocks
- Support the transition from our current fossil fuel-based industries to bio-based industries

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

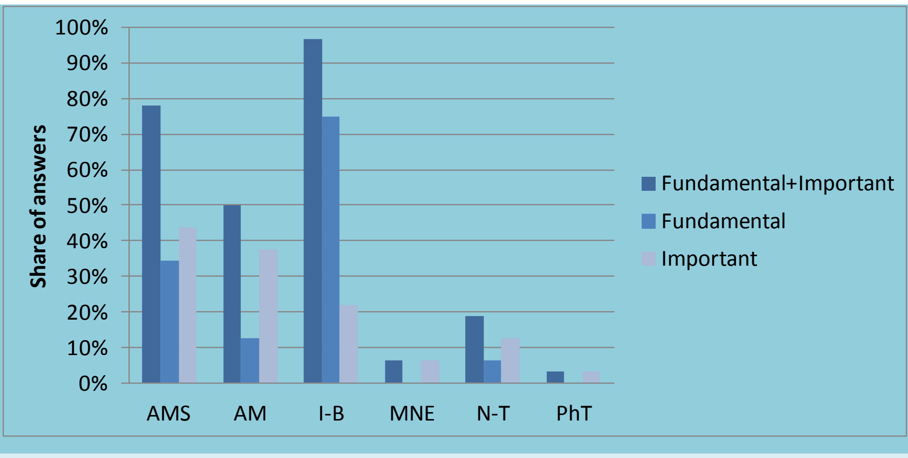
- Development of customized enzymes and modification of microorganisms for the production via biotechnological routes of basic chemicals and intermediates
- Development of customized enzymes and modification of microorganisms to use organic waste / residues as an efficient substrate
- Development of customized enzymes, which can cost-effectively break down cellulose to easily-fermentable glucose
- Development of thermo-chemical and biochemical conversion processes with feedstock flexibility for different lingo-cellulosic biomass
- Development of integrated biorefinery concepts making full use of a variety of biomass feedstocks to obtain diverse high-value bio-products
- Discovery, evolution and development of novel, robust and selective biocatalysts suitable for industrial use
- Development of methods to cope with the variability of raw materials derived from biomass
- Integration of bio-, chemical and catalytic processes into novel synthetic routes for efficient conversion of biomass-derived raw materials with high performance, stability and selectivity
- Development of robust processes based on new reactor engineering solutions to improve energy and process efficiency and economics, and which combine reaction and separation, paying special attention to cope with the natural variability in the quality of raw materials
- Development of separation agents (i.e. adsorbents, "green" extractants) and understanding of transport processes through membranes and bio-reaction mechanisms for in situ product removal in bio-reactive separations

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced bio-chemical and thermo-chemical conversion processes for the cost-efficient conversion of various types of biomass to basic chemicals and intermediates, characterized by high performance, stability and selectivity, thanks to the integration, into the industrial production within integrated biorefineries, of novel bio, chemical and catalytic processes allowing for the introduction of novel, improved synthetic routes for production.

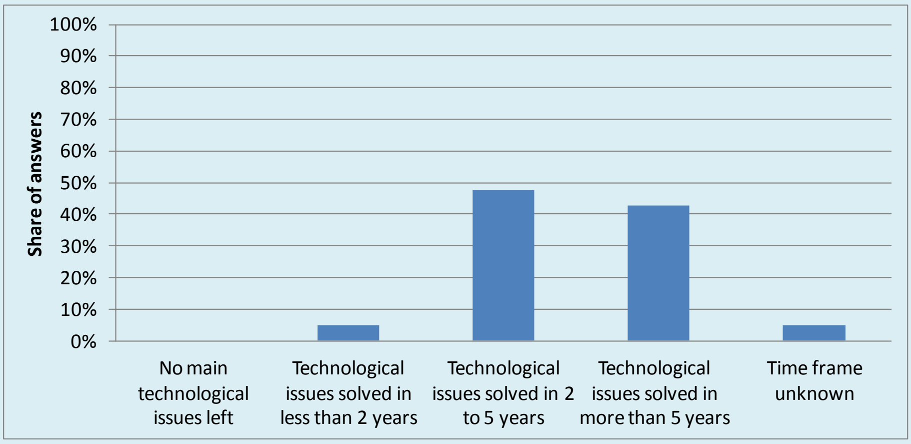
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Industrial Biotechnology (I-B)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

- Several forces, including high oil prices, consumer preference, corporate commitment, and government mandates and support, are driving development in the area of bio-based chemicals and materials (see as well Innovation Field CH1.2), for which production the production of basic chemicals and intermediates is necessary. As a result, the bio-based industry has reached a tipping point, with production expected to double in the upcoming years. Current developments (which include several investments being made in pilot production facilities) let assume that especially the bio-based chemicals sector will likely have a strong expansion in the next future. Platform chemicals obtained from renewable resources are expected to grow substantially over the next five years. This will open up perspectives for new applications for bio-based products including fine as well as specialty chemicals, bio-polymers and other bio-based derivatives and will also generate a strong boost for the cost effective production of biofuels within a biorefinery context (Source: IEA Bioenergy, Bio-based Chemicals, Value Added Products from biorefineries, 2012).
- As stated within COM(2012) 60 final, the bio-economy sectors in Europe are worth 2 trillion Euro in annual turnover and account for more than 22 million jobs and approximately 9% of the workforce. However, in order to remain competitive and maintain jobs in the light of major societal challenges and rising markets, the European bioeconomy sectors need to innovate and further diversify. Within this framework, it is

estimated that direct funding for research and innovation associated to the Bioeconomy Strategy under Horizon 2020 could generate about 130 000 jobs and 45 billion Euro in value added in bioeconomy sectors by 2025. Further growth is expected from other – direct and indirect – public and private investments in all parts of the bioeconomy (Source: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions titled 'Innovating for Sustainable Growth: A Bioeconomy for Europe' (COM(2012) 60 final)).

➢ ***Results of patents scenario analysis:***
- 10 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- No significant patent-related indicators can be reported in this field

CH.3.3: Processes for the cost-efficient utilization of CO_2 or CO as C1-synthetic building blocks

Scope:

As the result of carbon capture technologies, carbon dioxide (CO_2) is increasingly becoming available in vast quantities and in high purity as an economically attractive resource for chemical syntheses, new routes and processes (e.g. based on incorporation of CO_2 in polymers, hydrogenation of CO_2, as well as catalytic, organo-catalytic, photo-catalytic, electro-catalytic, etc., activation processes) are needed for the utilisation of CO_2 as C1-synthetic building block. Furthermore, utilisation of carbon monoxide (CO) as C1-synthetic building block can also be an opportunity.

Demand-side requirements (stemming from market needs) addressed:

- Reduce dependency on hydrocarbon-based chemicals as well as materials production, subject to a long-term price increase tendency, and related operational costs
- Decrease dependency of chemical production from oil by shifting the feedstock base towards alternative feedstocks

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

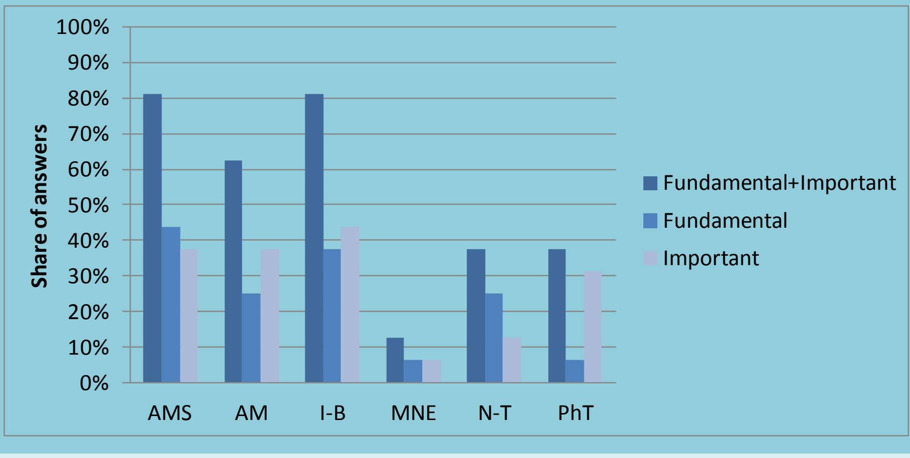
- Investigation and refinement of potential routes for CO_2 activation through catalytic processes as well as CO_2 incorporation in polymers, CO_2 hydrogenation, etc.
- Evaluation of the upstream and downstream processes, e.g. the intelligent production of reactants with high-energy content
- Development of efficient, robust catalysts that are less susceptible to catalyst poisoning to boost the chemical use even of less pure CO_2
- Development of novel organo-catalysts and cooperative catalytic procedures for the utilization of CO_2 and CO as synthetic building blocks
- Combination of catalytic pathways with the selective and local application of alternative energy options (e.g. photons, electrons, microwaves, ultrasound) to yield highest energy efficiency

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of processes for the cost-efficient utilization of carbon dioxide (CO_2) or carbon monoxide (CO) as C1-synthetic building block, by the development of new routes and processes (e.g. based on incorporation of CO_2 in polymers, hydrogenation of CO_2, as well as catalytic, organo-catalytic, photo-catalytic, electro-catalytic, etc., activation processes). The integration of KETs could moreover contribute to develop combinations of catalytic pathways with the selective and local application of alternative energy options (e.g. photons, electrons, microwaves, ultrasound) to yield highest energy efficiency during processing.

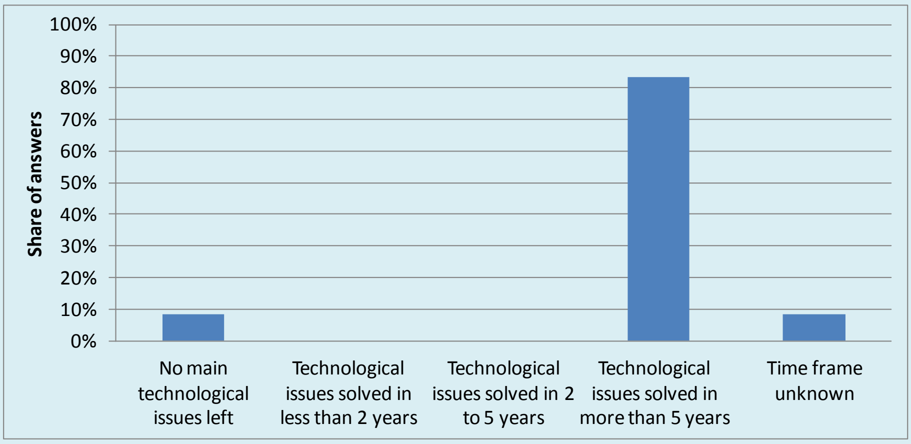
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Industrial Biotechnology (I-B)
- Advanced Materials (AM)



Timing for implementation:

A According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

- The possibility to use carbon dioxide (CO_2) or its reduced forms as C1-synthetic building block to produce industrially useful chemicals and materials has been proven over several years. By coupling chemistry with biotechnology new routes (e.g. based on incorporation of CO_2 in polymers, hydrogenation of CO_2, as well as catalytic, organocatalytic, photocatalytic, electrocatalytic, etc., activation processes) have been demonstrated on a reduced scale. In several cases quite interesting results have been obtained that make this way promising.
- Actually, CO_2 is already used by the chemical industry. The use of supercritical CO_2 as a solvent is a first example of exploitation by industry. Moreover, the synthesis of urea and the production of salicylic acid are examples of the synthesis of organic molecules using CO_2 as a reagent. Inorganic carbonates are also obtained using CO_2. While these reactions make no use of catalysts, many other reactions based on CO_2 for the production of chemicals are known that require catalysis. This has expanded in the last years the investigation of several catalytic, organocatalytic, photocatalytic, electrocatalytic, etc., pathways to provide for the chemical synthesis of various

molecules starting from CO_2 besides of other processes such as based on incorporation of CO_2 in polymers, hydrogenation or activation of CO_2.

- ***Results of patents scenario analysis:***
  - No significant patent-related indicators can be reported in this field

CH.3.4: Process intensification for increased energy- and resource-efficiency and reduced waste/emissions generation

Scope:

Intensified processes for increased energy as well as resource-efficiency and reduced waste as well as emissions generation, including through performance and control options as well as new reaction pathways and conditions, integration of reaction steps, integration of reaction and purification/separation/extraction steps, and intensification in the energy input.

Demand-side requirements (stemming from market needs) addressed:

- Increase energy- and resource-efficiency and reduce waste as well as emissions generation

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

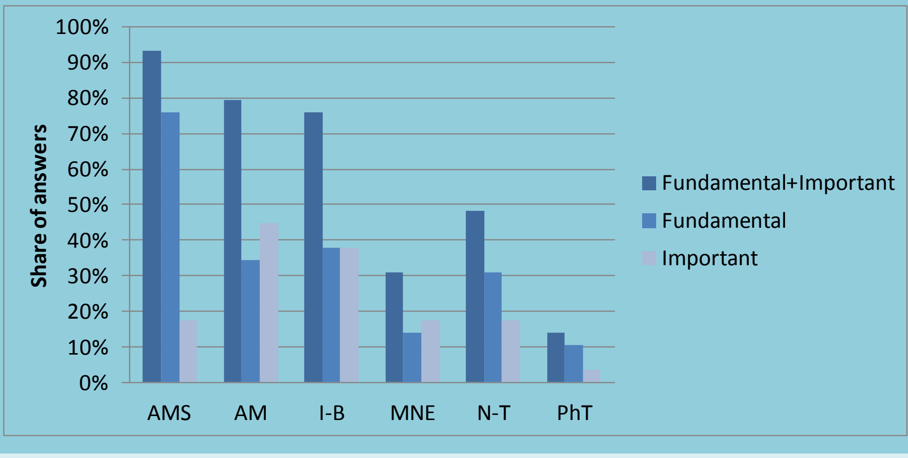
- Exploration of new reaction pathways and conditions, reduction of the number of reaction steps, introduction of intensified separation technologies and intensification in the energy input
- Development of hybrid / integrated reaction-separation systems combining (multi) reaction separation steps, or several separation processes, into one unit
- Design of integrated processes, adapted materials (i.e. membranes for hybrid separations), solvents (i.e. ionic liquids for extraction) as well as equipment
- Substitution of harmful organic solvents by other systems, such as organic safer solvents, water, supercritical fluids – most notably carbon dioxide – and ionic liquids for reaction and separation/purification purposes, as well as solventless reactions in neat reagents
- Development of high selectivity and specificity adsorbants and active or inert grading materials for drying, purification and particles/heavy metals filtering out
- Catalyst engineering moving towards the design of the next generation of multifunctional catalysts by integrating knowledge on hetero-, homo-, single-site and biocatalysts, in order to achieve near 100% selectivity in multi-step and complex syntheses
- Combination of catalytic pathways with the selective and local application of alternative energy options (e.g. photons, electrons, microwaves, ultrasound) to yield highest energy efficiency
- Development of clean, intensified processes using unconventional forms and sources of energy, such as microwaves, plasma, light or ultrasound, for manufacturing of functional products, and in particular products which are difficult to obtain using conventional processing methods
- Use waste energy (heat, pressure, steam,etc.) e.g. from ovens, hot stoves or furnaces waste heat, or from top gas pressure, to supplement pre-heating or other processes
- Allow partial substitution of coal by biomass, natural gas or even hydrogen, especially if produced on site

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced approaches toward process intensification for increased energy and resource-efficiency and reduced waste/emissions generation, including through performance and control options, the exploration of new reaction pathways and conditions, the integration of reaction steps as well as of reaction and purification/separation/extraction, the development of adapted materials and components (e.g. membranes for hybrid separations) as well as equipment, the development of solvent-less reactions in neat reagents, etc.

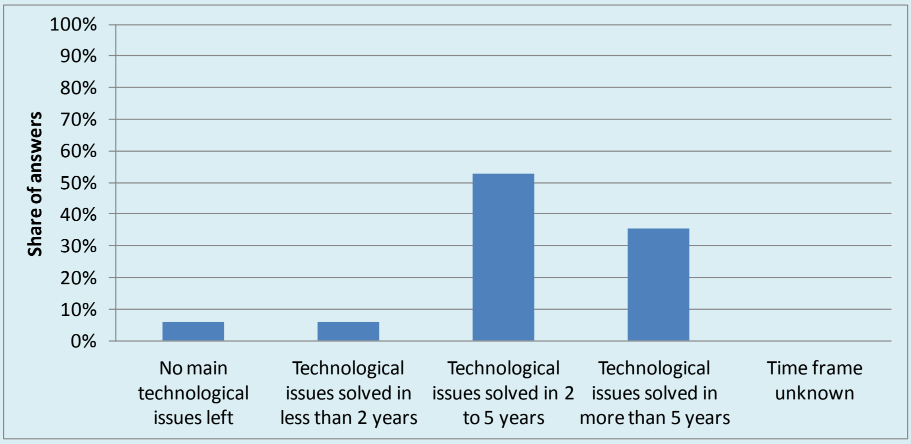
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Industrial Biotechnology (I-B)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

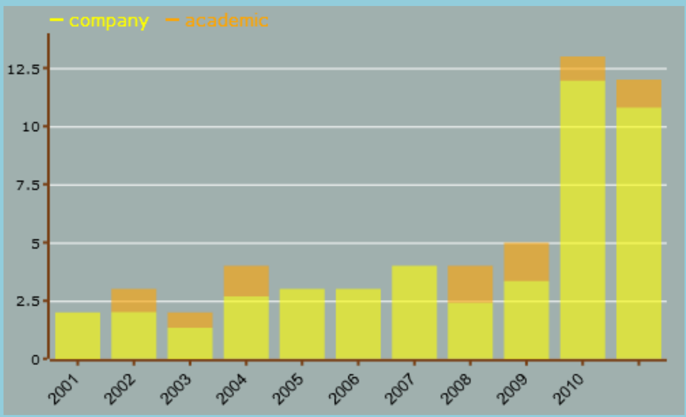
- The European chemical industry was worth 673 billion Euro in 2011 and the world's top exporter and importer of chemicals, with a record 49.1 billion Euro trade surplus in 2012. The sector produced 21.5% of the world's chemicals in 2011, employing 1.2 million workers and contributing 558 billion Euro to the EU economy. Despite losing its top spot in world chemicals sales in favour of China, whose world chemicals sales market share reached 30.5% in 2012, the European chemical industry still holds a very important position (Source: The European Chemical Industry Council, www.cefic.org).
- Germany is the largest chemicals producer in Europe, followed by France, The Netherlands and Italy, which altogether generated 62.6% of EU chemicals sales in 2012, which was valued at 349 billion Euro. The share rises to nearly 87.7% when including

UK, Spain, Belgium and Poland, while the other European countries generated together 12.3% of EU chemicals sales in 2012 (Source: The European Chemical Industry Council, www.cefic.org).

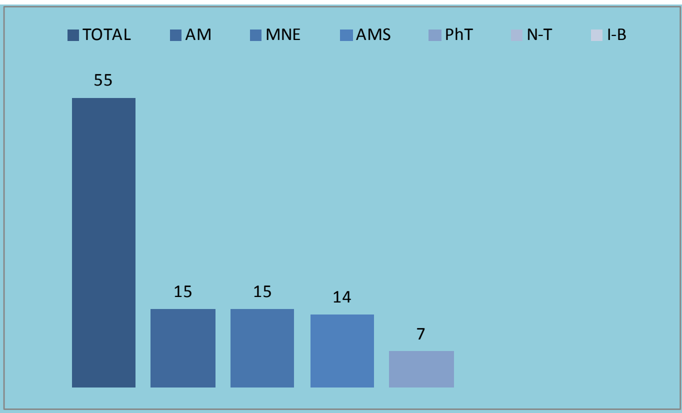
- The European chemical industry is furthermore a highly diversified sector. In terms of structure, a large number of SMEs dominate the scene besides fewer important large multinational players.
- The chemical industry underpins virtually all sectors of the economy, having a direct strategic impact on downstream chemicals users such as rubber and plastics, construction, pulp and paper, and the automotive industry, to name the biggest industrial users of chemicals. Other important users of chemicals are agriculture, textiles, metals, and the food and beverages industry (Source: The European Chemical Industry Council, www.cefic.org).
- Over the years, chemical processes have continually improved in terms of their greater utilisation of raw materials, improved safety and increased productivity whilst minimising waste and energy use. Yet, the European chemical industry is still facing the need to restructure and modernize by continuing to reduce energy as well as resources (i.e. both raw materials and water) consumption besides reducing waste as well as emissions generation at the same time. On the other hand, the European chemical industry faces the need to reduce time-to-market for new products, and a need to increase operational flexibility to enable swift responses to changing market trends in order to remain competitive in a global market. Within this framework technology leadership in the area of process intensification is of growing importance as commercial pressure on Europe from other lower cost production regions increases (Source: SusChem, www.suschem.org).
- Intensified reaction and process design covers many areas including smart design of the synthetic route itself, micro process technologies, catalytic reactions, fluid dynamics, separation technology, particle technology, advanced process control, integration and intensification of processes combined with new catalyst concepts and increasingly sophisticated computer modelling of chemical interactions and plant simulation (Source: SusChem, www.suschem.org).

➢ ***Results of patents scenario analysis:***

- 55 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Increasing trend curve (number of patents per year)
- Highest share of industrial applicants:



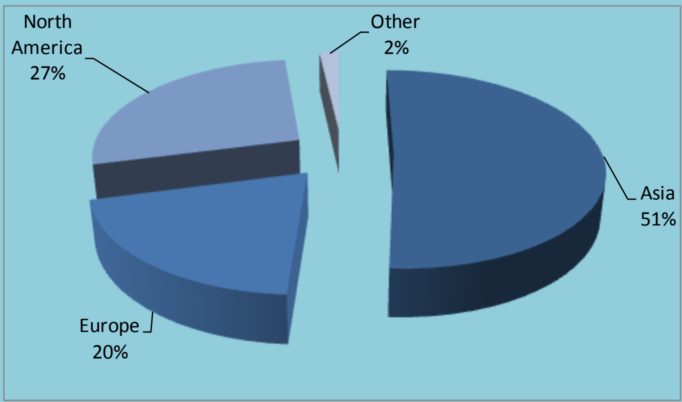
- Patents by KET(s):



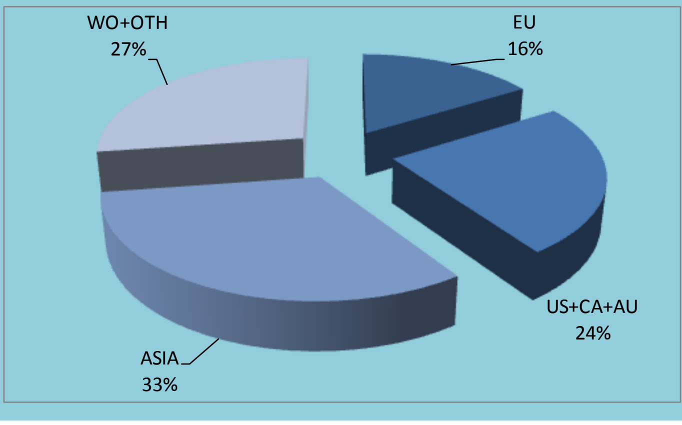
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	15
AM / MNE	1
AMS	14
AMS / MNE	2
IBT	12
MNE	15
MNE / PhT	5
PhT	7

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



CH.3.5: Condition-monitoring for continuous assessment of plant component state and residual life time

Scope:

Advanced condition-monitoring tools (based on e.g. robust miniaturised sensors and inline analyser technology) for continuous assessment of plant component state and residual life-time.

Demand-side requirements (stemming from market needs) addressed:

- Cope with highly flexible modes of plant operation, resulting in more frequent start-ups and shutdowns, thus in higher fatigue
- Improve reliability as well as safety of plants through the effective prediction (and then avoidance) of equipment failures
- Minimise down-time through the integrated planning and scheduling of repairs
- Maximise equipment and component life time by avoiding the conditions that would normally reduce it
- Maximise equipment performance and throughput
- Provide for preventive maintenance approaches in order to ultimately reduce operational and maintenance costs

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

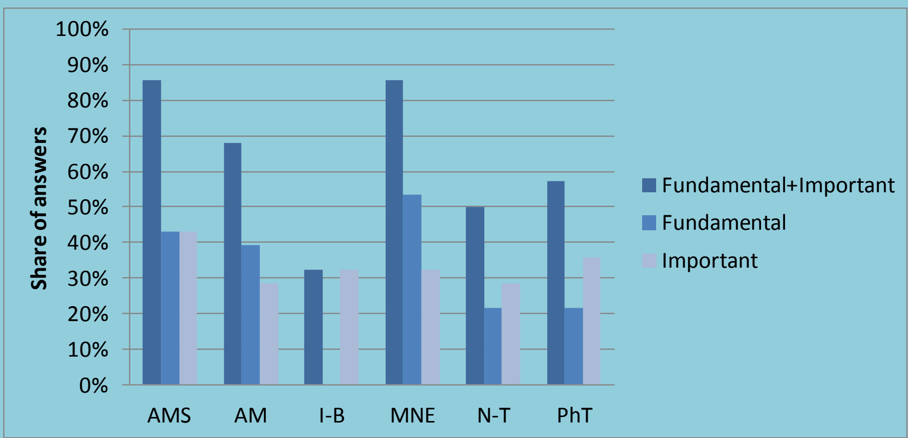
- Development of robust miniaturized sensors and inline analyzer technology utilizing advanced process analyzers which meet the requirements of process analytical technology to enable local process control
- On a global plant operation level, development of new monitoring tools for continuous assessment of plant component state and residual life time
- Development of methods allowing to achieve greater accuracy in failure prediction

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced condition-monitoring tools as well as approaches for the real-time, continuous assessment of the state as well as residual life-time of plant components, thanks to the integration of pervasive sensing approaches provided by a multitude of robust, miniaturised and highly specialized sensors and in-line analysers.

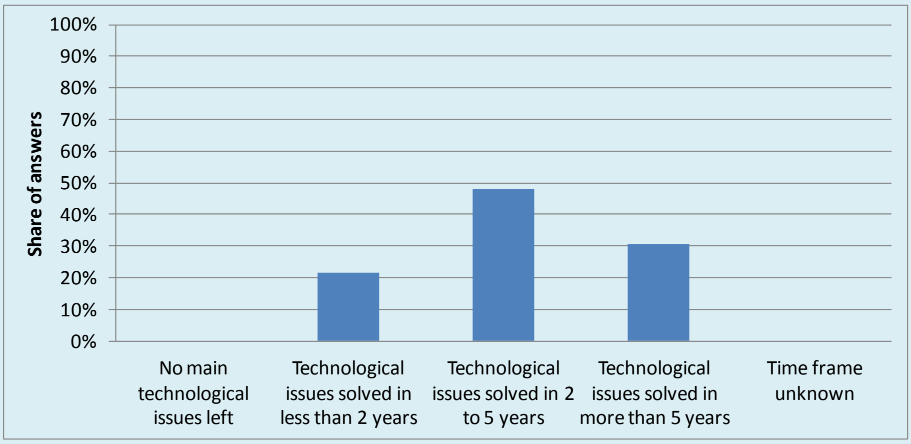
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also both shorter and greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Especially the power plants face today, more than in the past, the need to cope with highly flexible modes of operation, resulting in more frequent start-ups and shutdowns, hence in higher fatigue. Within this framework, preventive maintenance approaches can ultimately reduce operational and maintenance costs thanks to preventing failures, while ensuring safer operation. Online diagnostics enabled by the introduction of robust miniaturized sensors and inline analyzer technology can have a number of benefits in this respect when increasingly integrated into process control systems.
  - Stemming from the nuclear power sector, online condition monitoring and diagnostics nowadays enabled by the use of advanced technologies (such as, but not limited to, Vibration Measurement and Analysis, Infrared Thermography, Lubricating Oil Analysis and Tribology, Ultrasonics, Motor Current Analysis, Corrosion Analysis, etc.) that allow the determination of equipment condition, and potentially to predict failure, has more recently been introduced as well in conventional power plants as well as chemicals, petrochemicals, pulp and paper, metals production, and heavy equipment manufacturing, while it is also generating interest in smaller size manufacturing plants for machine performance monitoring.
  - Growth in the condition monitoring equipment market has long been driven by capital investments. Condition monitoring has gained importance, over the years, as companies critically focused on asset utilization and productivity. The need for eliminating catastrophic breakdowns and unnecessary maintenance costs in production processes has and will continue to drive the adoption of condition monitoring solutions across several industries. As a result, the global machine condition monitoring equipment market has been predicted to reach 1.5 billion Euro by 2015.
  - Similar to most technology-driven instrumentation industries, the condition monitoring market is dominated by large international players driving industry growth, price points, and technology innovation. Among the major players in the marketplace there are Brüel & Kjær Vibro, ClampOn AS, Corrpro Companies Inc, Data Physics Corporation, DLI Engineering Corp, Emerson Process Management, FLIR Systems Inc, GE Energy, Honeywell Process Solutions, ITT Corporation, Kittiwake Developments Limited, PCB Piezotronics Inc, Rockwell Automation Inc, Rohrback Cosasco Systems, Scientific Monitoring Inc, Shinkawa Electric Co Ltd, SKF Condition Monitoring Inc, SPM Instrument AB, The Timken Company, among others. This restricts the growth and business potential of some of the smaller participants who may not have the financial wherewithal or marketing strengths that their larger counterparts command in order to compete in the most conventional markets such as power generation, chemicals, petrochemicals, pulp and paper, metals production, and heavy equipment manufacturing.

- Yet the challenge can be overcome by the smaller players by focusing on emerging opportunities from geographical, technological, and application perspectives. Besides the demand from the bulky industries, there is in fact increasing interest for new and different approaches that fulfil condition monitoring requirements, relying on simple, yet efficient solutions that can analyze and provide insight into machine conditions without having to spend excessively or interpret large volumes of data.
- Trends indicate that in North America and Europe, the condition monitoring business will be driven by upgrade and retrofit opportunities. As such, it is likely that end users will continue working with their current suppliers or vendors. In other geographical regions, however, and in the industrial sectors not conventionally applying condition monitoring approaches, new equipment sales and new installations are expected to drive revenue and generate opportunities for the smaller market players and new participants. Renewable energy, particularly hydroelectric and solar power, is an end-user market that offers significant growth potential for the future. Moreover, customers with limited budgets who cannot afford permanent systems can opt for temporary online systems. Helping companies that have identified a particular asset or machine with regular problems by installing a temporary system to gather data over a certain period until the problem is identified and resolved, presents an important revenue opportunity for condition monitoring vendors.
- There are several smaller European players that specialize in process control, which can today expand their business to integrated process control providing condition monitoring and diagnostics as part of their offer. In terms of value chain, this encompasses condition monitoring equipment manufacturers and suppliers, condition-monitoring contractors, and organisations employing condition monitoring techniques for services aimed at effective plant operation and maintenance.
- Sources: Reliable Plant, www.reliableplant.com; PRWeb, www.prweb.com; Frost & Sullivan Research Service, www.frost.com; Global Industry Analysts Inc., Machine Condition Monitoring Equipment: A Global Strategic Business Report, 2011

➢ ***Results of patents scenario analysis:***

- 3 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- No significant patent-related indicators can be reported in this field

CH.3.6: Multifunctional catalysts characterized by highest activity, flexibility, selectivity and maximized lifetime

Scope:

Next generation of multifunctional organic and inorganic catalysts (including hybrid catalysts and bio-catalysts) characterized by highest activity and flexibility, even possibly regenerative/rejuvenable and in any case having maximized lifetime, capable to achieve near 100% selectivity in multi-step and complex syntheses.

Demand-side requirements (stemming from market needs) addressed:

- Maximize conversion efficiencies in the chemical industry in order to maximize yield
- Take advantage of European leadership on catalysts technologies to intensify processes, improve efficiency and allow minimum iteration processes

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of innovative material formulations
- Identification of alternatives for scarce chemical elements applied in catalyst technologies (such as Platinum, among others)
- Discovery, evolution and development of novel, robust and selective biocatalysts suitable for industrial use
- Catalyst engineering moving towards the design of the next generation of multifunctional catalysts by integrating knowledge on hetero-, homo-, single-site and biocatalysts, in order to achieve near 100% selectivity in multi-step and complex syntheses
- Development of regenerative / rejuvenable catalysts to optimize availability and reduce maintenance costs

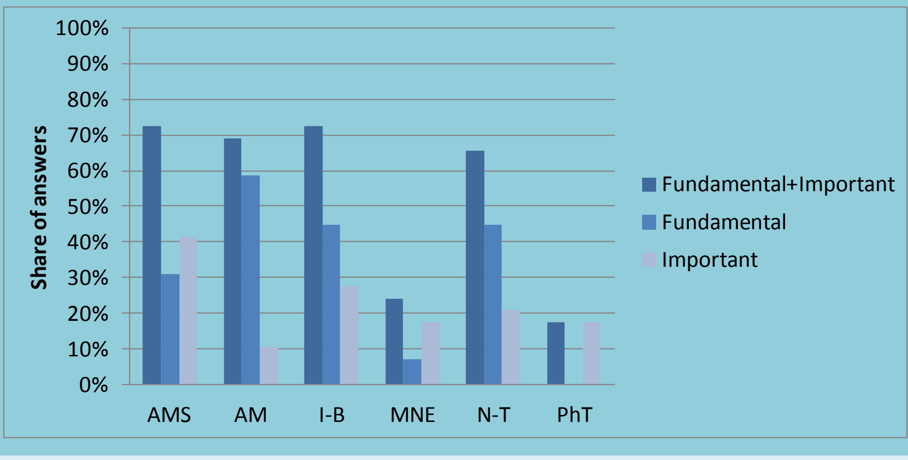
- Development of high activity, high flexibility and high selectivity, even possibly regenerative / rejuvenable, catalysts to optimize various chemical reactions
- Combination of catalytic pathways with the selective and local application of alternative energy options (e.g. photons, electrons, microwaves, ultrasound) to yield highest energy efficiency

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of the next generation of multifunctional organic and inorganic catalysts (including hybrid catalysts and bio-catalysts) characterized by highest activity and flexibility, even possibly regenerative/rejuvenable and in any case having maximized lifetime, capable to achieve near 100% selectivity in multi-step and complex syntheses, thanks to the development of innovative material formulations, the identification of alternatives for scarce chemical elements applied in catalyst technologies, and eventually the combination of catalytic pathways with the selective and local application of alternative energy options to yield highest energy efficiency.

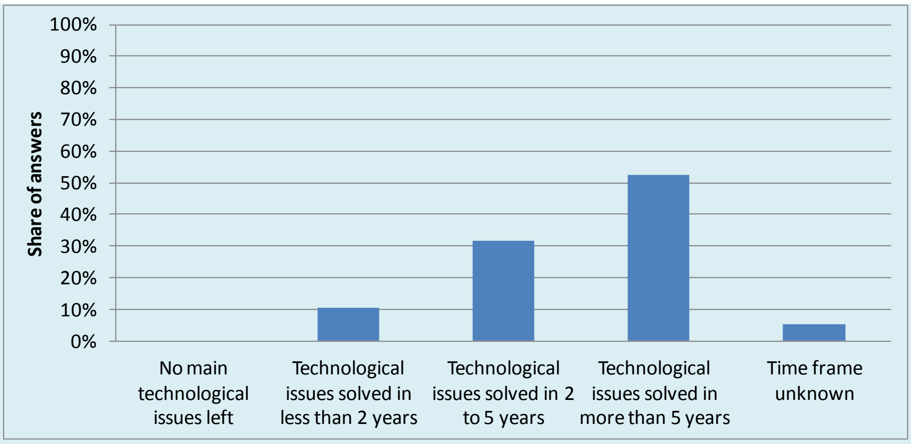
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Industrial Biotechnology (I-B)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus by experts indicates also shorter periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - According to the market research study by The Freedonia Group Inc, global demand for catalysts will rise annually of 5.8% to 14.4 billion Euro in 2016. Growth will reflect the continued expansion and modernization of the chemical, refining, and polymer industries especially of the world's developing nations, as well as a shift in product mix toward higher value, more efficient catalysts.
  - Both the polymerization and chemical catalysts markets are expected to grow the fastest through 2016, aided by healthy economies of developing countries that will drive increases in polymer and chemical production. New polymer and chemical capacity will continue to be sited in or near rapidly expanding consumer markets, as well as in countries with comparatively cheap supplies of natural gas (a primary polymer and chemical feedstock). As a result, rapid growth will occur in both Asia and the Middle East, while Brazil will lead strong growth in Central and South America.
  - Advances in both polymerization and chemical catalysts markets will reflect the adoption of higher value catalysts with increased activity and/or selectivity. For example, in polymerization catalysts, metallocene single-site catalysts will exhibit the fastest growth, while in chemical synthesis catalysts, biocatalysts will keep posting some of the fastest growth. The refining catalyst market will expand at a more moderate pace. Concerns about the impact of sulphur impurities in transportation fuels on environmental air quality have led most of the world's high-income nations to enact strict regulations on fuel sulphur content over the past decade. This in turn helped drive strong growth in hydrotreating catalyst demand in otherwise mature refining catalyst markets. However, while efforts to reduce sulphur content in marine fuel oil will continue to support some demand growth in developed countries, most advances in refining catalyst demand will occur in developing countries, such as China and India, that will continue to expand their refined product production. Additionally, several of these developing countries are moving forward with their own low fuel sulphur regulations, which will further support catalyst demand growth.
  - From a regional perspective, both the Asia/Pacific and Africa/Mideast regions will see high levels of growth in catalyst demand. In the Asia/Pacific region, modernizing industry, rising incomes, and increasing vehicle ownership will make the countries in that region attractive markets for producers. Companies will continue the trend of siting production facilities close to these markets, and expanding chemical, refined product, and polymer production will in turn necessitate higher levels of catalyst consumption. New capacity will be added in the Middle East as well, where the oil and gas resource-rich countries will continue to expand into downstream activities such as refining and polymer production. In North America, rising supplies of natural gas and oil have made these commodities available at prices lower than those seen in the developed economies of Western Europe and Japan. This situation is expected to persist and will have a significant impact on the refining, chemical, and polymer industries. Synthesis gas catalysts will post the strongest growth in the region as methanol capacity is once again expanded following a decade of rationalization, and as gas-to-liquid projects begin to come on stream near the end of the forecast period.
  - Amongst the European catalyst market participants there are a number of important

European headquartered companies as well as international companies also having production facilities in Europe. Important players are in this respect Akzo Nobel, Albemarle Catalysts Company, Arkema, Axens, BASF, Basell Polyolefins, Bayer, Borealis, Clariant International, CRE-Porocel, CRI/Criterion, (Royal Dutch Shell), Danisco (DuPont), DuPont, Evonik Industries, Eurecat, Eurosupport, Grace, Haldor Topsoe, Honeywell UOP, INEOS Polyolefins, Johnson Matthey, Novozymes, PQ Silicas UK (PQ Corporation), Polynt, Royal Dutch Shell, Süd-Chemie (Clariant International), Total.

- Sources: The Freedonia Group Inc., World Catalysts to 2016 - Demand and Sales Forecasts, Market Share, Market Size, Market Leaders, 2013; European Catalyst Manufacturers Association (ECMA), www.cefic.org; PR Newswire, www.prnewswire.com

➢ ***Results of patents scenario analysis:***

- 4 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- No significant patent-related indicators can be reported in this field

CH.3.7: Functionalized filter media for separation/purification/ extraction/classification

Scope:

Higher performance functionalized filter media for liquids and gases for application in purification/separation/extraction/ classification processes for use e.g. in chemical, pharmaceutical and biotechnological processes, as well as environmental treatment and water purification.

Demand-side requirements (stemming from market needs) addressed:

- Increase resource-efficiency and reduce waste as well as emissions generation
- Improve process efficiency

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

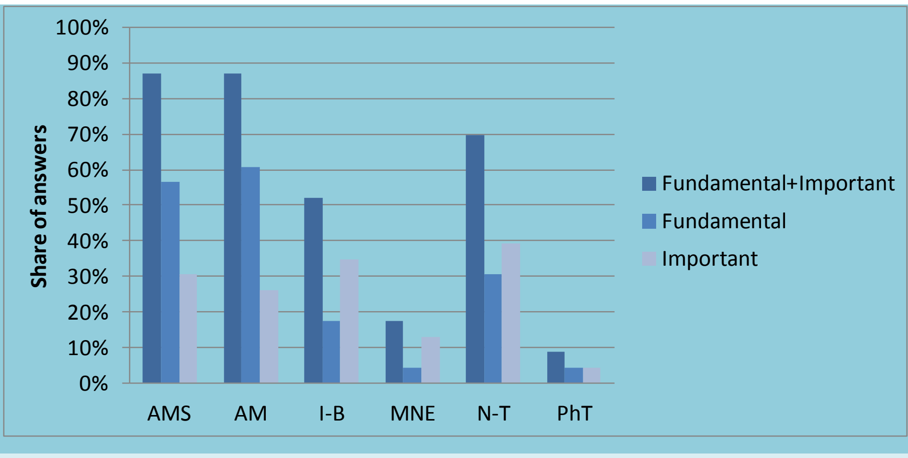
- Understanding of filter media microstructure and trans-medium transport to tailor filter media properties
- Evaluation, modelling and simulation of filter media properties and cake formation aimed at filter performance prediction in time
- Improvements in filtration equipment aimed at increased performance and reduced operating (including by reduced energy consumption) as well as maintenance costs (including by extending the lifetime of the filter media)

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of higher performance functionalized filter media for liquids and gases for application in purification/separation/extraction/classification processes thanks to the adaptation of materials, the tailoring of the filter media microstructure and trans-medium transport processes, and general improvements in filtration equipment aimed at increased performance and reduced operating (including by reduced energy consumption) as well as maintenance costs (including by extending the lifetime of the filter media).

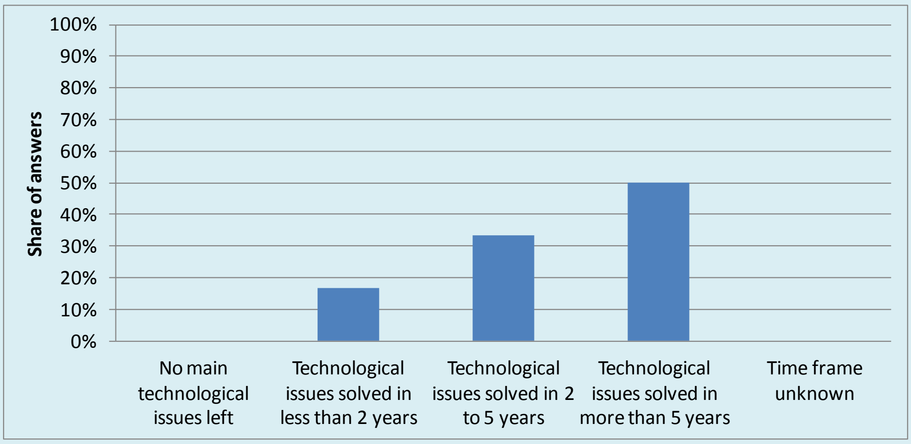
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus by experts indicates also shorter periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Advanced filter media for separation, purification, extraction and classification include a number of membrane filtration technologies such as microfiltration, ultrafiltration, nanofiltration, reverse osmosis and ion exchange.
  - Membrane filtration finds widespread applications in the pharmaceutical, biopharmaceutical and biotechnology industries as products of these industries and their intermediates are susceptible to degradation due to heat and chemical treatment, which makes it difficult to separate them using alternate technologies.
  - Membrane filtration is widely used as a separation and purification technique especially in the pharmaceutical, biopharmaceutical and biotechnology industries. Its adoption rate in Europe and North America is very high and has an increasing trend that reflects the increasing growth trends of the end use sectors mentioned above. The increasing adoption rate in the Asia-Pacific segment and the increasing demand for single use technology are further driving market growth. As a result, the market is expected to witness high growth in the period to 2018. The global membrane filtration market was valued at 2.7 billion Euro in 2013 and is expected to reach 5.9 billion Euro by 2018, at a compound annual growth rate (CAGR) of 16.6%.
  - In 2013, Europe was the largest market for membrane filtration. However, the North American market is expected to grow rapidly in the period between 2013 and 2018 and

is expected to be as large as that of Europe by 2018. Besides important North American players, the major European players in the membrane filtration market for pharmaceutical and biotechnology are Sartorius Stedim Biotech (France), Alfa Laval (Sweden), GEA Group (Germany), and Novasep (France).

- Sources: Research and Markets, 2014, Global Pharmaceutical Membrane Filtration (Microfiltration, Ultra filtration, Nano filtration, Reverse Osmosis and Ion Exchange) Market Report 2014-2018; Markets and Markets, marketsandmarkets.com

➢ ***Results of patents scenario analysis:***

- 4 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- No significant patent-related indicators can be reported in this field

Sub-domain: Key processes, tools and equipment for competitive plants

Demand-side requirements (stemming from Societal Challenges) addressed:

Depending from the application or the type of processes used for production, manufacturing and automation can especially contribute to tackle the following societal challenges:

- Secure, clean and efficient energy
- Climate action, resource efficiency and raw materials

Demand-side requirements (stemming from market needs) addressed:

- Provide for rapid and flexible production capabilities to match supply with volatile demand of today's rapidly changing markets
- Flexibly integrate design specifications into efficient operational routines by keeping a comparable throughput time in different configurations
- Provide for fast product/service systems able to combine rapid and flexible production capabilities with enhanced product design capabilities and exploit minimal distribution lead-times to match supply with volatile demand of today's rapidly changing markets
- Provide for the production of high-quality products
- Provide for the production of durable products
- Provide for alternative manufacturing approaches coping with the need of utilizing new and advanced materials in products, adding functionalities to products, dealing with complex structures and shapes

MA.1.1: Advanced joining technologies for long life joints of diverse materials

Scope:

Improved, new or hybrid joining technologies enable competitive incorporation of materials into structures, including "self-assembly", increase the lifetime of assemblies thus reducing maintenance costs and support products adapted to extreme environments (deep sea, space, engines, medical).

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

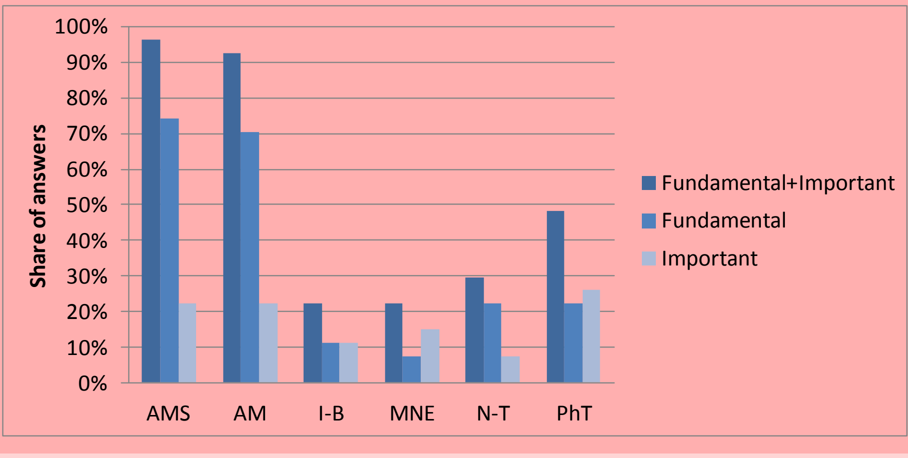
- Use welding, joining or other assembly technologies as a means for modularization and efficient use of (new) multi-materials and integration of new materials with a high degree of automation and quality control to accelerate their adoption into products
- Understand and control cause-effect relationships and materials process interactions for joining to maximize final product performance
- Development of improved, new or hybrid joining technologies to maximize material performance and material efficiency
- Development of high productivity and "self-assembly" technologies to reduce operational cost and to improve manufacturing competitiveness
- Practical validation of the new processes needs to be determined on demonstrator work pieces or early stage prototypes
- Optimization of rivet-less solutions for assembling metallic large structural parts
- Optimization of modelling of corrosion and ageing of materials at joints so as to limit structural weakening
- Use appropriate simulations of both equipment and manufactured parts to support prototyping

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced joining technologies for long life joints of diverse materials, building on solutions such as new or hybrid joining technologies , the efficient use of (new) multi-materials, the development of high productivity and "self-assembly" technologies, etc.

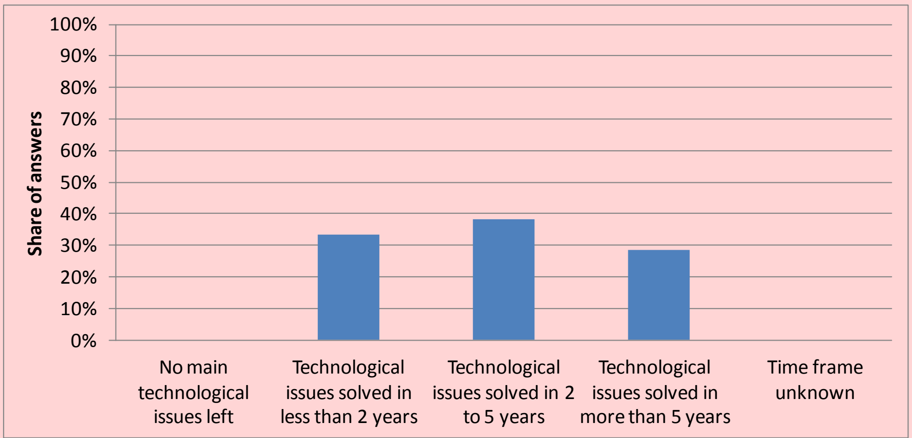
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Photonics (PhT), to some extent



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also both shorter and greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

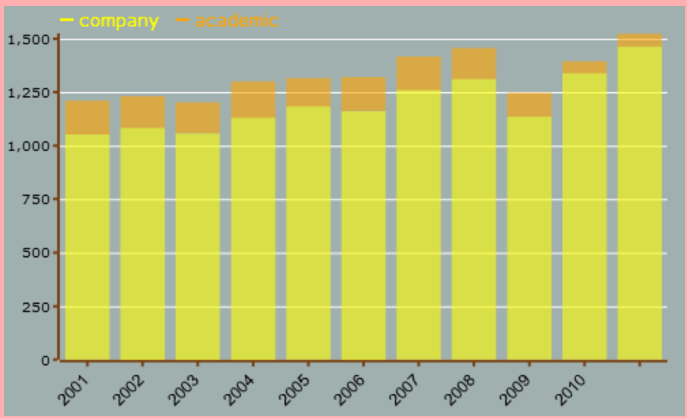
- The overall total of the production values for the manufacture of joining technology in Europe is composed of the production values for devices on the one hand and of the production values for complementary goods and services on the other hand. In the

EU27, the production value of devices and systems in 2010 was around 8 billion Euro and was associated with a gross value added of 2.7 billion Euro, earned by 45 000 employees.

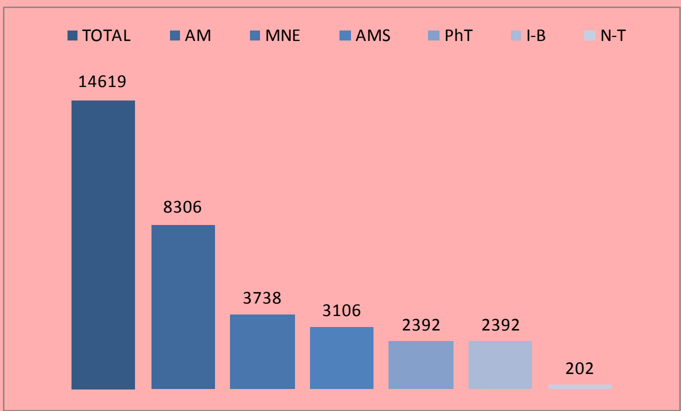
- As regards especially Germany, for devices and systems, the production value amounted to 3.8 billion Euro in 2011. This leads to a gross value added of 1.3 billion Euro which can be equated with the extra value created by the production. Around 18 000 employees contributed to this value added. In 2010, the production value in Germany amounted to 2.9 billion Euro and yielded a gross value added of 0.9 billion Euro, earned by around 15 600 employees (Source: DVS – German Welding Society, "Macroeconomic and sectoral value added by the production and application of joining technology in Germany and Europe in 2013"; 2012).

➢ ***Results of patents scenario analysis:***

- 14619 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Slightly increasing trend curve (number of patents per year)
- Highest share of industrial applicants:



- Patents by KET(s):

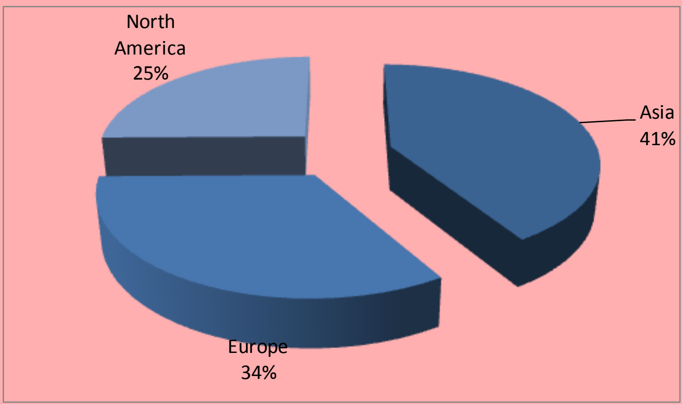


- Patents by KET(s) and relevant combinations of KETs:

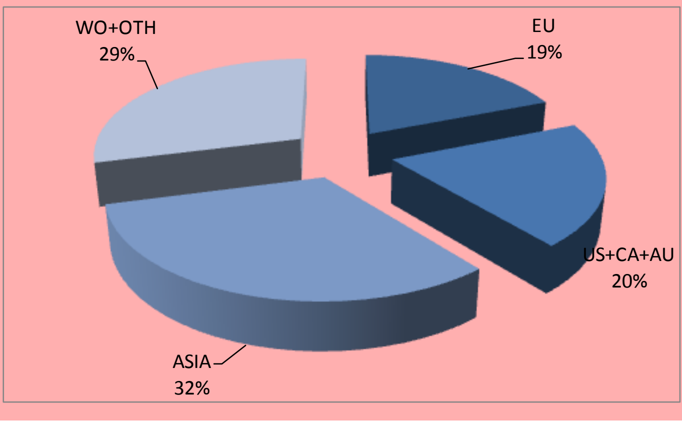
KET(s)	*Number of patents*
AM	8306
AM / IBT	11
AM / IBT / N-T	1
AM / MNE	915
AM / MNE / N-T	25
AM / MNE / N-T / PhT	4
AM / MNE / PhT	222
AM / N-T	141
AM / N-T / PhT	11
AM / PhT	622
AMS	3106

AMS / AM	292
AMS / AM / MNE	44
AMS / AM / MNE / N-T	1
AMS / AM / MNE / PhT	7
AMS / AM / N-T	4
AMS / AM / PhT	11
AMS / IBT	1
AMS / MNE	262
AMS / MNE / N-T	1
AMS / MNE / PhT	32
AMS / N-T	6
AMS / PhT	83
IBT	45
IBT / N-T	1
MNE	3738
MNE / N-T	44
MNE / N-T / PhT	10
MNE / PhT	1117
N-T	202
N-T / PhT	24
PhT	2392

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



MA.1.2: Tools and concepts to process new and advanced materials

Scope:

To develop new tools and concepts for precise and fast machining and processing of new and advanced materials, especially with respect to casting, forming, moulding, material removal, shaping, 3D printing, etc.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

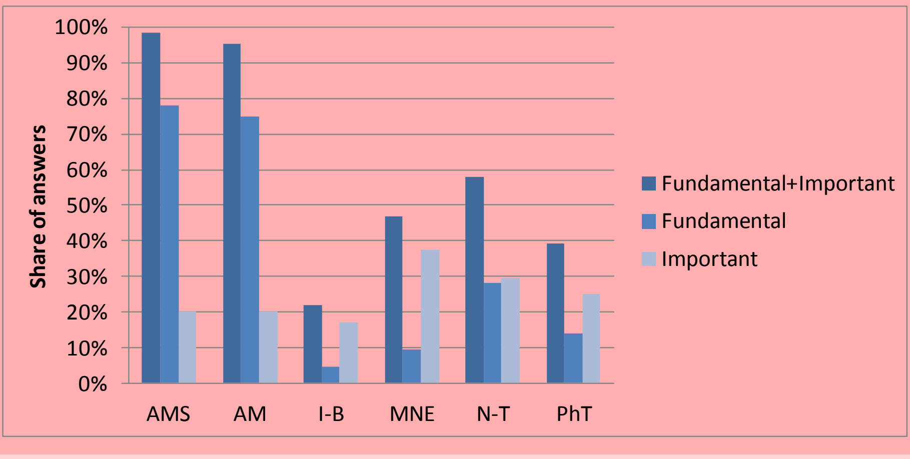
- High productivity and "self-assembly" technologies development of conventional (joining, forming, machining) and new micro/nano-manufacturing processes
- Development of micro-electromechanical systems (MEMS) for computer controlled deposition and curing of radiation-curable materials and for embedded (micro) sensors
- Development of high throughput processes (e.g. extrusion, forming, casting, coating and quick sintering) able to produce net-shape or semi-finished products as well as coatings, using nanotechnologies and nanomaterials
- Development of new process technologies to support casting, material removing and forming processes when applied to new materials, considering lifecycle impacts as well as the performance requirements for these processes (e.g. roughness, accuracy, robustness)
- Development of tailor-made solutions in the field of fibre-based structures and high value-added net- or near-net-shaped 3D products, produced at varying volumes
- Manufacturing of products such as Organic Light-Emitting Diodes (OLED) for lighting, displays and technical textiles, organic photovoltaics, organic sensor arrays using new organic functional polymers and hybrid materials
- Development of manufacturing processes for advanced energy systems optimizing the performance of the materials used for their construction and for functional purposes

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of new tools and concepts for precise and fast machining and processing of new and advanced materials, building on solutions such as "self-assembly", micro-electromechanical systems (MEMS) for computer controlled deposition, traditional and new fine output processes (e.g. extrusion, forming, casting, coating and quick sintering) , tailor-made solutions in the field of fibre-based structures, high value-added net- or near-net-shaped 3D products, etc.

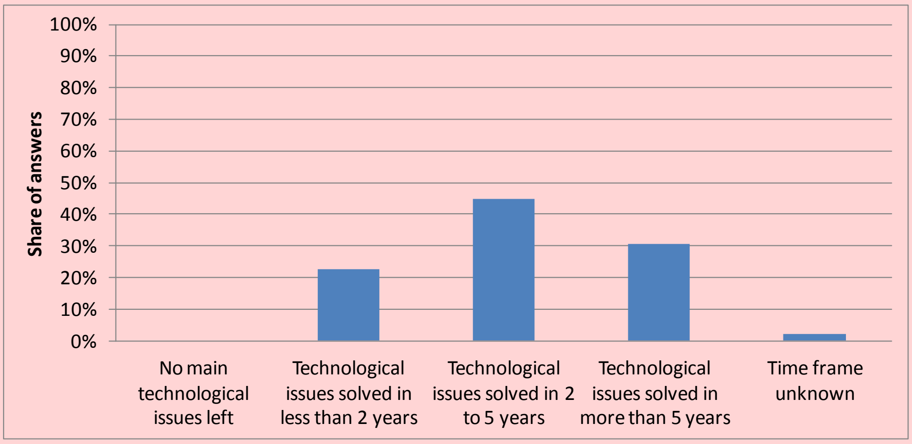
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - In 2010, the production of machine tools in Europe accounted to 16.6 billion Euro and was stable compared to 2009, but significantly lower than 24.4 billion Euro posted in record 2008. The production of the sector is highly concentrated in Germany and Italy, which accounted together for two thirds of 2010's output. The other significant producers with share in the total output higher than 3% are Switzerland, Austria and Spain.
  - Being a provider of purely investment goods, the machine tool industry is a cyclical business. All the fluctuations in the general economy are immediately reflected in the investment goods sector, but with increased magnitude. Customers tend to postpone investment decisions during economic downturns and they increase their spending on new production equipment during upturns. The machine tool industry is usually the first to be affected by economic recessions, as the first reaction of customers is to cut budget in capital expenditures.
  - Europe has borne witness to a radical shift of machine tool consumption to developing countries over the last decade. The global economic crisis has further accelerated this trend. Europe represented three quarters of the world consumption of machine tools at the turn of the century, whereas today Asia has taken over this share and Europe's share dropped to one quarter of world consumption. Asia is forecasted to maintain this share whilst consumption will grow even further. Today, 79% of European machine tool production is exported and 62% of these exports go to non-CECIMO countries. All important business opportunities for European manufacturers are and will be outside Europe.
  - Source: www.cecimo.eu
- ***Results of patents scenario analysis:***
  - 38 839 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - The very high number of patents identified within this framework depends from the openness of the field, which renders the use of patent-related indicators to provide for the evaluation of trends non-reliable in this case.

MA.1.3: Mass production of functionalized surfaces and materials

Scope:

To develop scalable processes, either physical (additive manufacturing, laser, Physical Vapour Deposition (PVD)) or chemical (Chemical Vapour Deposition (CVD), sol-gel), for treating or coating surfaces so as to provide them high added-value functionalities as embedded sensing, adaptive control, self-healing, antibacterial activity, self-cleaning.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

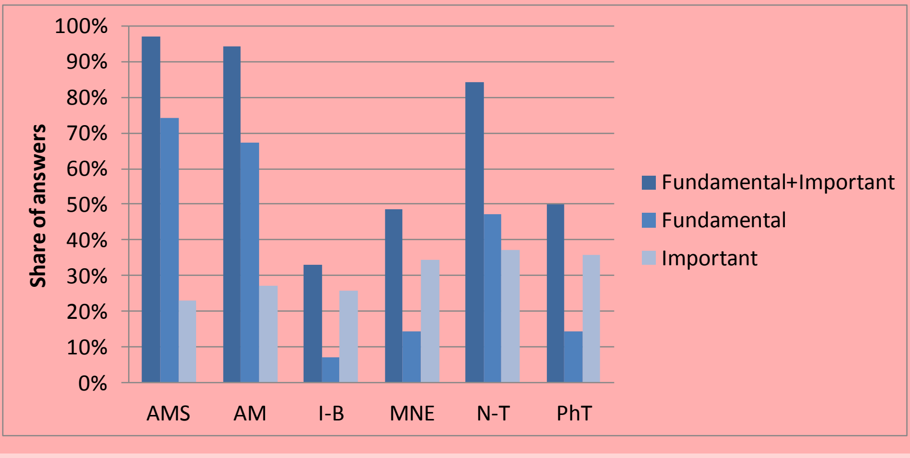
- Innovative use of physical, chemical and physicochemical processes
- Design functionality through surface modifications and coatings, using physical (additive manufacturing, laser or photon based technologies, Physical Vapour Deposition (PVD)) or chemical approaches (Chemical Vapour Deposition (CVD), sol-gel) to deliver high functionality and hence high value products
- Embed true smartness into structures through novel technologies and approaches and scale-up these processes

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced, scalable processes for treating or coating surfaces so as to provide them high added-value functionalities, thanks to the innovative use of physical, chemical and physicochemical processes, the development of material formulations for coatings as well as the related deposition processes, the development of processes for the modification of surfaces using physical (e.g. additive manufacturing, laser or photon based technologies, Physical Vapour Deposition (PVD)) or chemical approaches (e.g. Chemical Vapour Deposition (CVD), sol-gel).

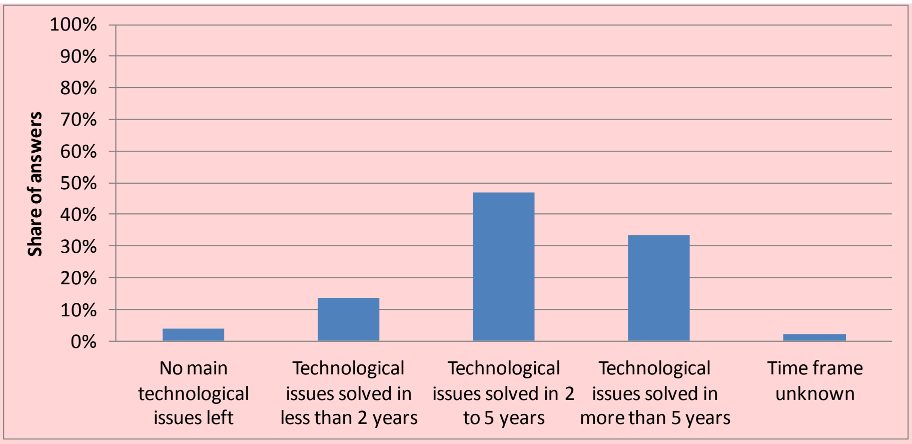
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

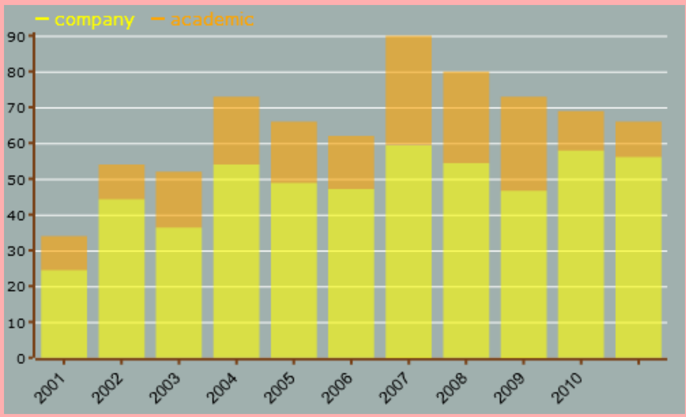
➢ ***Impact assessment:***

- Tailored surface modifications to impart specific physical, chemical or biological characteristics, different from the ones originally found, to the surface of a material have gained much attraction over the past 20 years. Such altering of the surface modifications, also termed surface engineering, can be brought to materials either through physical (e.g. additive manufacturing, laser, Physical Vapour Deposition (PVD)) or chemical means and methods (Chemical Vapour Deposition (CVD), sol-gel) or through coating. Despite the applied technique, the goal is altering the characteristics of the surface in order to provide enhanced capabilities of the material to stand external agents and environments. Characteristics of a surface that can be altered by surface engineering are, for example, its roughness, hydrophilicity, surface charge, surface energy, biocompatibility and reactivity.
- Surface engineering contributes very significantly in the manufacture of a vast variety of products, being particularly relevant in sectors like automotive, aerospace, power generation, electronics, biomedical, textile, steel, construction and even machine tools manufacturing. Surface engineering techniques can be used to develop a wide range of functional properties, including physical, chemical, electrical, electronic, magnetic, mechanical, wear-resistant and corrosion-resistant properties at the required substrate surfaces. Almost all types of materials, including metals, ceramics, polymers, and composites can be coated on similar or dissimilar materials. It is also possible to form coatings of newer materials (e.g., met glass. beta-C3N4), graded deposits, multi-component deposits, etc. (Source: P. Martin, Introduction to Surface Engineering and Functionally Engineered Materials, 2011).
- To highlight the relevance of surface engineering in manufacture one shall consider that some 6% of the costs of manufacturing engines and transmission is involved in coating technologies. Organic finishes are highly decorative and functional. The steel shell and structural members require preparation as substrates so that, for example, an increasing number of components are galvanised and provided with appropriate conversion coatings to receive paint. Whilst metal is usually finished with an organic coating, so plastic may be metallised: here the established 'wet' processes compete with developments in Physical Vapour Deposition (PVD) and Chemical Vapour Deposition (CVD). Last but not least, in the medical industry, instrumentation as well as devices that are either permanently (e.g. implantable devices) or temporarily introduced in the body's cavities (e.g. catheters) are superficially treated or coated in order to enhance their biocompatibility and their resistance to fouling or corrosion (Source: Surface Engineering Committee of the Institute of Materials, Foresight in surface engineering, 2000).

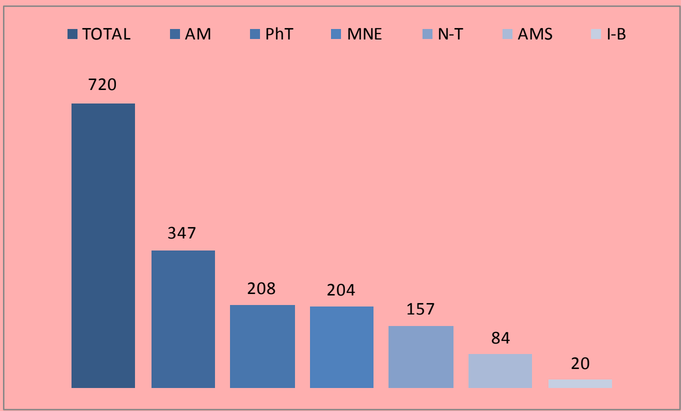
➢ ***Results of patents scenario analysis:***

- 720 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Initially increasing then decreasing trend curve (number of patents per year) with downturn since 2008

- Highest share of industrial applicants:



- Patents by KET(s):

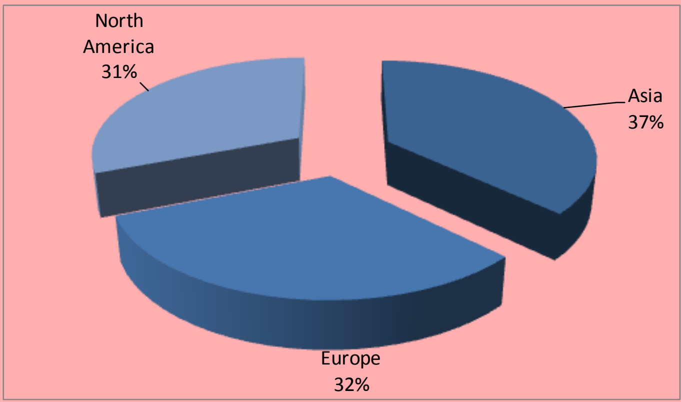


- Patents by KET(s) and relevant combinations of KETs:

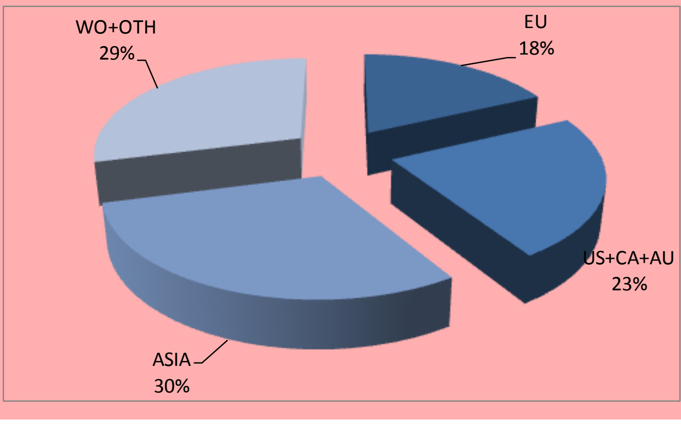
KET(s)	*Number of patents*
AM	347
AM / IBT	7
AM / IBT / N-T	4
AM / MNE	45
AM / MNE / N-T	17
AM / MNE / N-T / PhT	5
AM / MNE / PhT	16
AM / N-T	104
AM / N-T / PhT	9
AM / PhT	44
AMS	84
AMS / AM	9
AMS / AM / N-T	2
AMS / MNE	16
AMS / MNE / PhT	2
AMS / N-T	4
AMS / PhT	5
IBT	20
IBT / N-T	5
MNE	204
MNE / N-T	26
MNE / N-T / PhT	8
MNE / PhT	75
N-T	157

N-T / PhT	13
PhT	208

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



MA.1.4: Automated production of thermoset and thermoplastic composite structures/ products

Scope:

Combinations of methods (automated production, out-of-autoclave production, press forming and welding, laser cutting and joining) and materials (resins and polymer matrix combinations, curable, reusable and recyclable thermoplastics) for weight reduction and novel constructs.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of new manufacturing methods and concepts which will help to reduce cost and exploit the unique properties of composites
- Adaptation of processing techniques and procedures towards automated production
- Enhancement of the performance of materials such as resins as well as fibres to be applied as reinforcement in matrix materials to make the composite material stiffer but lightweight and with anisotropic properties
- Improvements in the reuse and recycling of composites

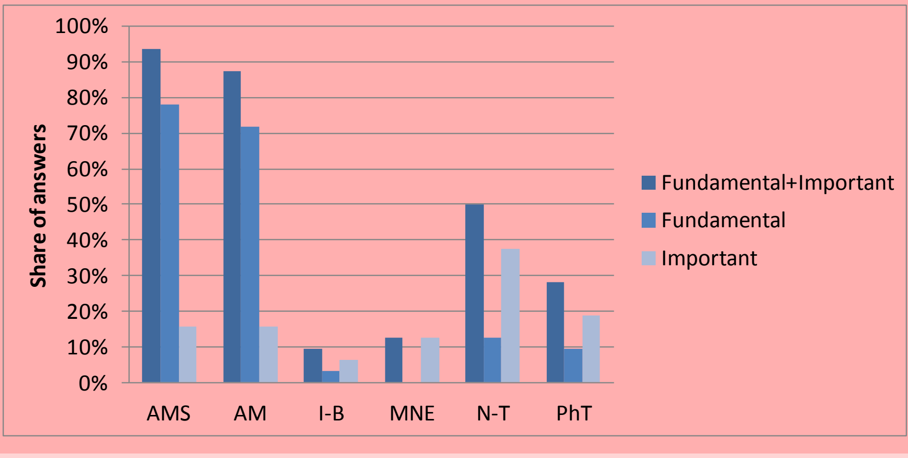
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced processes for the automated production of thermoset and thermoplastic composite structures/products along with the development of enhanced materials such as high performance resins or fibres to be applied as reinforcement in matrix materials.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting

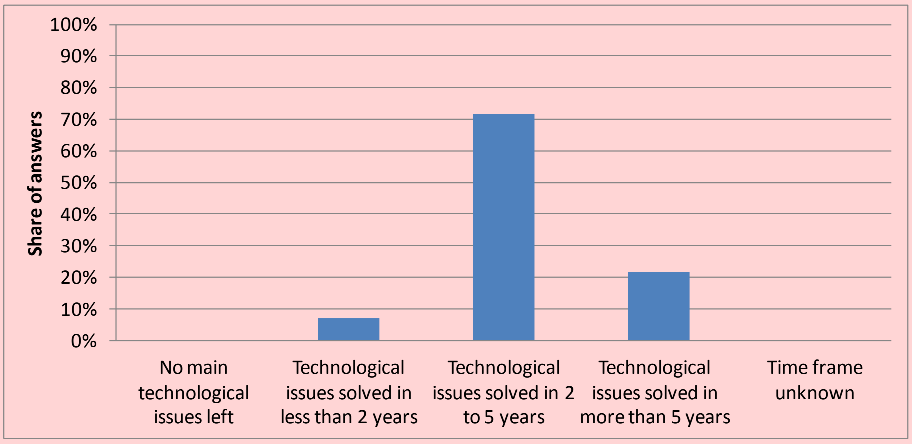
activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet consensus by experts indicates also greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework. Yet, as evidenced during some of the interviews and workshops carried out throughout the study, depending from the size of the products to be processed, greater periods might be necessary to achieve fully automated production of thermoset and thermoplastic composite structures/products if specific large area applications would need to be addressed (such as wind turbines or airplanes).

Additional information according to results of assessment:

➢ ***Impact assessment:***

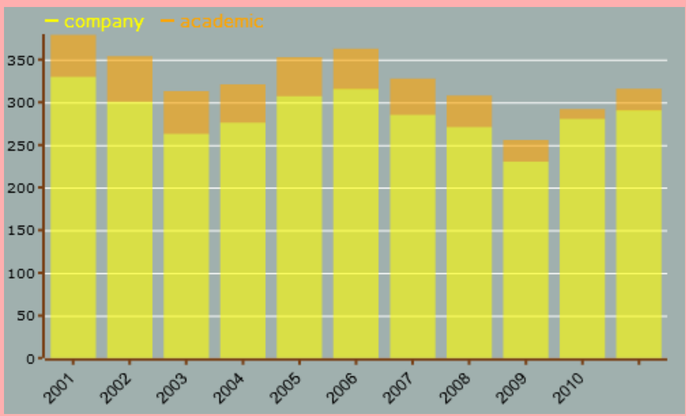
- The composites industry serves a wide range of different industrial applications. As a result, the European market for, especially, fibre-reinforced composites will reach 1.29 million tonnes by the end of 2013. Smithers Rapra forecasts an increasing growth rate over the next five years, reaching 1.55 million tonnes by 2018 (Source: Smithers Rapra; RAPRA Publishing, The Future of Fibre-Reinforced Thermoplastics in Europe: Market Forecasts to 2018).
- In Europe, above all, the German composites industry has expanded its share of total production volume becoming the most important manufacturing country in this sector in

Europe. The reasons for this are often stated as the high quality of its manufactured products and excellent standard of service offered. Innovation, carefully targeted development and refinement and the constant urge for renewal are reasons why German companies (including those in the composites sector) are able to compete successfully in the international market. Highly developed sectors that are particularly strong in Germany, such as the automotive, mechanical engineering and chemical industries are continuing to generate high levels of exports even in difficult economic times.

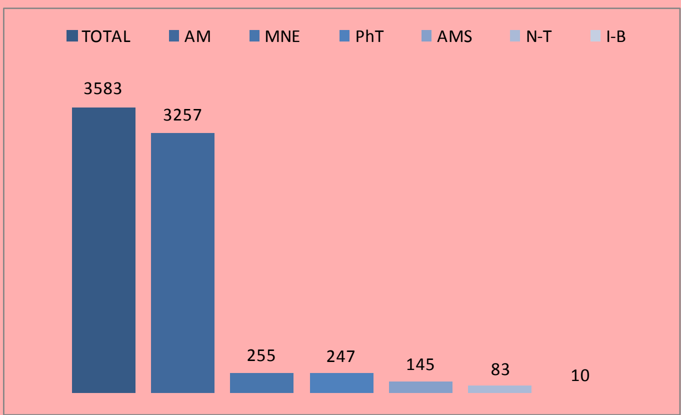
- Source: AVK, Composites Market Report 2013 - Market developments, trends, challenges and opportunities, 2013

➢ ***Results of patents scenario analysis:***

- 3583 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Oscillating trend curve (number of patents per year) with downturn in 2009 and then recovery
- Highest share of industrial applicants:



- Patents by KET(s):

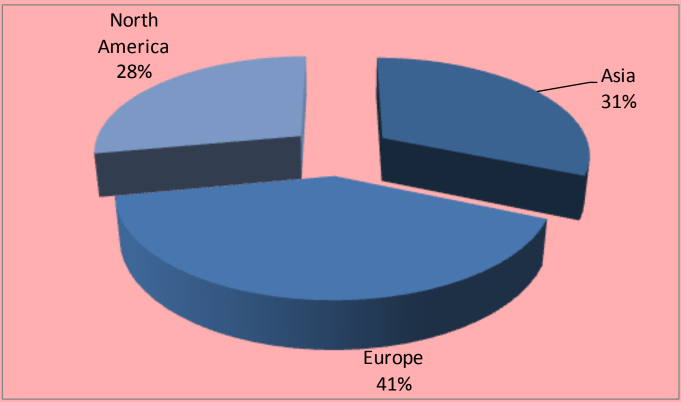


- Patents by KET(s) and relevant combinations of KETs:

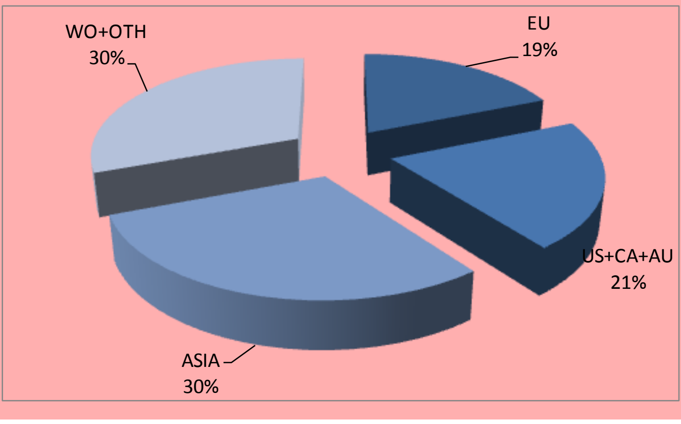
KET(s)	*Number of patents*
AM	3257
AM / IBT	6
AM / IBT / PhT	1
AM / MNE	119
AM / MNE / N-T	1
AM / MNE / PhT	22
AM / N-T	70
AM / N-T / PhT	4
AM / PhT	135
AMS	145
AMS / AM	34

AMS / AM / MNE	3
AMS / AM / MNE / PhT	2
AMS / AM / N-T	1
AMS / AM / PhT	2
AMS / MNE	9
AMS / MNE / PhT	2
AMS / N-T	2
AMS / PhT	4
IBT	10
IBT / PhT	1
MNE	255
MNE / N-T	5
MNE / N-T / PhT	1
MNE / PhT	57
N-T	83
N-T / PhT	7
PhT	247

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



MA.1.5: Integrated non-conventional processes to reduce manufacturing time to market and increase the quality on the workpiece

Scope:

Integration of non-conventional technologies (such as lasers, waterjet, electro discharge, ultrasonic, printing, 3D printing) to develop new multifunctional manufacturing processes (for inspection, thermal treatment, stress relieving, machining, joining, etc.) that reduce time to market and increase quality.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

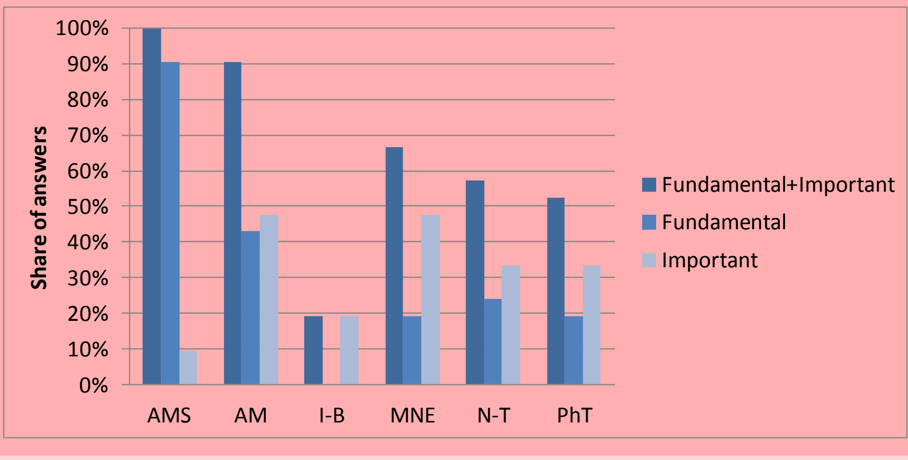
- Development of new and innovative technologies aiming at increasing the reliability and reproducibility of smart composites and metallics, and for further integration of functions
- Integration of non-conventional technologies (e.g. lasers, waterjet, electro discharge machining, ultrasonic, printing) towards the development of new multifunctional manufacturing processes (including in process concept: inspection, thermal treatment, stress relieving, machining, joining)

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of integrated non-conventional processes to reduce manufacturing time to market and increase the quality on the workpiece, thanks to the development and integration of non-conventional technologies (e.g. lasers, waterjet, electro-discharge machining, ultrasonic, printing) and of new multifunctional manufacturing processes (including in process concepts: inspection, thermal treatment, stress relieving, machining, joining).

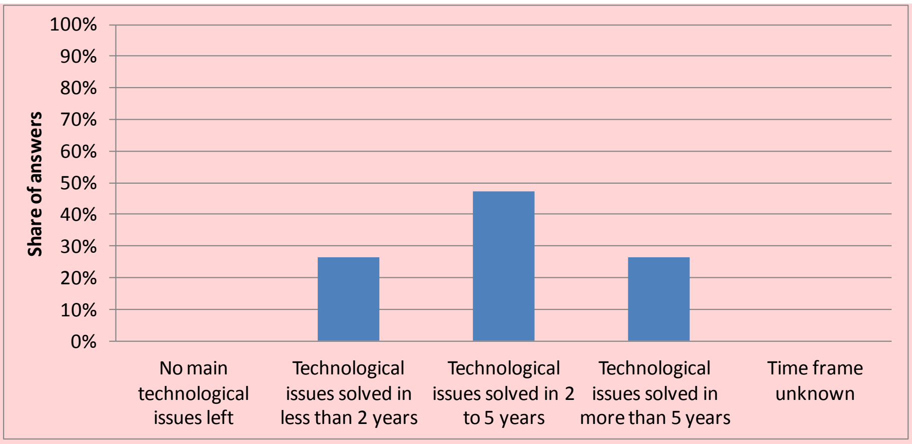
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Photonics (PhT)



Timing for implementation:

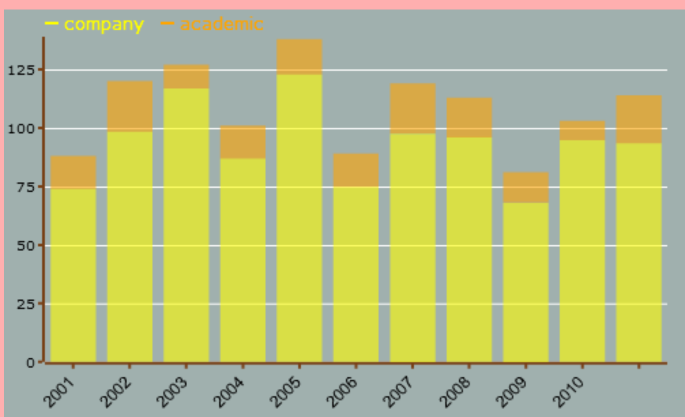
According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet consensus by experts indicates also both shorter and greater periods being necessary:



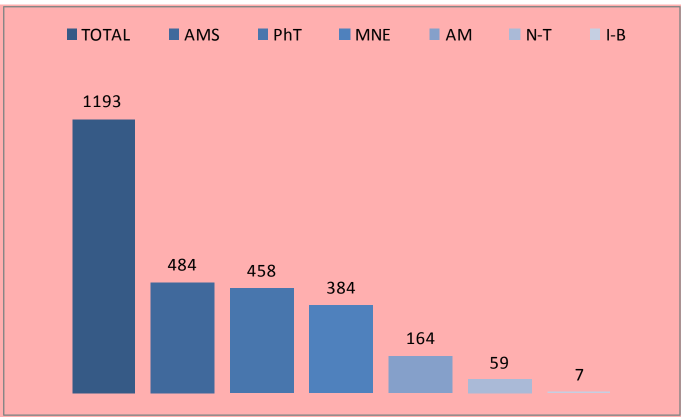
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Introduction in conventional manufacturing of non-conventional highly performing technologies (e.g. lasers, waterjet, electro-discharge, ultrasonic, printing, 3D printing) has several times been driven by the need to increase quality of the work pieces or the need to reduce time to market in manufacturing.
  - Despite the initial investments to provide for the new equipment and manufacturing infrastructures, gains in precision, reflecting in higher product quality and reduced scraps, and/or in the production rate, reflecting in higher productivity, have several times well justified the initial investment in the manufacturing sector.
  - In addition, the capability of the manufacturing industry to be as responsive as possible in satisfying customer needs is a great advantage of manufacturing methods capitalizing on non-conventional highly performing technologies.
  - Several are the operations in manufacturing that have already benefitted and that could still benefit from the introduction of non-conventional technologies. These include, among others, inspection, thermal treatment, stress relieving, machining, joining, etc.
- ***Results of patents scenario analysis:***
  - 1193 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Oscillating trend curve (number of patents per year)
  - Highest share of industrial applicants:



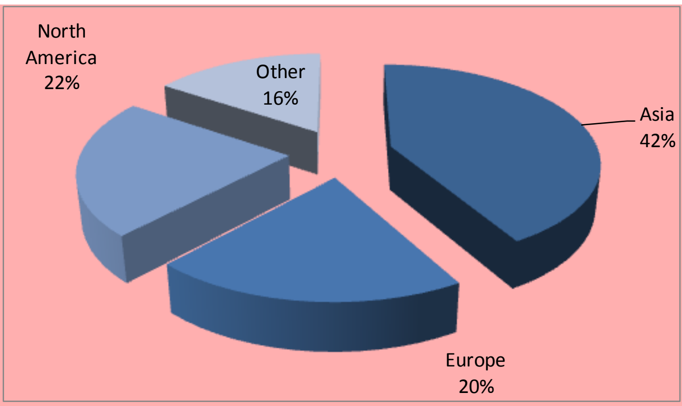
  - Patents by KET(s):



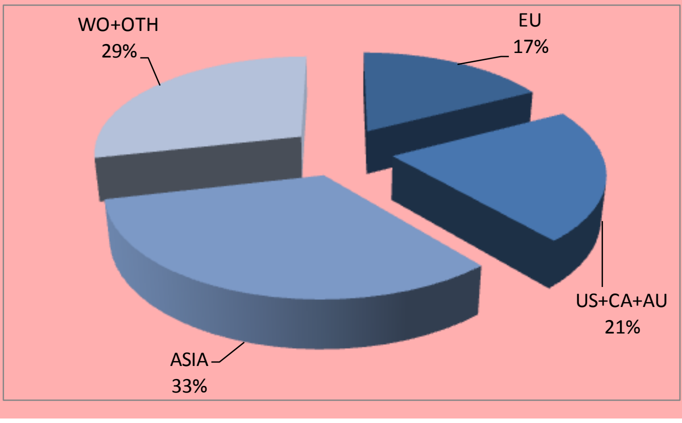
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	164
AM / MNE	25
AM / MNE / N-T	8
AM / MNE / N-T / PhT	4
AM / MNE / PhT	9
AM / N-T	24
AM / N-T / PhT	4
AM / PhT	11
AMS	484
AMS / AM	17
AMS / AM / MNE	2
AMS / AM / MNE / PhT	2
AMS / AM / PhT	2
AMS / MNE	82
AMS / MNE / PhT	23
AMS / N-T	2
AMS / N-T / PhT	1
AMS / PhT	72
IBT	7
MNE	384
MNE / N-T	22
MNE / N-T / PhT	12
MNE / PhT	142
N-T	59
N-T / PhT	21
PhT	458

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



MA.1.6: Rapid manufacturing for custom made parts

Scope:

To develop new processes enabling flexibility and rapid change, including optimal topological features, added functionality and levels of personalization not previously possible at large scale. Examples include printing inks/processes (including 3D printing), on-demand (nano)coatings, use of different materials.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Improvement of additive manufacturing, and extension of its applicability to various material classes (plastics, metals, composites, living tissue)
- Development of novel lasers including ultra-short pulse lasers emitting in the IR, VIS and UV and adaptive and dynamically-controlled laser-based materials processing systems and further development of their mass customization in manufacturing applications
- Photonics-based materials processing technologies
- Provide new custom made parts or spare parts on demand which are light-weight and topologically optimized either to sub-divisions of sectors/products or personalized to an individual
- Enable process flexibility and rapid change (e.g. laser processing, additive manufacture, modular tooling, direct fabrication with no tooling)
- On-demand manufacturing of customer-centric products
- Development of materials for optimal topological features, added functionality and levels of personalization not previously possible at scale
- Improvement of Rapid Manufacturing Technology (e.g. beam-based, scanning optics) to address high performance, process productivity and flexibility to frequently changing operating or product-mix conditions
- Derive a synchronized, closed loop between customer orders, production scheduling, and manufacturing execution; all while simultaneously coordinating the flow of materials

and information along the supply chain

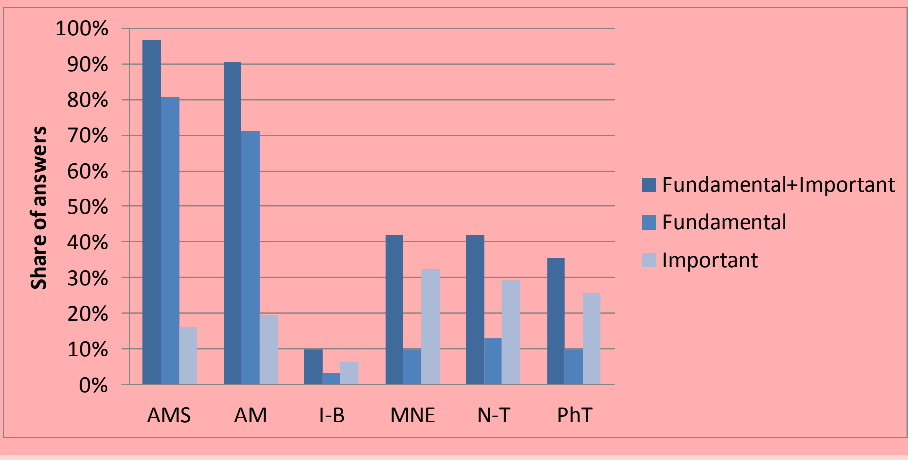
- Development of new manufacturing techniques that enable in parallel the fast customization, assembly and manufacturing of complex products as well as fast and effective product updatability, reconfigurability and disassembly by either the original manufacturer, the end user or specialized service providers
- Development of manufacturing solutions for modular, updatable, reconfigurable and disassemblable products

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced rapid manufacturing processes for custom made parts, building on the improvement of additive manufacturing and the extension of its applicability to various material classes (plastics, metals, composites, living tissue), the development of novel flexyble, easily reconfigurable and rapidly changing materials and technologies for mass customization in manufacturing (e.g. laser processing, additive manufacture, modular tooling, direct fabrication with no tooling), the development of photonics-based materials processing technologies in general, the improvement of process flexibility and rapid change capability.

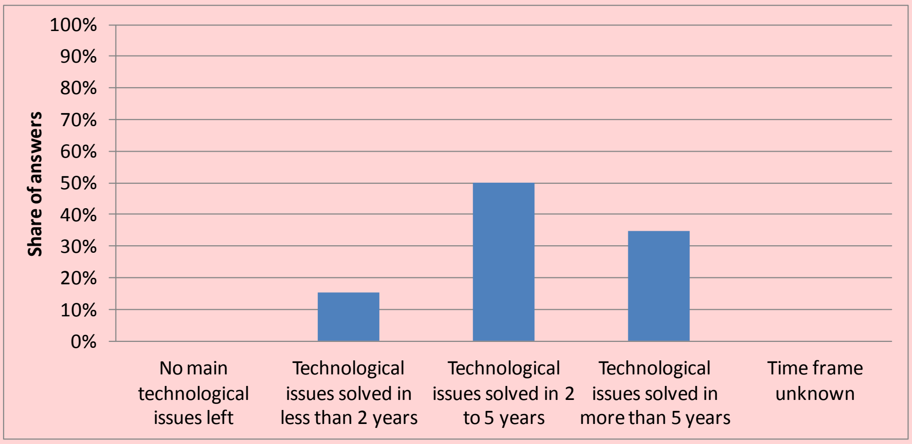
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

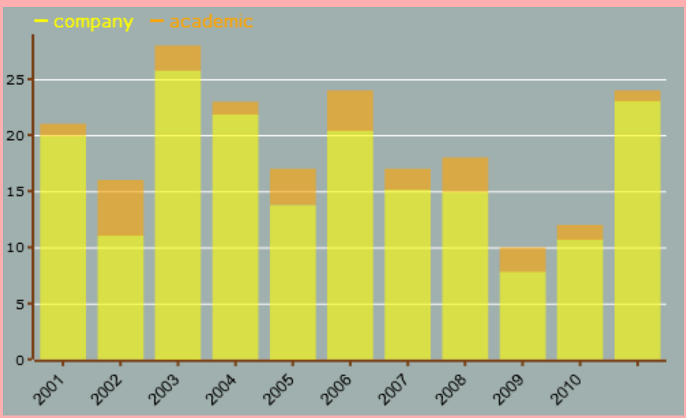
Additional information according to results of assessment:

➢ ***Impact assessment:***

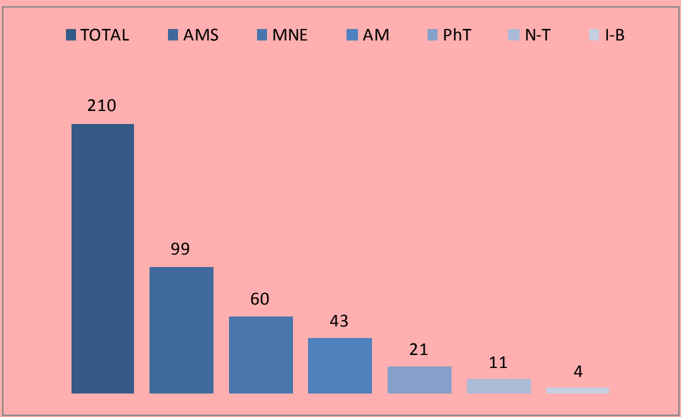
- Advanced manufacturing technologies are of cross-cutting nature, providing a crucial input for process innovation in any manufacturing sector. Their uptake in production process would increase the competitiveness of the EU's manufacturing industry.
- The global market for industrial automation solutions was estimated at 114 billion Euro in 2011, 35% of it in Europe, and is forecast to reach 140 billion Euro by 2015. In addition, the market volume for resource-efficiency technologies is estimated at 128 billion Euro.
- Within this framework, there are certain advanced manufacturing segments with particularly high growth, such as 3D printing for example, for which the global market volume is expected to increase from 1.6 billion Euro in 2012 to 8 billion Euro in 2021 (Source: Advancing Manufacturing paves way for future of industry in Europe; European Commission - MEMO/14/193, 17 March 2014).

➢ ***Results of patents scenario analysis:***

- 210 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Scattered trend curve (number of patents per year)
- Highest share of industrial applicants:



- Patents by KET(s):

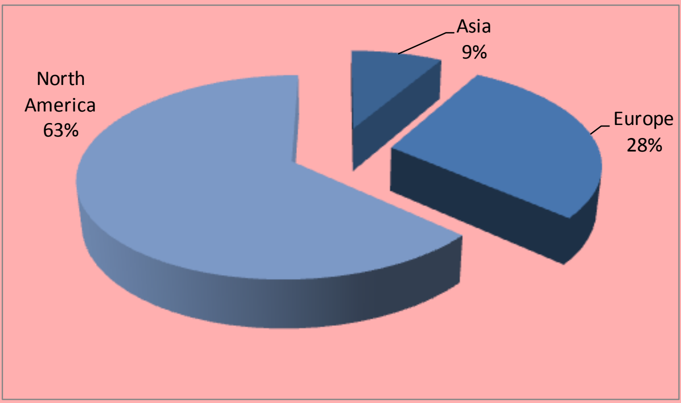


- Patents by KET(s) and relevant combinations of KETs:

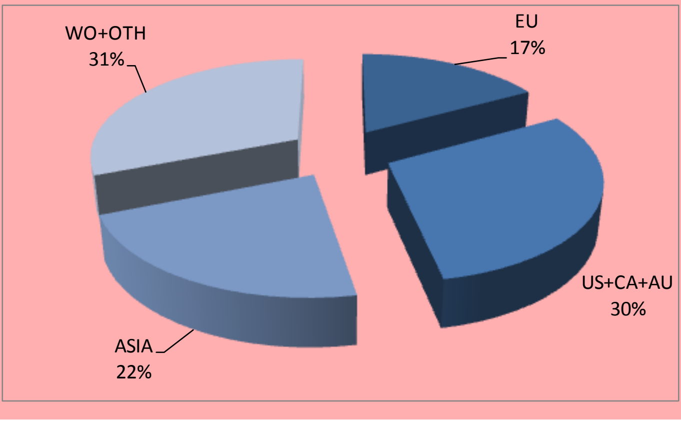
KET(s)	*Number of patents*
AM	43
AM / MNE	2
AM / N-T	7
AM / PhT	1

AMS	99
AMS / AM	1
AMS / MNE	5
IBT	4
MNE	60
MNE / N-T	1
MNE / PhT	10
N-T	11
N-T / PhT	1
PhT	21

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



MA.1.7: Micro-precision into micro- and macro-production equipment

Scope:

To provide for high-precision manufacturing and micro-precision or micro-manufacturing more accurate by one order of magnitude in both micro- and macro-production environments, from a few microns up to several metres.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Deployment of high precision manufacturing and micro-manufacturing of complex products to increase with one order of magnitude the accuracy of machines and controls
- Development of shaping technology such as forming and machining, to address challenges related to "difficult to shape" materials and to explore new processing methods to achieve micro-nano-sized microstructure components
- Design of new machine conception approaches together with innovative technologies for

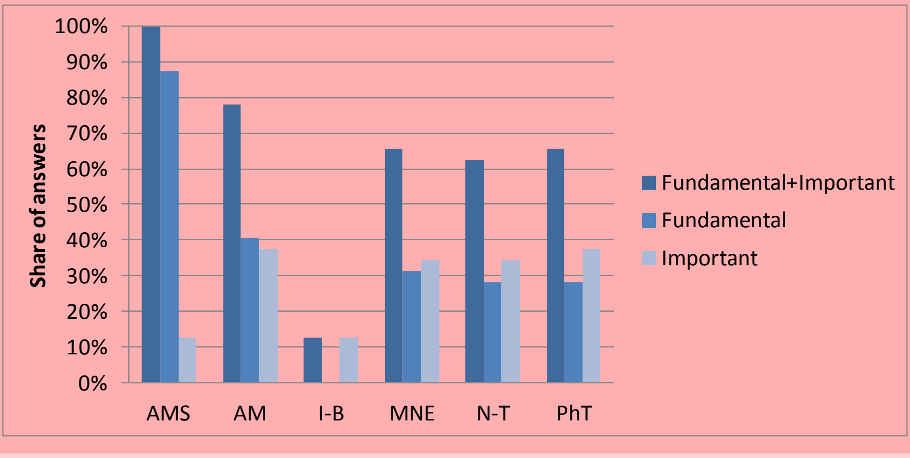
enabling manufacturers achieve high quality and high precision in manufactured products that can range in their size from a few microns up to several metres

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of micro-precision into micro- and macro-production equipment, thanks to the development and deployment of high precision manufacturing and micro-manufacturing of complex products to increase with one order of magnitude the accuracy of machines and controls (e.g. forming and machining), and to the exploration of new processing methods to achieve micro-nano-sized components.

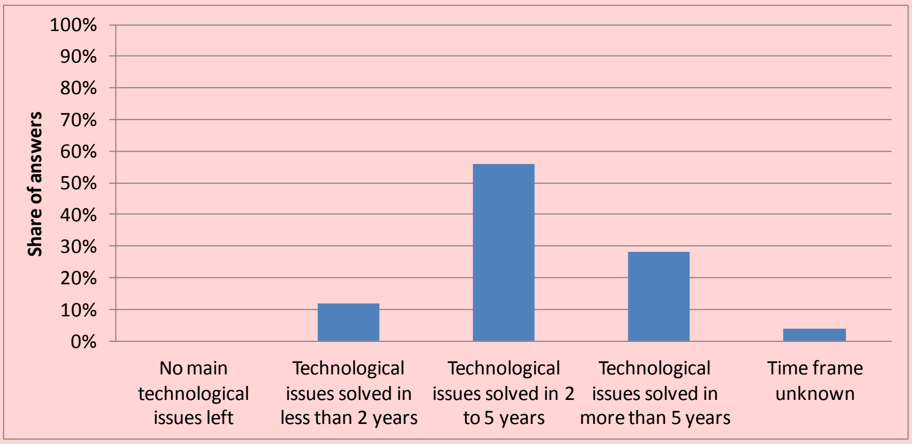
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:

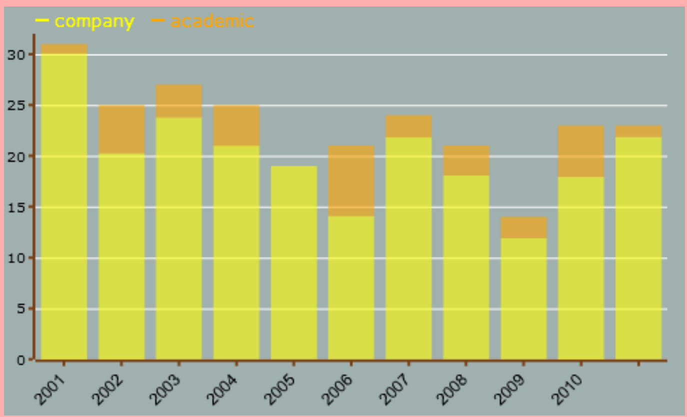


Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

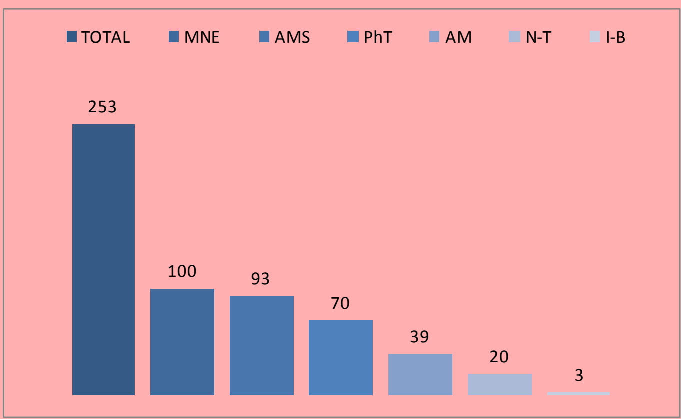
Additional information according to results of assessment:

- ***Impact assessment:***
  - Product miniaturization and micro-systems have been strong drivers of technological change, with a significant impact on the manufacturing industry. Precision micro-parts are the key enabler to product functionality and performance in a broad range of applications such as life sciences, medical devices, consumables and telecommunication facilities.
  - Within this framework, high-precision manufacturing, micro-precision manufacturing and micro-manufacturing, such as, but not limited to, micro-machining, micro-forming for metals and alloys, micro injection moulding for polymers, micro powder injection moulding for ceramics, and other methods, have significantly gained in importance. While computer aided, these technologies are capable of generating complex geometrical shapes despite the miniaturized environments in which they operate.
  - Yet, not only miniaturized and micro-systems/parts can benefit from especially high-precision and micro-precision manufacturing, as also macro-systems requiring micro-topographies can benefit greatly from these technologies.

- ***Results of patents scenario analysis:***
  - 253 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Stable/decreasing trend curve (number of patents per year)
  - Highest share of industrial applicants:



  - Patents by KET(s):

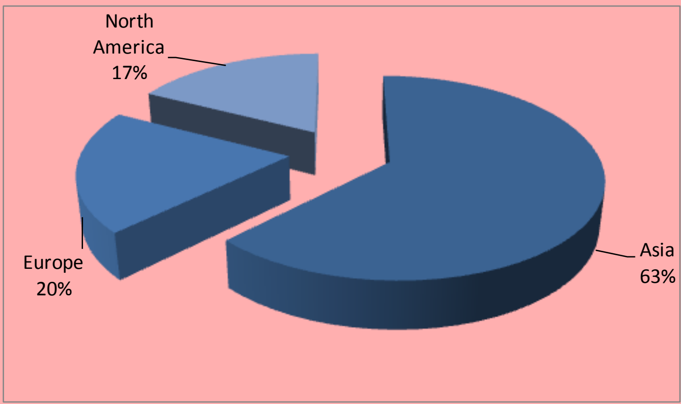


  - Patents by KET(s) and relevant combinations of KETs:

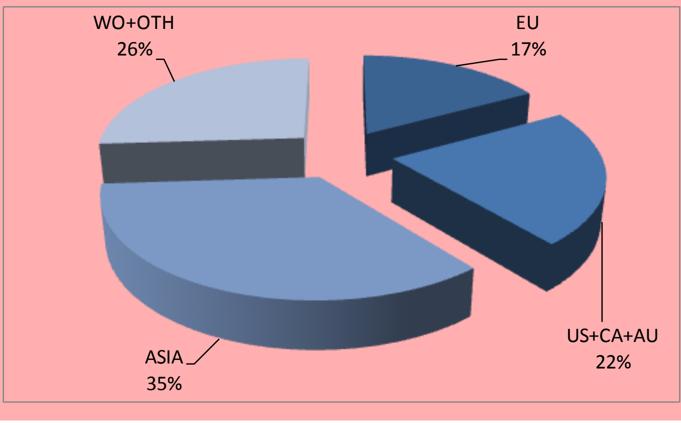
KET(s)	*Number of patents*
AM	39
AM / MNE	9
AM / MNE / N-T	1
AM / MNE / PhT	2
AM / N-T	7
AM / PhT	3

AMS	93
AMS / AM	3
AMS / AM / N-T	1
AMS / MNE	14
AMS / MNE / PhT	2
AMS / N-T	3
AMS / PhT	4
IBT	3
MNE	100
MNE / N-T	7
MNE / N-T / PhT	2
MNE / PhT	27
N-T	20
N-T / PhT	3
PhT	70

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



MA.1.8: Quality control for robust micro- and nano-enabled production

Scope:

To develop rigorous in-situ quality control systems with high 3D resolution and accuracy measurement capability, over large areas or with high aspect ratio on complex parts, in less temperature-controlled environments and a speed/throughput compatible with industrial standards.

Specific technical/industrial challenges (mainly resulting from gaps in technological

capacities):

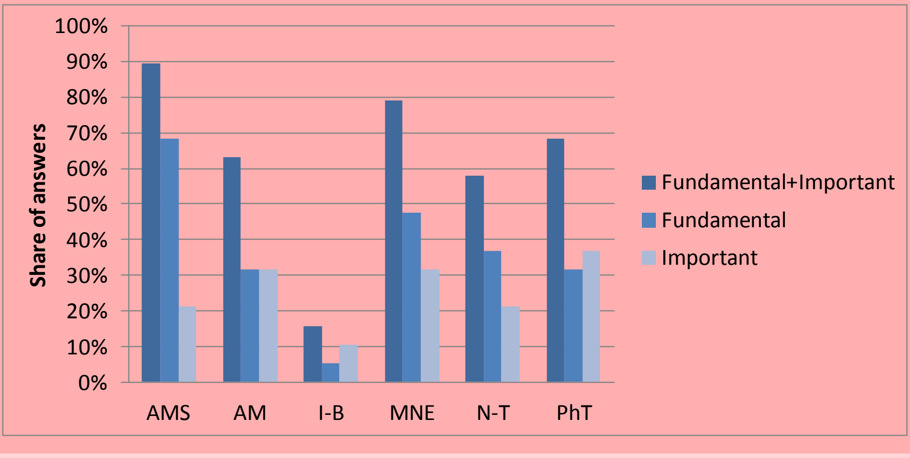
- Development of methods for handling of parts, metrology and inspection also to ensure ability to manufacture at scale (volume) with high reliability
- Development of fast and reconfigurable low/medium and high resolution measuring systems for accurate and time efficient measurements
- Use of new quality monitoring tools for multiple specifications on product shape and material quality able to quickly handle unusual or out-of-control situations
- Development of rigorous quality control systems which provide the ability to analyse or measure in three dimensions with high resolution and absolute accuracy over large areas or with high aspect ratio on complex parts, in less temperature-controlled environments and a speed/throughput compatible with industrial standards (in-situ control)
- Development of common, validated measurement methods, calibrated scientific instrumentation as well as qualified reference samples and a robust manufacturing of these reference samples

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced quality control for micro- and nano-enabled production, building on the development of methods for handling of micro- and nano-parts, of fast and reconfigurable low/medium and high resolution 3D measuring systems, of new quality monitoring tools for multiple specifications on product shape and material quality, robust enough for industrial environments.

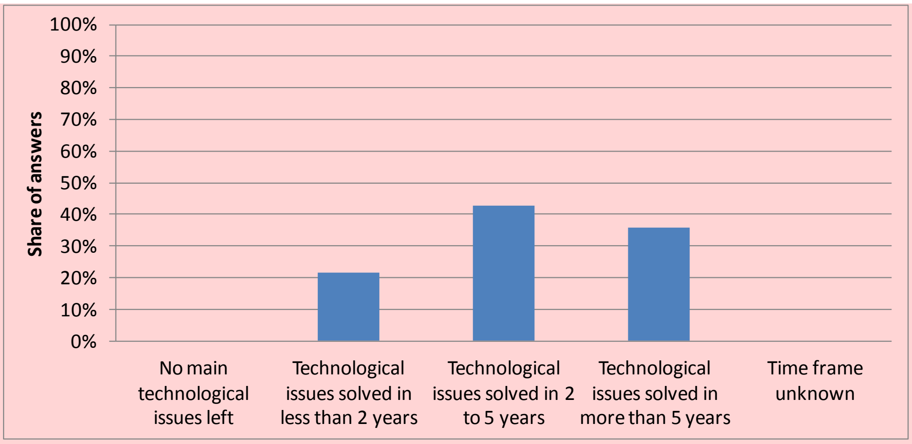
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

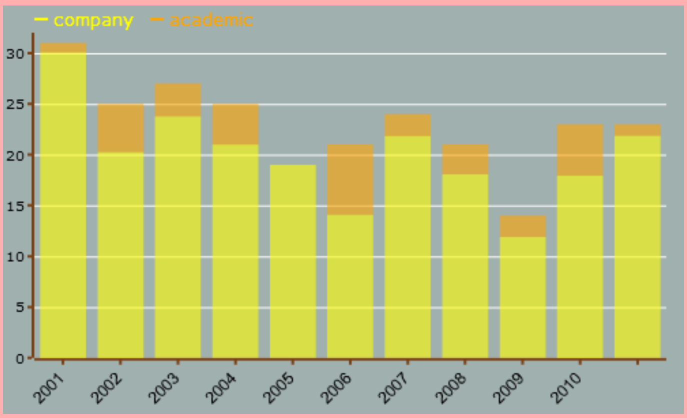
Additional information according to results of assessment:

➢ ***Impact assessment:***

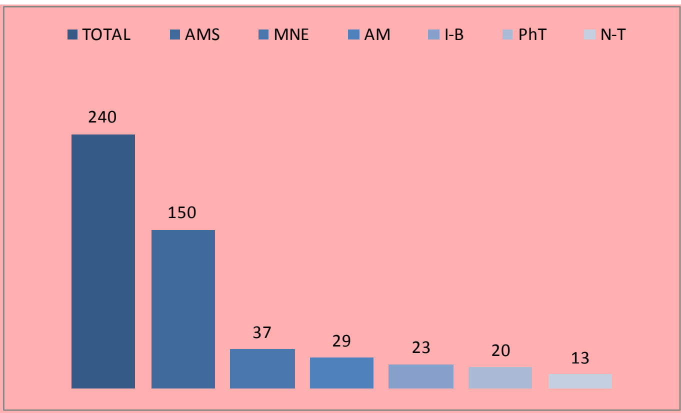
- High-precision manufacturing, micro-precision manufacturing and micro-manufacturing require not only reliable manufacturing technologies but also reliable testing and quality inspection methods and equipment that are capable of detecting faults at the same accuracy level that is provided by the manufacturing technologies themselves.
- Quality assurance of high-precision manufacturing, micro-precision manufacturing and micro-manufacturing fundamentally serves in this case as an integral component of the production chain.
- Applications of quality assurance of high-precision manufacturing, micro-precision manufacturing and micro-manufacturing can include printed circuit boards, nozzles, miniature dies, coated surfaces, height levels on calibration disks, galvanized and/or sputtered surfaces, drill holes including internal geometries, roughness measurements at milled components, and much more.

➢ ***Results of patents scenario analysis:***

- 240 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Decreasing trend curve (number of patents per year)
- Highest share of industrial applicants:



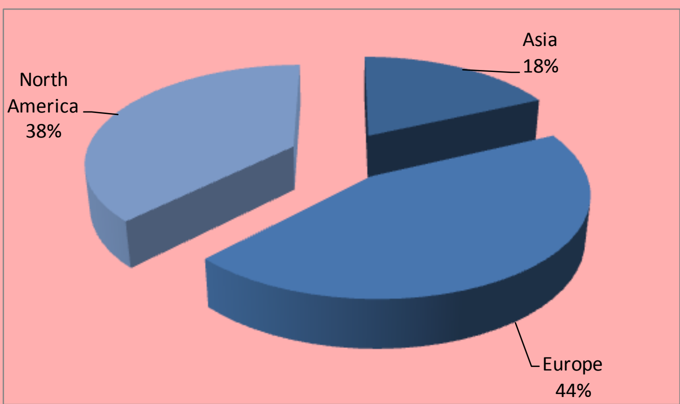
- Patents by KET(s):



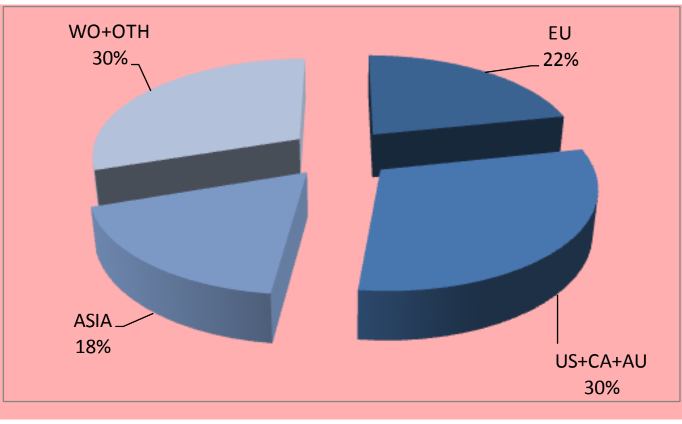
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	39
AM / MNE	9
AM / MNE / N-T	1
AM / MNE / PhT	2
AM / N-T	7
AM / PhT	3
AMS	93
AMS / AM	3
AMS / AM / N-T	1
AMS / MNE	14
AMS / MNE / PhT	2
AMS / N-T	3
AMS / PhT	4
IBT	3
MNE	100
MNE / N-T	7
MNE / N-T / PhT	2
MNE / PhT	27
N-T	20
N-T / PhT	3
PhT	70

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



MA.1.9: Tools and equipment for manufacturing of high performance flexible structures

Scope:

To develop methods and technologies realising the full potential of high performance polymers and advanced textiles, including for 3D structured, multi-layered and hybrid materials, joint-free complex shapes, automated joining and a wide range of surface engineering and functionalization techniques.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

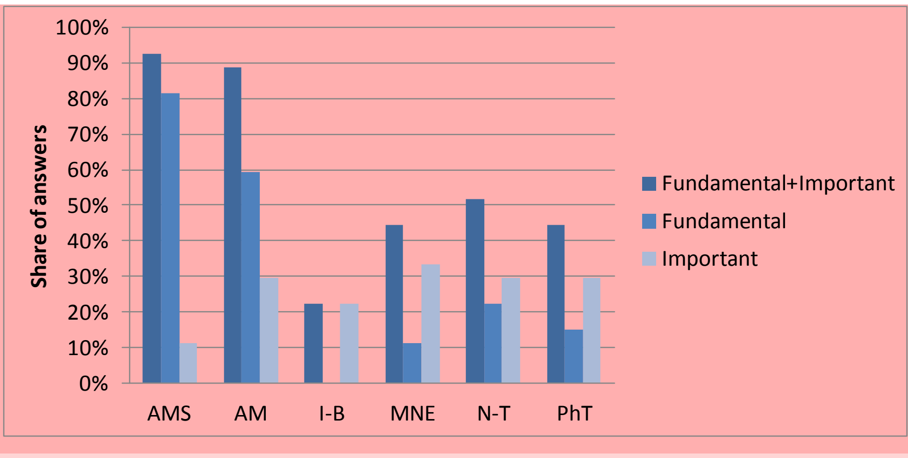
- Flexible Sheet-to-Sheet (S2S) and Roll-to-Roll (R2R), building in plastics electronics
- Increase use of polymers and advanced textiles (they are a large component of European manufacturing advantage)
- Combined benefits from processes, such as plasma, which can enhance functionality whilst also reducing energy consumption should be exploited. Other flexible structures are also relevant where they offer significant potential for European industry, examples include food products

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of methods, technologies, tools and equipment for the manufacture of flexible structures, capable of realizing the full potential of high performance polymers and advanced textiles, including for 3D structured, multi-layered materials and joint-free complex shapes, thanks to flexible Sheet-to-Sheet (S2S) and Roll-to-Roll (R2R) techniques along with surface engineering and functionalization techniques.

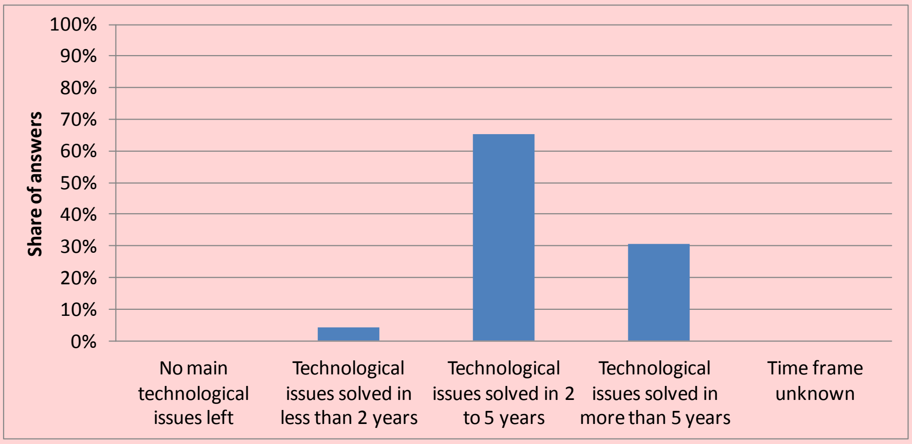
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet consensus by experts indicates also greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

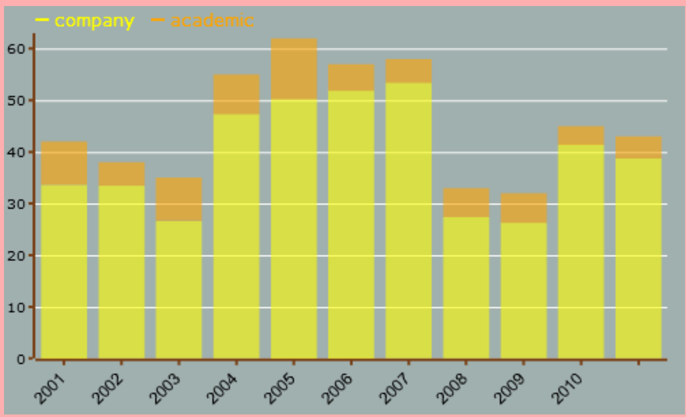
Additional information according to results of assessment:

- ***Impact assessment:***
  - Used in diverse fields such as printed electronics and flexible PVs, flexible devices represent a category of devices that in recent years have experienced strong market growth due to their advanced characteristics. Flexible devices that are lightweight and can bend and conform to curved surfaces due to their thin profile provide versatility and allow for the creation of new and low-cost applications. As flexible devices become more popular, the need increases as well to use high-volume processes for their fabrication. Consequently, the industry is steadily transitioning to the integration of roll-to-roll (R2R) and sheet-to-sheet (S2S) technologies for fabricating these devices. Actually, the global market for flexible devices manufactured by roll-to-roll (R2R) and sheet-to-sheet (S2S) technologies was valued at nearly 8 billion Euro in 2012 and is projected to increase to nearly 16 billion Euro in 2017 after increasing at a compound annual growth rate (CAGR) of 16.1% (Source: BCC Research, Global Markets for Roll-to-Roll Technologies for Flexible Devices, 2013).
  - For a number of applications the available materials and manufacturing processes are already commercially successful. Technologically more demanding products, such as large area printed OLEDs and OPV cells on flexible substrates, however, require more sophisticated approaches and have not yet been developed towards full readiness for market introduction. A major challenge in this respect is the transfer of the production from the research laboratory, where technology demonstrators are usually produced in small numbers by sheet-to-sheet (S2S) techniques, to a scale relevant to the industry,

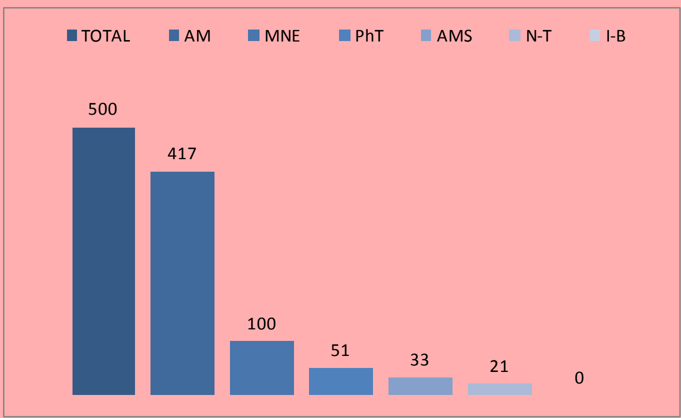
preferably on a roll-to-roll (R2R) basis (Source: E. Rubingh, Stepwise Process Optimisation for Printed Electronics Manufacturing from Small Scale Sheet-to-Sheet to Pre-Industrial Roll-to-Roll Production, 2014).

➢ ***Results of patents scenario analysis:***

- 500 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Oscillating trend curve (number of patents per year)
- Highest share of industrial applicants:



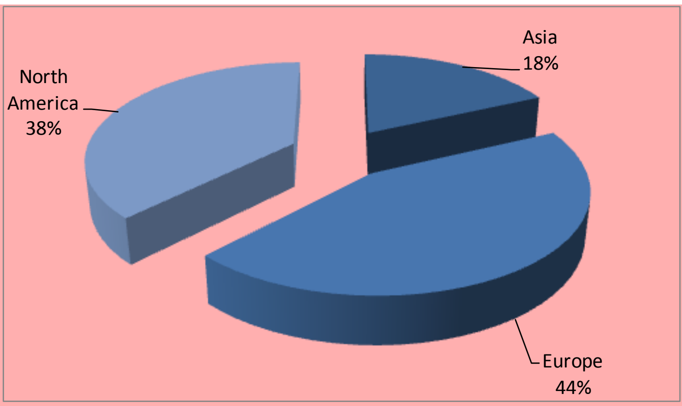
- Patents by KET(s):



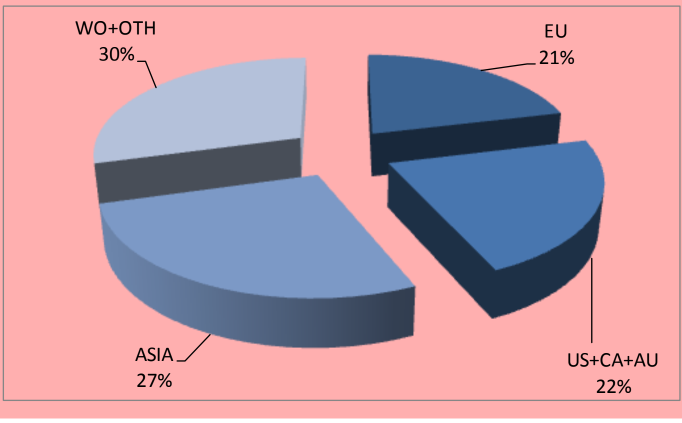
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	417
AM / MNE	42
AM / MNE / N-T	2
AM / MNE / PhT	11
AM / N-T	11
AM / N-T / PhT	1
AM / PhT	29
AMS	33
AMS / AM	6
MNE	84
MNE / N-T	9
MNE / PhT	22
N-T	21
N-T / PhT	1
PhT	51

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



MA.1.10: High volume manufacturing at the micro- and nano-scale

Scope:

Mass produced highly integrated functional 3D micro-products produced at high volume within a safe environment, encompassing design, tooling, assembly, joining and reliability issues, for automatic handling of parts, in-line metrology and inspection and their combination into systems.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

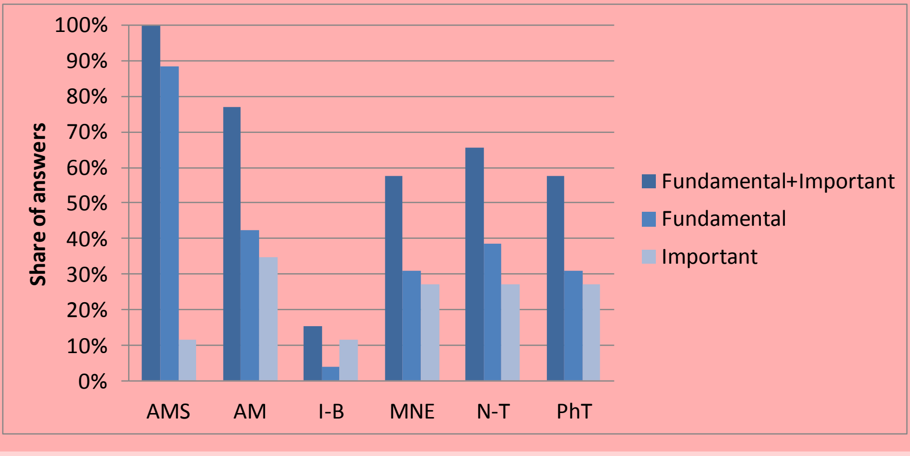
- Development of manufacturing methods based on new materials processing to move from batch to continuous formulation and to manufacture highly miniaturized components
- Development of 3D micro-components using a wide range of materials (metallic alloys, composites, polymers, ceramic) and on large volumes
- Development of conventional (forming, machining, replicating) and new manufacturing processes and related equipment - at the micro and nano-scale, encompassing design, tooling, assembly, joining and reliability issues
- Large volume patterning at nanoscale (photolithography) and new materials and greater use of space on CMOS
- Development of methods for automatic handling of parts, in line metrology and inspection to manufacture at scale with high reliability

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced approaches, encompassing design, tooling, assembly, joining and reliability issues, for the mass production of highly integrated functional 3D micro-products, including for automatic handling, metrology and inspection of parts. The integration of KETs could particularly contribute to the development of high volume manufacturing methods based on new materials and production processes, such as tooling and patterning of highly miniaturized 3D components.

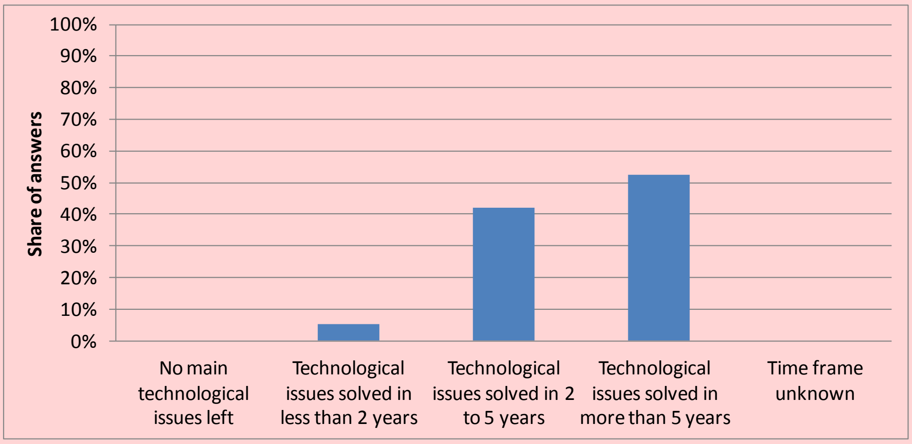
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus by experts indicates also shorter periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

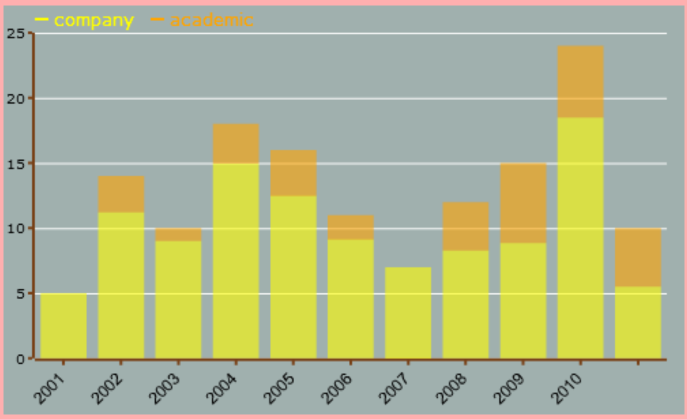
- Due to the commoditization of some MEMS devices, especially in the consumer electronics segment, MEMS manufacture has driven the development of mass scale production of highly integrated functional 3D micro-products.
- The critical physical dimensions of MEMS can range from several millimetres down to well below one micron. Moreover, MEMS can vary from relatively simple structures with

no moving elements to extremely complex electromechanical systems with multiple moving elements.

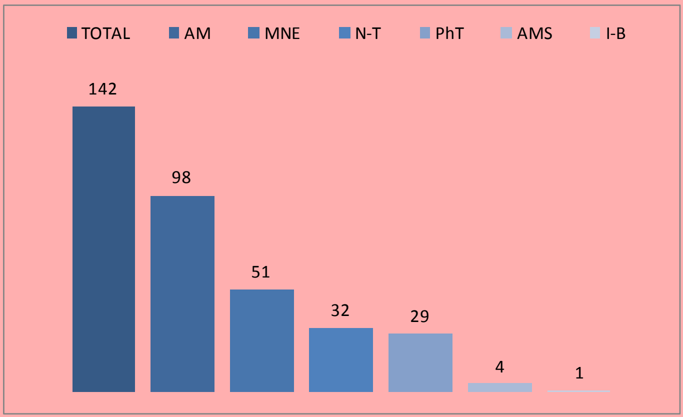
- Among these Micro-Electro-Mechanical Systems, an extremely large number of micro-sensors have been developed for almost every possible sensing modality, including temperature, pressure, inertial forces, chemical species, magnetic fields, radiation, etc. More recently, a number of micro-actuators including: micro-valves for control of gas and liquid flows; optical switches and mirrors to redirect or modulate light beams; independently controlled micro-mirror arrays for displays, micro-resonators for a number of different applications, micro-pumps to develop positive fluid pressures, micro-flaps to modulate airstreams on airfoils, as well as many other devices have been developed and demonstrated.
- As a result, MEMS find a very vast variety of applications in an even wider variety of products. To achieve this, their method of production leverages similar fabrication techniques used in the integrated circuit industry (such as oxidation, diffusion, ion implantation, Low-Pressure Chemical Vapour Deposition (LPCVD), sputtering, etc.), combining these capabilities with highly specialized micro-processes – which can translate into mass production and relatively low per-device production costs.
- Not surprisingly, silicon-based discrete micro-sensors were quickly commercially exploited and the markets for these devices continue to grow at a very rapid rate.
- MEMS fabrication uses many of the same techniques that are used in the integrated circuit domain such as oxidation, diffusion, ion implantation, Low-Pressure Chemical Vapour Deposition (LPCVD), sputtering, etc., and combines these capabilities with highly specialized micromachining processes.
- Source: www.mems-exchange.org

➢ ***Results of patents scenario analysis:***

- 142 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Oscillating trend curve (number of patents per year)
- Highest share of industrial applicants:



- Patents by KET(s):

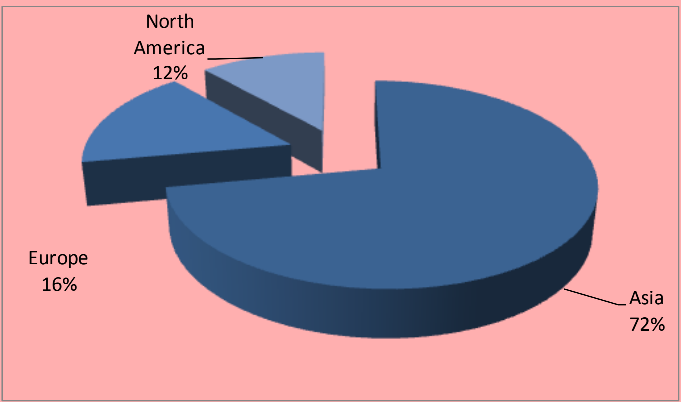


- Patents by KET(s) and relevant combinations of KETs:

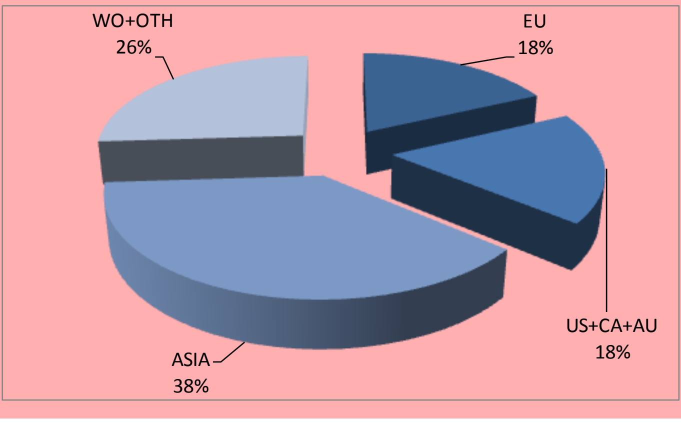
KET(s)	*Number of patents*
AM	98

AM / MNE	20
AM / MNE / N-T	3
AM / MNE / PhT	12
AM / N-T	21
AM / PhT	16
AMS	4
AMS / AM	3
AMS / AM / N-T	1
AMS / MNE	1
AMS / N-T	1
IBT	1
MNE	51
MNE / N-T	6
MNE / PhT	21
N-T	32
PhT	29

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



Sub-domain: Energy and resource efficient manufacturing

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "secure, clean and efficient energy" as well as the "climate action, resource efficiency and raw materials" societal challenge

Demand-side requirements (stemming from market needs) addressed:

- Reduce energy consumption (resulting in savings over the conventional energy purchase for industrial end-users and in the overall reduction of the energy demand on a global

scale)
- Reduce resources consumption including raw materials as well as water and other utilities required during production (resulting in savings over the conventional raw materials as well as utilities purchase for industrial end-users and in the overall reduction of raw materials as well as other resources (such as e.g. water) demand on a global scale)

MA.2.1: Energy-efficient factories

Scope:

To develop new and improved concepts for energy generation and recovery in production, including substitution of high-temperature processes.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

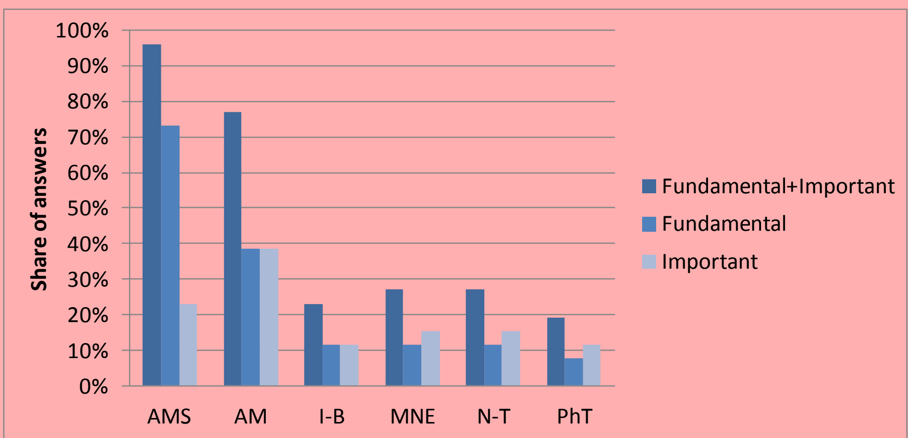
- Development of optimized self-adaptive and fault tolerant strategies, which lead to higher productivity and reduced energy consumption and process emissions (dust, air, water, noise, waste, etc.)
- Development of new solutions for green house gases emission reduction, in particular by using alternative materials and/or energy sources and innovative technology application
- Find flexible adaptation of energy resources for high performance machine drives
- Reduction in energy consumption in future manufacturing through ICT solutions to monitor and manage energy
- Complement decision-support systems by rich and intuitive energy management mobile dashboards available to the decision makers at plant and board levels of a manufacturing enterprise

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of new and improved concepts for energy generation and recovery in production, including the substitution of high-temperature processes, the use of alternative materials and/or energy sources and innovative self-adaptive technology application and ICT solutions and the flexible adaptation of energy resources for high performance machine drives.

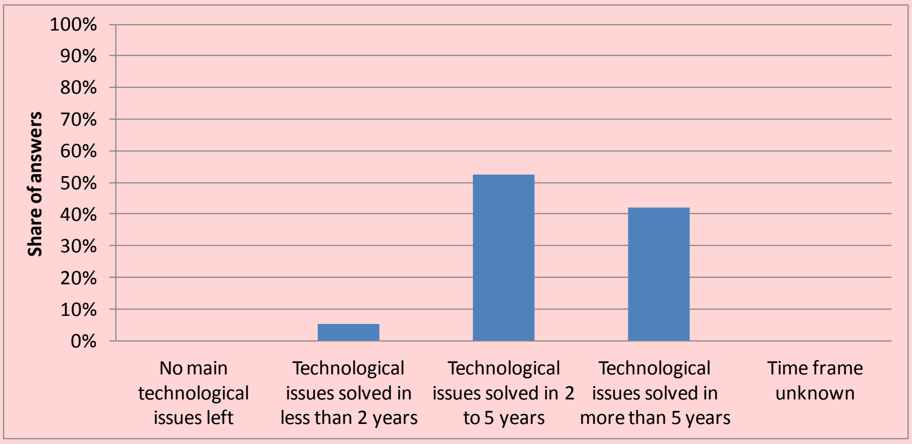
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Any manufacturing and process industries, but in particular energy-intensive industries are strongly incentivized to reduce their energy intensity due to the high share that electricity as well as heat usage have in their total production costs.
  - In order to decrease the total energy bill, optimized energy management approaches can be successfully applied. These encompass ICT solutions to monitor and optimally manage energy, optimized self-adaptive and fault tolerant strategies that can lead to higher productivity and reduced energy consumption, the use of alternative materials and/or energy sources that can substitute their counterparts in the production, and a variety of other approaches.
  - All these approaches can translate into reduced energy consumption, thus into savings over the conventional energy purchase for industrial end-users, as well as reduced process emissions (including greenhouse gases).
- ***Results of patents scenario analysis:***
  - 15 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Hence, no significant patent-related indicators can be reported in this field

MA.2.2: Material/resource-efficient manufacturing processes

Scope:

To provide for material-saving production processes with improved material efficiency and recovery, flexible use of substitute materials, near-net-shaped concepts and / or additive manufacturing, remanufacturing, recycling, hybrid processes, better use of waste streams and processes interactions.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of production solutions enabling low resource input, low emission, products tailored for different applications, surface treatments and functionalization, painting, coating and joining, development of compact processes, ensuring high process productivity while reducing environmental impact
- Save materials through new manufacturing approaches and material-saving production processes with improved material efficiency and enabling the (flexible) use of substitute

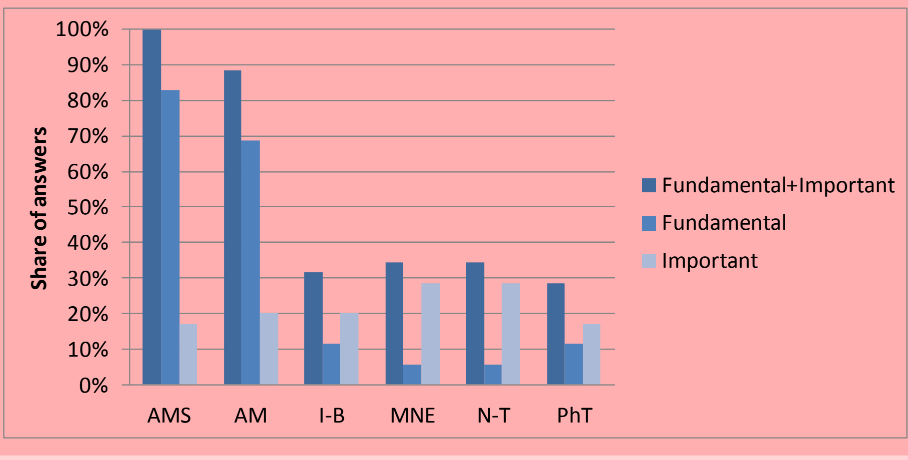
materials
- Minimization of energy consumption during manufacturing through novel, new or regenerative (i.e. Low C,) energy supply, better use of waste streams through recovery, and efficiency improvements in manufacturing equipment (e.g. through flow speed)
- Demonstration of greater manufacturing efficiency whilst minimizing use of raw materials and energy consumption
- Reduction in the consumption of water and other process resources
- Increase of material efficiency by better understanding various material efficiency measures and their interactions among different manufacturing processes and/or industries

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of material/resource efficient manufacturing processes, building on material-saving production processes with improved material efficiency and recovery, flexible use of substitute materials, near-net-shaped concepts and / or additive manufacturing, remanufacturing, recycling, hybrid processes, better use of waste streams and processes interactions along with environmentally friendly surface treatments, functionalization, painting, coatings and joining.

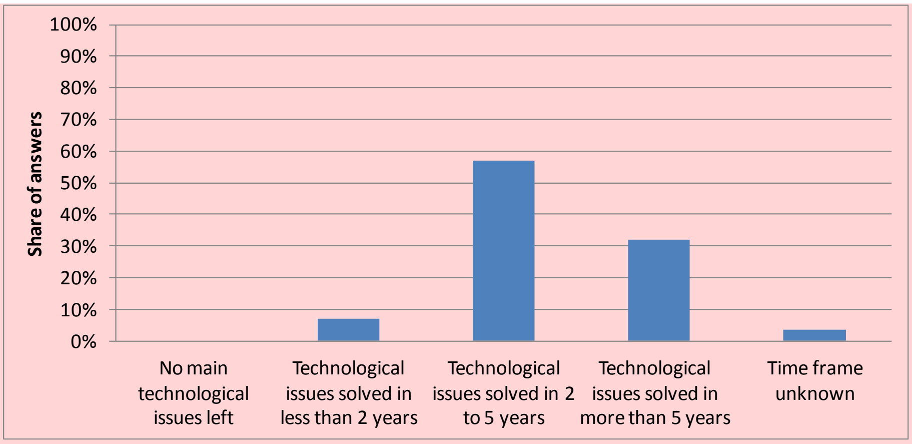
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet consensus by experts indicates also greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

- Besides to reduce energy consumption, any manufacturing and process industries are also strongly incentivized to reduce their resources' input intensity due to the high share that raw materials as well as other resources necessary to the production (such as water) have in their total production costs.
- This may be achieved by the introduction of new manufacturing / processing approaches allowing for intrinsic material-saving (including optimization of material consumption at the design level), a better use of waste streams through recovery of materials or other resources (such as water), and efficiency improvements in manufacturing or processing equipment.
- The flexible use of substitute materials, near-net-shaped concepts and/or additive manufacturing, remanufacturing, recycling, hybrid processes, and a better management of waste streams either within the factory or through processes interactions can also be an opportunity.
- All these approaches can translate into reduced resources consumption such as reduced raw materials input as well as water and other utilities required during production, which can result in savings over the conventional raw materials as well as utilities purchase for industrial end-users and in the overall reduction of raw materials as well as other resources (such as water) demand on a global scale.

➢ ***Results of patents scenario analysis:***

- 11 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Hence, no significant patent-related indicators can be reported in this field

Sub-domain: Smart and flexible manufacturing systems

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "secure, clean and efficient energy" as well as the "climate action, resource efficiency and raw materials" societal challenge

Demand-side requirements (stemming from market needs) addressed:

- Provide for cost optimization including through predictive maintenance
- Provide for rapid and flexible production capabilities to match supply with volatile demand of today's rapidly changing markets

MA 3.1: Monitoring, perception & awareness in manufacturing

Scope:

Monitor the actual state of components and machines in a continuous manner to allow diagnosis and context-awareness in the associated systems. Ubiquitous sensing approaches will monitor variables affecting the performance, energy-use and reliability of the manufacturing systems and the production.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

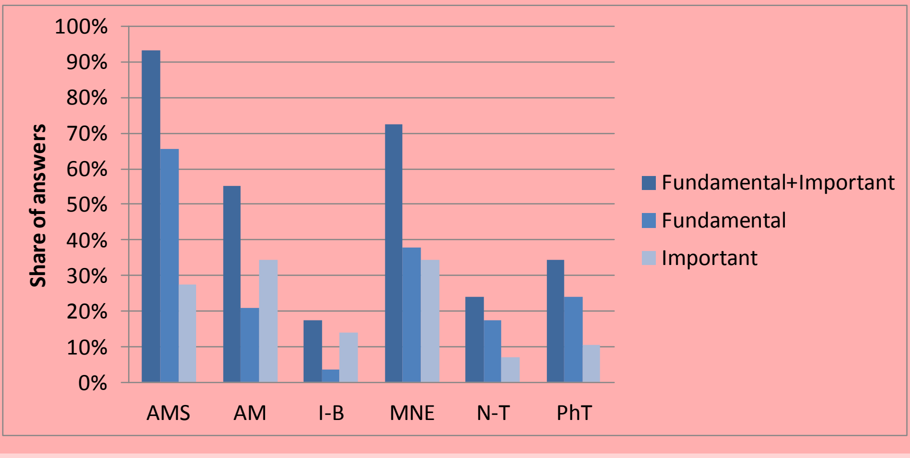
- Development of novel large-scale control-intensive applications for high yield performance and energy efficiency, in order to validate and benchmark the effectiveness and usability of the integrated automation and control systems, e.g. by means of fully integrated interfaces from Manufacturing Execution Systems (MES) to shop floor level or knowledge management of process data with shop floor relevance
- Software assisted diagnostics: software that identifies the reasons of break-downs after they take place
- Preventive maintenance: software that makes a forecast of machine break-downs before they take place
- Development of ubiquitous sensing approaches to actively support engineers in their aim of detecting, measuring and monitoring the variables, events and situations which affect the performance, energy-use and reliability of high value-adding manufacturing systems and the production at factory level

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced approaches for monitoring, perception and awareness of the actual state of manufacturing components and machines in a continuous manner to allow diagnosis and context-awareness in the associated systems. The integration of KETs could contribute to the development of large-scale control-intensive applications for high yield performance and energy efficiency, building on solutions such as Manufacturing Execution Systems (MES) and innovative diagnostics and preventive maintenance approaches.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

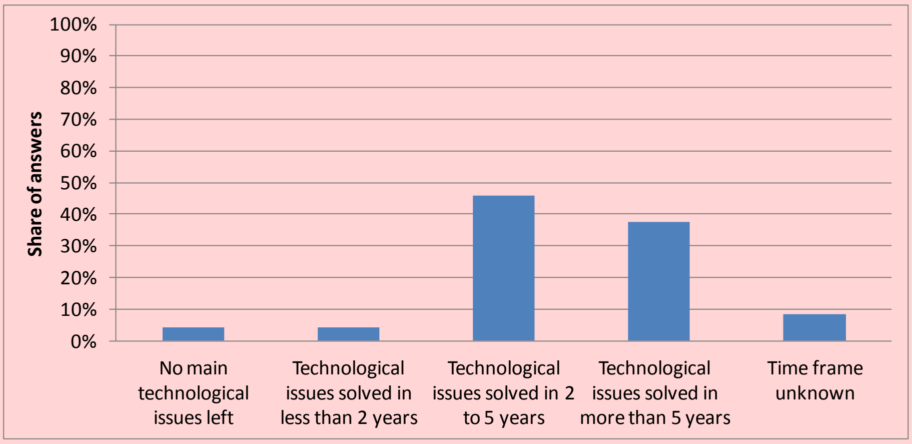
- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting

KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

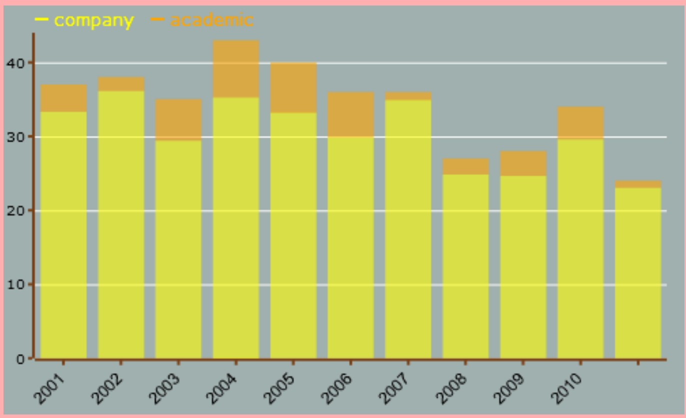
Additional information according to results of assessment:

➢ ***Impact assessment:***

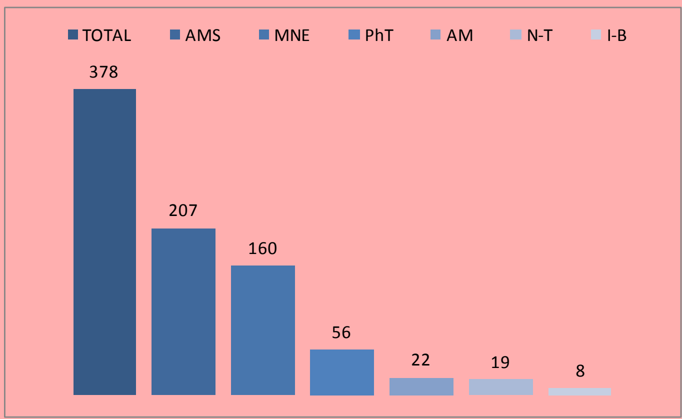
- The involvement of information technology in manufacturing processes has increased over the last years. Information technology is used to provide for improved management of energy as well as resources in manufacturing as well as processing operations, but also to monitor data and support in decision taking (thanks to decision support systems) or to plan maintenance thanks to condition monitoring. All these performances are possible today thanks to in-line monitoring of process parameters and other monitored data.
- In-line condition monitoring, which is an advanced major component of predictive maintenance, is capable to identify deviations from the standard operating conditions which are indicative of a developing fault. Condition monitoring allows maintenance to be scheduled, or other actions to be taken in order to prevent failures, thus avoiding consequences in terms of downturns or even accidents, which inevitably translate in costs. Condition monitoring can therefore have significant benefits in terms of costs savings.
- Condition monitoring techniques, such as vibration condition monitoring and diagnostics, lubricant analysis, acoustic emission monitoring, IR thermography, ultrasounds emission monitoring, motor condition monitoring and motor current signature analysis, are normally used especially on rotating equipment and other machinery (such as pumps, electric motors, internal combustion engines, presses), while periodic inspection using non-destructive testing techniques and fit for service evaluation are used for stationary plant equipment such as steam boilers, piping and heat exchangers.
- Furthermore, Manufacturing Execution Systems (MES) have helped many industries to improve their processes, leading to sustainable improvements. MES has changed the manual operations into paperless operations for faster data transfer and better decision making. Connected networks of various MES systems can particularly help senior managers to take decisions based on real time data from remotely. As a result, the MES market was estimated to be 4.8 billion Euro in 2014 and to be worth 10 billion Euro by 2020 at an estimated compound annual growth rate (CAGR) of 12.61%. Discrete and process industries are the two major categories of manufacturing that MES serves. MES has been used in process industries for a long time; however, discrete industries are very large in nature and have the potential to grow for MES to be implemented.
- Automobile, healthcare, aerospace and defence, and FMCG (Fast Moving Consumer Goods) are the major discrete industries that will highly profit from MES in the future.
- Source: Markets and Markets, Manufacturing Execution System Market by Applications (Process Industries- Chemicals, F&B, Oil & Gas, Pulp & Paper, Life Sciences Power, Water & Wastewater Management; Discrete Industries- Automotive, Medical Devices, Aerospace & Defense, FMCG) and Geography (Americas, EMEA, & APAC) - Global Trends & Forecasts to 2014 – 2020, 2013.

➢ ***Results of patents scenario analysis:***

- 378 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Decreasing trend curve (number of patents per year)
- Highest share of industrial applicants:



- Patents by KET(s):

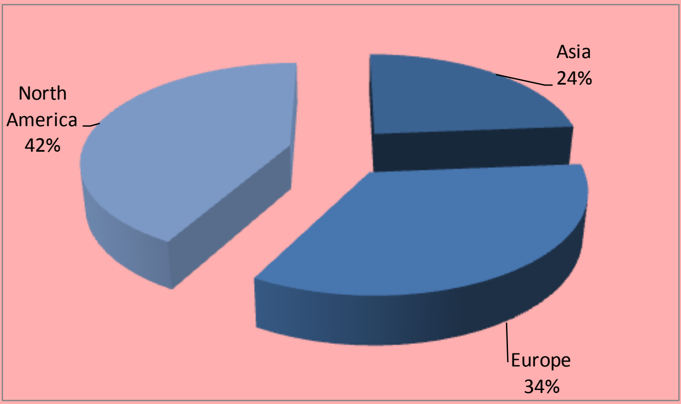


- Patents by KET(s) and relevant combinations of KETs:

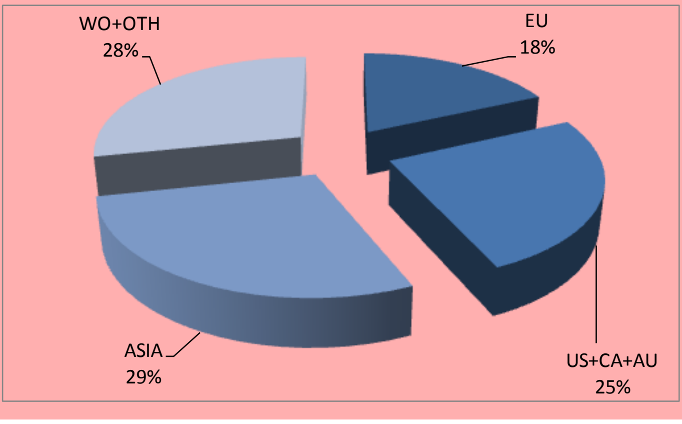
KET(s)	*Number of patents*
AM	22
AM / IBT	1
AM / IBT / MNE	1
AM / IBT / MNE / N-T	1
AM / IBT / N-T	1
AM / MNE	4
AM / MNE / N-T	3
AM / MNE / PhT	1
AM / N-T	6
AM / PhT	4
AMS	207
AMS / AM	5
AMS / AM / IBT	1
AMS / AM / IBT / MNE	1
AMS / AM / IBT / MNE / N-T	1
AMS / AM / IBT / N-T	1
AMS / AM / MNE	2
AMS / AM / MNE / N-T	1
AMS / AM / MNE / PhT	1
AMS / AM / N-T	2

AMS / AM / PhT	1
AMS / IBT	1
AMS / IBT / MNE	1
AMS / IBT / MNE / N-T	1
AMS / IBT / N-T	1
AMS / MNE	41
AMS / MNE / N-T	1
AMS / MNE / PhT	5
AMS / N-T	4
AMS / PhT	9
IBT	8
IBT / MNE	2
IBT / MNE / N-T	1
IBT / N-T	1
MNE	160
MNE / N-T	7
MNE / N-T / PhT	2
MNE / PhT	25
N-T	19
N-T / PhT	2
PhT	56

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



MA.3.2: Flexible, reconfigurable and modular machinery and robots

Scope:

As-autonomous-as-possible reconfiguration of machinery and robots to support mass customized and highly personalized products and fast reactions to shifts of market demands, e.g. through self-adjustment, correction, control and networking, to decrease, for example, changeover time and energy usage.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

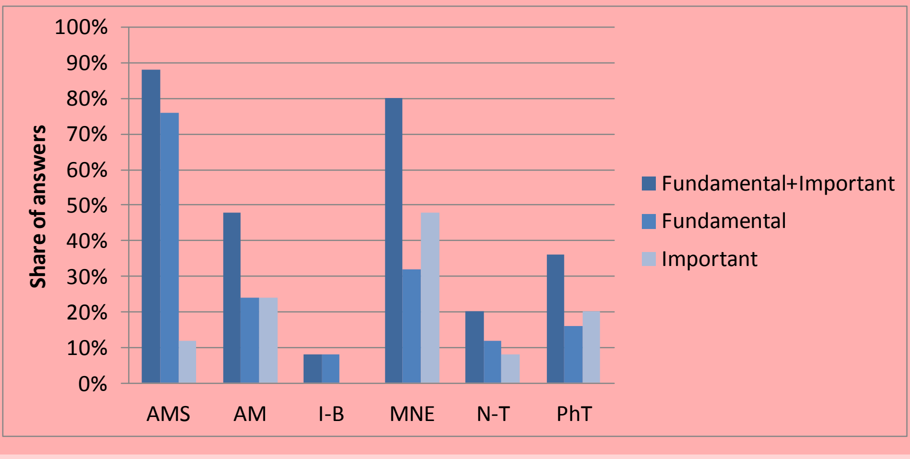
- Plug and play solutions for integration of factory components and modules
- Conceive manufacturing systems from scratch as combinations of smart and exchangeable mechatronic modules, taking the most out of a combination of electro-mechanical and embedded and learning controllers for adapting the system behaviour to changing environments and system degradations
- Development of multi-layer controls and model based real-time compensation routines, embedding machining process knowledge, for novel self-learning systems
- Development of intelligent plug-and-play systems which feature sensing and actuator structures integrated with adaptive control systems and with active compensation features for fully optimizing the performance of the manufacturing systems in terms of autonomy, reliability and efficiency along their lifecycle
- Development of innovative ICT tools for supporting the as-autonomous-as-possible reconfiguration of machinery and robots, as basis for supporting mass customized and highly personalized products and fast reactions to shifts of market demands

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced highly flexible, reconfigurable and modular machinery and robots to support mass customized and highly personalized products manufacturing. The integration of KETs could particularly contribute to the development of plug and play solutions, smart and exchangeable mechatronic modules, embedded and learning controllers for adapting the system behaviour to changing environments and system degradations, supported by the development of innovative ICT tools.

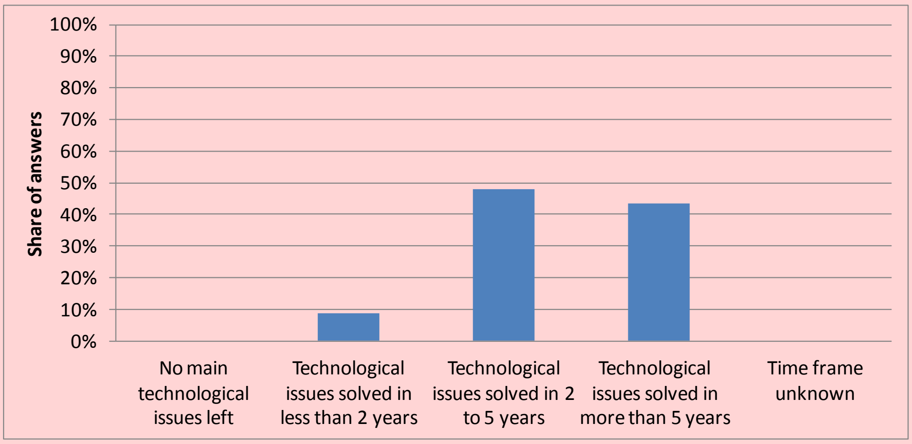
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Micro- and Nano-Electronics (MNE)
- Advanced Materials (AM)



Timing for implementation:

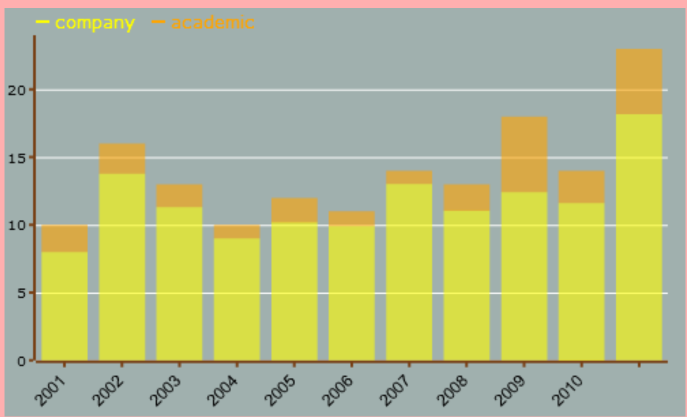
According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:



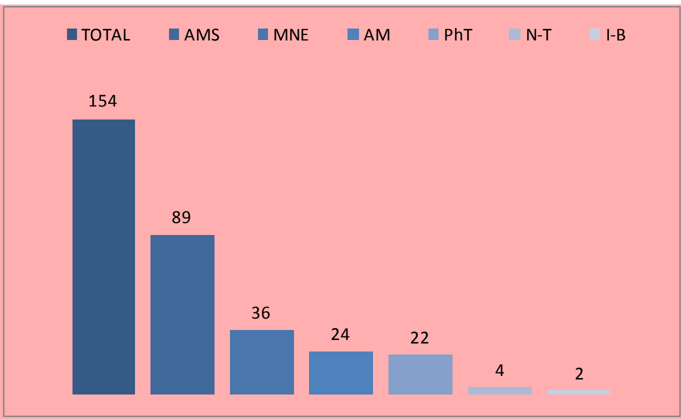
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Continuing market demands for specialist products at "mass production prices" are being met increasingly by agile manufacturing often making use of flexible, reconfigurable and modular machinery and robots.
  - Actually, agility in manufacturing extends through the supply chain, business management, design, production control, servicing, and product up-dating, also making wide use of Information Technology.
  - Yet, the introduction in this overall system of agile responsive machinery based on modular principles as well as of reconfigurable robots has already effected many improvements in manufacturing and will continue to do so.
  - Agile manufacturing represents particularly a very interesting approach to developing a competitive advantage in today's fast-moving marketplace. It allows for rapid response to the customer – turning speed and agility into a key competitive advantage.
  - Source: www.leanproduction.com
- ***Results of patents scenario analysis:***
  - 154 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Oscillating but increasing trend curve (number of patents per year)
  - Highest share of industrial applicants:



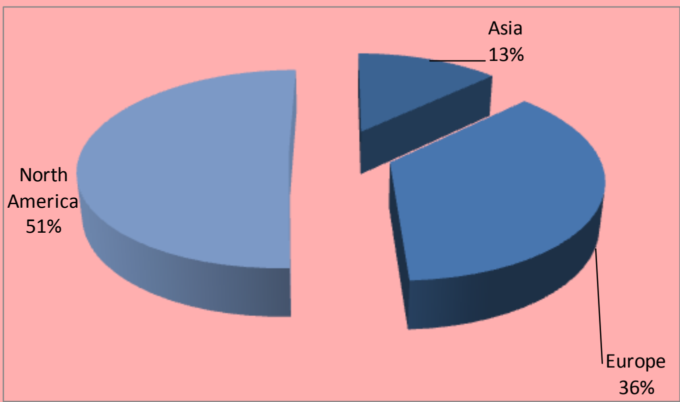
  - Patents by KET(s):



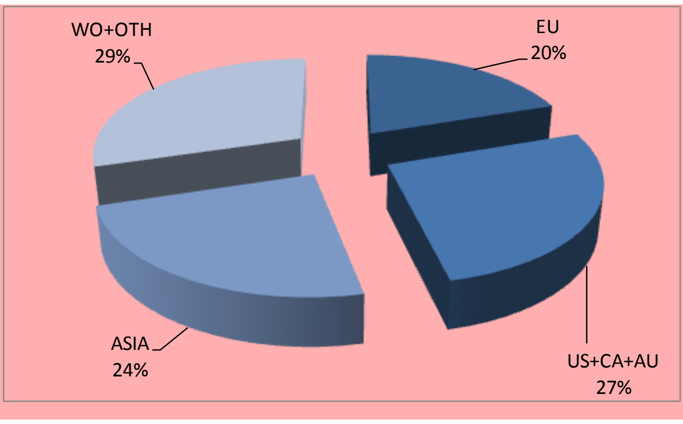
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	24
AM / MNE	2
AM / MNE / PhT	1
AM / N-T	3
AM / PhT	1
AMS	89
AMS / MNE	5
AMS / PhT	1
IBT	2
MNE	36
MNE / PhT	12
N-T	4
PhT	22

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



MA.3.3: Flexible design and manufacturing processes for implementing more creativity and user-driven innovation

Scope:

Flexibility to continuously modify products without drastic re-design of core-product base and operations, e.g. through integration of ICT design technologies and flexible production technologies (additive/subtractive technologies, multifunctional machines, flexible joining technologies).

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

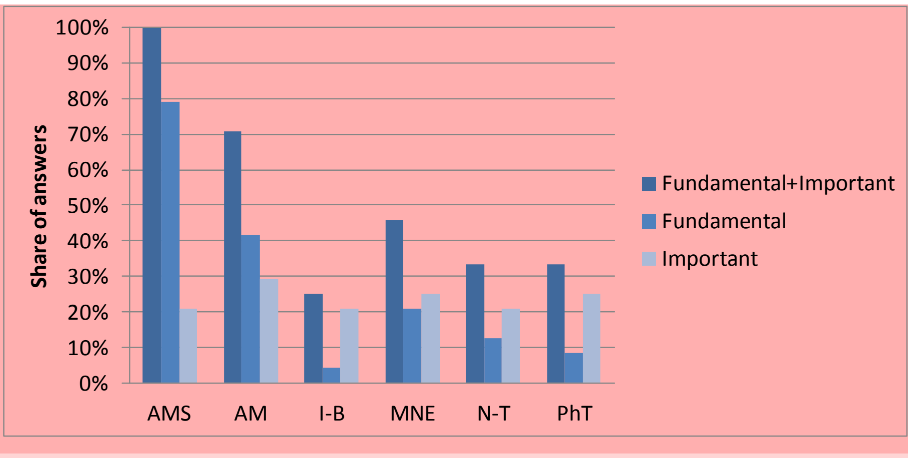
- Exploitation of the creativity potential through the improvement of mediated communication (e.g. via websites or via social media) with end users and their role in the creation/production or selling processes (via digital means)
- Integration of new data management systems and traditional CAD tools to get a design perspective in new disciplinary areas, like emotional engineering or co-design tools
- Use additive/subtractive technologies, multifunctional machines, flexible joining technologies to provide the basis for the new required variability
- Development of novel simulation and fast testing methodologies to assure that properties of such innovative products are compliant with common product quality requirements (i.e. reliability, safety, environmental-friendliness, etc.)

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of flexible design and manufacturing processes for implementing more creativity and user-driven innovation in products, through integration of flexible production technologies (additive/subtractive technologies, multifunctional machines, flexible joining technologies) and advanced ICT design technologies, including collaborative and social ones exploiting the creativity potential of large pools of designers and customers.

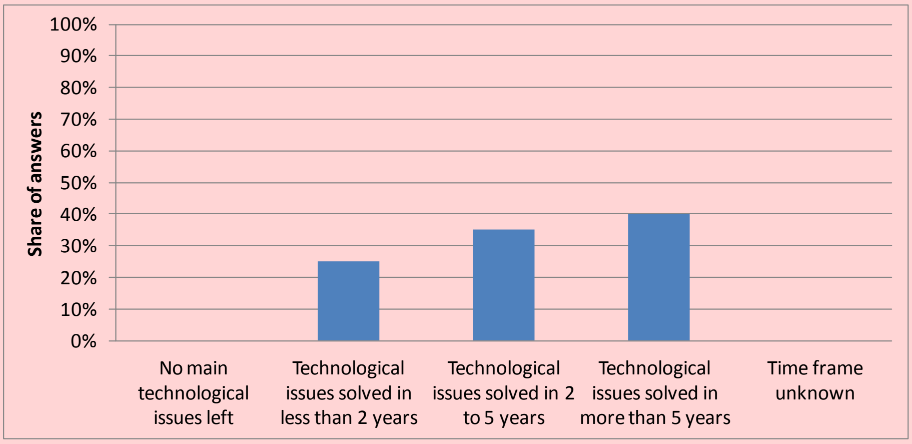
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus by experts indicates also much shorter periods being necessary, as actually some pilot experiences in this sense exist, which can however be significantly improved:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Today's consumers' generation increasingly demands for individualized performance of products, which can only result from a deep awareness on consumers' needs. Moreover, today's purchasing mechanisms rely on a close selection of products on the global product market. Pervasive use of Information Technology as associated to various hardware than can enable exchange of data, images, and product features in general terms, as well as of money, appears as a stable asset in the recent product proposition, as well as the virtual value of products and their quantitative performance assessment.
  - This new consumption pattern requires intelligent design of new products fitting with specific needs of highly sophisticated consumers. Particularly ICT technologies seems to condition the future key features of consumerism trend by enforcing the interaction between company and final users as well as the user-lead innovation and the information exchange in consumers communities.
  - Such ICT wave has been shift from the electronic market to the design based consumer goods by producing new quality area for the traditional products and more generally new service platform developments as a stable element of market proposition
  - Source: The Joint Research Roadmap - Final outcome of the PROsumer.NET Market/Innovation Trends and Technology Foresight activities serving as outlook on research and technology development priorities in the design-based consumer goods

sector up to 2020

- ***Results of patents scenario analysis:***
  - 13 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Hence, no significant patent-related indicators can be reported in this field

POTENTIAL AREAS OF INDUSTRIAL INTEREST RELEVANT FOR CROSS-CUTTING KETS IN THE ENERGY DOMAIN

Sub-domain: High potential renewable energy systems

Demand-side requirements (stemming from Societal Challenges) addressed:

- Contribute to achieving competitive, sustainable and secure energy
- Achieve levels of renewable energy consumption within the European Union of 20% by 2020 (as mandated by the Renewable Energy Directive (2009/28/EC))
- Achieve the largest proportion of renewables in the final energy consumption by 2050 as identified in the Energy Roadmap 2050
- Achieve net zero-energy buildings in the future, serving as driver to boost the market for novel renewable energy applications in the residential sector (according to the Energy Performance of Buildings Directive (2010/31/EU))

Demand-side requirements (stemming from market needs) addressed:

- Increase efficiency of energy generation systems and equipment in order to maximize yield
- Increase reliability of energy generation systems and equipment
- Reduce cost / payback of energy generation systems and equipment
- Reduce costs of installation as well as of operation and maintenance

E.1.1: Flexible solar cells (modules) enabling improved PV integrability

Scope:

To develop flexible solar cells (modules) based on thin-films layers, organic dyes, deposited organic polymers, etc., enabling flexibility for improved PV integration, major modularity, easier installation, better aesthetics, and in which cost is reduced thanks to optimization of materials' consumption as well as improvements at the manufacturing level.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

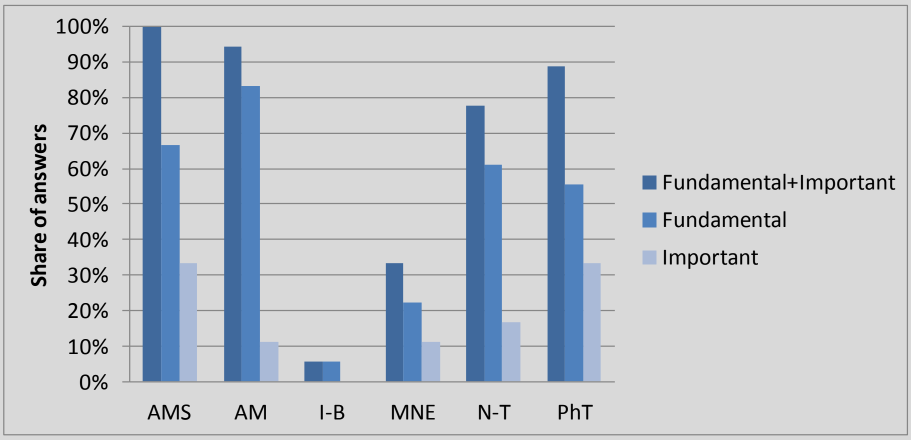
- Identification of alternatives for scarce chemical elements applied in PV technologies (such as Tellurium, Gallium, Indium, Selenium, among others)
- Research and innovation into recycling of solar panels in order to mitigate the risk of loss of precious metals, tackle dependence for these materials and eliminate negative impacts on the environment due to e.g. leaching of toxic metals and lead out of solar panels
- Increase of the recovery rates of critical materials used in solar technologies, encouraging more efficient practices for primary production and by-product separation and recovery of some primary metals (like Zinc, Copper, or Aluminium for extracting Tellurium, Indium or Selenium)
- Demonstration of new conversion principles and basic operation of new device concepts (active layers), toward PV cells performances improvement (efficiency, costs, functionalities, etc.)
- Improvement of nanoparticle synthesis methods for advancement in existing thin film technologies and novel PV cells (active layers) design
- Development of materials, processes and devices concepts for improved processing and higher cells efficiency
- Investigation and improvement of deposition techniques for advancement in existing thin film technologies and novel PV concepts design (toward improvements in cells performances and costs)
- Increase in reliability and cost-effectiveness of thin film technologies' production equipment
- Design of low-cost packaging solutions for flexible PV modules
- Development of processes and equipment for improved throughput, yield, standardization in thin film PV technology

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could trigger higher efficiencies at reduced costs thanks to the optimization of materials consumption (including through the identification of alternatives for scarce chemical elements and the substitution of critical raw materials) and improvements at the manufacturing level.

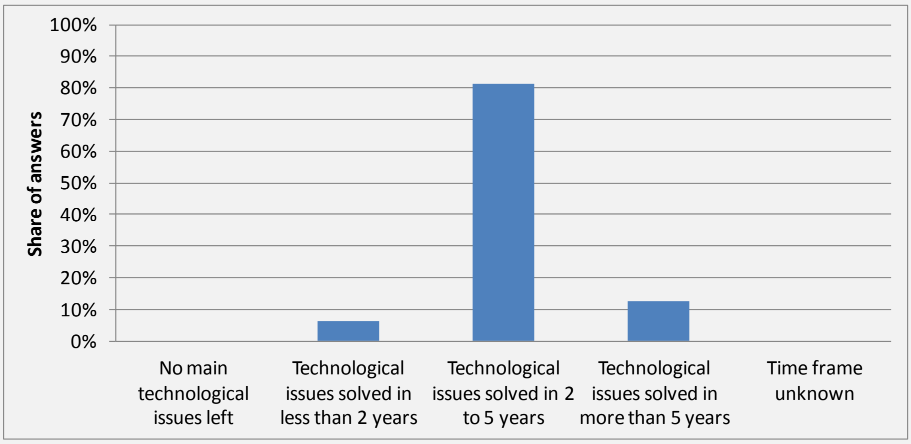
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Photonics (PhT)
- Nanotechnologies (N-T)
- Micro- and Nano-Electronics (MNE)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

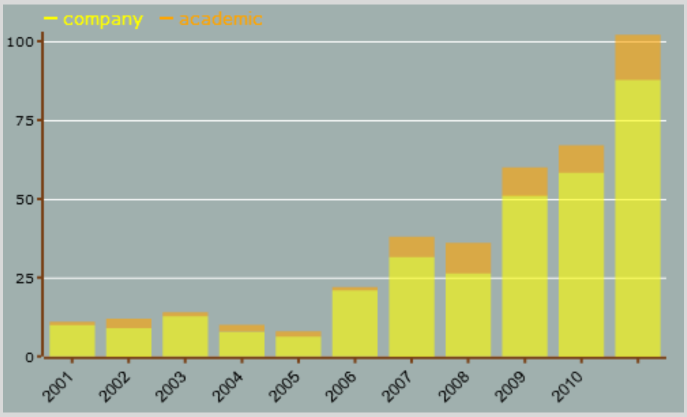
Additional information according to results of assessment:

➢ ***Impact assessment:***

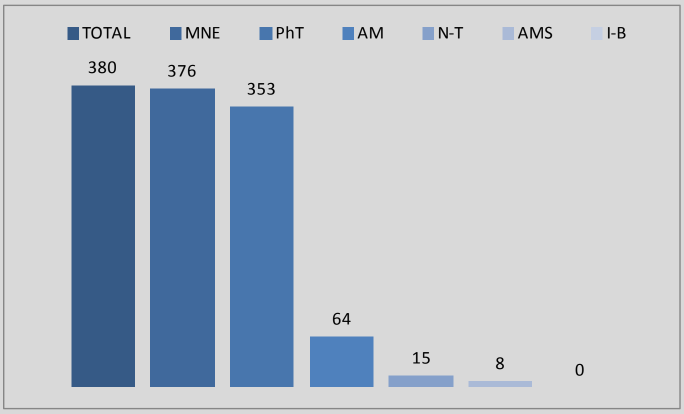
- The EU, whose global share in the solar photovoltaic market in 2011 was 73.6%, is now only 26.5%. Newly installed capacity in the EU was 9.9 GWp in 2013, significantly lower than in 2012, when it had been 16.7 GWp. For various reasons (including the fact that most of the EU Member States have either withdrawn or sharply reduced their incentive system) the European market is now clearly shrinking and no longer leads the world, leaving the main scene to the Asia-Pacific regions (Source: EurObserv'ER, Photovoltaic Barometer, April 2014).
- While however China plays the leading role in the production of rigid solar cells (modules), Europe remains competitive in the production of flexible solar cells (modules). With respect to thin film production, Europe played an important role in 2012 by keeping above 20% share in actual production (Source: EPIA, Global Market Outlook for Photovoltaics 2013-2017, May 2013).
- Flexible solar cells (modules) can have a number of applications; flexible PV installations can be foreseen in relation to building applications (i.e. Building Integrated Photovoltaics, BIPV) but also in relation to any other renewable power application requiring the flexibility feature (e.g. PV car roofs).
- Having this in mind, the flexibility feature enabling improved PV integrability allows value chain cooperations that are the smoother, the closest production and integration of the various components can be, which lets foresee chances for Europe to maintain its share in the domestic market. In this respect, opportunities for growth and jobs creation will not only be linked to production, but also to the integration of the PVs in the final components according to the application, thus having impact at the whole value chain level.

➢ ***Results of patents scenario analysis:***

- 380 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Increasing trend curve (number of patents per year)
- Highest share of industrial applicants:



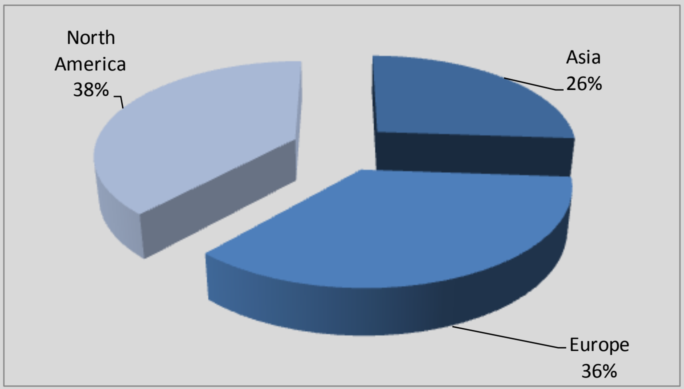
- Patents by KET(s):



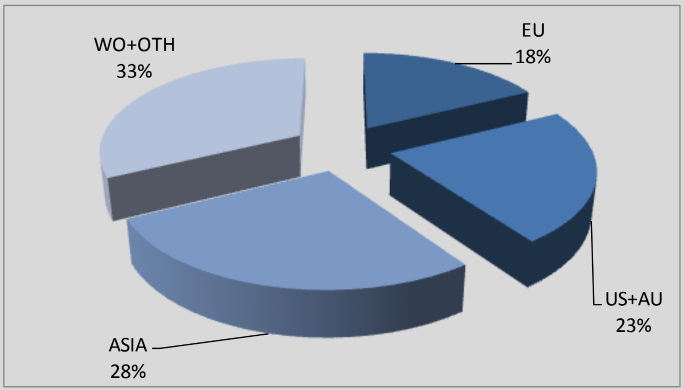
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	64
AM / MNE	63
AM / MNE / N-T	3
AM / MNE / N-T / PhT	2
AM / MNE / PhT	60
AM / N-T	3
AM / N-T / PhT	2
AM / PhT	60
AMS	8
AMS / MNE	8
AMS / MNE / PhT	8
AMS / PhT	8
MNE	376
MNE / N-T	14
MNE / N-T / PhT	11
MNE / PhT	351
N-T	15
N-T / PhT	11
PhT	353

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



E.1.2: Concentrated Photovoltaics (CPV) for large scale electricity production

Scope:

To develop concentrated photovoltaic (CPV) systems utilizing improved materials and components - such as optical systems (i.e. lenses or curved mirrors), tracking systems, etc. - for enhanced reliability and stability, and in which cost is reduced thanks to optimization of materials' consumption as well as improvements at the manufacturing level.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

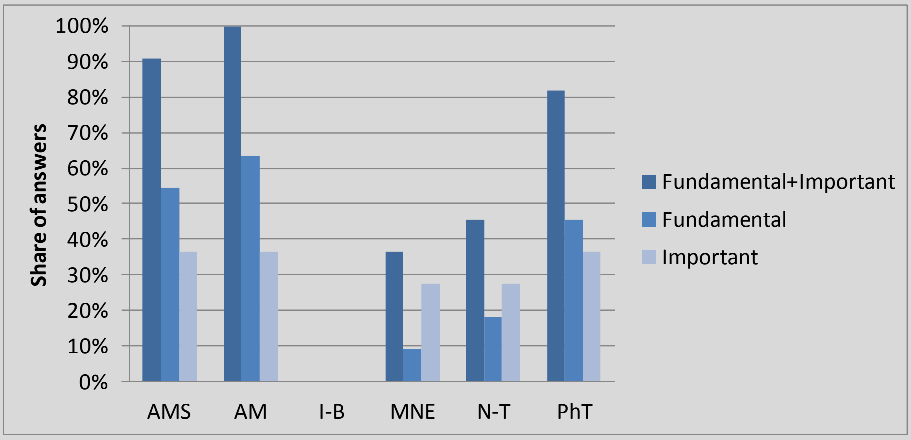
- Identification of alternatives for scarce chemical elements applied in concentrated photovoltaic (CPV) technology
- Development of materials and components for concentrator photovoltaic systems (optical systems, module assembly, tracking) to improve reliability, stability, cost-effectiveness, stiffness, material consumption, etc.
- Development of improved devices and production technologies for high efficiency concentrated photovoltaics (CPV) (Si-cells, multijunction III-V-compound cells)
- Optimization and scaling up of manufacturing as well as installation procedures (system integration, automated production, installing, testing and cost evaluation)

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the improvement of materials and components - e.g. optical systems, tracking systems, etc. - for enhanced reliability and stability. Moreover they could contribute to reduce costs thanks to optimization of material consumption as well as improvements at the manufacturing level.

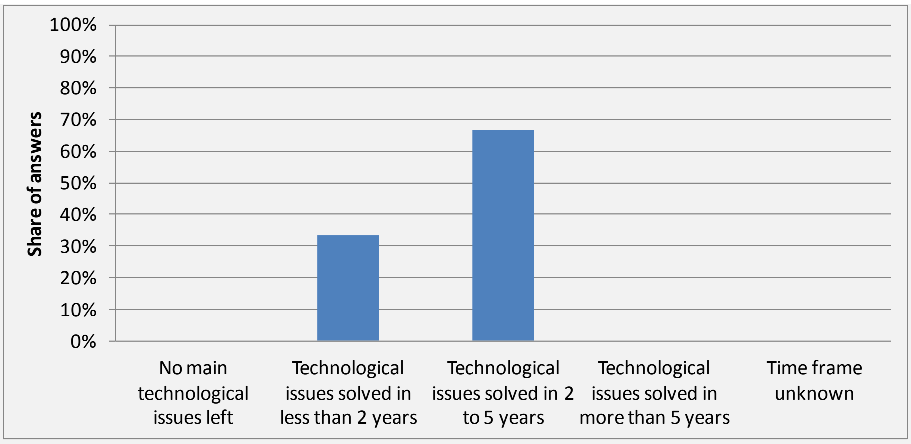
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Photonics (PhT)
- Nanotechnologies (N-T)
- Micro- and Nano-Electronics (MNE)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:

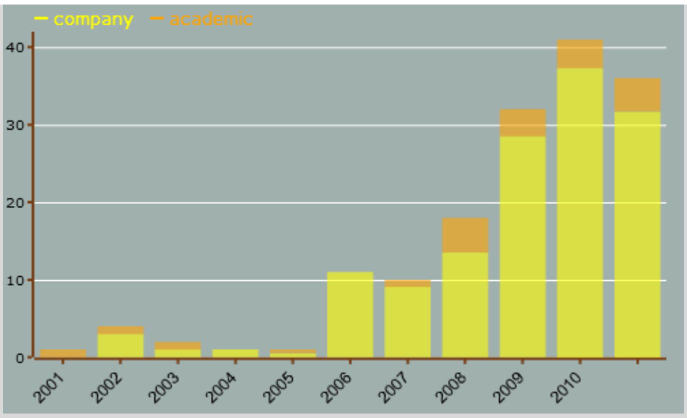


Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

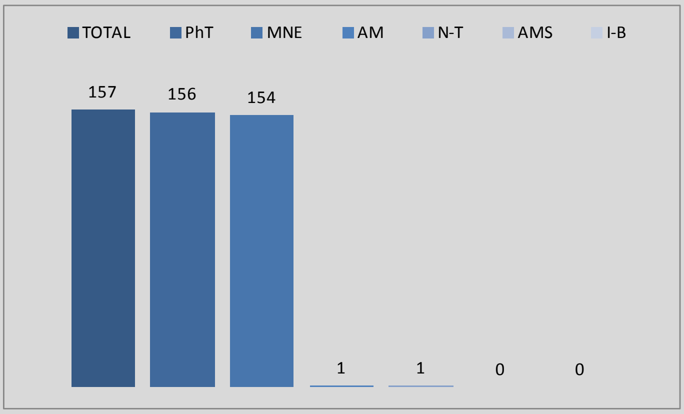
Additional information according to results of assessment:

- ***Impact assessment:***
  - Concentrated photovoltaics (CPV) is an emerging market that will start to represent a sustainable market niche in the coming years, promising to provide cost-effective power generation at high levels of efficiency. Potential markets for CPV in Europe are represented by the Mediterranean countries.
  - The cumulative installed capacity for CPV systems was around 23 MW in 2010. Spain dominated the global CPV market with 70% of the global concentrated photovoltaics (CPV) installed base, amounting to around 16 MW.
  - As the technology is still in a development stage, most of the CPV projects are today in the pilot or prototype stage, with large-scale concentrated photovoltaics (CPV) global installations already planned.
  - The emerging CPV market offers many investment opportunities across the value chain. With the planned large-scale CPV global installations, the market will create an increase in demand for concentrated photovoltaic (CPV) systems and their respective components, such as trackers, inverters, multijunction cells, Si-cells, and optics. As a result, the companies that manufacture these components are planning investments to increase their respective production capacities and thus diversify into upcoming concentrated photovoltaics (CPV) market regions such as Italy, China, Australia, and India.
  - The governments of these countries have initiated investment support programmes for the concentrated photovoltaics (CPV) market players in the form of Feed-In Tariffs (FIT) schemes, loan guarantees, grants, and funding through their respective solar initiative programmes.
  - Sources: www.renewableenergyworld.com; EPIA, Global Market Outlook for Photovoltaics 2013-2017, May 2013.

- ***Results of patents scenario analysis:***
  - 157 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Increasing trend curve (number of patents per year)
  - Highest share of industrial applicants:



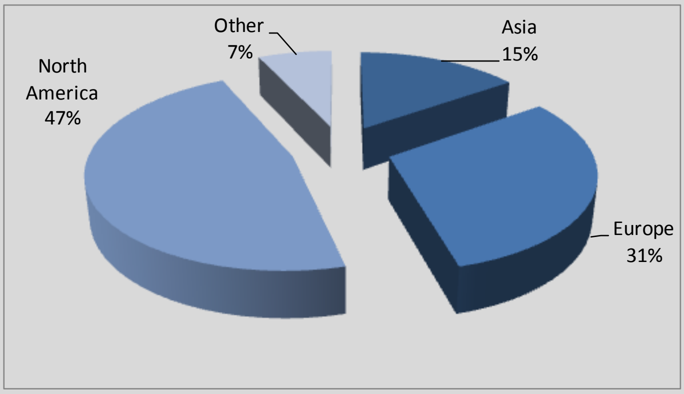
- Patents by KET(s):



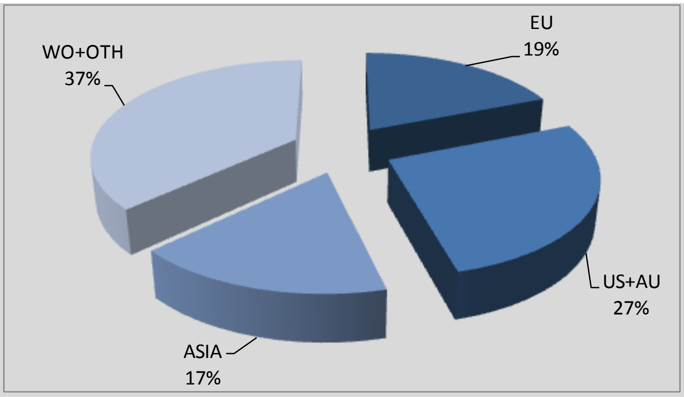
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	1
AM / PhT	1
MNE	154
MNE / N-T	1
MNE / N-T / PhT	1
MNE / PhT	153
N-T	1
N-T / PhT	1
PhT	156

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



E.1.3: Concentrated Solar Power (CSP) collectors for large scale electricity production

Scope:

To develop advanced concentrating solar power (CSP) collectors (whether for parabolic trough, power tower, or dish systems) whose components are improved to operate at the high temperatures needed to significantly increase conversion efficiency and whose cost is reduced by improved collector designs and advanced optical materials that have lower cost, higher performance, and better durability.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Identification of alternatives for scarce chemical elements applied in concentrating solar power (CSP) technologies
- Development and testing of the next generation of concentrating solar power (CSP) collectors (whether for parabolic trough, power tower, or dish systems) through improved reflectors development
- Reducing the cost of concentrating solar power (CSP) systems by improved collector designs and advanced optical materials that have lower cost, higher performance, and improved durability
- Development of advanced concentrating solar power (CSP) system components that operate at the high temperatures needed to significantly increase conversion efficiency
- Development of concentrating collectors using lightweight, stable, highly performing and dirt-proof or self-cleaning reflectors which are resistant to degradation due to mechanical cleaning and weathering
- Development and validation of advanced thermal receiver technologies
- Characterization and improvement of selective coatings for both line-focus and power tower receivers as well as advanced cleaning methods that ensure high performance and durability of concentrating solar power (CSP) systems

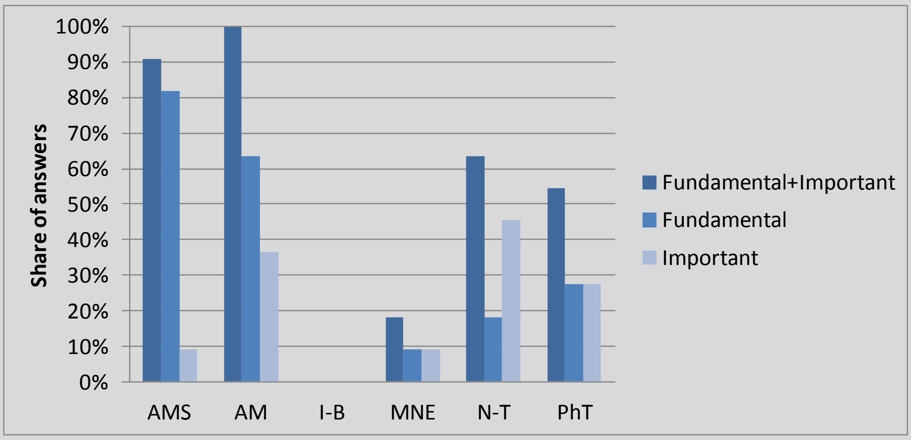
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the improvement of components of concentrating solar power (CSP) collectors allowing them to operate at the high temperatures needed to significantly increase conversion efficiency. Moreover, the integration of KETs could contribute to achieve reduced costs by improved collector design combined with advanced optical materials with lower cost, higher performance and better durability.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

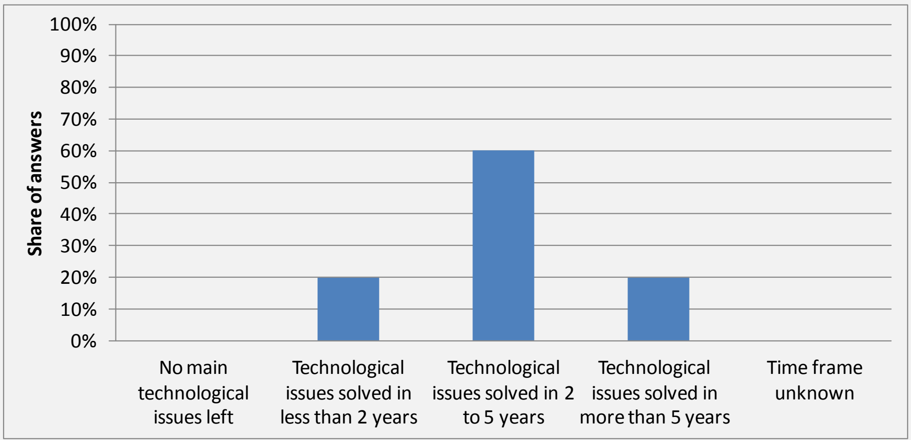
- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)

- Photonics (PhT)
- Nanotechnologies (N-T)
- Micro- and Nano-Electronics (MNE) to a lesser extent



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

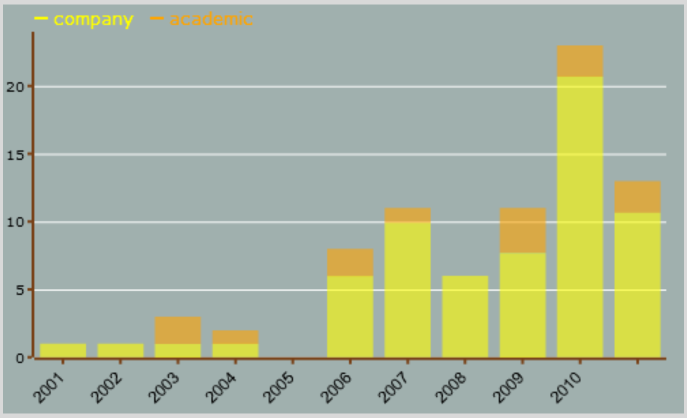
- Europe's concentrating solar power (CSP) plants had a total installed capacity of 1957.7 MWe at end-2012. After an excellent 2012, when 17 new plants totalling 802.5 MW of capacity were installed in Europe, the number of projects under construction is however significantly smaller today, as a result of the moratorium on renewable energy power plants introduced by Spain, coupled with its subsidy cut for new projects and 7% tax on energy generation, and pressure from the photovoltaics (PVs) sector.
- As a result of these events, analysts such as the International Energy Agency (IEA) had to downgrade their initial very promising sector growth forecasts, currently predicting 1.5 GW of global annual growth to 2017, for a global total of 8 GW in 2015 and 11 GW in 2017 – as opposed to their previous (2010) forecast of 148 GW in 2020. Despite the downscaled forecasts, however, the sector is growing, though lower than initially forecast.
- In terms of production, several European manufacturers had to revise their original business plans, foreseeing to consolidate their technological skills in the European domestic market, because of the above, favouring instead an earlier entry into the global market. Several are the European players enjoying good business today from the

international concentrating solar power (CSP) market growth.

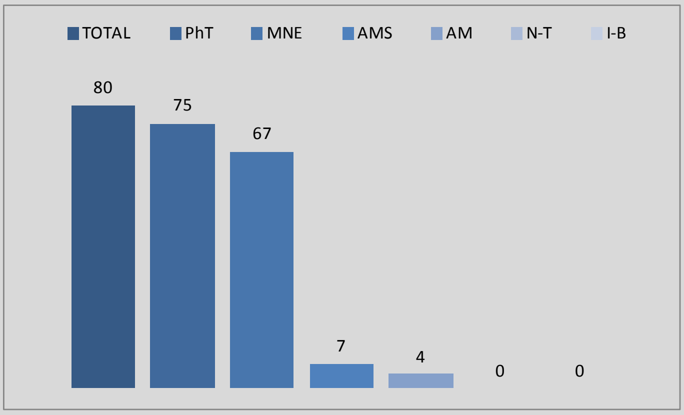
- Source: EurObserv'ER's, Solar Thermal and Concentrated Solar Power Barometer, May 2013.

➢ ***Results of patents scenario analysis:***

- 80 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Increasing trend curve (number of patents per year) with downturn in 2011
- Highest share of industrial applicants:



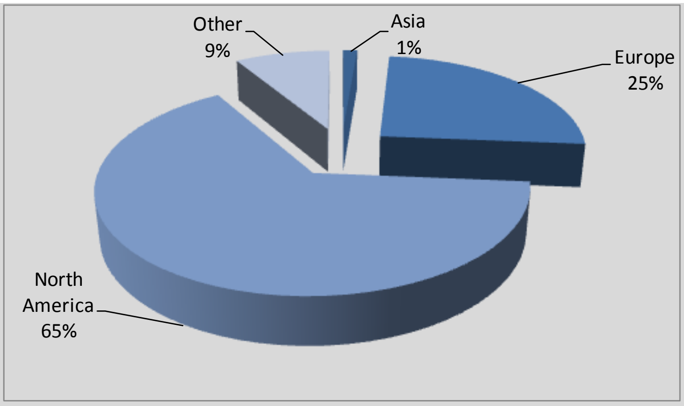
- Patents by KET(s):



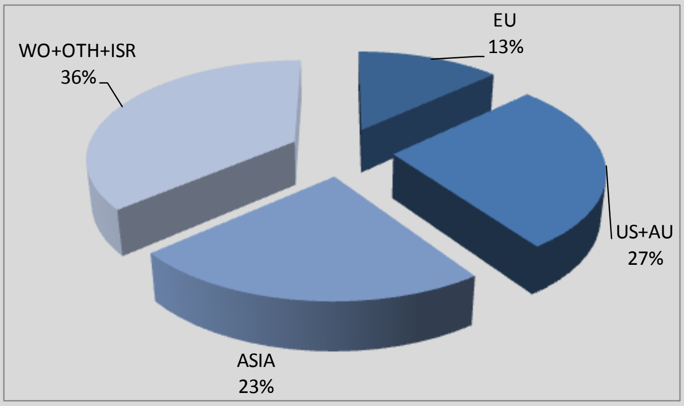
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	4
AM / MNE	3
AM / MNE / PhT	3
AM / PhT	3
AMS	7
AMS / MNE	2
AMS / MNE / PhT	2
AMS / PhT	3
MNE	67
MNE / PhT	67
PhT	75

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



E.1.4: Solar thermal collector systems with improved efficiency and increased integrability

Scope:

To develop solar thermal collector systems for low temperature application whose efficiency is improved thanks to higher performing new surfaces, coatings and materials, and whose integrability is enhanced thanks to new design concepts, as well as solar thermal collector systems for medium and high temperature (100–400°C) application benefitting of high temperature-resistant materials.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of higher performing new surfaces, coatings and materials for solar thermal collectors (e.g. transparent cover materials with anti-reflection coatings for high optical transmission; switchable coatings that reduce the stagnation temperatures; highly reflective, light materials for reflectors; new absorber materials with low-emission coatings and optimized heat transfer; temperature-resistant and switchable super insulating materials and alternative medium and high temperature materials like polymers or rubbers for collector parts)
- Development and demonstration of medium and high temperature (100-400°C) collectors for industrial applications through the development of new, high temperature-resistant materials, as well as new collector designs
- Adaptation and improvement of collector technology (flat-plate and evacuated tube) which is currently used in low-temperature applications (e.g. either through better insulation or noble gas atmospheres)
- Optimization of large-scale solar collector arrays for uniform flow distribution and low pumping power
- Development of advanced solutions for the integration of large solar thermal systems into smart thermal/electrical grids
- Development of higher performing controllers to optimally manage heat flows

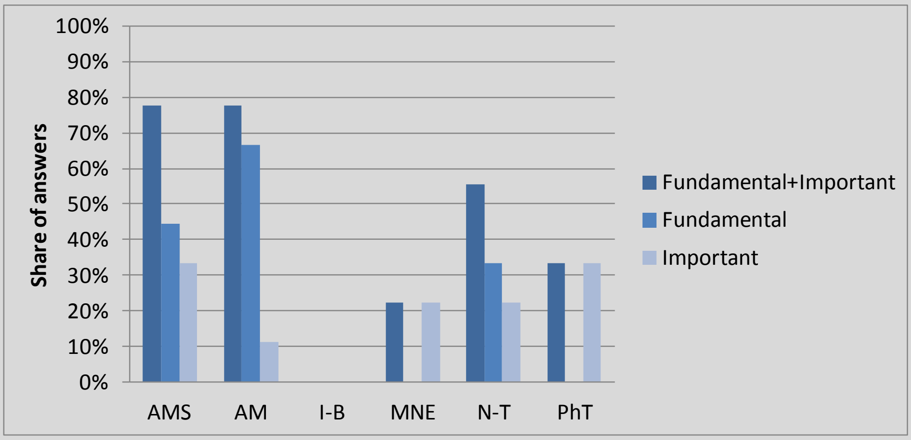
- Development of new design concepts for the integration of solar thermal collectors area and storage volume into buildings

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of solar thermal collector systems for low temperature application whose efficiency is improved thanks to higher performing new surfaces, coatings and materials, and whose integrability is enhanced thanks to new design concepts, as well as solar thermal collector systems for medium and high temperature (100–400°C) application benefitting of high temperature-resistant materials as combined with advanced manufacturing technologies providing for lower cost production.

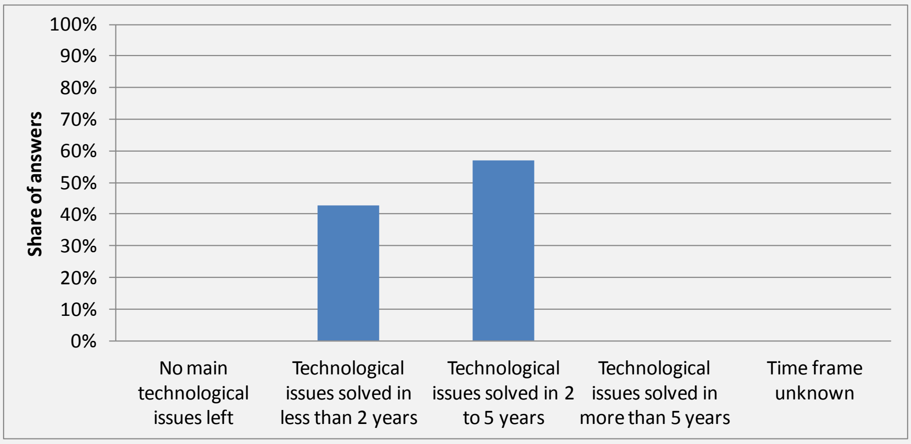
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also shorter periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

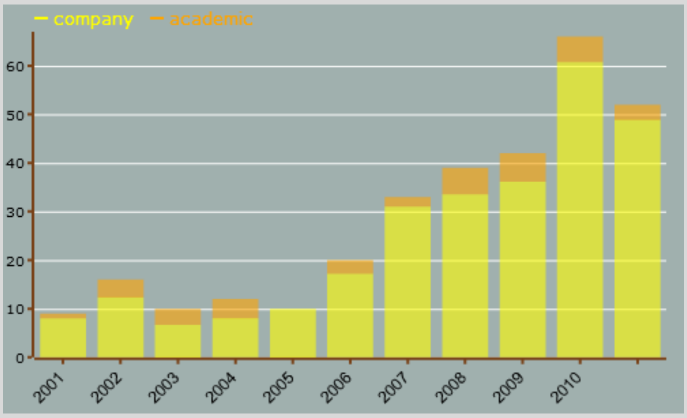
Additional information according to results of assessment:

➢ ***Impact assessment:***

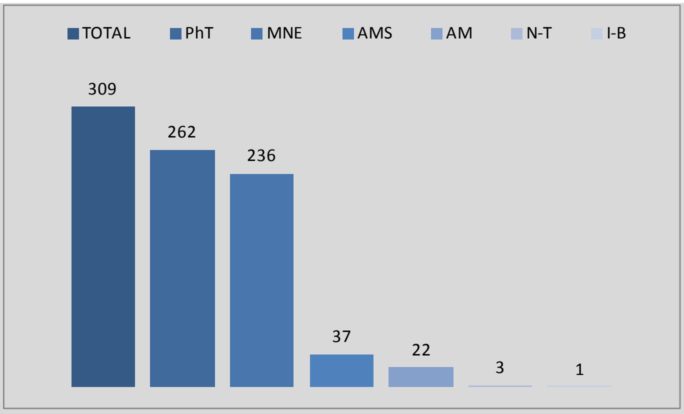
- The European solar thermal market, which experienced a peak year in 2008 after a continuous uptrend in its growth rate over the past ten years, contracted for the fourth consecutive year in 2012, suffering from the constraints imposed by the financial and economic crises, which resulted in a suffering construction sector and reduction of public support schemes for solar thermal.
- The 2.41 GWth sold in 2012 are well above the 2007 sales (2 GWth) but are a far from the 3.36 GWth reached in 2008. However, the steep decline of 2009 and 2010 has flattened out in 2011 and 2012.
- In spite of the decrease recorded over the last four years, the annual market size has doubled, over the past decade at an average annual growth rate of 10%. Over the last five years (2007-2012), an absolute growth can be observed in the annual sales of 20% and an average annual growth rate of 3.6%.
- While the market in Germany, which is the only country to install more than 1 million m^2 per year of solar thermal systems, and in the high-potential area of Spain, Italy and Portugal as well as in Austria and the UK, has contracted, the French market held steady thanks to development of the multi-occupancy sector, and Greece, Poland, Hungary and Denmark are coming up due to an increase in gas and heating oil prices. Markets in the Benelux countries are also emerging, though not quickly or strongly enough to reverse Europe’s overall downward trend.
- Residential applications still represent the bulk of the solar thermal market. Nevertheless, large installations are increasing apace. Large size systems above 35 kWth (50 m^2) for commercial heating and cooling applications have shown a positive development, while for very large systems (above 350 kWth / 500 m^2) the market has been moving rapidly.
- Sources: ESTIF, Solar Thermal Markets in Europe - Trends and Market Statistics 2012, June 2013; EurObserv’ER’s, Solar Thermal and Concentrated Solar Power Barometer, May 2013.

➢ ***Results of patents scenario analysis:***

- 309 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Increasing trend curve (number of patents per year) with slight downturn in 2011
- Highest share of industrial applicants:



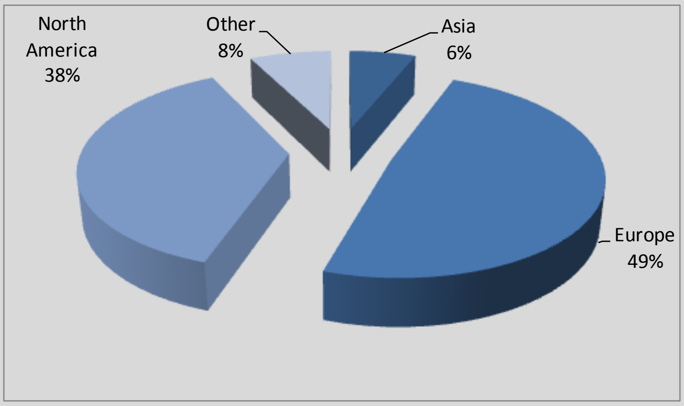
- Patents by KET(s):



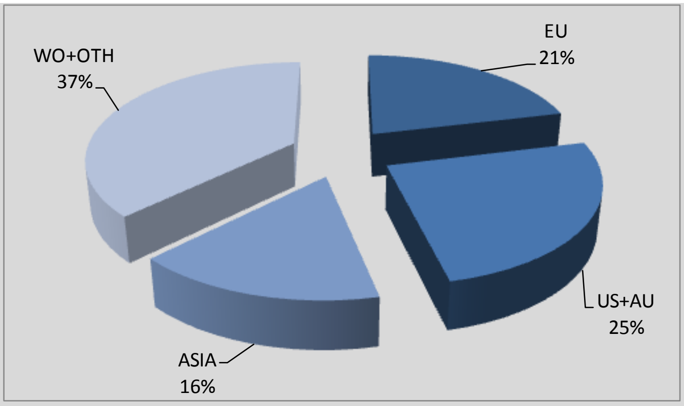
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	22
AM / MNE	7
AM / MNE / PhT	7
AM / PhT	12
AMS	37
AMS / MNE	9
AMS / MNE / PhT	9
AMS / PhT	10
IBT	1
IBT / PhT	1
MNE	236
MNE / N-T	1
MNE / N-T / PhT	1
MNE / PhT	228
N-T	3
N-T / PhT	1
PhT	262

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



E.1.5: Highly cost-efficient and reliable large wind turbines

Scope:

To develop large wind turbines based on lightweight materials and designs for improved flow dynamics, structural integrity, and recyclability, as well as including failure identification, condition monitoring and fault prediction capabilities, along with large and more flexible rotors with improved performance.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Investigation of wind turbine as a flow device: fluid dynamics methods (CFD) and aero-elastic models, experimentals for large and more flexible rotors with improved performance
- Investigation of wind turbine as mechanical structure/materials: materials and design for improved structural integrity and recycling
- Investigation of wind turbine as an electricity plant: light-weight, low-speed and low maintenance power electronics, power converters and new generators for improved system performances
- Development of control systems in wind turbines and wind farms to optimize the balance between performance, loading and lifetime: advanced control strategies and devices, sensors and condition monitoring systems
- Development of a full systematic design methodology (integrated design) and investigation of innovative solutions for wind turbines and sub-system concepts (e.g. for rotors) to increase system efficiency (reduction in the lifetime cost of energy)
- Development of automated manufacturing solutions for large wind turbines enabling cost-efficient manufacture
- Development and adoption of wind turbine operation and maintenance (O&M) strategies: failure identification, condition monitoring and fault prediction capabilities
- Development of models, simulation tools, and experimental campaigns; exploitation of new installation contexts for small size wind turbine with high efficiencies, low environmental impacts and reduced costs for distributed energy production
- Optimization of wind power plant capabilities: tools and methods for operation and interoperability for adapting to electricity grid code requirements (e.g. power electronics, control strategies, monitoring, prediction tools, automation, etc.)
- Adoption of grid planning and operation strategies for improved transmission capacity: grid extension and reinforcement, improved EU wide operation and interoperability, models and simulation of the EU interconnected power system, new power and monitoring systems, analysis of offshore grid options
- Adoption of energy and power management systems for improved flexibility on both generation and demand-side: management tools for Transmission System Operators (TSOs) and market parties; options for ancillary services (i.e. transmission of electric power from seller to purchaser) and power balancing in higher wind penetrations; energy storage and interaction with other renewables
- Siting of wind farms in sites with poor accessibility: improved and reliable design criteria of turbine components (mast, blade and nacelle) for the installation of large scale wind turbines with reduced costs

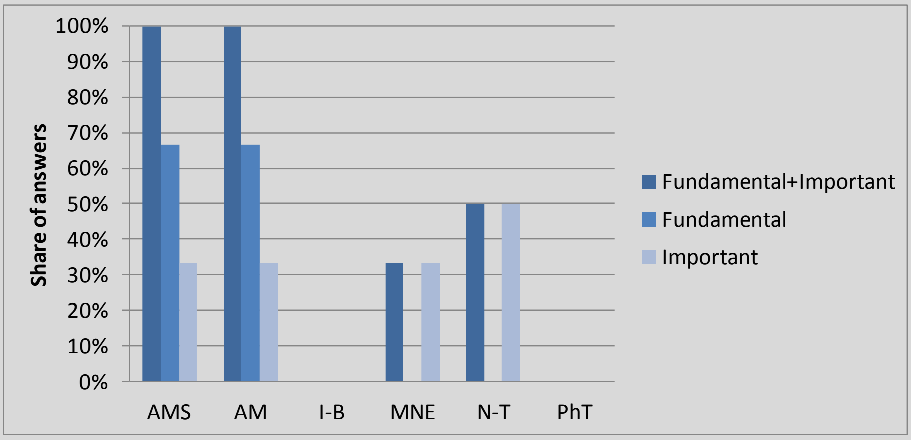
- Investigation of models and systems to optimize integration of wind energy in Smart Grids, including regulation strategies, compensation systems and storage

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of high-strength, lightweighter large wind turbines, including thanks to the use of high-strength/low-weight fibre-reinforced polymer composite materials or of advanced materials and new material architectures with added functionalities, enabling designs for improved flow dynamics, enhanced structural integrity, and recyclability, along with large and more flexible rotors with improved performance. The integration of KETs could moreover contribute to integrating failure identification, condition monitoring and fault prediction capabilities as well as to the development of automated manufacturing methods for large and very large structures.

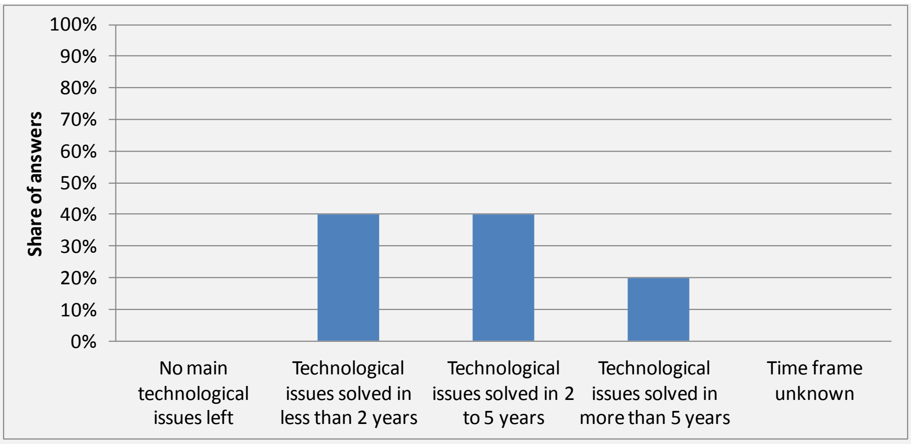
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)



Timing for implementation:

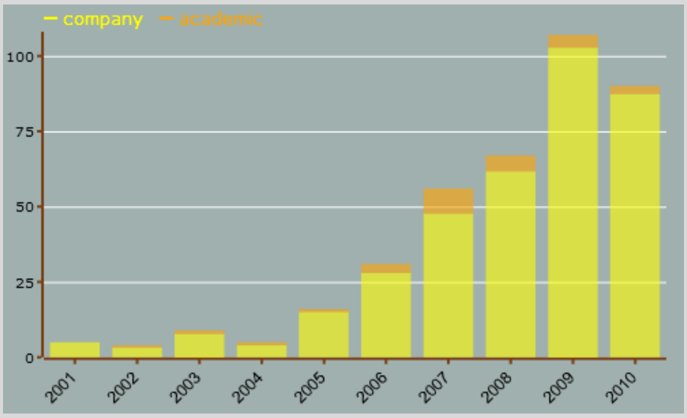
According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, or shorter (less than 2 years), yet a pool of KETs experts indicates also greater periods being necessary. According to the interviews carried out throughout the study and as confirmed during some of the workshops that took place during the period when the study was active, it emerged that while the main technological issues holding back the wind turbines as equipment can be solved in a short time frame, manufacturing issues would instead require more time:



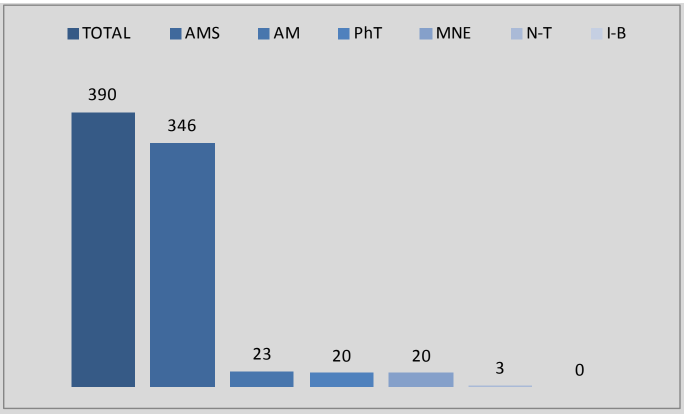
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration to solve the main technological issues holding back the wind turbine as equipment, while the provision of support in the medium term would be more appropriate to solve the main technological issues holding back the automated manufacture of large wind turbines.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Global wind energy capacity experienced an increase by 12.4% in 2013 to 318.6 GW, while for the first time the global market decreased (to 35.6 GW dropping of 10 GW). The worldwide market contraction is to be attributed to the collapse of the US market. The European market also contracted because of investors' lack of confidence in the new renewable electricity promotion policies by a number of countries. If the US and Europe are taken out of the equation, the global market continued to grow, driven by the Chinese and Canadian wind power sectors.
  - Despite the European market slowed down in 2013, it managed to keep above the 11 GW threshold, which represents the sector's second best performance for annual installations.
  - On the crest of the wave, there is clearly the offshore market, with 1.5 MW out of every 10 MW of capacity installed offshore in 2013.
  - Source: EurObserv'ER's, Wind Energy Barometer, February 2014.
- ***Results of patents scenario analysis:***
  - 390 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Increasing trend curve (number of patents per year) with very slight downturn in 2011
  - Highest share of industrial applicants:



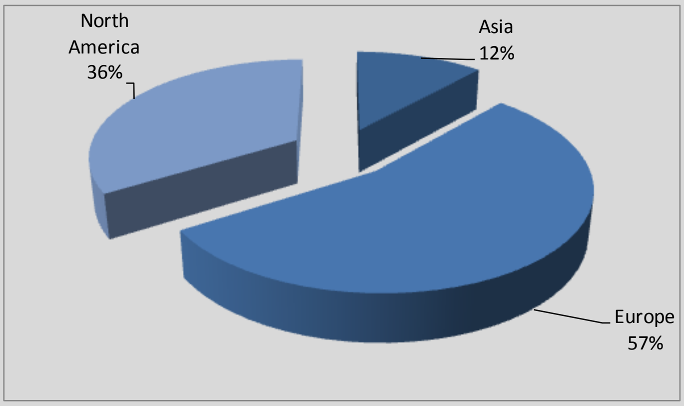
  - Patents by KET(s):



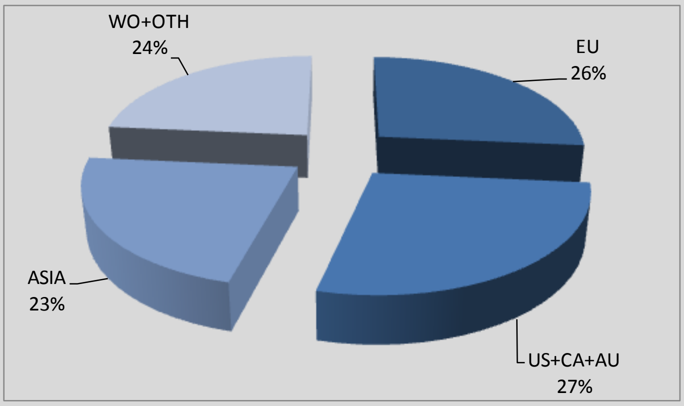
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	23
AM / N-T	1
AMS	346
AMS / AM	3
AMS / MNE	4
AMS / PhT	2
MNE	20
MNE / PhT	12
N-T	3
PhT	20

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



E.1.6: Offshore power generation systems' deployment and operation

Scope:

To develop solutions for offshore power generation systems' (such as wind farms, tidal power plants, wave power plants) deployment and operation, comprising solutions for substructure manufacturing and maintenance, large scale systems assembly, installation, and decommissioning.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

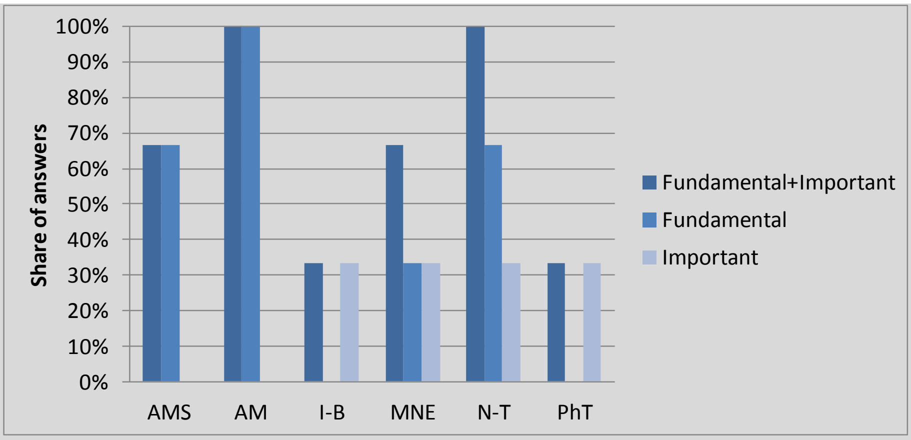
- Improvement of offshore substructures design along with improvement of materials and manufacturing methods (e.g. welding, casting, concreting) including through automation and robotics
- Development of improved and reliable methods, facilities, equipment for the assembly, installation, and decommissioning of large-scale offshore wind farms
- Optimization of electrical infrastructures (cabling and integration of offshore wind into the grid), including by design tools and life-cycle approaches in order to reduce costs, increase reliability and lifetime of facilities
- Optimization of offshore turbines design (including through modelling and simulation) to increase reliability and reduce costs as well as ease turbines manufacturing thus increasing manufacturing capacity to address EU market demand
- Further development of offshore operation and maintenance (O&M) strategies, such as advanced condition and risk-based maintenance techniques, management systems (control, monitoring), improved systems and vessels for operation and access, systems to reduce human intervention
- Development of models and solutions for platforms, anchorages and wind turbines to increase reliability and reduce costs in deep sea installations

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced solutions for cost-effective substructure manufacturing and maintenance and for large scale system assembly, installation and decommissioning, thanks to the improvement of materials and manufacturing/assembly methods, including through automation and robotics. It could moreover contribute to the further development of offshore operation and maintenance (O&M) strategies, such as advanced condition and risk-based maintenance techniques, management systems (control, monitoring), improved systems for operation and access, systems to reduce human intervention, etc.

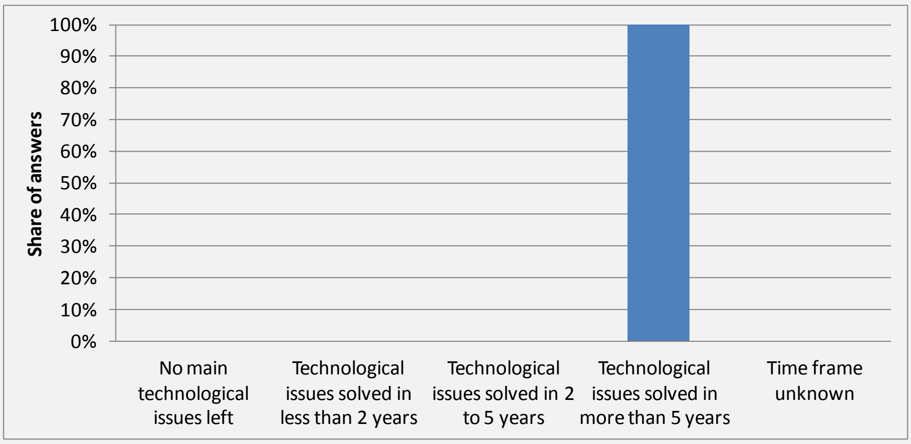
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Materials (AM)
- Advanced Manufacturing Systems (AMS)
- Nanotechnologies (N-T)
- Micro- and Nano-Electronics (MNE)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Strictly connected to the offshore wind energy market, there is an urgent need to cut costs associated to wind turbines commissioning. Today costs for commissioning wind farms amount to around 0.16 Euro/kWh. Both constructors and developers are looking however to cut those costs to less than 0.10 Euro/kWh by 2020. One of the conventional solutions to achieve this objective is to increase the unit capacity of the wind turbines so that installation costs per kWh would be cut. Accordingly, the size of wind turbines for offshore wind farms has increased from 450 kW (which was the size of the first offshore turbine installed in 1991) to 8 MW (which is currently the size of the largest offshore turbine being tested). This calls not only for improved manufacturing processes but also for innovative methods and processes for the deployment of the wind turbines among the solutions that can be exploited for the purpose of reducing costs.
  - Within this framework, contracts signed by wind turbines manufacturers with players such as contractors and developers that can provide for installation and maintenance with the idea of offering developers a one-stop shop for all the procedures required are increasing.
  - Within this framework, opportunities for growth and jobs creation will not only be linked to wind turbines manufacture, but also to their deployment, operation and maintenance, thus having an impact at the whole value chain level.
  - Source: EurObserv'ER's, Wind Energy Barometer, February 2014.
- ***Results of patents scenario analysis:***

- No exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- No significant patent-related figures can be reported in this field

Sub-domain: Advanced non-renewable energy solutions

Demand-side requirements (stemming from Societal Challenges) addressed:

- Contribute to tackle the "secure, clean and efficient energy" challenge
- Contribute to the reduction of greenhouse gas emissions

E.2.1: Next generation thermal energy storage

Scope:

To develop next generation thermal energy storage solutions and systems for the storage of heat and cold towards reducing costs of actual systems and improving their ability to effectively and efficiently shift heat demand over days, weeks or seasons.

Demand-side requirements (stemming from market needs) addressed:

- Increase use of effective energy storage solutions into existing energy distribution networks in order to resolve the mismatch issue between energy generation and demand

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

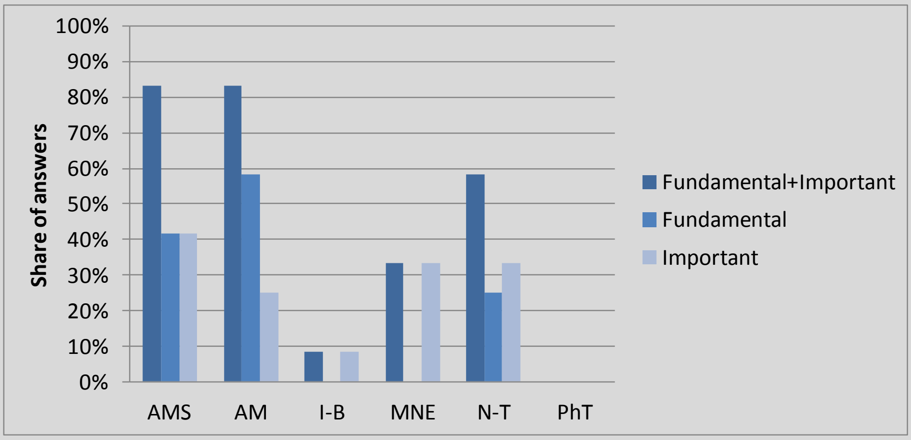
- Increase of the energy density of storage materials relevant for all different heat storage types
- Development of latent heat storage solutions based on solid-to-liquid as well as solid-to-solid phase change
- Development of new technologies and solutions for the storage of thermo-chemical energy
- Further development and improvement of fluids that combine the heat transfer function with thermal energy storage
- Development of novel and compact heat exchangers using improved concepts, geometries and perhaps new materials, like polymers, in order to improve the charging and discharging process by increased heat transfer power and therefore reduce charging and discharging time and disturbances of the temperature stratification
- Reduction of thermal losses and therefore increase in the efficiency of the heat storage system
- Improvement of storage insulation by the development of long lasting, low-cost and easy to apply high performance insulation materials or solutions, e.g. vacuum insulation
- Improvement of charging and discharging as well as stratification devices, i.e. intelligent state-of-charge determination systems fully integrated in the storage
- Reduction of the costs and thermal conduction of containment materials by replacing metal with polymer casings, with or without fibre reinforcement

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of the next generation thermal energy storage solutions, thanks to increasing the energy density of storage materials, which is relevant for all different heat storage types, along with improving charging and discharging as well as stratification devices, e.g. by intelligent state-of-charge determination systems fully integrated in the storage. To this end, the integration of KETs could contribute to the development of latent heat storage solutions based on solid-to-liquid as well as solid-to-solid phase change, or of new technologies and solutions for the storage of thermo-chemical energy, or the further development and improvement of fluids that combine the heat transfer function with thermal energy storage. Moreover it could contribute to the development of novel and compact heat exchangers using improved concepts, geometries and new materials.

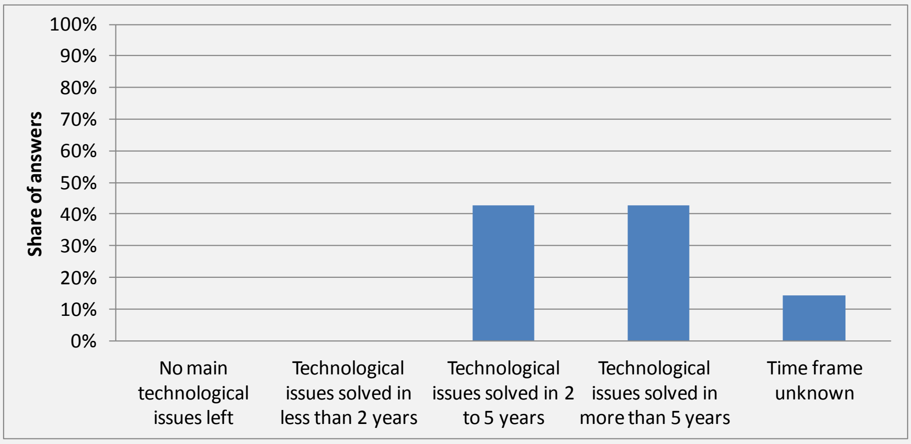
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years or longer (more than 5 years):



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

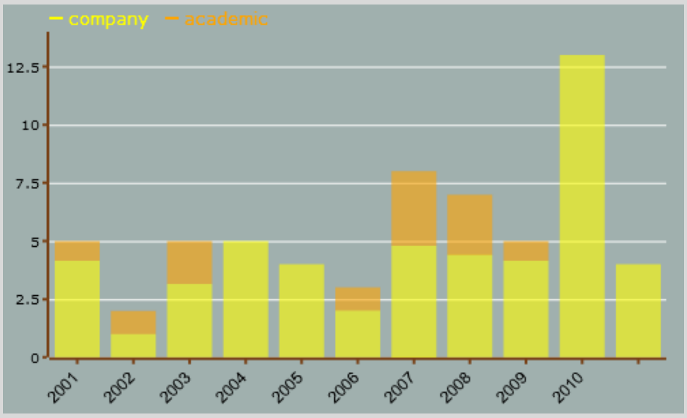
- ***Impact assessment:***
  - Thermal energy storage will be key, along with other energy storage systems and methods, in supporting the transition towards a secure, competitive and decarbonised energy system in Europe. The increasing intermittency at the generation side due to an increased integration of renewable as well as distributed energy generation in the energy system requires technologies and procedures for balancing energy demand and

supply on a daily, weekly and even seasonal basis, thus allowing displacement between consumption and generation to take place in both time and space. Within this framework, thermal energy storage will become an integral part of future's energy systems and related value chains.

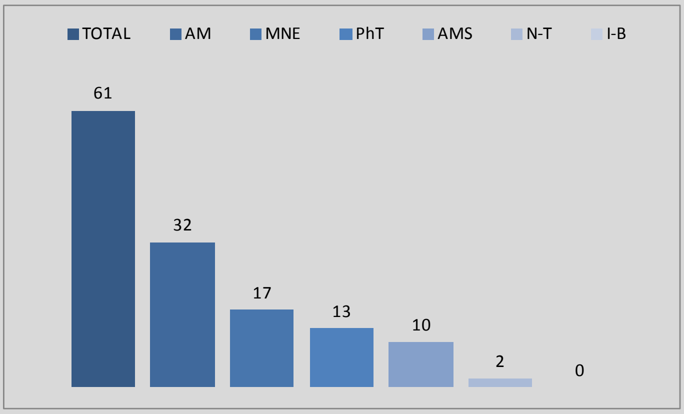
- Thermal energy storage systems are used particularly in buildings and industrial processes. Furthermore, the conversion and storage of variable renewable energy in the form of thermal energy can also help increase the share of renewables in the energy mix. Thermal energy storage is for instance becoming particularly important for electricity storage in combination with concentrating solar power (CSP) plants where solar heat can be stored for electricity production when sunlight is not available.
- In Europe, it has been estimated that around 1.4 million GWh per year could be saved—and 400 million tonnes of CO2 emissions avoided—in the building and industrial sectors by more extensive use of heat and cold storage.
- Today, thermal energy storage technologies still face some barriers to market entry, cost being in most cases a major issue. Though, if such market barriers will be overcome, potential market perspectives for thermal energy storage technologies will be high, their market being very strictly related to the energy efficiency solutions' market.
- Sources: IEA-ETSAP and IRENA©, Thermal Energy Storage - Technology Brief, January 2013; Joint EASE/EERA recommendations for a European Energy Storage Technology Development Roadmap towards 2030, March 2013.

➢ ***Results of patents scenario analysis:***

- 61 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Stable trend curve (number of patents per year)
- Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants, most probably standing for new technologies having been patented in the corresponding periods:



- Patents by KET(s):

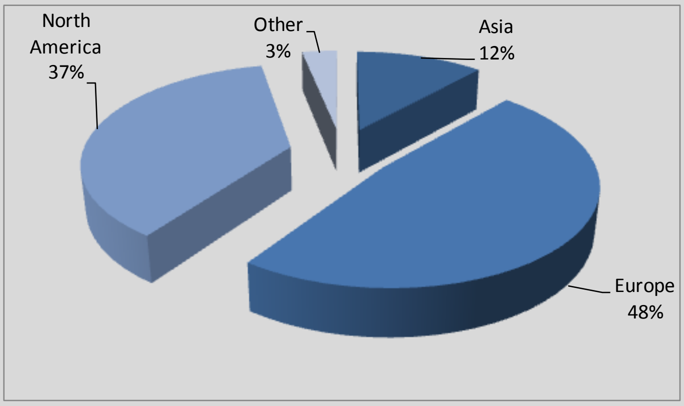


- Patents by KET(s) and relevant combinations of KETs:

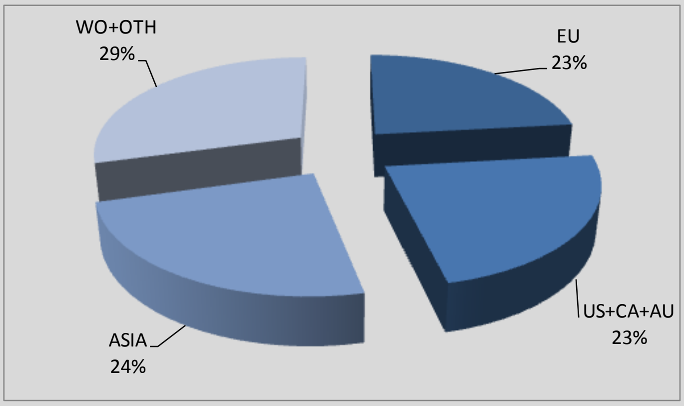
KET(s)	*Number of patents*
AM	32
AM / N-T	2

AMS	10
MNE	17
MNE / PhT	11
N-T	2
PhT	13

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



E.2.2: Coal-fired power plants based on clean coal technologies

Scope:

To develop coal-fired power plants based on clean coal technologies towards coal-based near-zero emission power production.

Demand-side requirements (stemming from market needs) addressed:

- Reduce greenhouse gas emissions associated with power plants
- Cope with regulation related to greenhouse gas emissions
- Keep costs low under the EU's Emissions Trading Scheme (ETS)
- Meet public acceptance

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

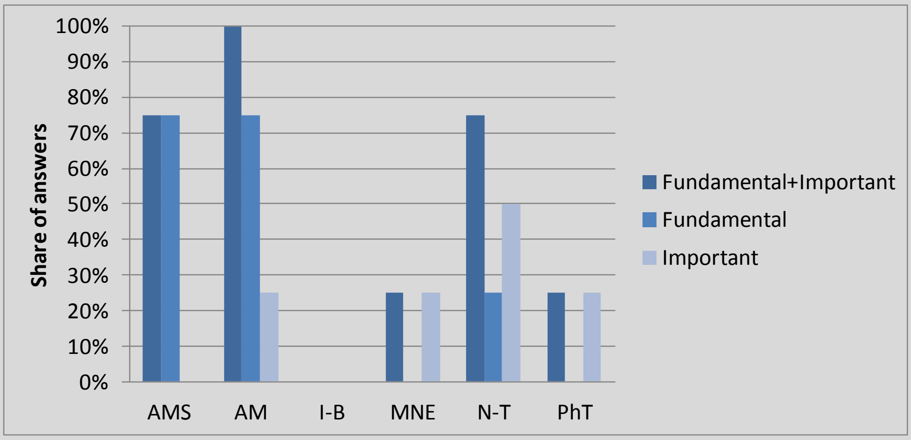
- Development of the new generation of coal-fired power plants with higher efficiencies and thus lower emissions
- Improvements and up-scaling of gasifiers, hydrogen-gas turbines, carbon monoxide-shift and CO2 capture for pre-combustion technology
- Development of supercritical cycles and equipment
- Development of high temperature materials (superalloys, ceramics, etc.) and surface treatments for high temperature resistance

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of the new generation of coal-fired power plants with higher efficiencies and thus lower emissions, thanks to improvements and up-scaling of gasifiers, hydrogen-gas turbines, carbon monoxide-shift and CO_2 capture for pre-combustion technology, the development of supercritical cycles and equipment, the development of high temperature materials (superalloys, ceramics, etc.) and surface treatments for high temperature resistance, etc.

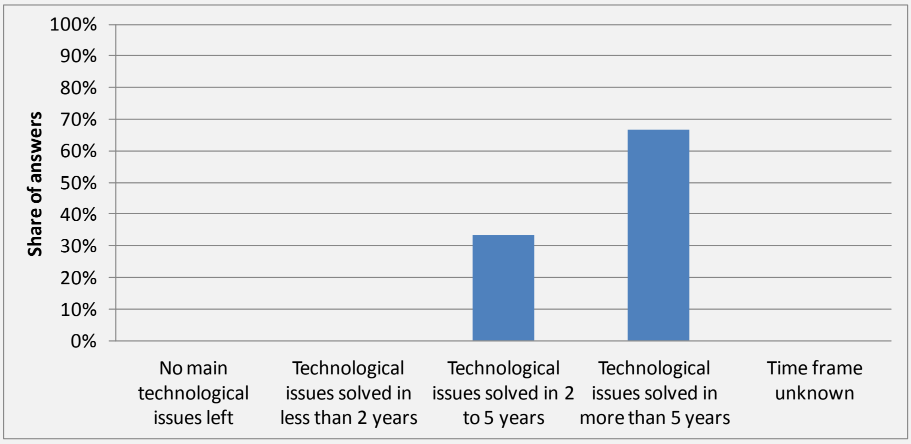
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:

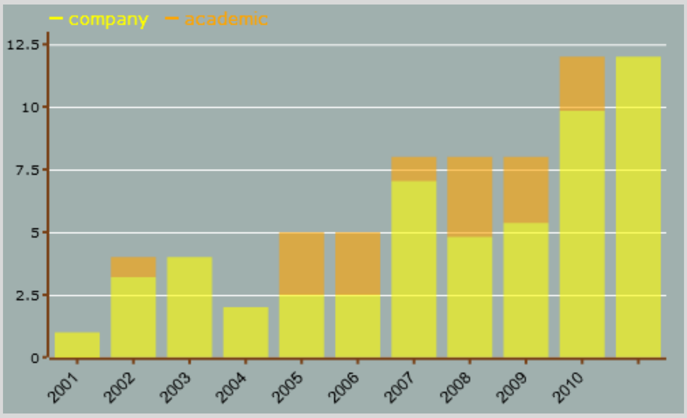


Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

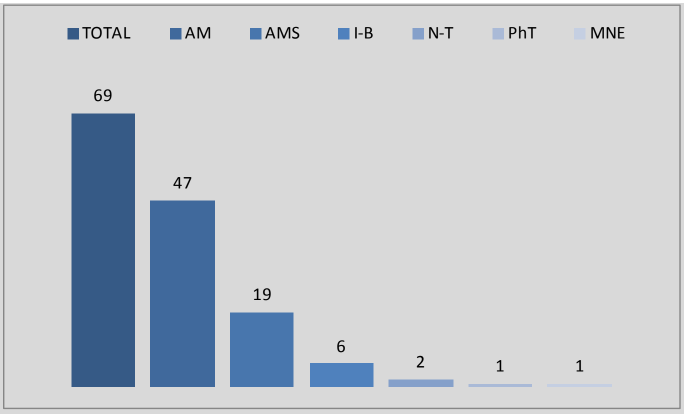
Additional information according to results of assessment:

- ***Impact assessment:***
  - Due to its low cost and abundance, coal is today a vital fuel and is expected to continue to be a dominant fuel in power generation. Some 25% of primary energy needs are met by coal and about 40% of electricity is generated from coal today. The International Energy Agency (IEA) furthermore expects that the use of coal will increase of 43% from 2000 to 2020. Nonetheless, as it is widely known, conventional coal power generation is a leading contributor to global greenhouse gas emissions as coal is the most carbon-intensive among the fuels. However, given coal's abundance, this resource will continue to be exploited among the energy mix for energy security and economic reasons.
  - Clean coal technologies are expected to enable coal to remain an attractive fuel option thanks to improving the environmental performance of coal power generation. As clean coal technologies are being developed and increasingly adopted, the global value of electricity generated using clean coal technologies is reported to amount to around 48 billion Euro in 2010 and is further expected to grow to 65 billion Euro by 2020.
  - While coal washing, particulate control and emissions treatments have been in use for several decades, recent advances in technologies aimed at reducing SO_2, NO_x and particulate emissions have substantially improved the effectiveness and reduced the cost of these solutions, while advanced combustion technologies along with advanced power plant designs, incorporating gasification and combined cycle power generation, are increasing the power conversion efficiencies of coal power plants, thus enabling simultaneous improvements in emissions and economics of coal-fired generation. Yet, the greatest opportunity for the coal industry to significantly improve its environmental performance seems to lie today in the maturation and deployment of carbon capture and sequestration technologies (CCS).
  - Having the above situation in mind, from a value chain perspective the clean coal industry can represent an important opportunity for both the many EPC contractors and equipment manufacturers established in Europe; opportunities for growth and jobs creation will mainly be linked to the engineering, procurement and construction (EPC) related to plants upgrading as well as to the manufacture and supply of new equipment by equipment producers.
  - Sources: International Energy Agency Coal Industry Advisory Board, Clean Coal Technologies, Accelerating Commercial and Policy Drivers for Deployment, February 2008; MarketResearch.com, Clean Coal Technologies Markets and Trends Worldwide, 2nd Edition, January 2012.

- ***Results of patents scenario analysis:***
  - 69 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Increasing trend curve (number of patents per year)
  - Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants, most probably standing for new technologies having been patented in the corresponding periods:



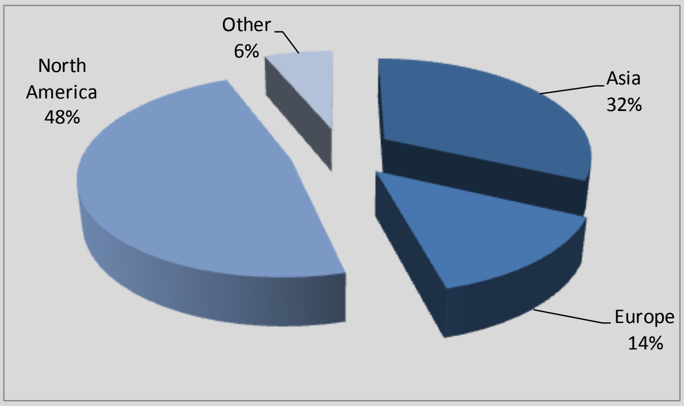
  - Patents by KET(s):



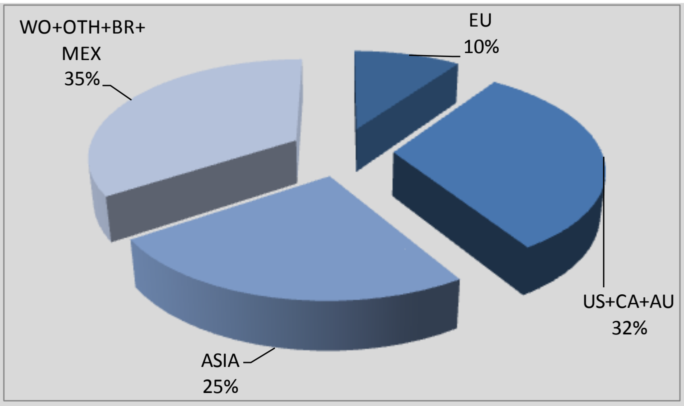
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	47
AM / IBT	1
AM / MNE	1
AM / N-T	2
AMS	19
AMS / AM	2
AMS / AM / N-T	1
AMS / N-T	1
AMS / PhT	1
IBT	6
MNE	1
N-T	2
PhT	1

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



E.2.3: Carbon Capture and Storage (CCS)

Scope:

To develop new and improved carbon capture technologies – i.e. post-combustion, pre-combustion, oxy-fuel – as well as to optimize the storage capacity and efficiency along with the development of a complete storage infrastructure (encompassing Enhanced Oil or Gas Recovery (EOR/EGR), depleted Oil and Gas fields, deep saline aquifers, etc.), all allowing for the reduction of costs and energy consumption in carbon capture and storage (CCS).

Demand-side requirements (stemming from market needs) addressed:

- Cope with regulation related to greenhouse gas emissions
- Keep costs low under the EU's Emissions Trading Scheme (ETS)

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Further R&D on the current portfolio of capture technologies – post-combustion, pre-combustion and oxy-fuel – and identification of improvements in those closest to commercial maturity
- Development of new CO_2 sorption media and processes for post-combustion technology
- Improvements in combustion, flue gas treatment and CO_2 cleaning for oxy-fuel technology
- Development of integrated processes for pre-combustion and oxy-fuel technologies
- Plant integration for all three capture technologies
- Improvements and up-scaling of gasifiers, hydrogen-gas turbines, carbon monoxide-shift and CO_2 capture for pre-combustion technology
- Enhancement of CO_2 compression
- Development of a complete transportation infrastructure (encompassing onshore pipeline, offshore pipeline, ships, rail/road tankers), including industrial sources of CO_2
- Optimization of storage capacity and efficiency and development of a complete storage infrastructure (encompassing Enhanced Oil or Gas Recovery (EOR/EGR), depleted Oil and Gas fields, deep saline aquifers, etc.)

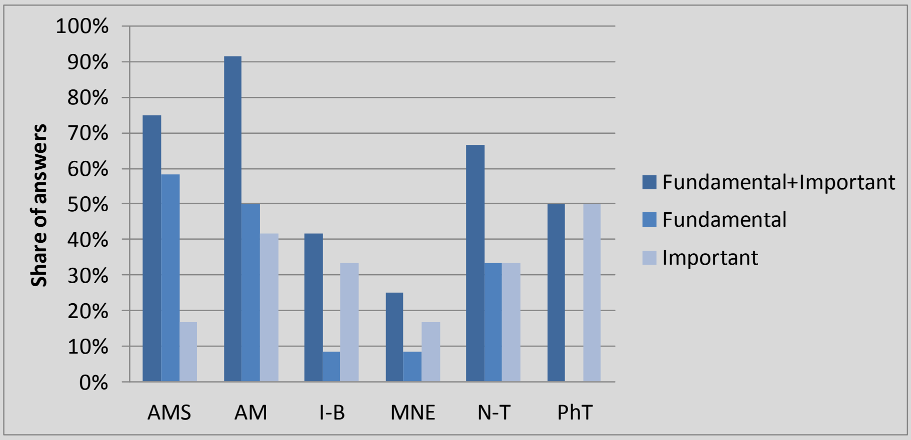
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the further development of the current portfolio of carbon capture technologies, along with the improvements and up-scaling of gasifiers, hydrogen-gas turbines, CO_2 compression, and the development of a complete transportation and storage infrastructure (encompassing pipelines, ships, rail/road tankers, reservoirs, etc.).

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

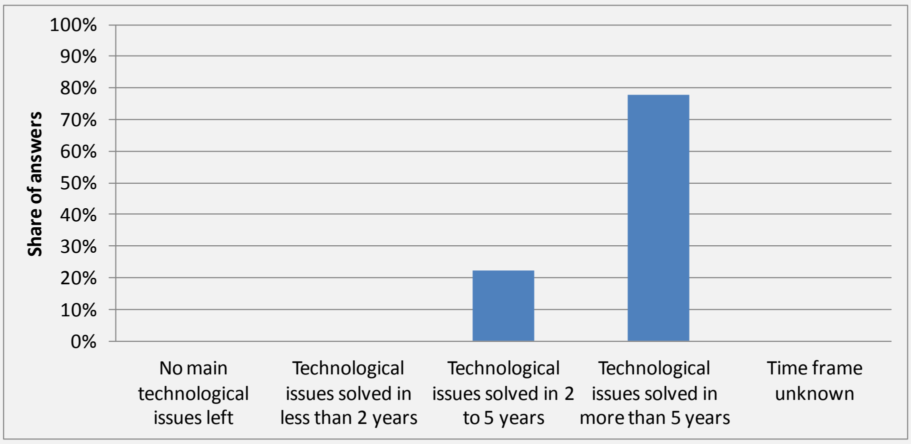
- Advanced Manufacturing Systems (AMS)

- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

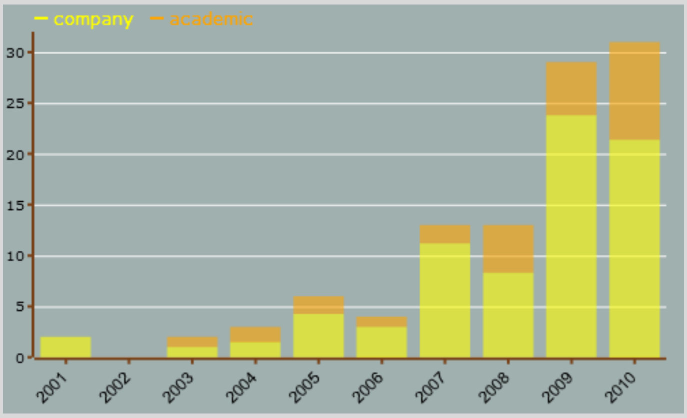
➢ ***Impact assessment:***

- Though carbon capture and storage (CCS) technologies and processes have been leveraged in industrial and oil and gas applications for decades, only in recent years they have been adapted and demonstrated on large-scale coal power plants. The driving force behind capturing and sequestrating carbon is the need to find cost-effective solutions for the reduction of CO_2 emissions globally where there is a continuous and rising demand for energy worldwide.
- Carbon capture and storage is likely to spread globally through expanded international collaboration and financing for the deployment especially in developing countries. Within this framework, the competitive landscape for supplying the equipment and the engineering in the carbon capture and sequestration market is rapidly intensifying. Among the leading market players of this industry there are European companies operating worldwide such as Aker Clean Carbon (Norway), Siemens (Germany), Linde AG (Germany) and ALSTOM Carbon Capture (France) that are competing mainly with companies from the US.
- Sources: International Energy Agency Coal Industry Advisory Board, Clean Coal Technologies, Accelerating Commercial and Policy Drivers for Deployment, February 2008; MarketResearch.com, Clean Coal Technologies Markets and Trends Worldwide,

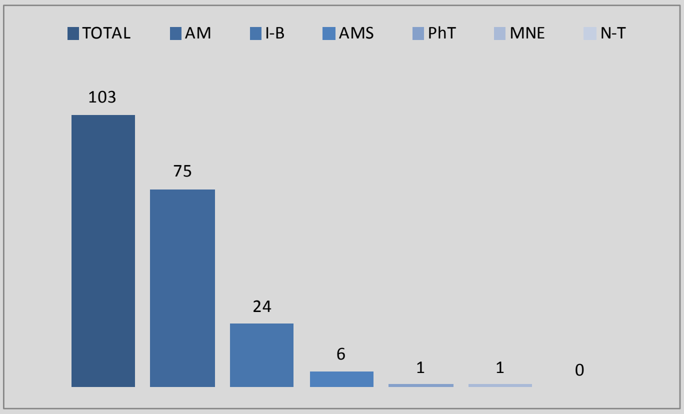
2nd Edition, January 2012.

➢ ***Results of patents scenario analysis:***

- 103 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Increasing trend curve (number of patents per year)
- Highest share of industrial applicants with intensification in the patenting activity by academic applicants in most recent periods, most probably standing for new technologies having been patented in the corresponding periods:



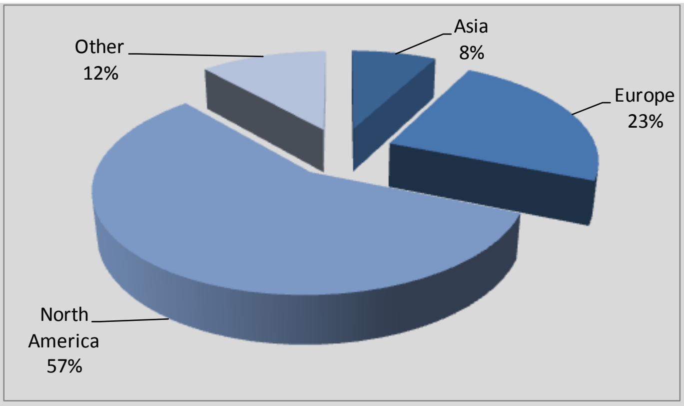
- Patents by KET(s):



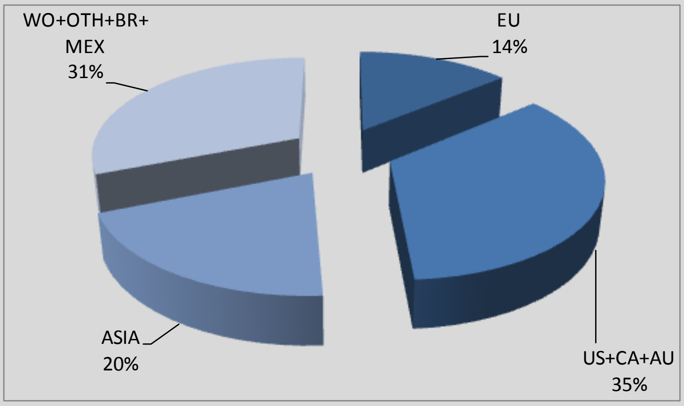
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	75
AM / IBT	2
AMS	6
AMS / AM	1
IBT	24
MNE	1
MNE / PhT	1
PhT	1

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



E.2.4: High flexibility combined cycle gas turbine power generation

Scope:

To develop Combined Cycle Gas Turbine power generation systems whose flexibility is maximized along with efficiency including through improvements in materials addressing the important issue of durability.

Demand-side requirements (stemming from market needs) addressed:

- Cope with fluctuating power demand
- Increase durability of energy generation equipment in order to ultimately reduce operation and maintenance costs

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

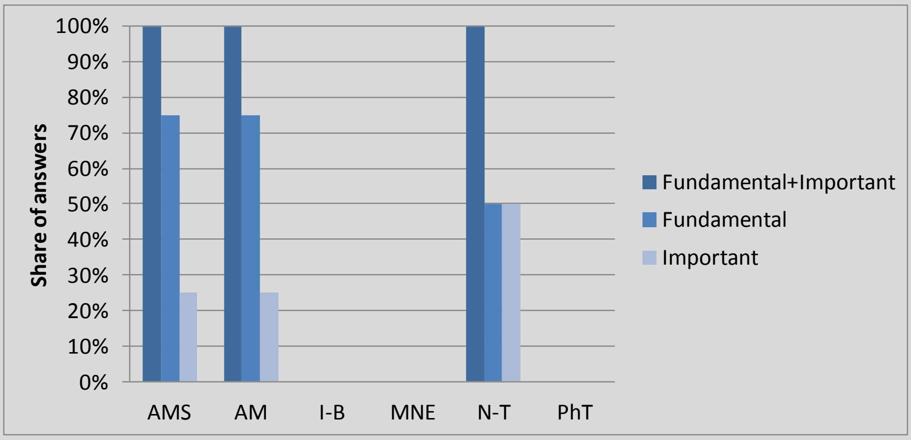
- Development of novel materials for energy applications addressing the important issues of durability, efficiency and cost of energy systems
- Increase the steam data, i.e. pressure and temperature, of power plants through developments in new materials (austenitic alloys, Ferritic alloys, FeCrAl alloys, ceramics) tackling problems such as creeping, cracking, Thermal Mechanical Fatigue (TMF), corrosion, erosion, etc.
- Development of efficient hydrogen turbine systems, including system optimization for combined heat and power (CHP) generation, trigeneration, combined cycle, etc.
- Development of heat transfer concepts that avoid deposit formation on and fouling of heat exchangers for combustion-based cogeneration
- Improvements in combustion systems and high temperature chamber testing (towards high efficiency and low environmental impact)

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of novel materials for energy applications addressing the important issues of durability, efficiency and cost of energy systems, allowing to increase the steam data of power plants through developments in new materials, tackling problems such as creeping, cracking, Thermal Mechanical Fatigue (TMF), corrosion, erosion, etc., along with the development of specialized coatings improving heat transfer concepts and avoiding deposit formation on and fouling e.g. of heat exchangers for combustion-based cogeneration. The integration of KETs could moreover contribute to improvements in combustion systems (towards high efficiency and low environmental impact).

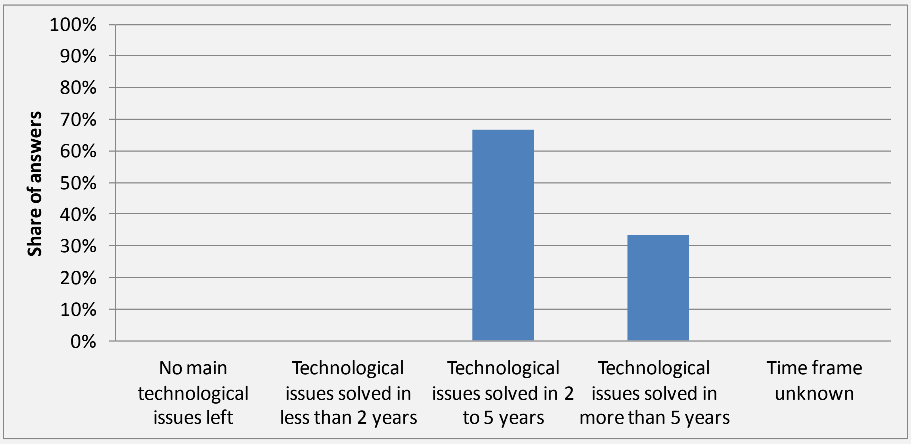
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
    - Gas turbines, increasingly in combined cycle applications with heat recovery steam generators converting waste heat into steam, and steam turbine generators using that steam for increased generation efficiency, will continue to be the workhorses in the power generation industry. In evaluating the market for gas turbine electrical power generation over the next decade, many factors lead to the conclusion that annual growth will most likely exceed 2.5-3.0% worldwide in order to keep up with demand, while the market is forecast to reach a value of over 110 billion Euro over 10 years (Sources: The Market for Gas Turbine Electrical Power Generation, Special Focused Market Segment Analysis by Forecast International, 2011; MarketResearch.com, Industrial & Marine Turbine - Gas & Steam Turbines: The Market for Gas Turbine Electrical Power Generation, 2012).
    - Europe is home to important and well-known manufacturers of both heavy gas turbines (such as Alstom, Rolls-Royce, Siemens) and light gas turbines (such as MAN Diesel & Turbo, OPRA Turbines, Safran Turbomeca among others) that actively participate the global market. Furthermore, as the segment of micro-turbine machines of under 250 kW grows along with distributed generation, there are several smaller and lesser-known players participating mainly the domestic market.
    - According to the Diesel & Gas Turbine Worldwide’s Power Generation Order Survey 2013, providing details on the market of larger reciprocating engines, steam turbines and gas turbines used in power generation, gas turbine orders fell 34% compared to 2012 in favour of reciprocating engines. The 2013 survey revealed 447 gas turbine orders while 2012 had reported 677 units. Yet, steam turbine orders rose by 4% compared to 2012, with 128 steam turbine orders catalogued in 2013 and 123 units in 2012. It is also reported that steam turbines continued to grow in popularity, boasting a 64% growth in the last two years. Total units ordered in 2012 (combined gas turbine, steam turbine and reciprocating engine order data) were 32 271.
    - The top five markets revealed in the 2013 Power Generation Order Survey are North America (19%), Western Europe (16%), the Middle East (14%), Central Asia (13%) and the Far East (12%), with Middle and Far East markets driving demand.
- ***Results of patents scenario analysis:***
    - No exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
    - No significant patent-related figures can be reported in this field

Sub-domain: Smart Grid enforcement

Demand-side requirements (stemming from Societal Challenges) addressed:

- Contribute to achieving competitive, sustainable and secure energy
- Cope with the various European efforts (directives, policies as well as initiatives) aimed at deploying Smart Grids
- Cope with the various European efforts (directives, policies as well as initiatives) aimed at developing a single energy market for Europe
- Cope with the increasing levels of renewable energy deployment within the European Union (the Renewable Energy Directive (2009/28/EC) mandating to achieve levels of renewable energy consumption of 20% by 2020)

Demand-side requirements (stemming from market needs) addressed:

- Reduce energy consumption (resulting in savings over the conventional energy purchase for private as well as industrial end-users and in the overall reduction of the energy demand on a global scale)
- Provide for easier integration of renewables in general with existing energy distribution networks and with other energy generation systems
- Increase use of effective energy storage systems into existing energy distribution networks (to resolve the mismatch issue between energy generation and demand)
- Increase electricity usage flexibility in order to cope with today’s lifestyles

E.3.1: Voltage level-dependent energy storage facilities in the grid

Scope:

To develop voltage level-dependent energy storage facilities for the grid, meaning storage facilities for the transmission, distribution and consumer grid to cope with the volatility of renewable energy sources, including bulk energy storage (at grid level to maximize use of distributed energy sources) and small size storage (in the distribution network).

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

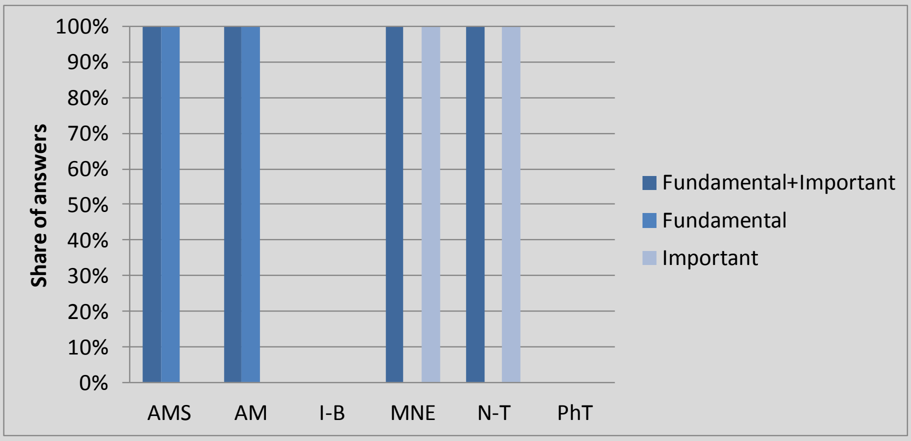
- Adaptation of electrical equipment (in this case, electricity storage, at different voltage levels) to the increased share of electricity generated through renewable energy sources and its special characteristics (intermittent or DC)
- Development of longer-lasting rechargeable batteries, supercapacitors or of other energy storage devices able to store more energy per volume and per weight

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the adaptation of electrical equipment (in this case, electricity storage, at different voltage levels) to the increased share of electricity generated through renewable energy sources and its special characteristics (intermittent or DC) thanks to the development of longer-lasting rechargeable batteries, supercapacitors or of other energy storage devices able to store more energy per volume and per weight.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)



Timing for implementation:

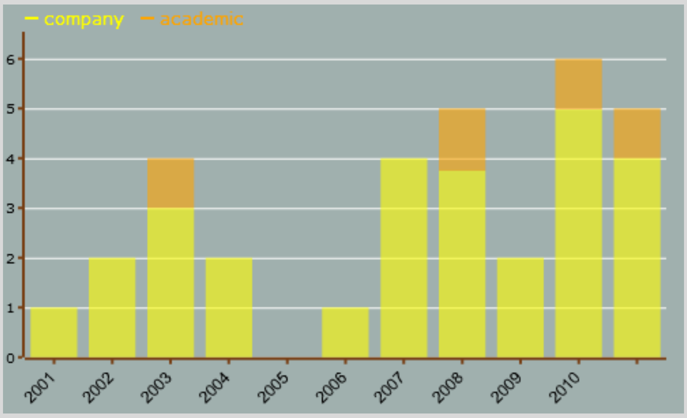
No consensual indication could be retrieved from KETs experts' opinions concerning the time frame required for solving the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field. However, considering the specific technical and/or industrial challenges and the maturity of technologies in this field, the provision of support in the short term is suggested within this framework.

Additional information according to results of assessment:

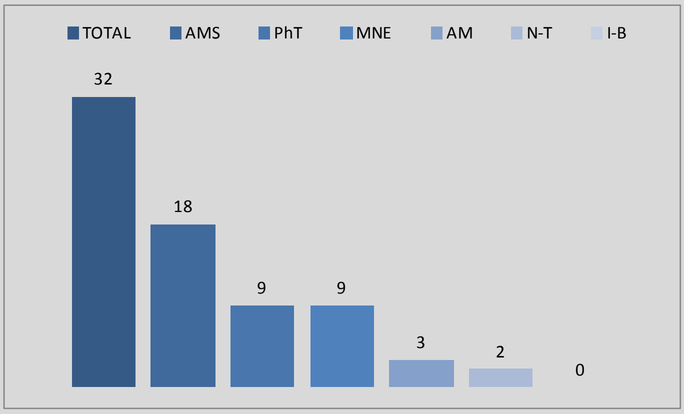
- ***Impact assessment:***
  - Similarly to what reported for thermal energy storage, electrical energy storage will be key, along with other energy storage systems and methods, in supporting the transition towards a secure, competitive and decarbonised energy system in Europe. The increasing intermittency at the generation side due to an increased integration of renewable as well as distributed energy generation in the energy system requires technologies and procedures for balancing energy demand and supply, thus allowing displacement between consumption and generation to take place in both time and space. Within this framework, electrical energy storage, like thermal energy storage, will become an integral part of future's energy systems and related value chains, being expected to solve, in on-grid areas, issues related to power fluctuation and undependable power supply, which are typically associated with the use of large amounts of renewable energy. In the off-grid domain, electric vehicles using electric storage will be among the most promising technology to replace fossil fuels by electricity from mostly renewable sources (Source: Joint EASE/EERA recommendations for a European Energy Storage Technology Development Roadmap towards 2030, March 2013).
  - Most promising markets for electrical energy storage systems will be for achieving time shift, smoothing of output fluctuations and efficiency improvement of conventional generators and adjusting power supply to meet demand that fluctuates within short periods. These two applications are reported to be promising due to the expected broad introduction of renewable energies on the one side and the consequent need for balancing energy that is likely to rise as renewable energy generation causes fluctuations on the supply side to increase, and more and more power markets will introduce sophisticated market mechanisms for the procurement of balancing energy (Source: Joint EASE/EERA recommendations for a European Energy Storage Technology Development Roadmap towards 2030, March 2013).
  - Global demand for advanced energy storage systems is expected to grow to 32 000 TWh by 2035, a 70% increase from 2012. The global consumption of electricity is expected to grow by over 60% from 2011 to 2030. This huge rise in demand has to be met by increased power generation which requires 6 000 GW of added new capacity, apart from the existing capacity. The bulk of required electricity, though could be generated, has to be managed due to frequently changing demand peaks, making energy storage an imperative element within the system. Globally, the advanced energy storage systems market that includes grid storage and transportation is expected to grow at a compound annual growth rate (CAGR) of 10% in from 2013 to reach over 8 billion Euro by 2018. The key growth drivers include growing renewable implementation, new transmission and distribution grid construction and upgrades, smart grid installation, and growing demand for electric and hybrid vehicles (Source: Markets and Markets, Advanced Energy Storage Systems Market by Technology (Pumped Hydro, Compressed Air, Batteries, Flywheels, Supercapacitors), By Applications (Grid Storage & Transportation), & Geography - Global Trends & Forecast to 2018, 2013).
  - Pumped hydro-storage is the most prominent and oldest of all the storage technologies. Yet, numerous other technologies with different capabilities are now in the market with continuous research and development in progress. These include Compressed Air Energy Storage (CAES), batteries, supercapacitors, and flywheels. Emerging and developing technologies include hydrogen storage as combined with fuel cells or combustion engines/turbines, super magnets and synthetic gas.
  - The European industry has a strong market leadership in large-scale energy storage technology. Three market leaders for hydro-pumped storage are based in Europe. Similarly, although Compressed Air Energy Storage technologies are not widely deployed, at least two of the two projects currently in operation were built with European technologies. For intermediate or smaller scale technologies, the European industrial base is weaker. Flywheels and flow battery manufacturers are mostly based outside Europe. For batteries and supercapacitors, although there are world-class European manufacturers, the global battery storage market was dominated by North America in 2012, followed by Asia-Pacific and Europe. Increasing grid storage needs and encouraging policies for electric vehicles in the US are the key drivers for this market. Asia-Pacific is expected to become the key market gainer in the next five years (Sources: Electricity storage in the power sector, http://setis.ec.europa.eu; Markets and Markets, Advanced Energy Storage Systems Market by Technology (Pumped Hydro, Compressed Air, Batteries, Flywheels, Supercapacitors), By Applications (Grid Storage & Transportation), & Geography - Global Trends & Forecast to 2018, 2013).

➢ ***Results of patents scenario analysis:***

- 32 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Increasing trend curve (number of patents per year)
- Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants, most probably standing for new technologies having been patented in the corresponding periods:



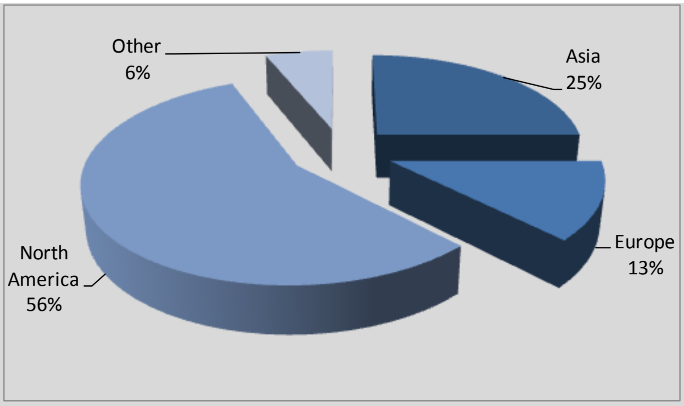
- Patents by KET(s):



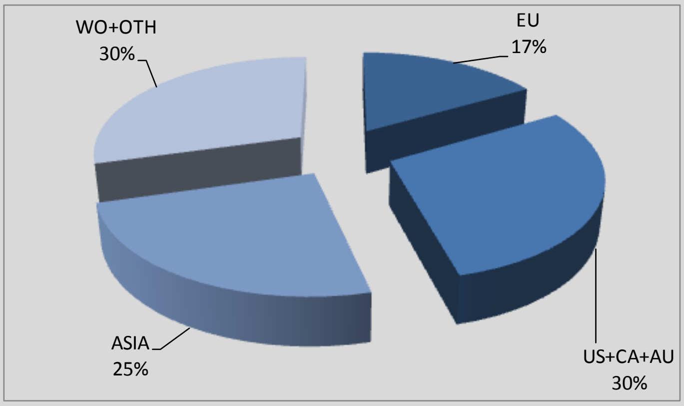
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	3
AM / N-T	1
AMS	18
AMS / AM	1
AMS / MNE	1
MNE	9
MNE / PhT	6
N-T	2
PhT	9

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



E.3.2: High Voltage AC-DC converters and High Voltage as well as Ultra High Voltage DC transformers for grid applications

Scope:

To develop High Voltage AC-DC converters and High Voltage as well as Ultra High Voltage DC transformers for grid applications to transmit electric power efficiently and reliably over long distances and distribute power to utilities while helping to reduce costs of operation and maintenance of energy transmission/distribution facilities.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of improved equipment to increase the distance of electric power transmission (especially equipment for subsea application for offshore wind energy and in any case for transmission to or from remote areas)
- Development of improved equipment to increase efficiency and reliability of power transmission and distribution

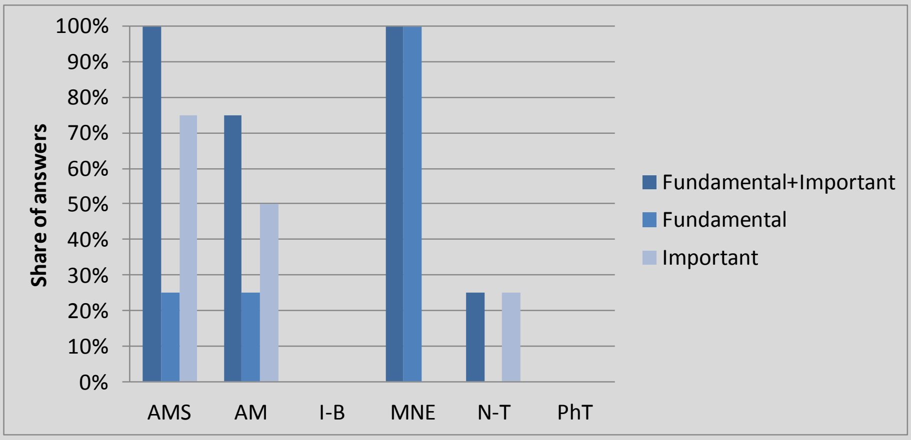
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced High Voltage AC-DC converters and High Voltage as well as Ultra High Voltage DC transformers, building on improved semiconductors and equipment able to increase efficiency and reliability of power transmission and distribution over long distances.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

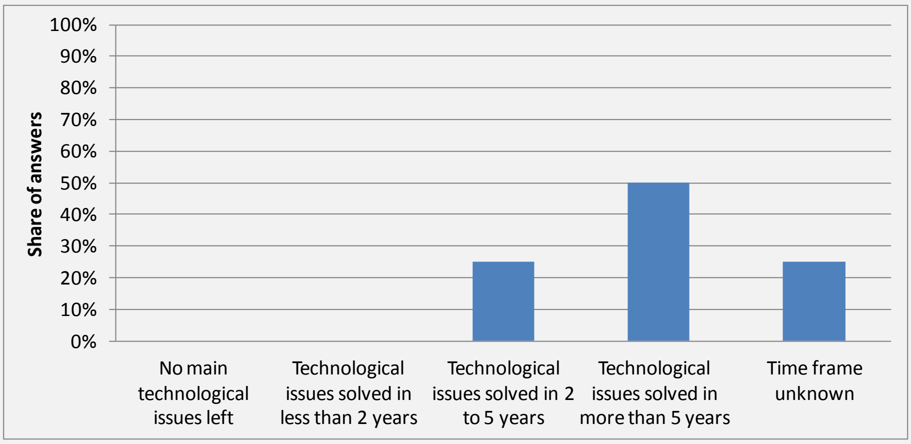
- Advanced Manufacturing Systems (AMS)

- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

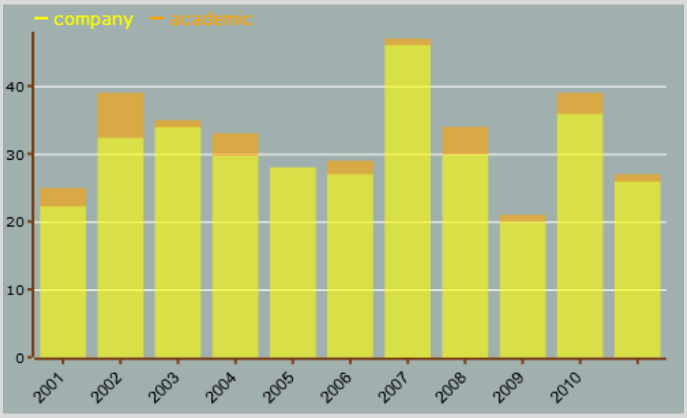
- Along with the increasing basic electrification of remote areas as well as the growing offshore as well as remote area power generation facilities installations, improved High Voltage as well as Ultra High Voltage DC converters / transformers are needed to enable power transmission to occur to or from remote areas over long distances. These systems allow the transmission of power over long distances and are also solutions for interconnection of networks with different characteristics and frequencies.
- Furthermore, the combination of an ageing infrastructure, the rising use of renewables which need to be integrated into the existing grid, the rising demand for electricity, and the need to improve transmission as well as distribution efficiency including by minimizing losses are translating into growth in the electric power transmission and distribution transformer market. Within this framework, Visiongain has calculated that the global electric power transmission and distribution transformer market would reach 24.7 billion Euro in 2012 (Source: Visiongain, The Electric Power Transmission and Distribution (T&D) Transformer Market 2012-2022, 2012).
- Over the forecast period many regions and countries will experience strong growth in the electric power transformer market as a number of governments and utility companies rush to upgrade and expand the transmission and distribution infrastructure.

Emerging national electric power transmission and distribution equipment markets such as China, India, and Brazil will drive growth in the market while the US and major European countries will remain central to transmission and distribution transformer market sales over the forecast period to 2012-2022, as these economies continue to invest heavily in their electricity generation, transmission and distribution networks. Growth in other national and regional markets is expected to increase sharply, as national, regional and continental electricity grids are interconnected. Competition between transformer manufacturers will be stiff as new entrants into the global market from China, South Korea and India challenge the market dominance of European and American manufacturers (Source: Visiongain, The Electric Power Transmission and Distribution (T&D) Transformer Market 2012-2022, 2012).

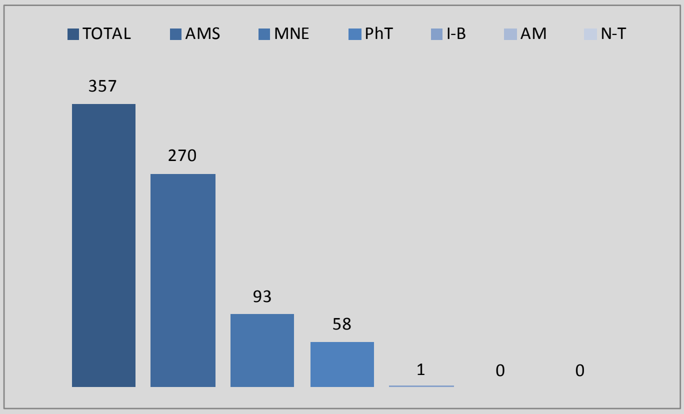
- Within the framework of High Voltage as well as Ultra High Voltage DC transformers for grid applications, Europe is home to top multinational leading players in this field, particularly ABB, Alstom Grid, Arteche, EFACEC Engenharia, Schneider Electric, Siemens and Siemens Energy, SGB-SMIT International and SMIT Transformatoren, capable of supplying all the required critical materials and components as well as providing for the design, manufacture, and installation or installation supervision. As regards High Voltage AC-DC converters, leading European players on the market are STMicroelectronics and Philips.

➢ ***Results of patents scenario analysis:***

- 357 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Stable trend curve (number of patents per year)
- Highest share of industrial applicants:



- Patents by KET(s):

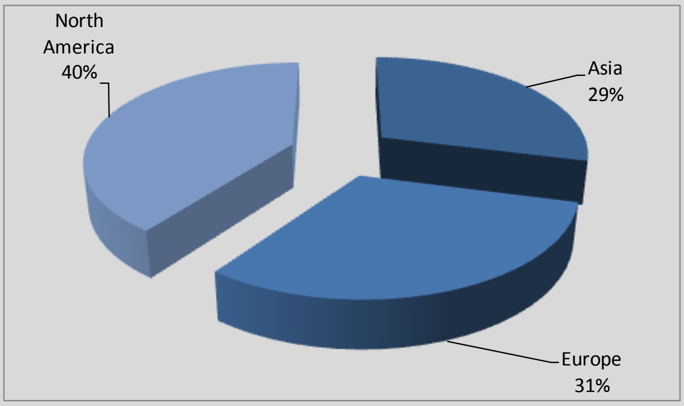


- Patents by KET(s) and relevant combinations of KETs:

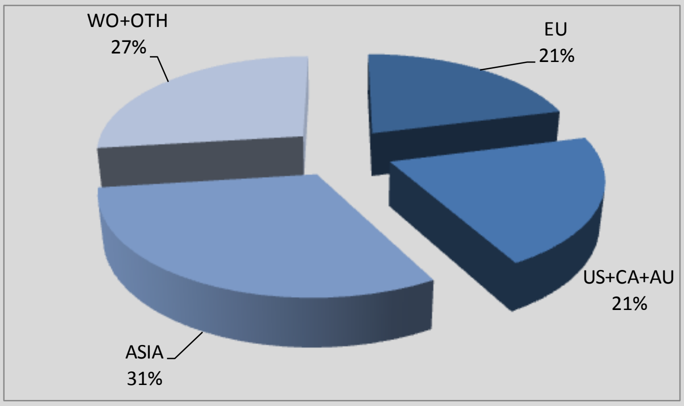
KET(s)	*Number of patents*
AMS	270
AMS / MNE	21
AMS / MNE / PhT	2
AMS / PhT	9
IBT	1

MNE	93
MNE / PhT	37
PhT	58

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



E.3.3: Flexible, high-speed, self-healing AC power transmission/distribution

Scope:

To develop flexible AC power transmission/distribution systems based on high-speed power routing equipment and systems, allowing for self-healing grids.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

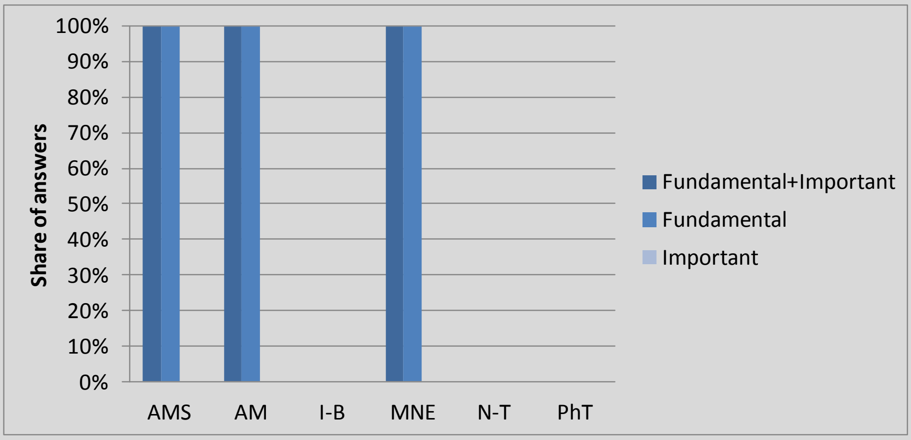
- Integrate electricity transmission, distribution and storage while keeping or increasing reliability and quality
- Provide for standards, protocols and control architectures to communicate network elements

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more flexible AC power transmission/distribution systems based on high-speed power routing equipment and systems and thanks to intelligent digital systems capable of providing self-checking and self-healing, moreover allowing for bidirectional communication and huge information and data flow, highly benefitting for this also from information and communication technologies.

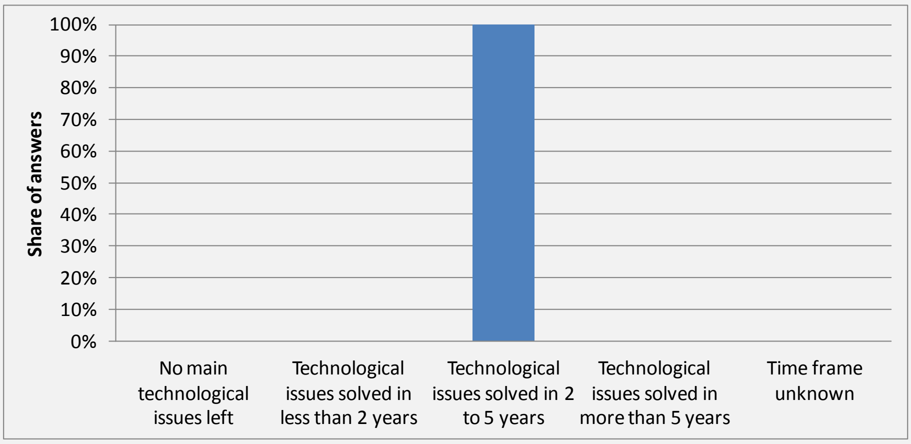
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

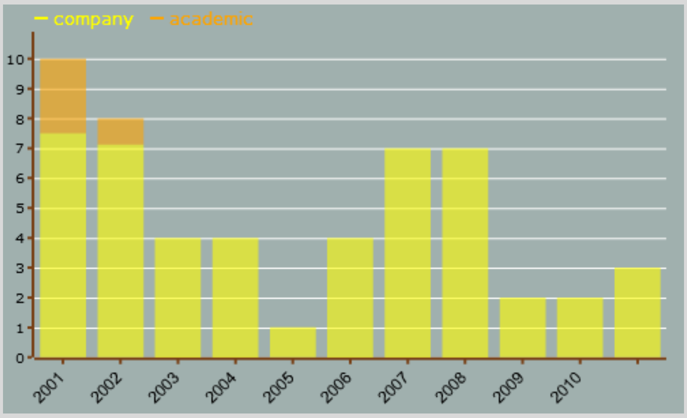
- Power system reliability is key to avoiding failures potentially resulting in blackouts that can have social and economic burdens for billions of Euro every year. The likelihood of blackouts has been increasing because of various physical and economic factors, and, as the portion of electricity in the total energy consumption continues to grow, the value of power system reliability is also increasing. Yet, as the digital age prevails, more efficient systems based on computers and power electronics have come to dominate the scene.
- Self-healing grids will require a high performance IT infrastructure to address gaps in the geographical and temporal coordination of power system monitoring and control. Considerable improvements are required at various hierarchical levels, including

substations, control areas, regions and the grid. Temporal coordination will require improvements in adapting the faster and often local controls to the slower global controls (ABB, Vision for a self-healing power grid).

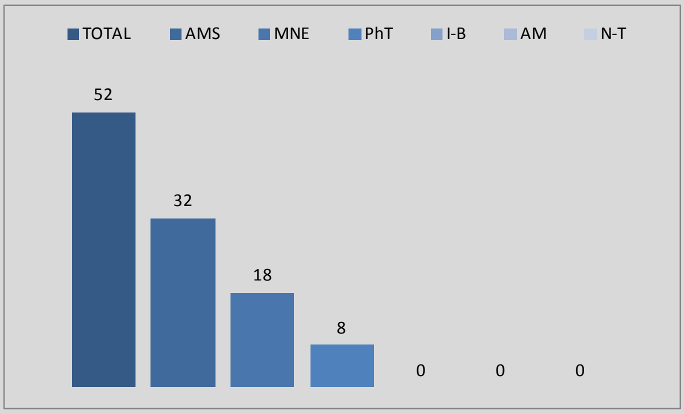
- Global demand for electric transmission and distribution equipment is forecast to rise of 6.7% per year to nearly 131 billion Euro in 2017. Sales growth will accelerate relative to the 2007-2012 period, aided by both continued strong growth in electricity consumption in developing regions and economic recovery in developed countries. China, which accounted for 32% of global demand in 2012, will continue to be the largest and fastest growing national market for electric transmission and distribution equipment (Source: Freedonia Group, World Electric Distribution Equipment & Power Transmission Market 2017, 2013).
- As reported for Innovation Field E.3.3, in Europe, leading multinational suppliers of electric transmission and distribution equipment are particularly ABB, Alstom Grid, Arteche, EFACEC Engenharia, Philips, Schneider Electric, Siemens and Siemens Energy, SGB-SMIT International, and SMIT Transformatoren, STMicroelectronics.

➤ ***Results of patents scenario analysis:***

- 52 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Decreasing trend curve (number of patents per year)
- Exclusive share of industrial applicants in most recent years:



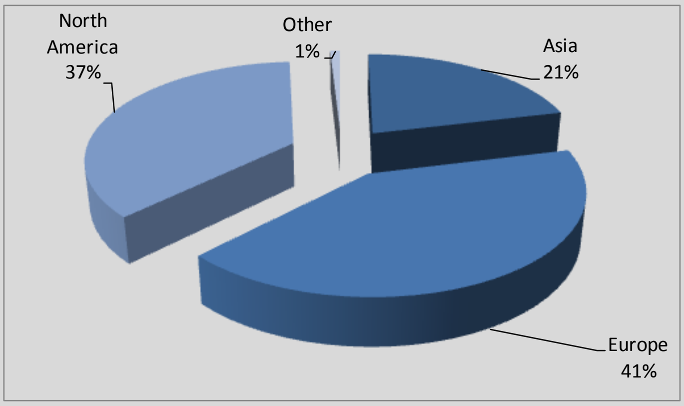
- Patents by KET(s):



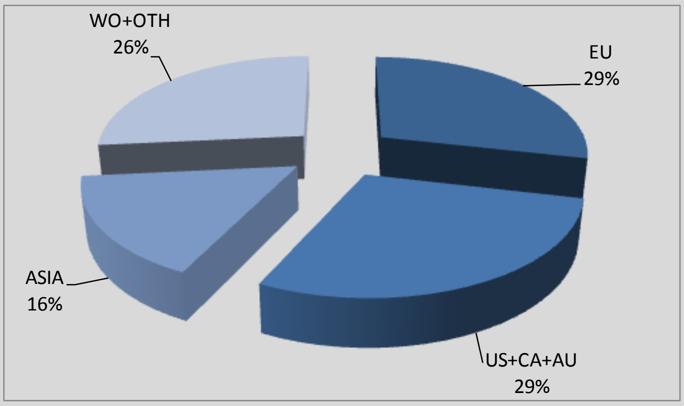
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AMS	32
AMS / MNE	3
AMS / MNE / PhT	1
AMS / PhT	1
MNE	18
MNE / PhT	3
PhT	8

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



E.3.4: Energy-efficient and smart household appliances

Scope:

To develop more energy-efficient and smart household appliances, i.e. auto-balancing or active appliances with built-in sensors [smart-grid ready], interoperable, internet-linked, enabling smart home and home automation concepts.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development and, most importantly, integration (including thanks to making them interoperable and easy to use) of smart (home) appliances, home automation, and systems for the "smart home"
- Development of low power embedded modules (including power modules) and/or embedded computation mechanisms
- Integration of more, and more embedded, sensing capabilities to allow more situational awareness
- Development of novel materials for better design with better properties (e.g. more wear resistant, lightweight), etc.

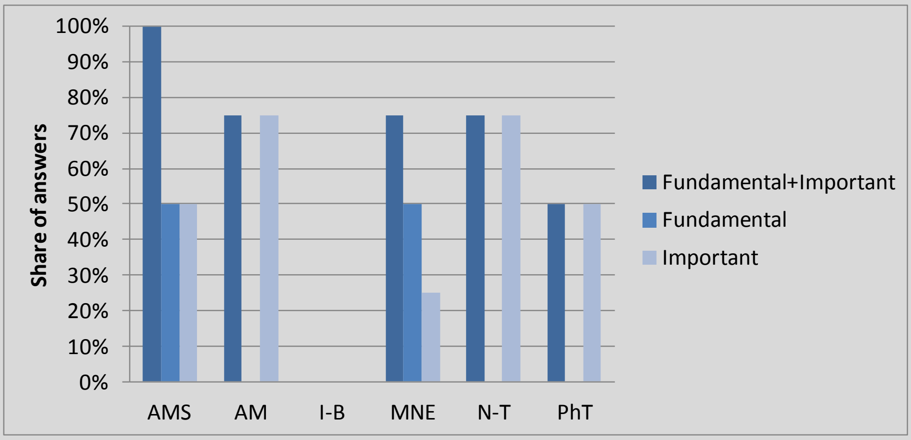
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more energy-efficient and auto-balancing or active smart-grid ready appliances, thanks to optimized power consumption approaches (including context-dependent system adaptation), the improvement of human-machine-cooperation, the development of usable, scalable and built-in security, trust, dependability and privacy for mobile- or other device-enabled communications.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting

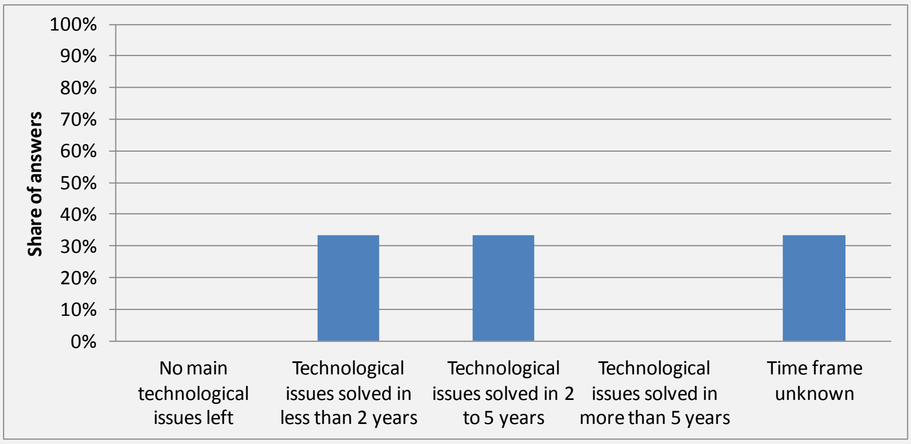
activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years or shorter (less than 2 years):



Considering the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework mainly in order to support the deployment of product-like prototype equipment to demonstrate the benefit of the technology on a sufficiently large demonstration scale.

Additional information according to results of assessment:

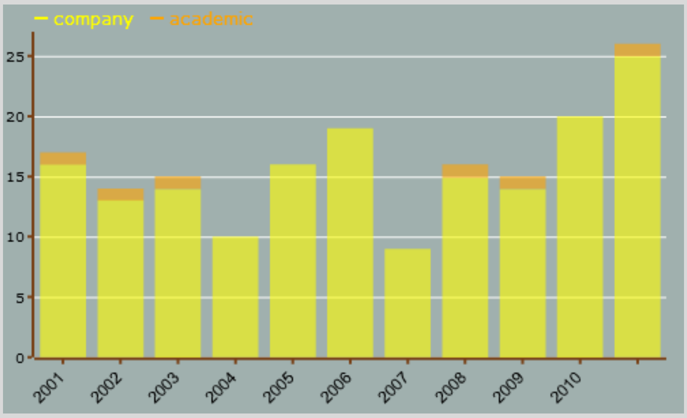
➢ ***Impact assessment:***

- As utilities increasingly deploy smart meters, smart household appliances (which use advanced control combined with intelligent power management strategies and networking technologies to optimize the load on the power distribution grid) will have an increasingly significant role to play within smart grids.
- Currently, there is already a very limited commercial availability of such appliances, which will start to represent an increasing share of the total appliance market after 2015. According to analysts of Pike Research, the annual value of the smart household appliances market will grow from around 450 million Euro in 2012 to more than 25 billion Euro in 2020.

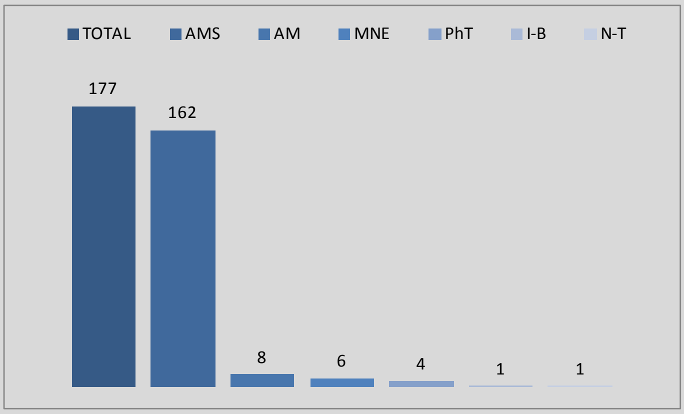
- Key industrial appliance manufacturers are Bosch, Electrolux, GE Appliances, Indesit, LG Electronics, Miele, Samsung Electronics and Whirlpool, most of them established in Europe with manufacturing facilities in Europe and elsewhere.
- Source: Pike Research, Smart Appliances, February 2013, www.navigantresearch.com

➢ ***Results of patents scenario analysis:***

- 177 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Increasing trend curve (number of patents per year)
- Highest almost exclusive share of industrial applicants:



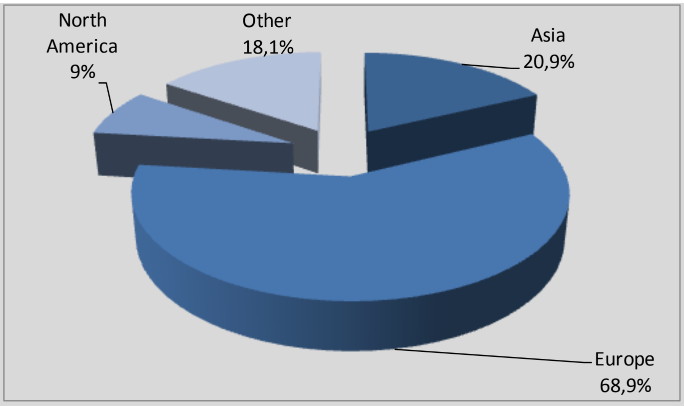
- Patents by KET(s):



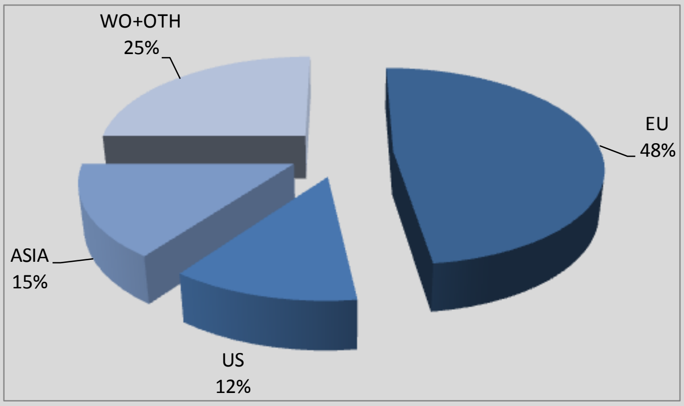
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	8
AM / N-T	1
AMS	162
AMS / AM	1
AMS / IBT	1
AMS / MNE	1
IBT	1
MNE	6
MNE / PhT	1
N-T	1
PhT	4

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



Sub-domain: Embedded energy systems

Demand-side requirements (stemming from Societal Challenges) addressed:

- Contribute to achieving competitive, sustainable and secure energy

Demand-side requirements (stemming from market needs) addressed:

- Enable more efficient power storage in order to guarantee power supply to mobile, portable and consumer products
- Larger supply availability of more reliable as well as small-sized / low-weight systems for power supply
- Increase power to weight ratio of storage systems in order to maximize yield at overall system level

E.4.1: Fuel cell-based systems for transport applications

Scope:

To develop fuel cell-based systems for transport applications with improved performance at both single component and system level eventually combined with efficient and reliable units for fuel processing of liquid fuels to hydrogen (reforming of, for example, gasoline, diesel and kerosene) for on board application.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Improvements in fuel cells toward increasing efficiency, reliability, cost-effectiveness
- Understanding of degradation mechanisms including through methods for lifetime prediction and testing for polymer electrolyte fuel cells (PEFCs) and solid oxide fuel cells (SOFCs)

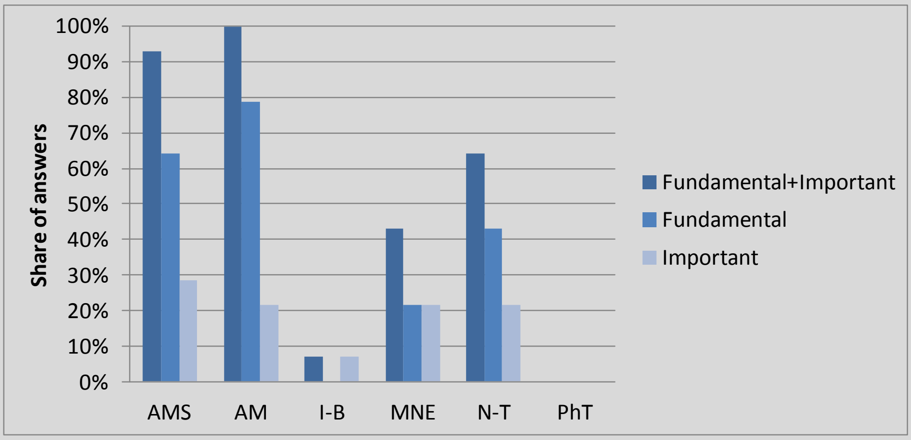
- Improvement of performances of polymer electrolyte fuel cells (PEFC) stacks such as power density, durability, humidification, cathodic water management and contaminant tolerance
- Improvement of performances of solid oxide fuel cells (SOFC) stacks (with main use in Auxiliary Power Units (APUs) due to easy reforming) such as thermal cycling stability, robustness and reliability, tolerance to fuel impurities (e.g. sulphur)
- Development of high temperature polymer electrolyte fuel cells (HT PEFC), electro-catalysts and new materials for fuel cell (FC) components
- Development of fuel cell & battery hybrid systems
- Development of new reversible hydrogen storage materials
- Development of efficient and reliable units for fuel processing of liquid fuels to hydrogen (reforming), in particular for on board application (e.g. gasoline, diesel and kerosene)
- Increase system integration and system efficiency, including electronic equipment and components, in particular for polymer electrolyte fuel cells (PEFC) (sensors, control and power electronics, etc.)
- Development of cost-efficient manufacturing

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more performing fuel cells thanks to deploying solutions for solving degradation issues including through methods for lifetime prediction and the deployment of enhanced materials and structures. The integration of KETs could also contribute to the development of fuel cell and battery hybrid systems, of new reversible hydrogen storage materials and related equipment, of efficient and reliable units for fuel processing of liquid fuels to hydrogen (reforming), and of integrated systems, including electronic equipment and components (sensors, control and power electronics, etc.). The integration of KETs could finally contribute to render manufacturing of such systems and equipment more cost-efficient.

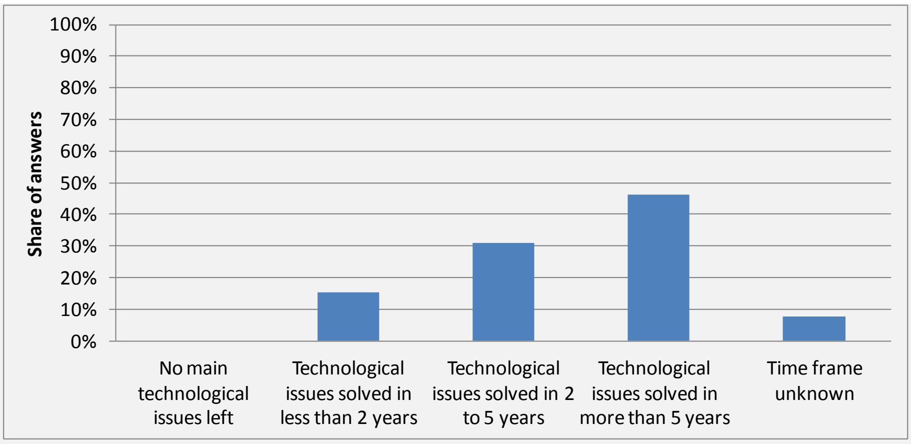
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus by experts indicates also shorter periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

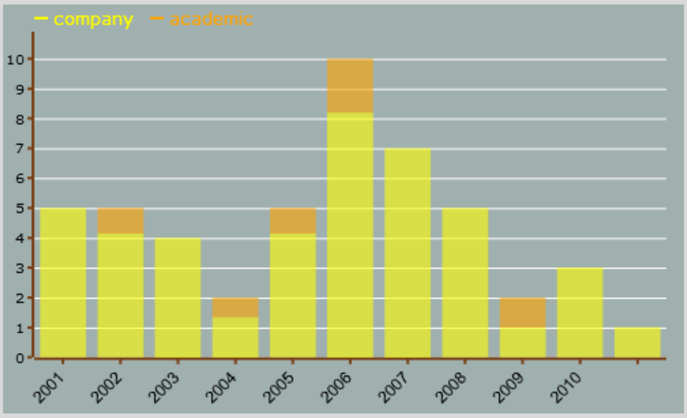
Additional information according to results of assessment:

➢ ***Impact assessment:***

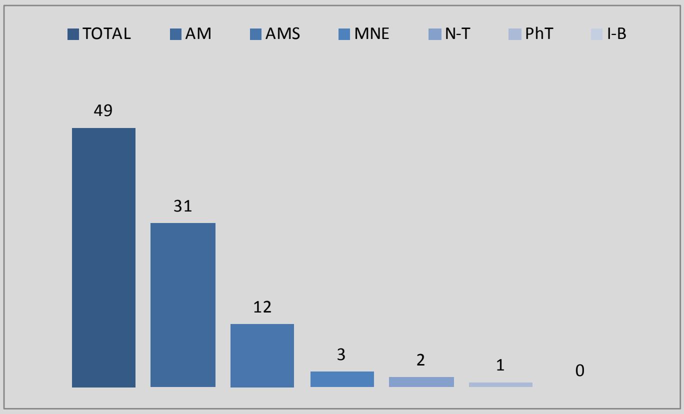
- Fuel cells can improve energy efficiency in the transportation sector and contribute to mitigating climate change, especially when being fuelled by pure hydrogen produced by renewable primary energy sources. Transportation applications of fuel cell technology include motive power for passenger cars, buses and other fuel cell electric vehicles (FCEV), specialty vehicles, material handling equipment (e.g. forklifts), and auxiliary power units (APUs) for off-road vehicles. Today, fuel cell technology based vehicles are considered to be in the demonstration stage, requiring to become more cost-competitive with conventional and advanced vehicle technologies in order to gain the market share.
- Nonetheless, according to the US Department of Energy (DOE), the trends for the fuel cell industry were encouraging in 2012. Total fuel cell shipments (i.e. including any application for fuel cell technology) increased in 2012 (34% over 2011 and 321% over 2008) while costs continued to decline, especially for light duty vehicle applications. In several European countries such as Germany, Sweden, Denmark, and Finland, besides in the US and Japan, efforts are being dedicated to deploying hydrogen fuelling infrastructures. There were moreover several collaboration announcements between car producers with regards to fuel cell electric vehicles, including Toyota and BMW's long-term strategic collaboration to develop a fuel cell system jointly, and Daimler, Ford, and Nissan joining forces to jointly develop a common fuel cell system and launch commercial fuel cell electric vehicles (FCEVs) as early as 2017.
- Nearly 80% of total investment in the fuel cell industry was made in US companies in 2012, although UK was the next follower; 8 of the top 10 largest investors in fuel cell companies were from either the US or the UK, and collectively US and UK investors accounted for roughly 73% of all investment in the sector between 2000 and 2012. Despite this, however, the capacity to produce fuel cell systems at high manufacturing rates does not yet exist, and significant investments will still have to be made in manufacturing development and facilities in order to enable it. Once the investment decisions are made, it will take several years to develop and fabricate the necessary manufacturing facilities. Furthermore, the supply chain will need to develop which requires negotiation between suppliers and system developers, with details rarely made public.
- Nonetheless, in Europe, by 2030, the United Kingdom is projected to have 1.6 million FCEVs on the road, with annual sales of 300 000 fuel cell electric vehicles (FCEVs) in the UK alone, while the German Ministry of Transport announced its intention to build 35 new hydrogen fuelling stations, increasing the total number of stations to 50 by 2015.
- The Defence sector (in particular the US Department of Defense) is a world leader in the research, development, and demonstration of fuel cell technologies. Its support has contributed to significant improvements in fuel cell performance and reliability. This consolidated military knowledge is being implemented for civilian application, exploiting dual use technology.
- Sources: Breakthrough Technologies Institute Inc. for DOE, 2012 Fuel Cell Technologies Market Report, October 2013; Strategic Analysis Inc., Mass Production Cost Estimation of Direct H2 PEM Fuel Cell Systems for Transportation Applications: 2012 Update;

October 2012

- ***Results of patents scenario analysis:***
  - 49 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Scattered yet decreasing trend curve (number of patents per year)
  - Highest share of industrial applicants:



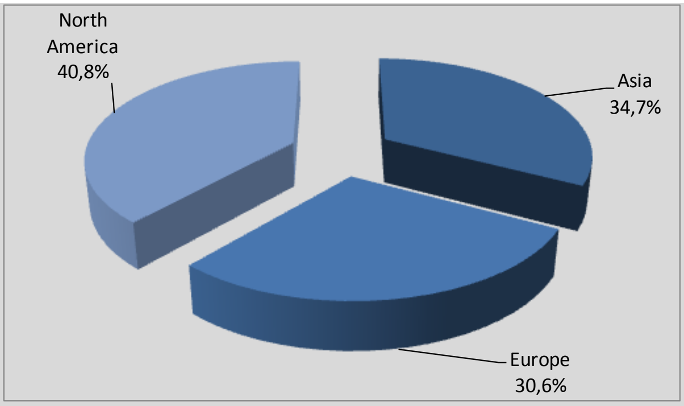
  - Patents by KET(s):



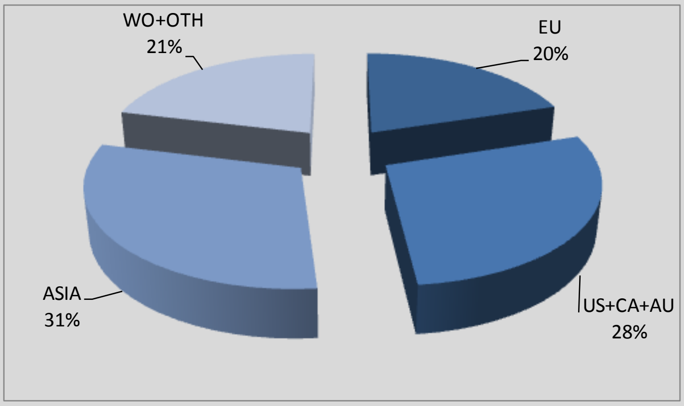
  - Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	31
AM / IBT	1
AM / N-T	1
AMS	12
IBT	2
MNE	3
N-T	2
PhT	1

  - Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



E.4.2: Fuel cell-based systems for portable applications

Scope:

To develop fuel cell-based systems for portable applications with improved performance at both single component and system level toward miniaturisation, compatibility, simplicity and cost-effectiveness including hybrid systems solutions capable to optimizing system efficiency, dynamics and start-up time.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

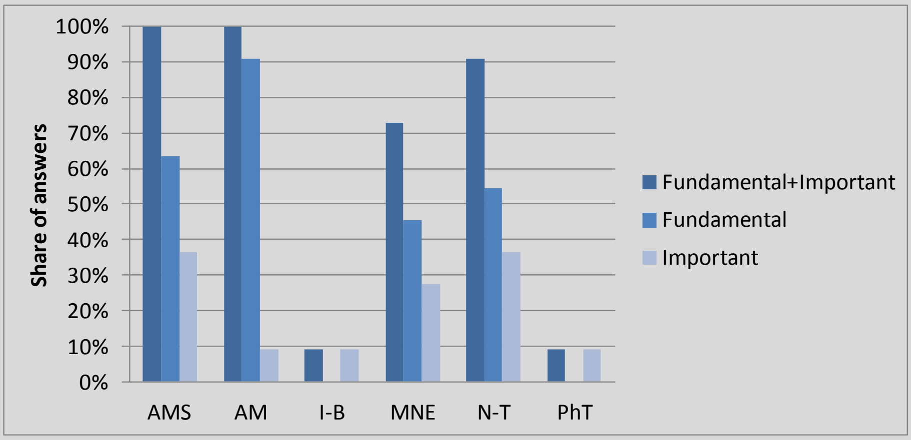
- Improvement of the performances of polymer electrolyte fuel cells (PEFCs) and direct methanol fuel cells (DMFCs) stacks: efficiency, power density, reducing precious metals, low costs stack components, decreasing methanol crossover
- Increase of system performance in fuel cell portable applications, toward miniaturization, compatibility, simplicity and cost-effectiveness: system efficiency, dynamics and start-up time (e.g. hybrid systems solutions), fluid handling components, water recovery, thermal integration, electronic equipment and components
- Improvement of the technology through developments in high temperature membranes, carbon-monoxide- and sulphur-tolerant catalysts, new membrane electrode assemblies (MEAs), components for polymer electrolyte fuel cells (PEFCs); cathode catalysts, and composite membranes for direct methanol fuel cells (DMFCs); alternative options for humidification, new battery and stack concepts
- Development of cost-efficient manufacturing

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more performing fuel cells for small-scale, portable applications thanks to deploying solutions for solving degradation issues including through methods for lifetime prediction and the deployment of enhanced materials and structures. The integration of KETs could moreover contribute to increasing miniaturization, compatibility, simplicity and cost-effectiveness of small-scale, portable systems, contributing to enhance system efficiency, dynamics and start-up time. The integration of KETs could finally contribute to render manufacturing of such systems and equipment more cost-efficient.

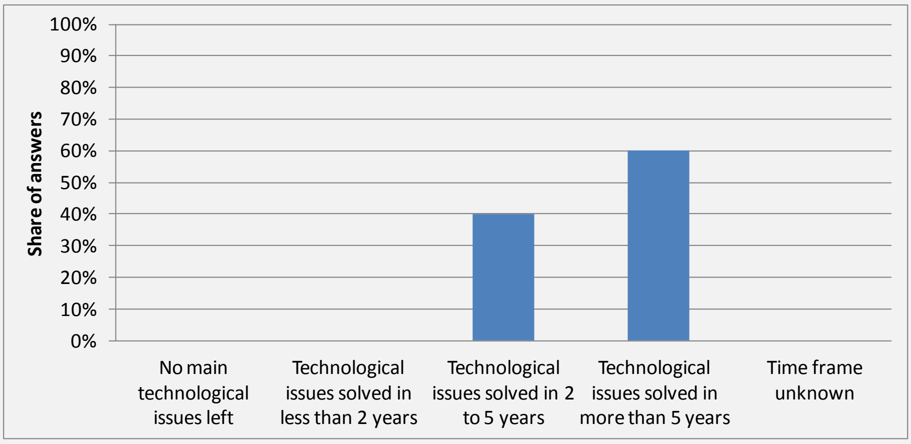
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus indicates also shorter periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Portable power applications use fuel cells that are not permanently installed or fuel cells in a portable device. As for transport applications, fuel cell technology in this domain is also considered to be in the demonstration stage, requiring to become more cost-competitive with conventional technologies, such as batteries for cell phones and computers, in order to gain the market share.
  - The portable market segment is characterized primarily by fuel cell kits and toys, as well as by small battery chargers that are starting to enter the market. The kits and toys continue to be successful and to account for the largest proportion of annual fuel cell shipments by unit, whereby, according to the US Department of Energy (DOE), total fuel cell shipments (i.e. including any application for fuel cell technology) increased in 2012 by 34% over 2011 and 321% over 2008. Sales of battery chargers and other similar portable applications have yet to take off, in part because the business case for these products vis-à-vis batteries remains unclear.
  - Among the list of commercially available portable and micro fuel cells in 2012, two European companies appear (namely myFC, Sweden, and SFC Energy, Germany) besides one from the US and one from Singapore.
  - Soldier wearable and portable power systems have already been largely developed in the defence sector, thus this application may significantly benefit from technologies already developed in the defence field.
  - Source: Breakthrough Technologies Institute Inc. for DOE, 2012 Fuel Cell Technologies Market Report, October 2013
- ***Results of patents scenario analysis:***
  - 14 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - No significant patent-related figures can be reported in this field

E.4.3: Systems for hydrogen storage for fuel cells transport as well as portable and consumer applications

Scope:

To develop systems for hydrogen storage for fuel cells transport as well as portable and consumer applications (e.g. hydrogen cylinders, metal-hydride tanks, chemical-hydride tanks, methanol cartridges (for direct methanol fuel cells, DMFCs).

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

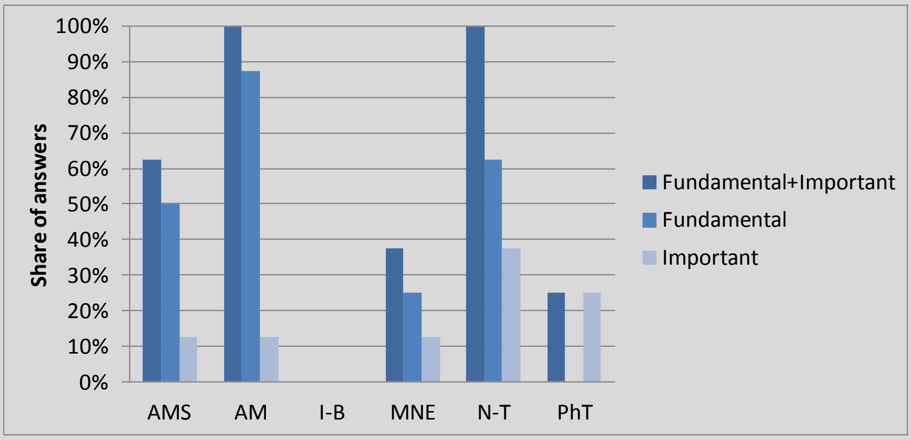
- Development of safe and effective reversible and non-reversible hydrogen storage solutions for portable applications (non-reversible chemical storage, compressed hydrogen, metal hydrides): components, infrastructures, supply management
- Investigation of methanol as an high energy density (compared to hydrogen) energy carrier (e.g. for portable direct methanol fuel cells (DMFCs) applications)
- Developments in basic research for safe, reliable and cost effective hydrogen storage and distribution: new materials for hydrogen storage and storage containers (e.g. alanates, aminoboranes, porous materials, high surface materials): investigation of failure mechanisms including through modelling; development of standardized material screening and testing procedures, understanding of absorption and adsorption mechanisms
- Development of cost-efficient manufacturing

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of safe, reliable and cost-effective reversible and non-reversible hydrogen storage solutions for transport and portable applications, encompassing components, infrastructures, and supply/distribution management. The integration of KETs could particularly contribute to the development of new materials for hydrogen storage and storage containers, and to the development of integrated systems, including electronic equipment and components for the reliable and safe management of the supply/distribution. The integration of KETs could finally contribute to render manufacturing of storage systems and equipment more cost-efficient.

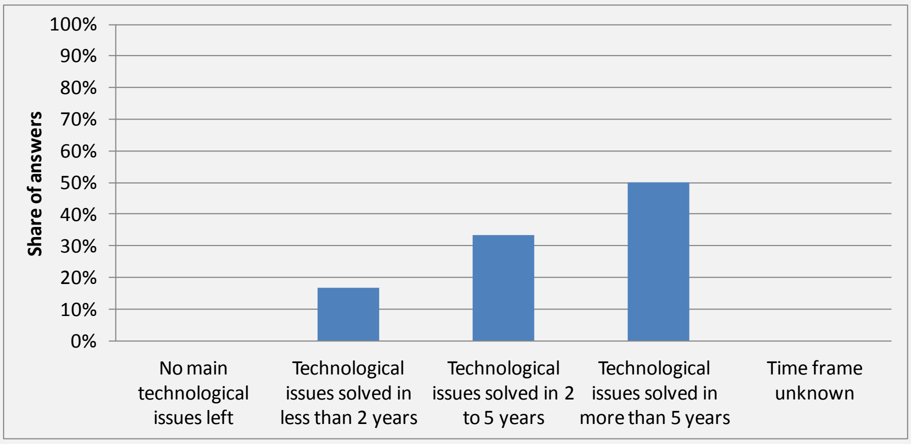
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Advanced Manufacturing Systems (AMS)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus indicates also shorter periods being necessary, which depends from the type of storage solution being considered:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

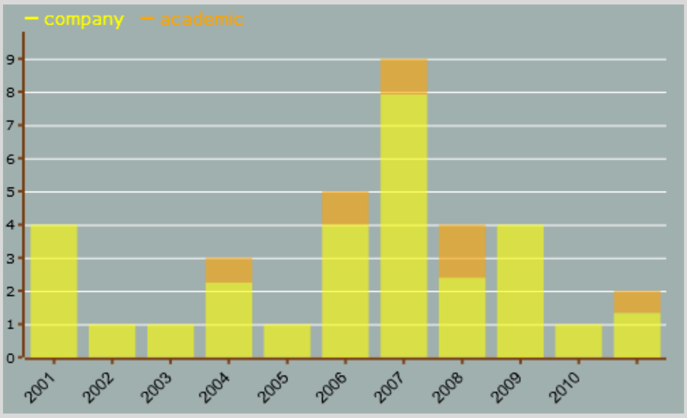
➢ ***Impact assessment:***

- Along with fuel cell systems, hydrogen storage systems need to be deployed in order to provide for fuelling of the fuel cells. Applications and markets for hydrogen storage technologies therefore strictly relate to the fuel cell technology applications and markets. At the same instance, systems for the generation of hydrogen need to be deployed as well in order to feed storage capacity (with except from the case of non-reversible chemical storage).

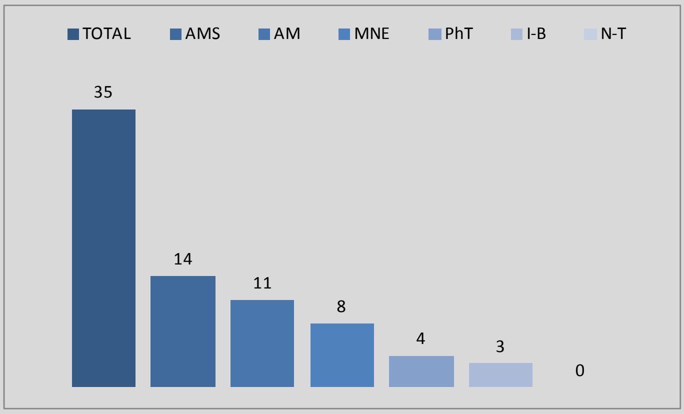
- While the focus for hydrogen generation technologies' development is on enabling renewable energy to be exploited for the purpose of producing hydrogen, the focus for hydrogen storage technologies' development is instead enabling the highest volume of hydrogen to be stored at the lowest weight while guaranteeing safety as well as a high number of charging and discharging cycles in the case of reversible hydrogen storage solutions (which are the focus especially in the transportation market segment). Within this framework, hydrogen storage technologies that have near-term potential to be readily available, reliable, and capable of satisfying the demanding operation environment are necessary for market acceptance.
- While compressed hydrogen tanks are the most common hydrogen storage technology implemented and capable of satisfying many of the performance needs for early markets, there is potential for performance gains by developing alternative hydrogen storage technologies for the future.
- In the defence sector, hydrogen storage technologies have been used and developed. In order to support the building and operation of systems that integrate multiple fuel cell and hydrogen technologies to demonstrate and enhance their long-term potential. This background knowledge would be useful for potential dual use applications in the civilian field.
- Source: NREL Technical Report, Hydrogen Storage Needs for Early Motive Fuel Cell Markets, November 2012

➢ ***Results of patents scenario analysis:***

- 35 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Scattered trend curve (number of patents per year)
- Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants, most probably standing for new technologies having been patented in the corresponding periods:



- Patents by KET(s):

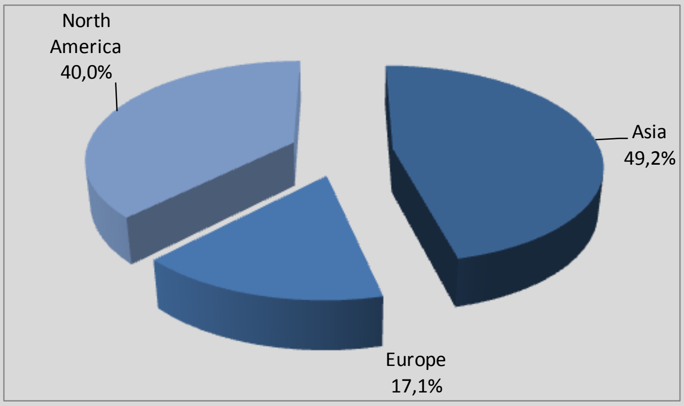


- Patents by KET(s) and relevant combinations of KETs:

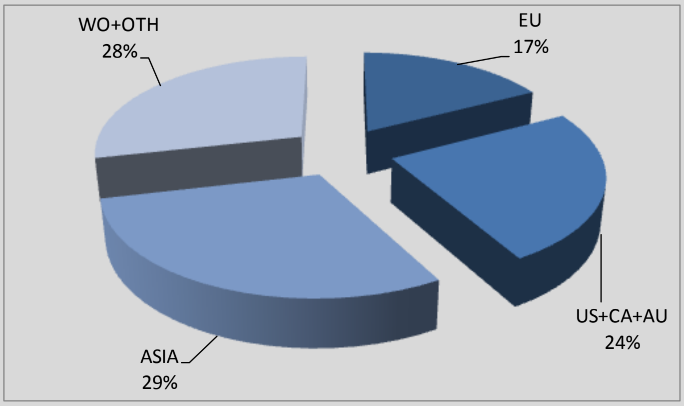
KET(s)	*Number of patents*
AM	11
AMS	14
AMS / AM	1

IBT	3
MNE	8
MNE / PhT	4
PhT	4

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



POTENTIAL AREAS OF INDUSTRIAL INTEREST RELEVANT FOR CROSS-CUTTING KETS IN THE TRANSPORT AND MOBILITY DOMAIN

Sub-domain: More sustainable and green vehicles

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "Smart, green and integrated transport" societal challenge
- Contribute to the achievement of the EU Transport 2050 strategy (COM/2011/0144 final) objective of a 60% reduction of CO_2 emissions from transports, at least 40% for shipping
- Support the Smart Vehicle initiative of the i2010 strategic framework on the innovation society (COM(2005) 229 final)
- Continuously enhance safety, resistance/resilience and security of vehicle operation all along end-to-end transport chains
- Increase recyclability of vehicles and systems and resource efficiency in the manufacturing processes and reduce dependency to rare or foreign controlled materials and components (as per the Raw Materials Initiative (COM(2008)699) and numerous waste management regulations)

Demand-side requirements (stemming from market needs) addressed:

- Reduce vehicle operation costs, including through increasing energy efficiency and reducing final vehicle energy bill, but also through optimising overall vehicle lifecycle cost of ownership, including maintenance, repair and overhaul
- Reduce or maintain numbers and rates of accidents in Europe at an acceptable number, whatever traffic growth
- Enable new transportation services dealing with changing mobility and transportation needs, changing trade patterns as well as citizen and logistic chains request for affordable, timely, comfortable, seamless and ubiquitous transport services
- Enable time to market reduction and production ramp up / adaptation so as to cope with European and global market requests on new vehicle supply

T.1.1: Advanced on board energy generation or recovery

Scope:

To develop systems and solutions for the generation or recovery of energy on board vehicles, from internal (motion, heat) as well as ambient sources (solar, wind, etc.) in order to improve the overall energy consumption of the vehicle and power embedded systems.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

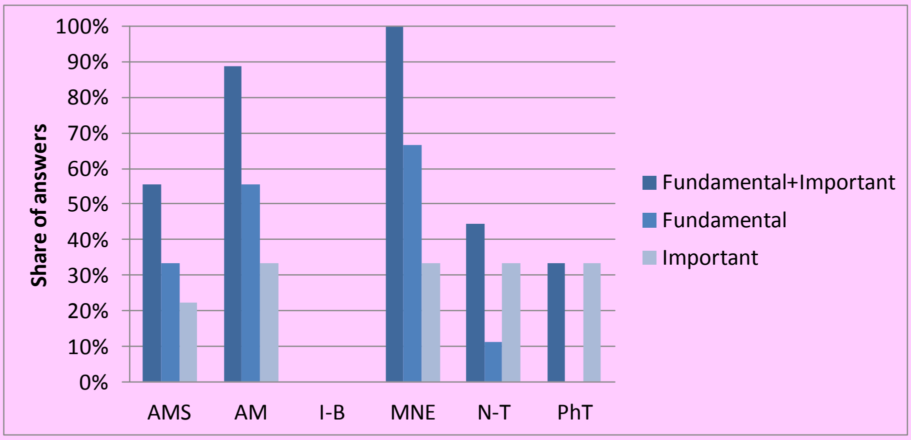
- Development of solar modules of high energy efficiency, light-weight, easy to integrate and resistant to harsh operational conditions, able to remain in operation all along vehicle campaign life
- Integration of advanced kinetic and breaking energy recovery means and energy storage or power generation means
- Development of long-life low volume low weight capacitors and other power electronics
- Development of efficient embedded heat exchangers, thermo-electric generators and integrated heat-to-power systems taking advantage of all vehicle heat losses for generating power
- Investigation of the interest for regenerative fuel cells for power generation
- Enabling of optimal on board power management taking advantage of various power sources

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced solutions for the generation or recovery of energy on board vehicles, both from internal (e.g. motion, heat) and ambient sources (e.g. sun, wind). Solutions may consider advanced kinetic and breaking energy recovery and energy storage, thermo-electric generators and integrated heat-to-power systems, or, for example, (flexible) solar modules having high efficiency.

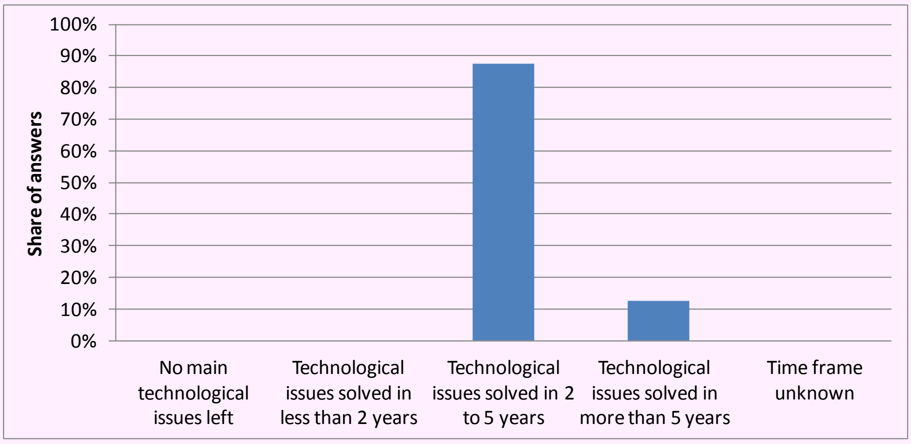
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Advanced Materials (AM)
- Advanced Manufacturing Systems (AMS)
- Nanotechnologies (N-T)
- Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:

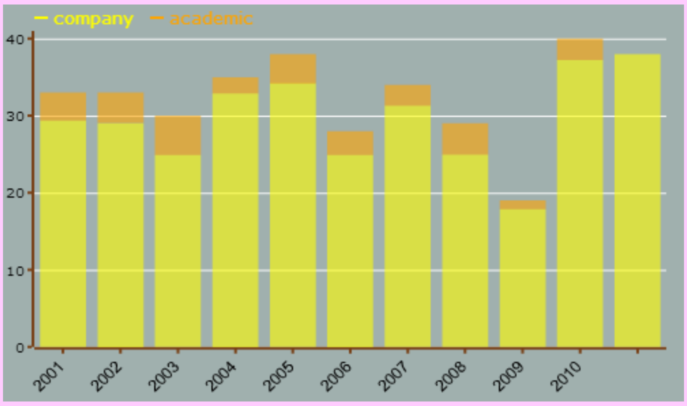


Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

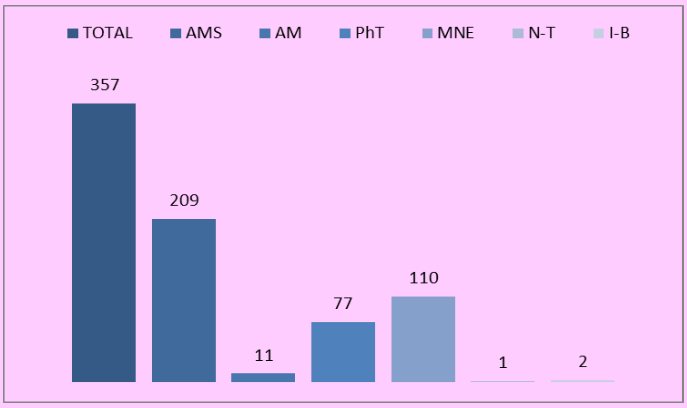
Additional information according to results of assessment:

- ***Impact assessment:***
  - On board energy generation or recovery systems have a key role to play into the new vehicle energy architectures, including urban e-Mobility, Green Cars, more electric or even all electric aircraft, electric boats.
  - The electronic components involved in such Innovation Field will be operated in constrained environments and will benefit from high quality, high-energy efficiency electronics technologies, taking place in the high added-value part of such market.
  - The space sector has a significant experience in vehicle autonomy optimisation and advanced on board power generation, recovery and management, enabling cross-cutting opportunities on these technologies.
  - Considering its knowledge base on related topics, value chains and strengths in the transportation industries, Europe is in a position to be a major player in this Innovation Field, calling for actions on related KET and cross-cutting KET components.
  - In the patents scenario analysis, main applicants dominantly come from the automotive industry, mainly European and Japanese (top 10 patent applicants are Robert Bosch, Toyota, Michelin, Siemens, Honda, Nissan, Continental, Hitachi, Valeo, Pirelli).

- ***Results of patents scenario analysis:***
  - 357 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Stable trend curve (number of patents per year)
  - Highest share of industrial applicants:



  - Patents by KET(s):

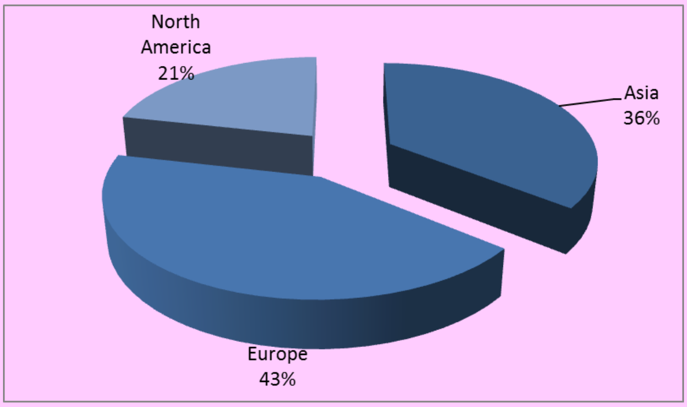


  - Patents by KET(s) and relevant combinations of KETs:

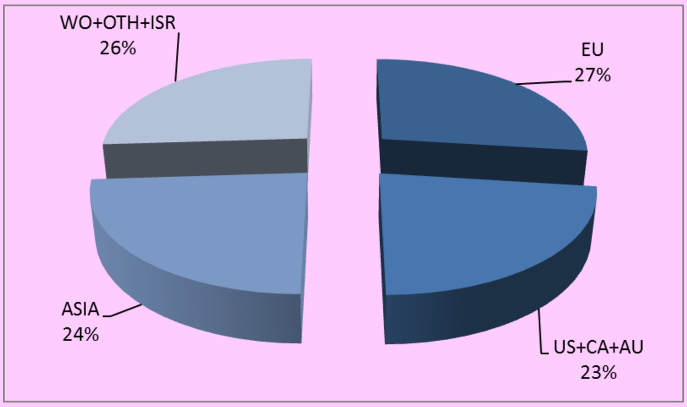
KET(s)	*Number of patents*
AM	11
AM / MNE	1
AM / PhT	1
AMS	209
AMS / MNE	15
AMS / MNE / PhT	2

AMS / PhT	5
IBT	2
MNE	110
MNE / N-T	1
MNE / PhT	32
N-T	1
PhT	77

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



T.1.2: Unmanned vehicle controls

Scope:

To develop complete vehicle control chains - including environment data acquisition and processing, choice of reaction strategy and related actuation - enabling high level capabilities for autonomous or remote controlled operations of all sorts of unmanned vehicles, including driverless trains, drones, autonomous cars, satellites, space probes, planetary exploration robots, etc.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of unmanned mobile platforms adapted to the different types of payloads/services, as flying, aerostatic, for rails or roads, off-road, for planetary exploration, for extreme conditions as near fires, etc.
- Development of payloads enabling civilian unmanned / automated services, as search and rescue, traffic observation, freight transportation, area surveillance, humanitarian demining, sport events filming, infrastructure inspection, phytosanitary products precision spreading, etc.
- Setup of system architectures and sensing/actuation subsystems supporting

autonomous or remote controlled operation

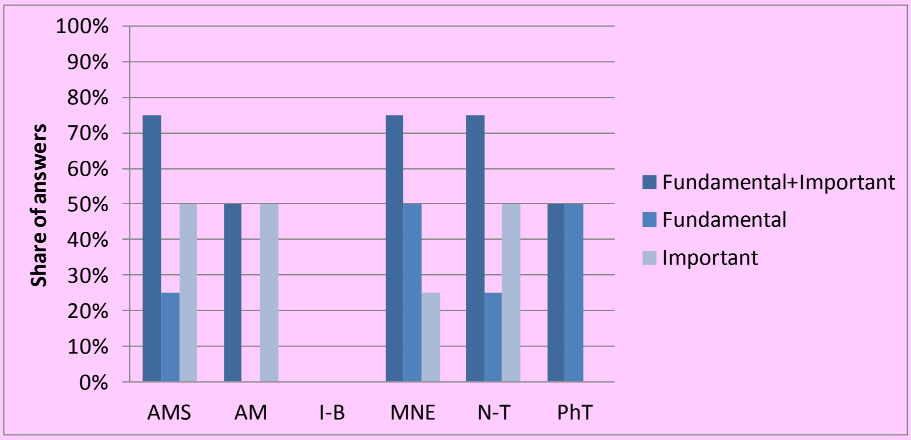
- For space missions necessitating the vehicle to come back on Earth, development of capsules (possibly re-usable) with deployable and / or inflatable heatshield, ablative or permanent, and aero-braking systems for safe atmosphere re-entry, and setup European capabilities for plasma shock testing
- Equipment of vehicles with accurate guidance systems for precision operation / parking / landing / docking, potentially at high speeds as in the case of space rendez-vous
- Enabling of long duration full operational autonomy of unmanned systems in case of control link spoofing, masking or other reason for being cut
- Development of lightweight automated features, including robotic arms / robotic systems for potentially complex activities (e.g. drillers and container sealing and handling systems for soil sample collection, excavation and handling capability for landmine removal, etc.)
- Setup of highly secure reliable low power data transmission, potentially for long distances and with high volumes of data to be transferred
- Development of sense & avoid navigation systems allowing safe unmanned vehicle insertion and control into normal traffic and human activities

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced complete vehicle control chains - including environment data acquisition and processing, choice of reaction strategy and related actuation - enabling high level capabilities for autonomous or remote controlled operations of all sorts of unmanned road, rail, flying and space vehicles, robots and drones, enabling civilian unmanned/automated services (as search and rescue, traffic observation, freight transportation, area surveillance, humanitarian demining, sport events filming, infrastructure inspection, phytosanitary products precision spreading, etc.).

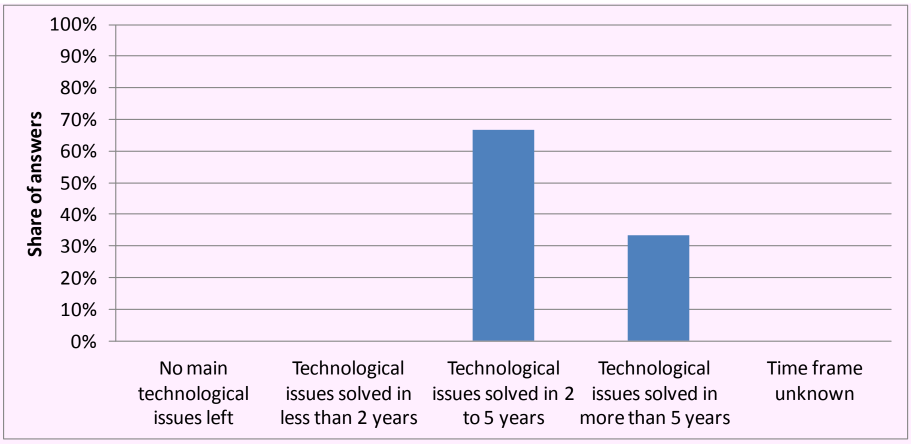
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Photonics (PhT)
- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

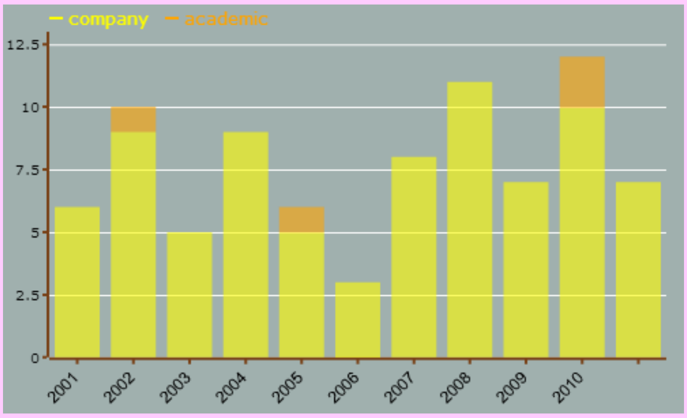
According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:



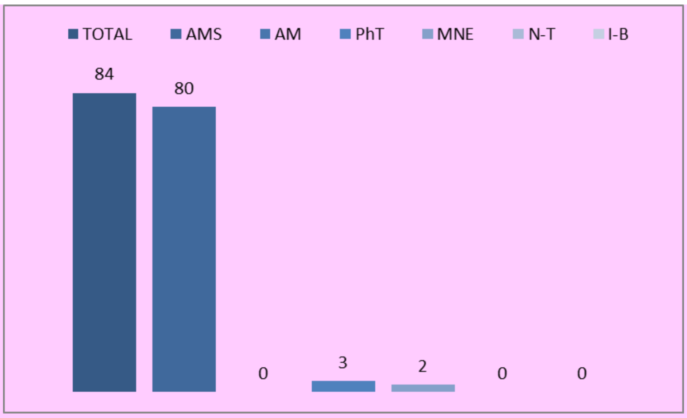
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Formerly military, drone technologies are now well recognized as inherently dual, and drone platforms being equipped with various sorts of sensing or communicating payloads are now well identified as key elements for innovative and cost-effective solutions in civil security, environment monitoring, scientific research, journalism and entertainment, meteorology.
  - Fully automated urban transport or space vehicles have been in operation for years, with resultant impact on operational costs, timeliness and safety. Further developments to apply vehicle control automation to vehicles evolving in more complex frameworks or under high responsibility conditions have the potential to bring similar progress.
  - Amongst possible applications: increasing car driver assistance gradually moving to full automation capability, single pilot passenger air transport, autonomous robots operating in severe environment or sharing workspace with other machines and humans in factories or warehouses, etc.
  - In addition to technology, the legal and regulatory framework is a major enabler or showstopper for development in this Innovation Field.
  - In the patents scenario analysis, the top 30 patent applicants show a large national diversity, with a large number of players from the USA, some from 6 European countries (Germany, Italy, France, Netherlands, UK, Sweden) but also from Japan, Russia, Israel, Canada, Korea.
- ***Results of patents scenario analysis:***
  - 84 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Unstable number of patents per year
  - Highest share of industrial applicants:



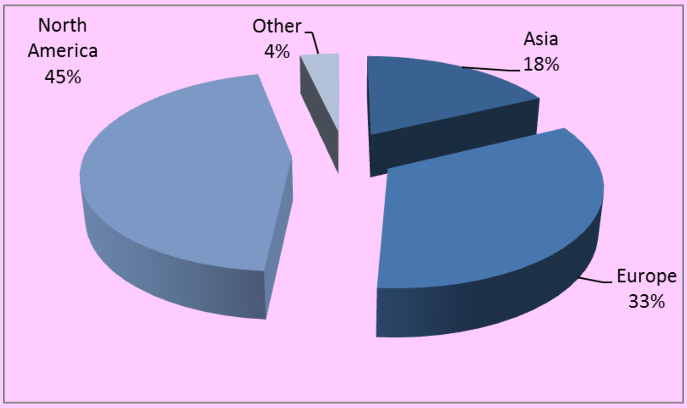
  - Patents by KET(s):



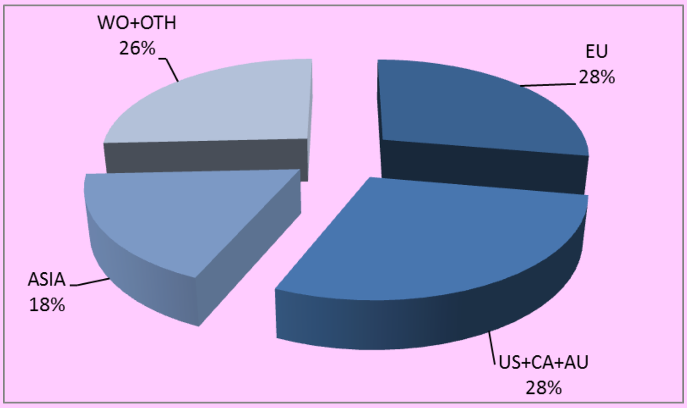
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AMS	80
AMS / MNE	1
MNE	2
PhT	3

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



T.1.3: Eco-efficient Maintenance, Repair and Overhaul (MRO) strategies and systems

Scope:

To design vehicles and systems for maintainability, including regular, condition-based, predictive and preventive maintenance, based on eco-efficient Maintenance, Repair and Overhaul (MRO) systems, as non-destructive testing, robotic maintenance or advanced retrofit strategies.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

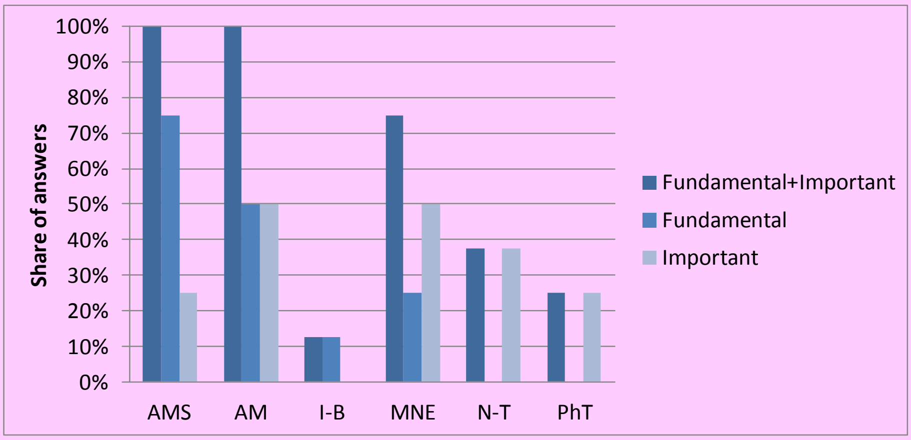
- Development of low-operational impact maintenance and upgrades processes (through advanced monitoring, diagnostic and prognostic for all relevant vehicle systems), including predictive maintenance and non-intrusive inspection capabilities
- Development of smart materials and/or sensor networks for on-line structural health monitoring & load or temperature control capabilities to support preventive and condition-based maintenance
- Development of vehicles and systems taking into account integrated life cycle management concerns, including usage modularity and focus on easy retrofit and refurbishment
- Development of advanced monitoring and prevention strategies for normal usage corrosion, wear and fatigue
- Development of mobile, self-guiding, self-referring robotic maintenance and repair modules
- Design of systems for maintainability, including self-healing, modular architectures and automatic reconfiguration capabilities in case of failure (for hardware and software)
- Improvement of non-destructive testing capabilities (time-saving, materials-saving, maintenance optimization)
- Implementation of repair strategies adapted to high cost / high environmental impact elements

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of condition-based, predictive and preventive maintenance strategies based on solutions such as smart materials, sensor networks for on-line monitoring of structural health, load, temperature, corrosion, wear and fatigue, or self-guiding, self-referring robotic maintenance and repair modules. Solutions may also include self-healing architectures that would automatically reconfigure in case of failure (for hardware and software).

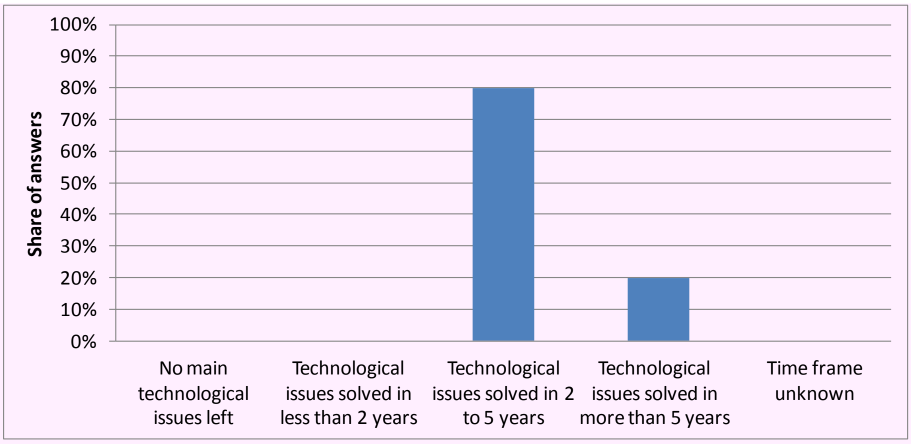
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)



Timing for implementation:

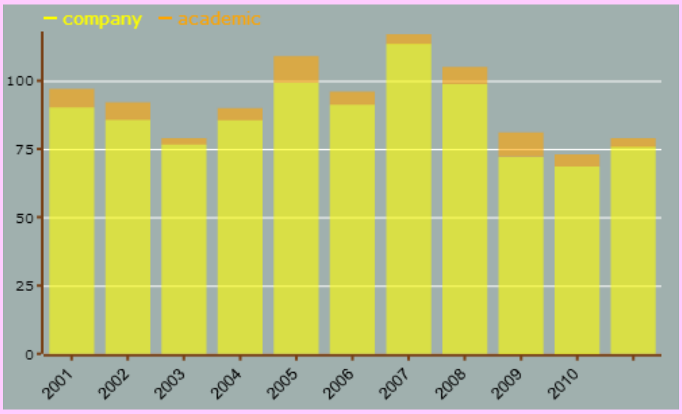
According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



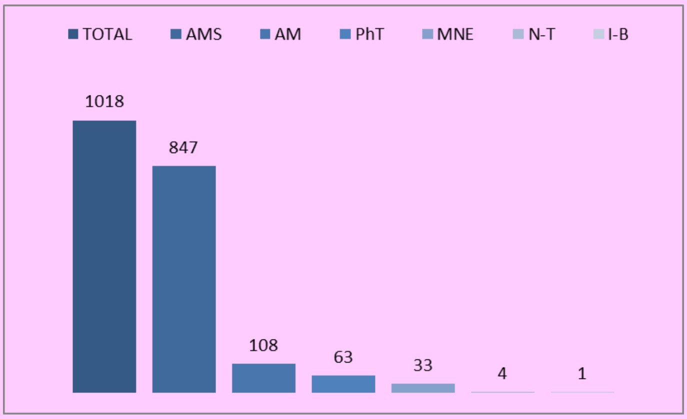
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Considering vehicles' campaign life, the impact of a vehicle being stopped in a fleet and the special care needed for ensuring passenger and crew safety, maintenance costs usually account for a significant part of overall ownership costs. Improving vehicle maintainability or maintenance processes can support a major progress in competitiveness of transport services.
  - Major approaches for improving maintenance are in health monitoring, non-destructive testing, predictive and preventive maintenance, self-healing structures, all solutions with a potential benefit to be expected from KET technologies.
  - Traditional maintenance operations use much chemicals, produce much scrap and waste, and expend significant amounts of energy. New processes and strategies have a real potential for environmental impact minimization.
  - The defence sector reached a high level of performance in Maintenance, Repair and Overhaul (MRO) in the past years, which had an important effect on the availability of the equipment: in many armed forces, one-third to half of the total capability of key assets is out of action for maintenance at any time. Furthermore, Maintenance, Repair and Overhaul (MRO) accounts for more than 10% of the total defence budget and as much as 70% of all aircraft related costs. This shows how the level of knowledge in this field in the defence sector has reached a high standard which could therefore be applied into the civil segment, thus showing its duality.
- ***Results of patents scenario analysis:***
  - 1018 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Stable trend curve (number of patents per year)
  - Highest share of industrial applicants, with main applicants being mainly from large aerospace or automotive industries, illustrating the technological advance of these sectors compared to other transport sectors:



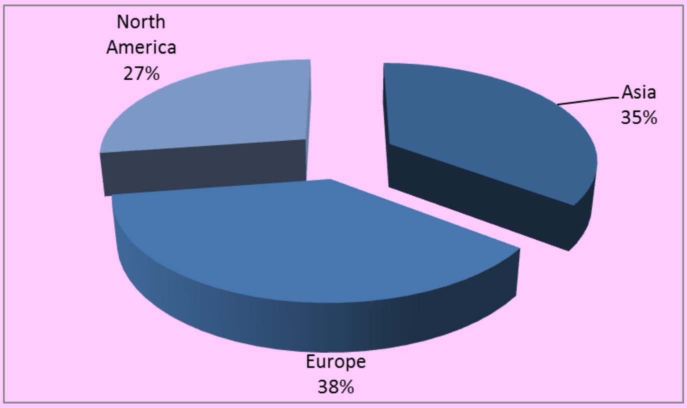
- Patents by KET(s):



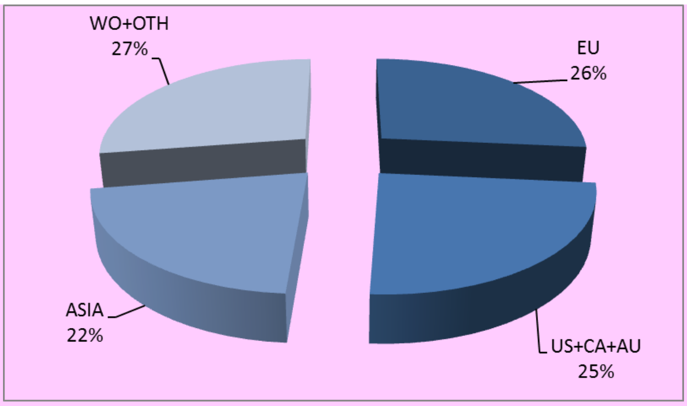
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	108
AM / N-T	2
AM / PhT	5
AMS	847
AMS / AM	6
AMS / AM / N-T	1
AMS / MNE	9
AMS / MNE / PhT	3
AMS / N-T	1
AMS / PhT	6
IBT	1
MNE	33
MNE / N-T	2
MNE / PhT	11
N-T	4
PhT	63

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



- Europe is ahead in the patent race, as the 1st region of origin of applicants as well as a priority region of protection. Asia – mainly Japan – and the USA are nevertheless not so far behind. This is visible also through main applicants' list, Japan and Germany coming first, then USA and France.

T.1.4: Advanced vehicle structures

Scope:

To develop vehicle structures – such as car chassis, aircraft airframes, ship hulls, train or satellite platforms, rocket fuselages, etc. - that are light-weight, crashworthy and wear/fatigue resistant (e.g. single-piece or rivet-less complex shapes), eventually functionalized, coated or otherwise treated for improved properties, and produced with minimal use of materials and chemicals, recyclable and cost-effective.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

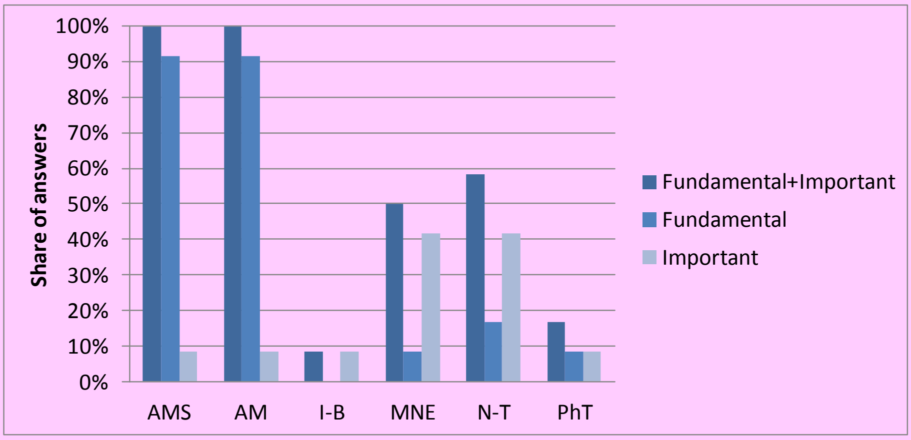
- Development of low density resistant, reinforced, resilient (against fatigue, corrosion, incidents, attacks, etc.), shock absorbent and/or even self-healing / self-repairing materials (as fibre reinforced composites, ceramic/metal composites, advanced metallic alloys, etc.), including to allow operations in most severe conditions
- Understanding and modelling of structural fatigue of materials depending on operational constraints as vibrations, temperature, radiation levels, etc.
- Use of low energy and material consumption manufacturing processes, including re-use of manufacturing process energy (e.g. through heat exchangers), additive manufacturing, re-use of machine chips
- Develop one-piece / net-to-shape / molecular connection / advanced wielding manufacturing techniques for complex shapes (to limit joints, scraps and machining)
- Pre-shaping of high-value raw materials to reduce manufacturing operations, costs and waste and reduce supply constraints on structural designs
- Fill in of structural parts with functional properties (electrical or thermal conductivity, vibration dampening, radiation shielding, stealth, lightning protection, anti-icing, aesthetics, friction or shock resilience, emissivity, etc.), possibly with functional coatings
- Increased production ramp up capability (through out-of-autoclave and other manufacturing means)
- Enabling of high quality low cost mass production and ramp up, possibly including with mass-customization capabilities
- Consideration of lifecycle from design, including fatigue, wear, maintenance, repair and end of life
- Ensuring of compliance of materials used with REACH, RoHS and any other regulation on toxic, environmentally damaging, rare or critical for any other reason materials

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced vehicle structures building on multifunctional, resilient and self-healing/self-repairing materials and coatings to allow operations in most severe conditions, along with low energy/resource consumption manufacturing processes to reduce manufacturing operations, costs and waste.

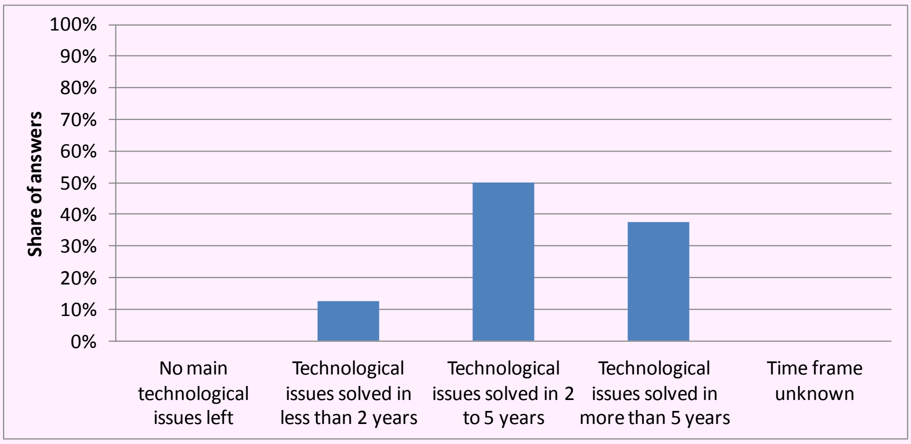
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

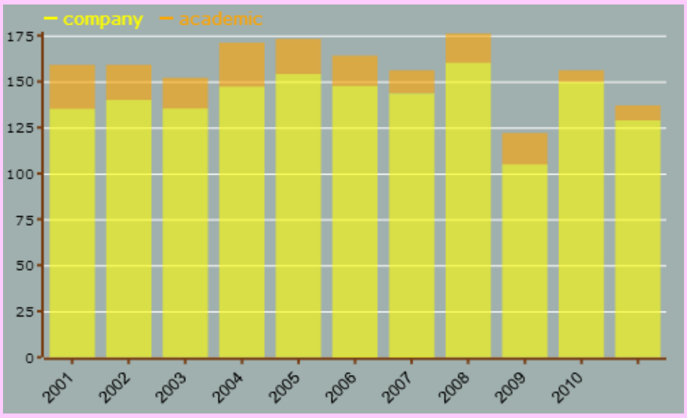
➢ ***Impact assessment:***

- Composites were first introduced into aerospace vehicles for weight reduction, with a direct link to energy efficiency. There is still a significant potential on this aspect, in all forms of transport, and this is considered as double environmental interest since most composites use carbon structures, potentially created from waste carbon rejects.

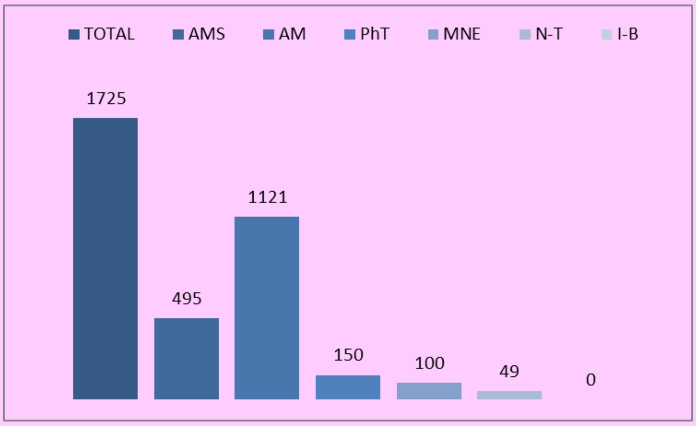
- However the composite revolution is not just about weight and carbon, but it also opens new ways of designing vehicle structures, developing the material in parallel with the structure, looking for the right properties and shapes for the exact functional need at a given place in the overall vehicle design. This finally goes beyond composites and renews the approach for looking at more traditional steel or aluminium alloys (which benefit from nanoscience or new processes as net shape manufacturing, advanced joining/welding surface treatments and coatings).
- Taking best advantage of composites or metal alloys, eventually integrating micro-devices or functionalization capabilities is nevertheless not always straightforward and strong efforts are needed to make sure new vehicle structures do not create safety issues (including with ageing), services offered by traditional materials (as Faraday cage effect of metal structures protecting against thunderbolt) are otherwise compensated and production capabilities in supply chains are able for ramp up when needed (consider Boeing 777 difficulties with composites supply, with volumes far from what would be needed by the automotive industry).
- Systematic deployment of advanced vehicle structures means that quite traditional steel and aluminium industries have to adapt to a brand new world, and be partially replaced by new supply chains still not completely operational at sufficient scale. This is of high potential impact on European industry.

➢ ***Results of patents scenario analysis:***

- 1725 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Stable trend curve (number of patents per year)
- Highest share of industrial applicants, with the top 30 patent applicants being especially shared between large industries from Japan, Germany and France and (to a lesser extent) USA. These players are all large industries, either vehicle OEMs (Boeing, Airbus, Honda, Toyota, GE, Siemens, Daimler, etc.) or more chemistry and materials players (Bridgestone, BASF, Michelin, Bayer, Saint Gobain, Nippon Steel, Arkema, etc.).



- Patents by KET(s):

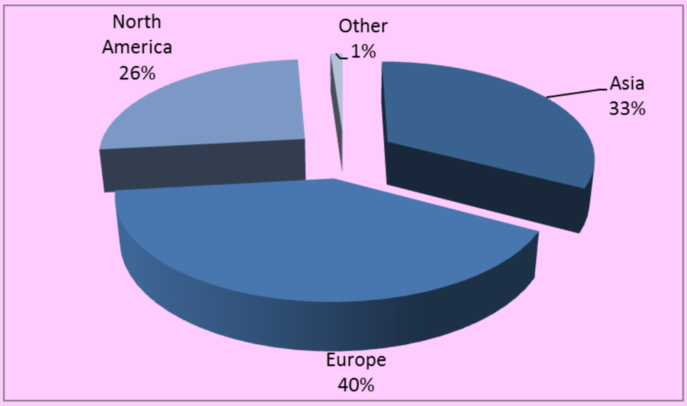


- Patents by KET(s) and relevant combinations of KETs:

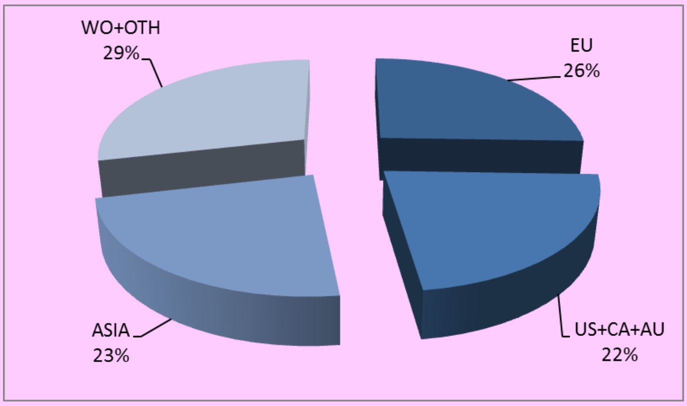
KET(s)	*Number of patents*
AM	1121

AM / MNE	22
AM / MNE / N-T	4
AM / MNE / PhT	7
AM / N-T	44
AM / N-T / PhT	7
AM / PhT	29
AMS	495
AMS / AM	41
AMS / AM / MNE	4
AMS / AM / MNE / N-T	2
AMS / AM / MNE / PhT	1
AMS / AM / N-T	4
AMS / AM / PhT	1
AMS / MNE	17
AMS / MNE / N-T	2
AMS / MNE / PhT	4
AMS / N-T	4
AMS / PhT	8
MNE	100
MNE / N-T	5
MNE / PhT	43
N-T	49
N-T / PhT	7
PhT	150

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



T.1.5: Vehicle embedded power and heat systems

Scope:

To develop more efficient embedded subsystems, utilities and power components that require less energy provision and entail less heat dissipation altogether, facilitating overall on-board energy management and making it possible to address most demanding needs as electric propulsion or broadband communications.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

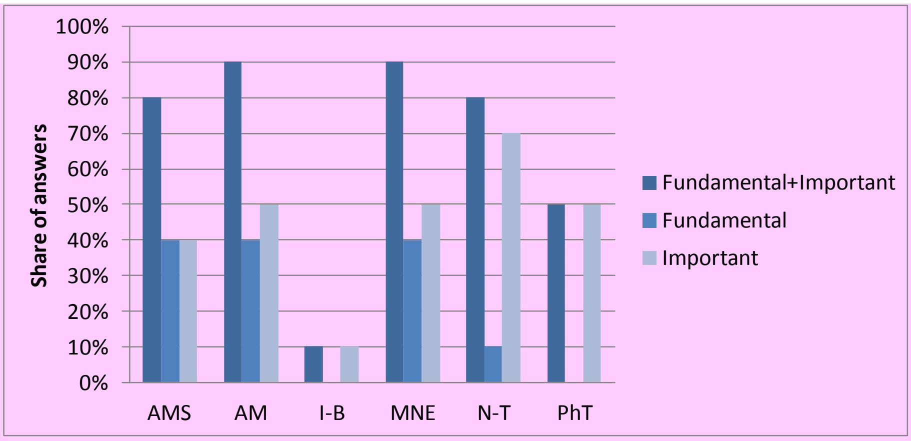
- Replacement of on board mechanic / hydraulic / pneumatic energy transfers by more energy-efficient / lighter / smaller / more robust electric utilities
- Development of low consumption lighting, heating, air renewing/filtering/conditioning, de-icing, etc.
- Increase of the power density of embedded energy storage systems, in particular batteries and low power super capacitors, whilst mastering lifetime and resilience to severe operational conditions
- Development of high efficiency light and low heat dissipation power conversion capabilities (power electronics), including with low required peak power, i.e. lower mass
- Development of cabling superconductivity
- Optimization of on-board power management and architecture, including between on-board power generation, energy storage, propulsion and non-propulsive electric subsystems
- Extension of voltage operational range of embedded power electronics and electrical systems, in particular for supporting electrical propulsion or high performance telecommunication payloads
- Perform efficient thermal management, including with high efficiency heat pipes, advanced radiating structures and other cooling systems
- Enhancement of thermal rejection for high energy missions (as telecommunication) with the help of advanced deployable radiators or other fluidic and mechanical solutions
- Development of energy recovery capability (from braking, waste-heat, suspension, environment energy harvesting), including thermo-electricity solutions for reliable and cost-effective reversible generation of cold or power

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more efficient vehicle-embedded power and heat subsystems, utilities and components, including solutions such as high-efficiency, light-weight and low-heat dissipation power electronics, superconductive cabling, energy recovery systems along with efficient thermal management approaches, including thermo-electricity solutions for reliable and cost-effective reversible generation of cold or power.

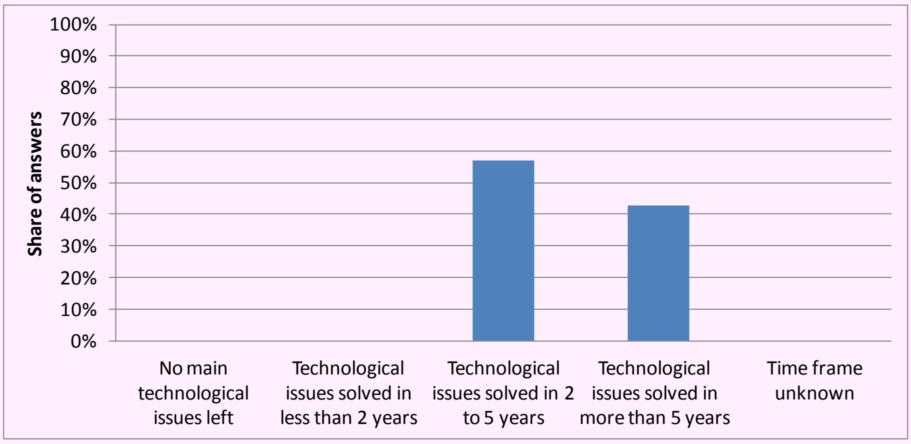
To this aim, the combination of KETs experts’ opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

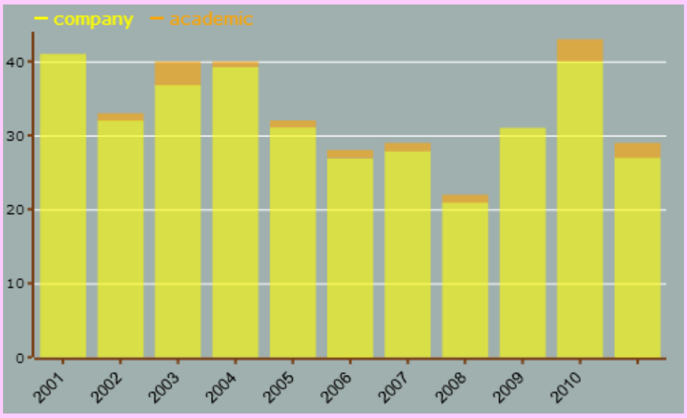
- ***Impact assessment:***
  - Vehicles are getting more and more electric, not only for propulsion but for all sorts of subsystems. An efficient power management in all on board subsystems is therefore a growing contributor to the overall vehicle energy efficiency. *An example of the gains was given in aeronautics by FP5 POA and FP6 MOET projects around the "More electric aircraft" concept, with potential progress from improving power systems demonstrated on direct energy consumption, power systems weight and maintenance costs reduction, better designs enabling lesser unexpected events.*
  - Heat, mainly produced by the propulsion systems, has for long been considered as an undesirable spoiler to be dissipated. Knowledge and technologies, especially supported by advanced simulation means, are now enabling to see it as a resource to be valued, or at least optimally managed. In the automotive sector, the Exhaust Gas Reinjection (EGR) systems in combustion engines are a good example on how a better management of heat can participate to the overall consumption reduction.
  - With the development of KETs-based solutions as advanced heat exchanger materials, thermoelectricity and power electronics, a holistic approach of on board energy management is at hand for contributing to continued improvement of on board energy-consuming services while keeping energy consumption on a decreasing trend.
  - Space (advanced energy management for maximum satellite autonomy) and military (e.g. heat signature control) have synergies to be explored with civil applications in this

Innovation Field.

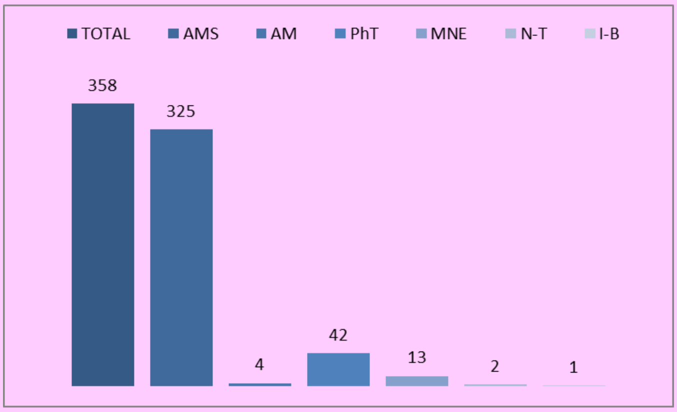
- Embedded systems must perform many different tasks to support war- fighters, and as technology advances the power consumption increases, leading to greater excess heat and a higher demand for systems that can control their power use. On this regard, the significant knowledge of such systems developed for the defence sector may be transferred to civilian applications where systems designers struggle with ever-increasing computing power and the intense levels of heat, and look for innovative ways to cool systems without compromising performance.

➢ ***Results of patents scenario analysis:***

- 358 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Quite stable trend curve (number of patents per year)
- Highest share of industrial applicants, with many of the main applicants coming from the German automotive industry, a significant number from the Japanese industry, then from large aeronautical firms:



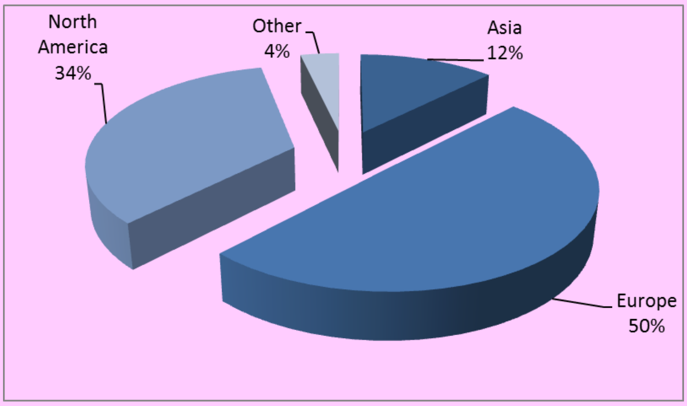
- Patents by KET(s):



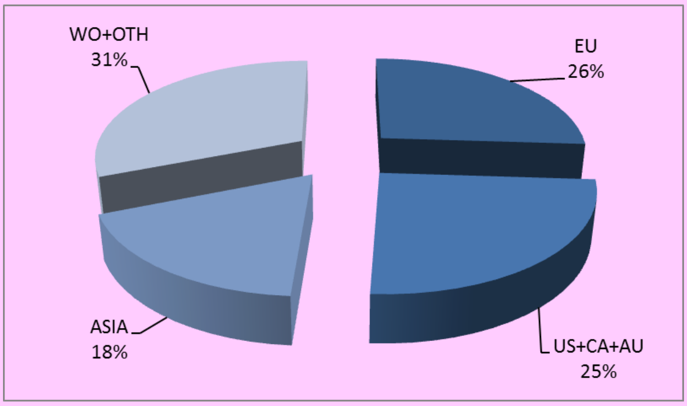
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	4
AM / N-T	2
AMS	325
AMS / MNE	3
AMS / MNE / PhT	1
AMS / PhT	4
IBT	1
MNE	13
MNE / PhT	11
N-T	2
PhT	42

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



Sub-domain: Greener combustion-based vehicle propulsion

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "Smart, green and integrated transport" societal challenge
- Contribute to the achievement of the 10% minimum Member States target for the share of biofuels in liquid fuel consumption in transport in 2020, to be introduced in a cost-effective way (Renewable Energy Directive (2009/28/EC))
- Contribute to the achievement of the EU Transport 2050 strategy (COM/2011/0144 final) objectives of no more conventionally-fuelled cars in cities, 60% reduction of CO_2 emissions from transports, 40% use of sustainable low carbon fuels in aviation and at least 40% cut in shipping emissions
- Reduce emissions of soot, particles, NOx and other harmful residues of combustion
- Reduce individual vehicle noise emission levels as well as traffic noise and vibration footprints around transport axis (highways, airport climb and descent paths, railways, etc.) and transport nodes (airports, harbours, stations, freight loading/unloading facilities, etc.)

Demand-side requirements (stemming from market needs) addressed:

- Reduce dependency on hydrocarbon-based propulsion, subject to a long-term price increase tendency, and related operational costs
- Enable short-term transport greening without waiting for full scale mature and financeable revolutionary propulsion means, making best use of retrofit and improvement capabilities of existing fleets of vehicles and vehicle production capabilities
- Lower local constraints and resistances on infrastructure operation or new construction projects

T.2.1: Low emissions (and noise) vehicle powertrain

Scope:

To develop combustion powertrains taking into account fuel feeding and real operational conditions so as to reduce energy consumption and pollutants emissions, taking advantage of advanced simulation means to optimize combustion conditions, engine architecture and control loops, powertrain subsidiary components, lubrication and power transmission, vibration and noise energy losses.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

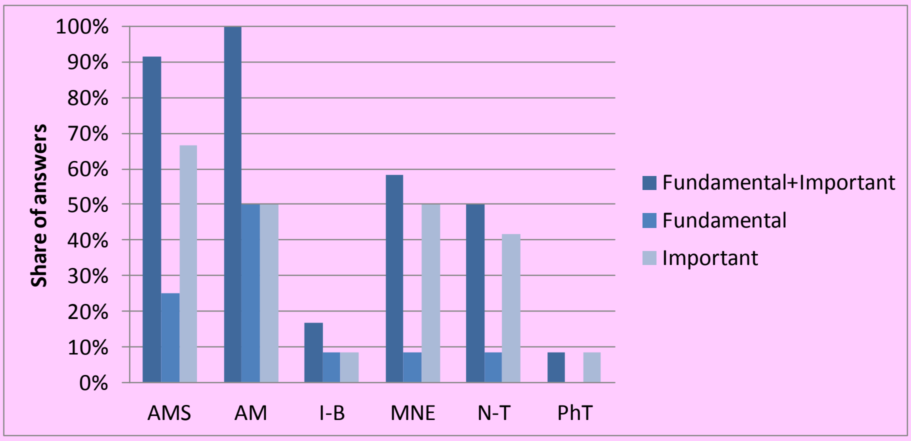
- Development of holistic approaches of vehicle powertrain design, optimizing altogether powertrain architecture, all individual components and fuel/propellant and lubricant formulation (including bio-fuels), so as to reduce fuel consumption, pollutant emissions (CO_2, NO_x, SO_x, particles, soot, volatiles, etc.), use of chemicals falling under REACH constraints (as hydrazine or xenon for space thrust), needs for maintenance and production costs.
- Development of high thermodynamic efficiency combustion engines (diesel/gasoline for road or sea transport, jet aircraft engines, rocket upper stage re-ignitable cryogenic propulsion, etc.), taking advantage of active architectures, advanced combustion management, extreme condition/constraint materials and coatings, advanced supercharging, etc.
- Development of and improve flex-fuel engines and enable mass-production and efficient distribution of best alternative fuels
- Optimization of engine combustion conditions, pressure and feed flows
- Development of non-intrusive (in-operation) measurement techniques, including optical techniques for pollutant characterization in combustion chamber
- Development of small volume engine architectures, enabling “downsizing”, i.e. weight and volume reduction of powertrains including packaging structures as nacelles, car hood, etc.
- Enable weight reduction of engine parts based on materials and/or manufacturing improvements
- Optimization of post-combustion gas treatment and exhaust thermal energy recovery, so as to optimize the catalytic reduction of metals and other pollutants and increase the overall powertrain efficiency, while using less precious catalytic metals
- Development of high power density, low vibration and low roller resistance gearboxes, transmission and associated lubrication
- Development/optimization of different concepts of compact, modular, lightweight and reasonable production cost hybrid powertrain solutions that optimize on board energy management and reduce overall energy consumption, including electrical power boost on core engine for transient and emergency operations
- Optimization of tyre and brake design so as to optimize safety while minimizing roller resistance and particle-emitting wear (including through co-improvements of asphalt surfaces and tyres)
- Continue maturing modelling and prediction tools (Computational Fluid Dynamics, evaporative emissions, fuel permeation, tribologic simulation, air/water cooling and heat exchange, aeroacoustics, combustion, rig testing, engine emission and fuel properties prediction and modelling tools, etc.)
- Development of active and advanced noise controls (including 3D nozzles, simulation based exhaust pipe design, noise dampers, optimized fans, morphing structures, liners, etc.)
- Enable energy recovery (waste heat, braking energy, etc.) and optimal reuse
- Design of engine intake, bypass and exhaust to reduce energy lost in noise

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced vehicle powertrain designs, benefitting of solutions such as high thermodynamic efficiency or flex-fuel combustion engines, taking advantage of active architectures, non-intrusive (in-operation) measurement techniques, advanced combustion management, extreme condition/constraint materials and coatings, advanced supercharging, and innovative post-combustion gas treatment and exhaust thermal energy recovery.

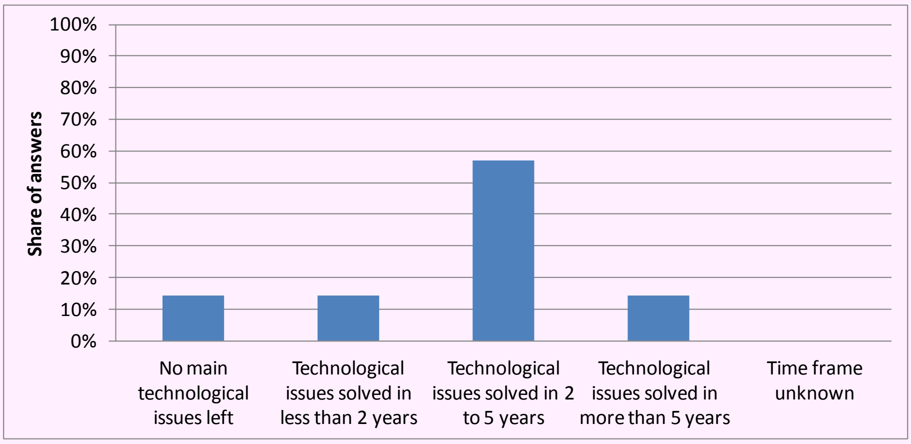
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

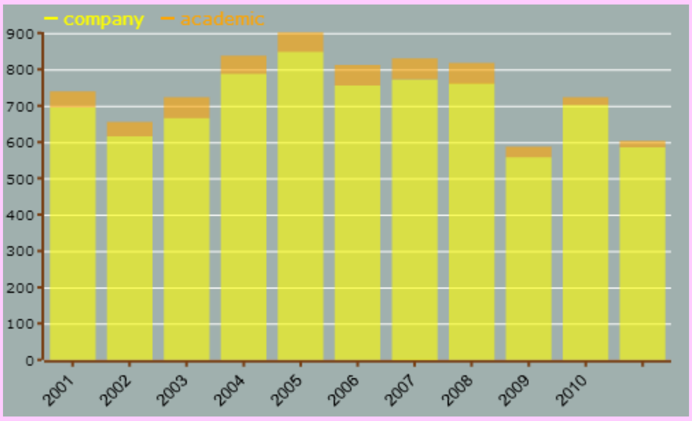
Additional information according to results of assessment:

- ***Impact assessment:***
  - Considering the size of vehicle series in the automotive sector, or the quantity of Jet A1 fuel burnt by an aircraft over its campaign life, a few % gained in fuel consumption can have already a dramatic impact on pollution and operational cost reductions. This requires however that the new powertrain technology is effectively adopted, which in this highly structures and constrained sector may be a challenge. The pilot line here really makes sense.
  - The need to consider this innovation field with a holistic approach is true also as regards interaction with green fuels, with cross-fertilization to be expected from progress in powertrain depending on best management of the combustion, fuel circulation in engines and surface effects at the points of contact of the fuel and engine internal surfaces.
  - A specific aspect relates to waterborne transport, since the historical distribution of petroleum cuts attributed the heaviest fuel oils, rich in sulphur and other dirty elements, to ship propulsion.
  - Progress in mastering engine combustion is not always straightforward and reducing CO_2 emissions may in some cases increase NOx or particles emissions, calling for a balance between objectives and/or regulations.
  - As regards noise, the best-known issues are the ones concerning immediate surroundings of railways or aircraft take-off and landing at airports, but the concern about urban ambient noise is growing and a smart individual or public urban transport is also a silent one.

- ***Results of patents scenario analysis:***

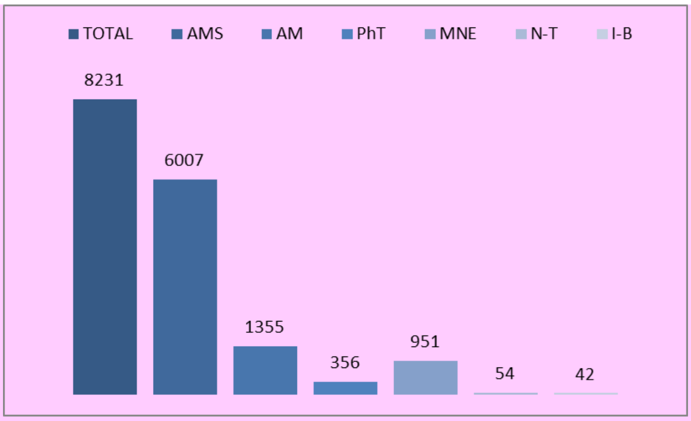
Many KETs-related patents apply to this innovation field (8231, 2% of all KETs-related patents identified in the period 2001-2011)

- Stable trend curve (number of patents per year), maybe slowly declining in most recent years
- Highest share of industrial applicants, with Applicants in the top 30 being first German, then American, Japanese or French engine manufacturers or first tier subcontractors, and half of the total 8231 patents being from European players, highlighting a strong and active European position in this field:



- The split of patents by KETs reveal a major interest for modernizing the production of vehicle powertrains.

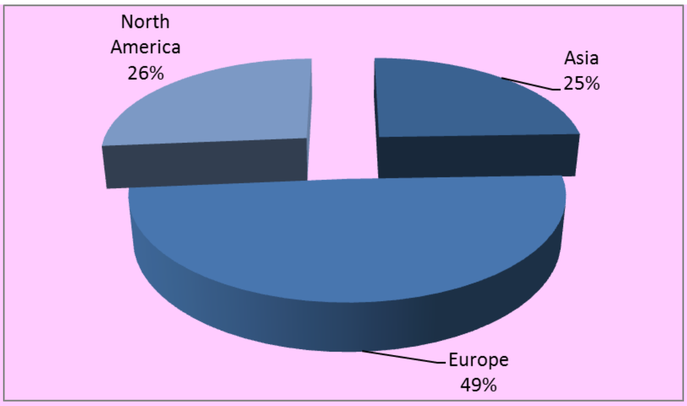
- Patents by KET(s):



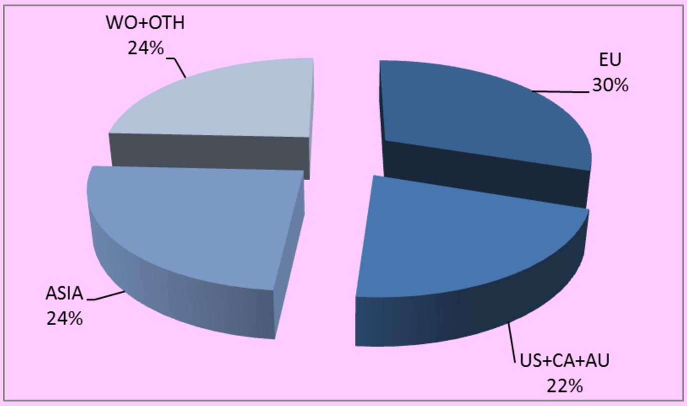
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	1355
AM / IBT	1
AM / MNE	38
AM / MNE / N-T	1
AM / MNE / PhT	2
AM / N-T	33
AM / N-T / PhT	1
AM / PhT	7
AMS	6007
AMS / AM	178
AMS / AM / MNE	1
AMS / IBT	1
AMS / MNE	95
AMS / MNE / N-T	2
AMS / MNE / PhT	24
AMS / N-T	4
AMS / PhT	79
IBT	42
IBT / MNE	1
IBT / MNE / PhT	1
IBT / PhT	1
MNE	951
MNE / N-T	11
MNE / PhT	116
N-T	54
N-T / PhT	1
PhT	356

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



T.2.2: Green fuels

Scope:

To develop cost-effective fuels from biomass and other sustainable resources that demonstrate sufficient energy density and satisfying operational characteristics while being producible at reasonable costs with clean highly energy-efficient processes.

Note: green fuels are addressed here within the "transport" point of view but may be dedicated to other usages (e.g. combustion for energy generation). See also the correlated Innovation Field in the Chemical Processes, Chemicals, Chemical Products and Materials Domain.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

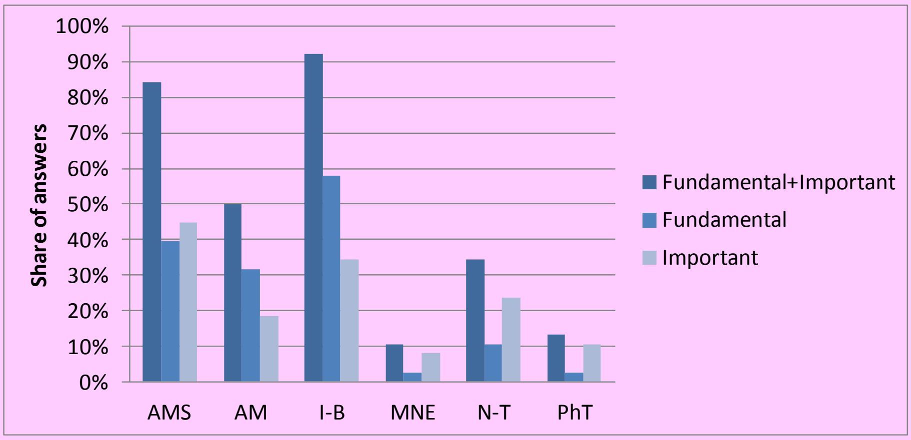
- Demonstration of biofuel or other alternative drop-in fuel for vehicle operation, including storage, engine injection, combustion and exhaust capabilities
- Development of holistic approaches of fuels, vehicle powertrain lubricants and all individual components, so as to reduce fuel consumption, pollutant emissions (CO_2, NO_x, SO_x, particles, soot, volatiles, etc.), use of chemicals falling under reach constraints (as hydrazine or xenon for space thrust), need for maintenance and production costs.
- Master characterization, quantification and modelling of non-volatile and volatile particles/pollutants/species from fuel combustion emissions (including chemical kinetics database for alternative fuels) so as to optimize fuel formulation for minimal emissions
- Setup of eco-efficient processes for cost-effective sustainable mass sourcing and production of optimal regulation compliant fuels from all forms of feedstock, including synthetic crude oils from bio sources, liquefied coal or gas, etc.
- Development of the usage of non-hydrocarbon energy sources for vehicles (electricity, hydrogen, compressed gases, sail support, etc.)

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced biofuels or other alternative drop-in fuels for vehicle operation, which should ensure optimal vehicle operation and be thus demonstrated as far as storage, engine injection, combustion and exhaust capabilities are concerned.

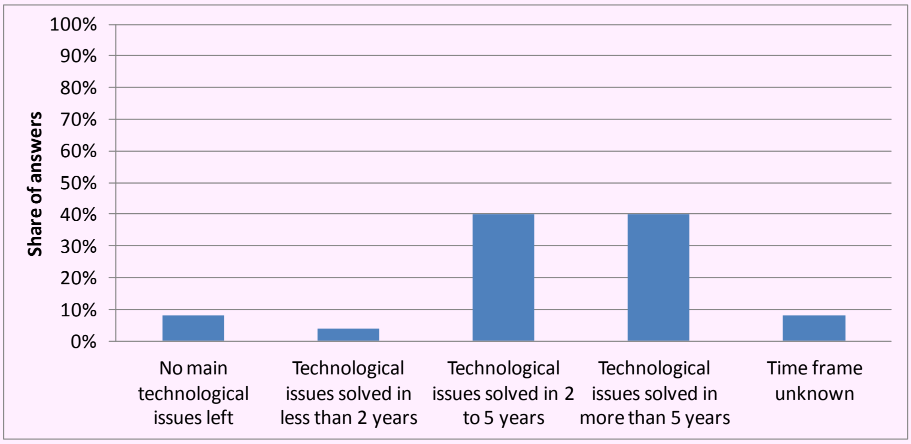
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Industrial Biotechnology (I-B)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of either 2 to 5 years or more than 5 years:

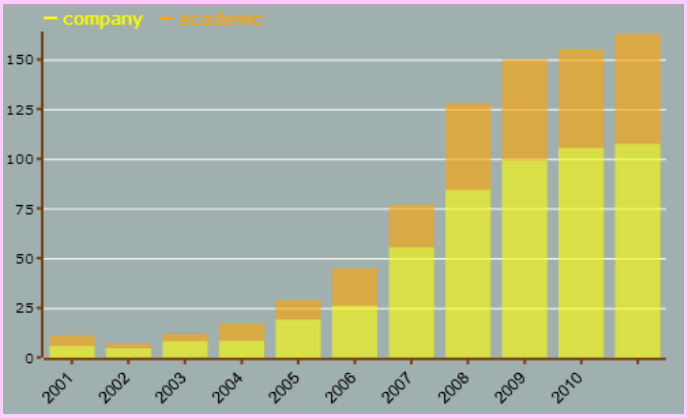


Depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, and considering also the strict correlation of this Innovation Field with its counterpart focused on the processes for the cost-efficient conversion of biomass to biofuels (that is addressed within the Chemical Processes, Chemicals, Chemical Products and Materials domain), the provision of support in the short term should be taken into consideration within this framework.

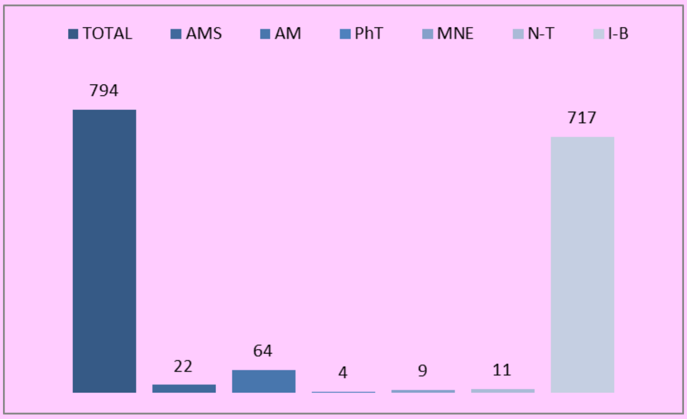
Additional information according to results of assessment:

- ***Impact assessment:***
  - "The future of EU transport development should be based on alternative, sustainable fuels as an integrated part of a more holistic approach to the transport sector. The Commission has therefore not proposed new targets for the transport sector after 2020 (current targets: 10% renewable energy for the transport sector. The share of renewables in transport rose to 4.7% in 2010 from 1.2% in 2005). Based on the lessons of the existing target and on the assessment of how to minimise indirect land-use change emissions, it is clear that first generation biofuels have a limited role in decarbonising the transport sector. A range of alternative renewable fuels and a mix of targeted policy measures building on the Transport White Paper are thus needed to address the challenges of the transport sector in a 2030 perspective and beyond" (Source: EC Communication on Climate and Energy Policy Framework 2020-2030, January 2014).
  - "The main drivers for the production and use of biofuels are the security and diversification of energy supply, reduction of oil imports and dependence on oil, rural development and the reduction of greenhouse gas (GHG) emissions." (Source: European Union Strategic Energy Technologies Information System (SETIS) website).

- ***Results of patents scenario analysis:***
  - 794 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Increasing trend curve (number of patents per year) with the paradigmatic shape of a technology on the move for reaching technological maturity:



  - Patents by KET(s):

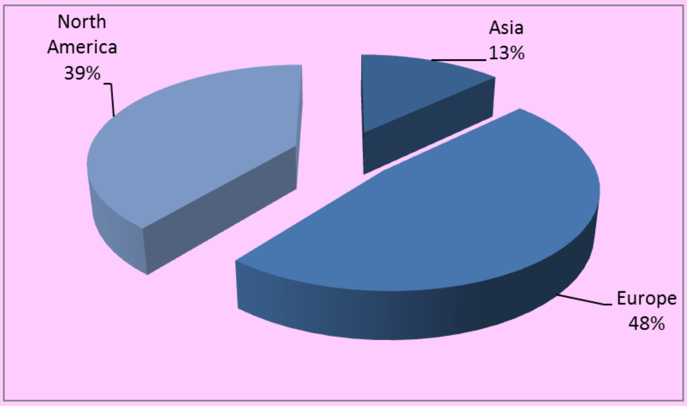


  - Patents by KET(s) and relevant combinations of KETs:

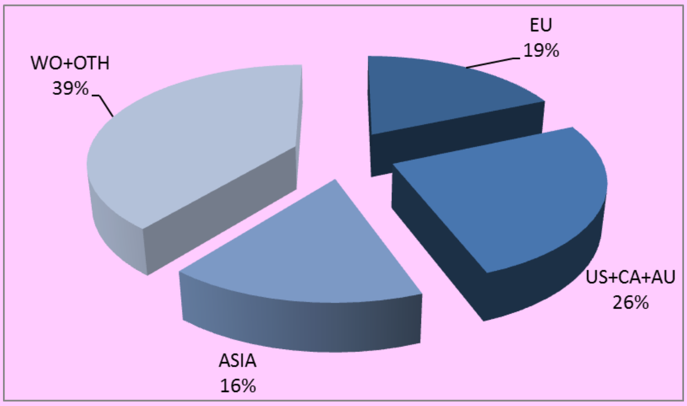
KET(s)	*Number of patents*
AM	64
AM / IBT	16
AM / IBT / N-T	1
AM / N-T	5
AMS	22

AMS / AM	1
AMS / IBT	3
IBT	717
IBT / N-T	4
MNE	9
MNE / N-T	1
MNE / PhT	4
N-T	11
PhT	4
AM	64
AM / IBT	16
AM / IBT / N-T	1
AM / N-T	5
AMS	22

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



Sub-domain: E-propulsion and wider e-mobility

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the “Smart, green and integrated transport” societal challenge
- Contribute to the achievement of the EU Transport 2050 strategy (COM/2011/0144 final) objectives of a 60% reduction of CO_2 emissions from transport and no more conventionally-fuelled cars in cities
- Achieve levels of renewable energy consumption within the European Union of 20% (as mandated by the Renewable Energy Directive (2009/28/EC)), considering use of renewable electricity in electric vehicles
- Ensure sufficient critical resource efficiency and recyclability so as to enable large scale

deployment of e-Mobility without creating shortages, dependencies or environmental issues (as per the Raw Materials Initiative (COM(2008)699))

- Bring a mobility and transport contribution to the smart grids and smart cities projects

Demand-side requirements (stemming from market needs) addressed:

- Support development of innovative, green, fluid, resilient and efficient end-to-end urban mobility solutions
- Enable new transportation services dealing with changing mobility and transportation needs, including ageing and citizen ability for making informed real-time mobility choices
- Make sure energy grids are able to deal with a shift towards e-Mobility, or even that transports are an active support of smart grids deployment
- Enable e-Mobility to act as a growth driver for the European transport industry in the global competition

T.3.1: Electric vehicle powertrain

Scope:

Even though at widely different levels of maturity depending of the category of vehicle (trams and trains, cars, ships, aircraft and even satellites with ion thrusters), electric propulsion is physically the most energy efficient way of moving vehicles, with a high potential for also for operation optimization. Around the electric vehicle powertrain, shared challenges appear on embedded energy storage and charging, on-board power management, overall cost-effectiveness, use of rare materials and all sorts of hybridization.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

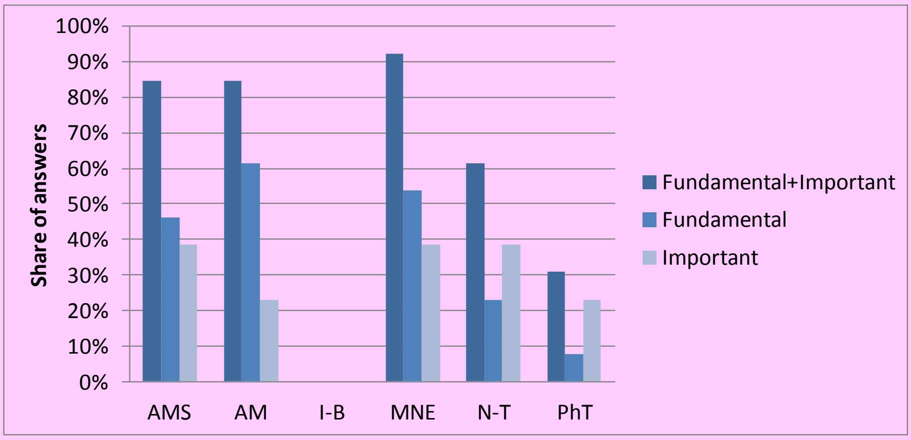
- Development of affordable high energy density, long lifetime embedded storage, mainly batteries, and the charging systems suited for each type of vehicle application
- Development of lightweight, compact and cost-effective electric engine and related embedded electrical equipment, including in case of hybrid propulsion
- Development of low consumption electric power components (power electronics, converters, engines, supra-conductors) for electric powertrain
- Development of miniaturized low cost, highly efficient multi-purpose and modular technologies for electric thrusters, including for small satellites, for all sizes of Low Earth orbit (LEO) to Geostationary orbit (GEO) satellites
- Development of range extending thermal power generators able to supplement the normal vehicle autonomy when needed
- Development of human assistance systems including power management assistance, charging infrastructure finding and subsidiary systems to manage change in operational habits (artificial noise creation or driving sensations, vehicle brio reproduction, reaction times, etc.)
- Development of optimized on board power monitoring and management, potentially relying on supercapacities, for feeding the electric powertrain as well as all non-propulsive electric subsystems
- Development of synthetic equivalent of rare materials for electric engine magnets and other rare and costly materials in the electric power chain
- Enable energy recovery (from braking energy, waste heat or other losses)
- Make sure the power grid is able to match the energy requirements for charging electric vehicles, whatever charging technologies are in use and including while electric vehicles are being deployed on a large scale
- Implementation of low and very low electric thrust for spacecraft station keeping and attitude control, including with full electric or hybrid propulsion systems

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced electric vehicle powertrains, building on solutions such as affordable high energy density and long lifetime storage, versatile charging systems, and lightweight, compact and cost-effective electric engines. The integration of KETs could also contribute to optimized on board power monitoring and management and to the development of technologies enabling energy recovery. It may also contribute to the development of synthetic equivalents of rare materials for electric engine magnets.

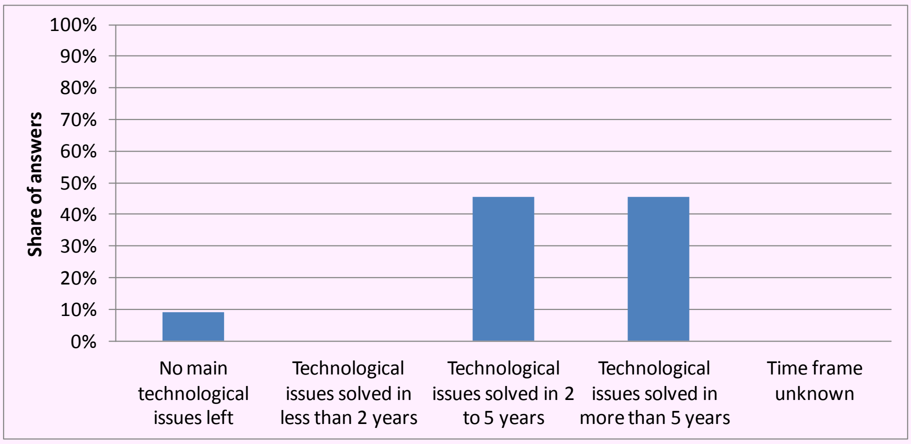
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)



Timing for implementation:

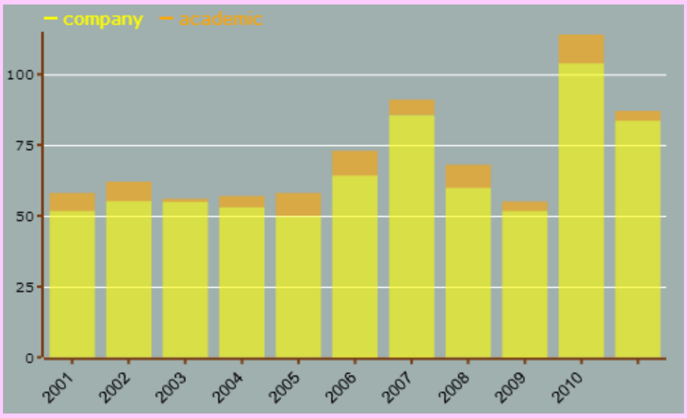
According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of either 2 to 5 years or more than 5 years:



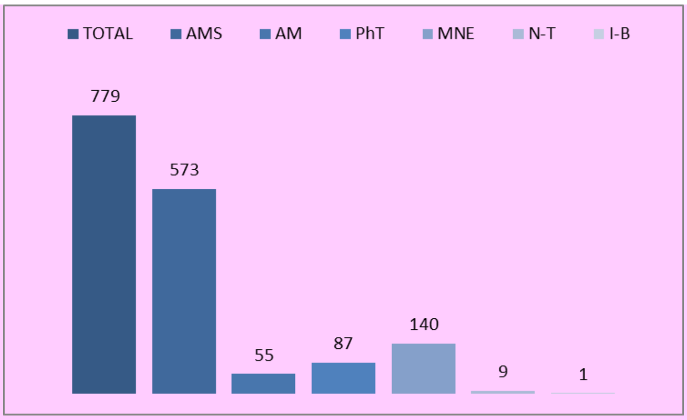
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field and from on the families of technologies in this field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Transport accounts for 13% of global greenhouse gas emissions (Source: IEA 2009). Except for trains and urban transports where it is already widely applied, electric mobility is considered a mandatory enabler for Europe to meet its CO_2 reduction target. Even in sectors where it remains technically very exploratory, as in aeronautics and space, electric propulsion is being investigated.
  - Moving from fossil fuel combustion to electric mobility will be a paradigm shift for the whole EU economy and society, with impacts on whole industrial sectors, including energy, chemistry (from petro-chemistry to bio-base), many raw materials and of course the transport industries. In the latter, it is to be recognized that combustion engine expertise has for long been one of the strengths of Europe and adaptation to electric mobility requires a huge card reshuffling, along with long-term effort. Setting up the bricks for electric mobility, including breaching the remaining barriers on the existence of a European industrial capability on the electric vehicle powertrain, is definitely one of the major axes of what a European industrial policy can be about.
  - The battery can account for as much as 40% of an electric vehicle's manufacturing cost. The global market for automotive Lithium-ion batteries is estimated to increase from 3.3 billion Euro in 2014 to 16.4 billion Euro in 2020 (according to Japanese research firm B3 (Source: Bloomberg)). Sales of hybrid and electric vehicles are projected to grow steadily to reach 5.2 million units by 2020, or 7.3% of all passenger vehicles (Source: November 2010 report by J.D. Power & Associates).
  - Considering the efforts given on this topic in other parts of the world as well as issues on some critical materials to be used in this field (e.g. rare earths in permanent magnets), securing a strong European capability in this field is also a matter of strategic non-dependence.
- ***Results of patents scenario analysis:***
  - 779 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Slightly increasing trend curve (number of patents per year)
  - Highest share of industrial applicants, with a strong presence to be noted of Japanese large industries in the top applicants (Toyota is world leader in the topic, by far), but European players are still evident in the top positions (better than US):



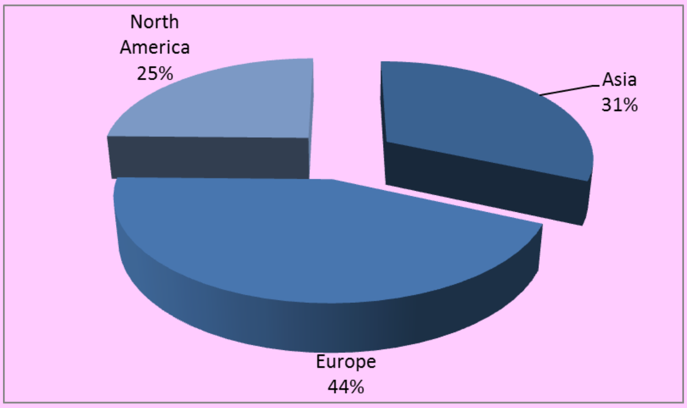
  - Patents by KET(s):



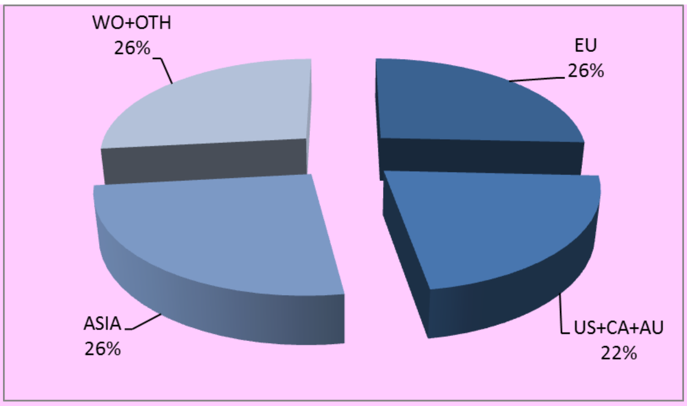
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	55
AM / MNE	5
AM / MNE / PhT	1
AM / N-T	2
AM / PhT	3
AMS	573
AMS / AM	2
AMS / MNE	10
AMS / MNE / PhT	4
AMS / PhT	11
IBT	1
MNE	140
MNE / N-T	3
MNE / N-T / PhT	1
MNE / PhT	55
N-T	9
N-T / PhT	1
PhT	87

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



T.3.2: Integrated electric transport systems and infrastructures

Scope:

To adapt transport systems, and especially road transport, re-thought holistically to take into account the shift towards electric mobility, considering not only the electric vehicles but also the charging infrastructure and related power grid management able to provide efficient services (as relatively fast vehicle charging) whilst keeping resilient against use peaks typical of transport systems (daily peak times, holyday periods, etc.) and constraints of the power grid (use of renewables, pace of production ramp up, etc.).

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

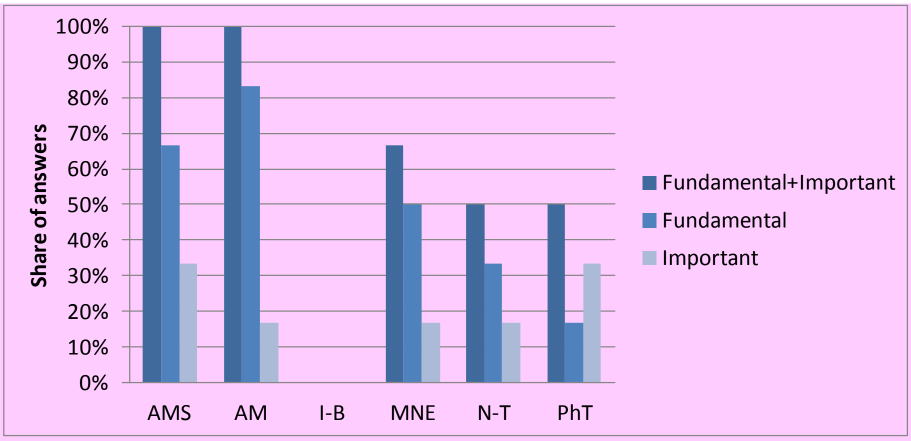
- Preparation of the power grid infrastructure to the large scale deployment of integrated transport systems based on electric vehicles
- Development of electric vehicles and electric powertrains with sufficient performance to enable reaching the threshold volume for operation deployment of electric transport systems on transport modes where they do not yet exist
- Development of embedded systems for energy monitoring and recording in order to have a clear picture of the energy production, cost of primary energy consumed and amounts of GHG emitted
- Development of new processing algorithms to supervise the complete system (adaptive control, learning process, etc.) while maintaining a high degree of comfort and a low consumption of auxiliary electricity
- Development of automation, control and solutions for long term reliability assessment for the network control

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the adaptation of transport systems, also considering the charging infrastructure and related power grid management and to the development of automation, control and monitoring solutions for the long-term reliability assessment of the network.

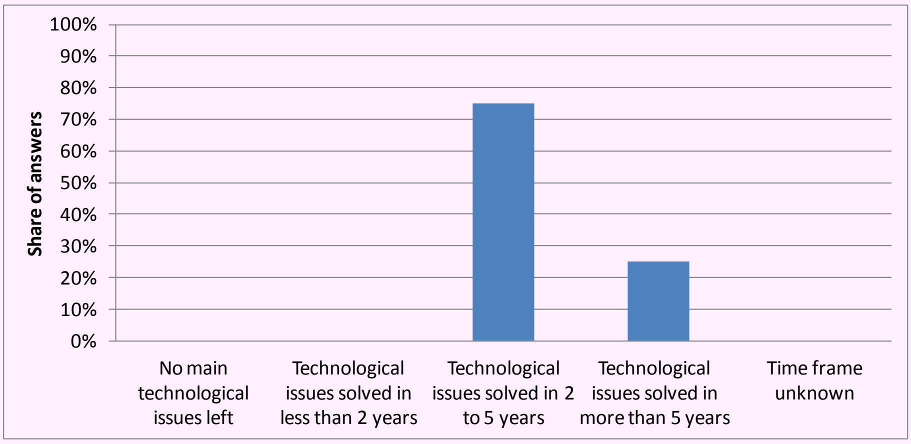
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Photonics (PhT)



Timing for implementation:

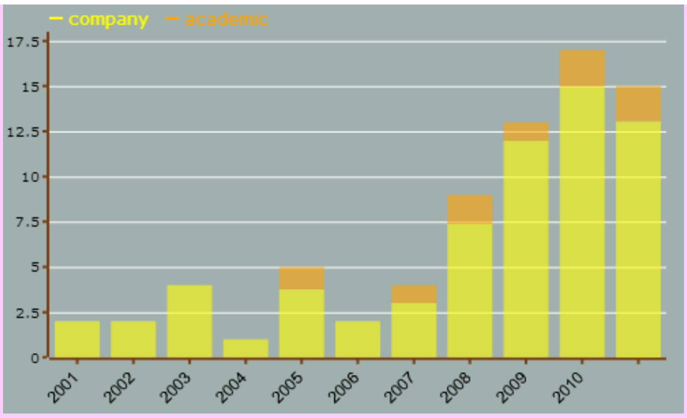
According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



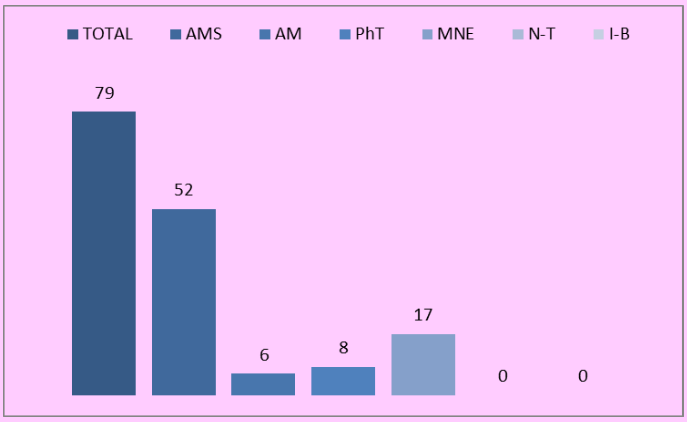
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Transport account for 13% of global greenhouse effect gas emissions (Source: IEA 2009). Except for trains and urban transports where it is already widely applied, electric mobility is considered a mandatory enabler for Europe to meet its CO_2 reduction target.
  - Deploying electric mobility requires adaptation of many sectors including electricity production, distribution, and storage, but also requires a sufficient quality of service and allows the deployment of new transport, logistics, on board vehicle and fleet based services.
  - Based on development in this field, new industrial links have to be built between up to now isolated value-chains (as automotive and power generation industries), giving room to new potentials.
- ***Results of patents scenario analysis:***
  - 79 exclusively KETs-related patents identified in the period 2001-2011 for this highly application-related Innovation Field
  - Quickly increasing trend curve (number of patents per year) in the recent years, illustrating the fact e-mobility seen from the integrated system point of view is about to reach industrial maturity:



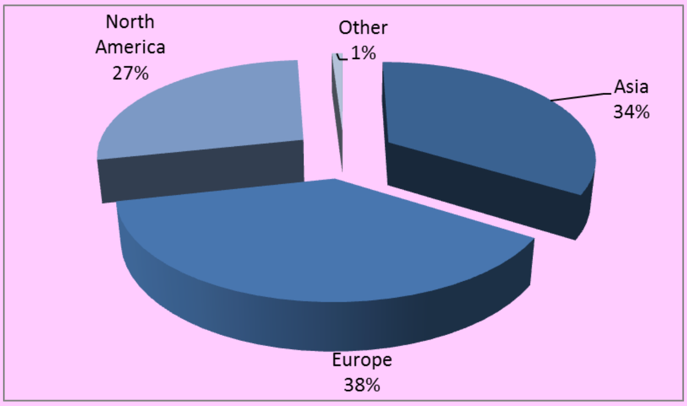
- Patents by KET(s):



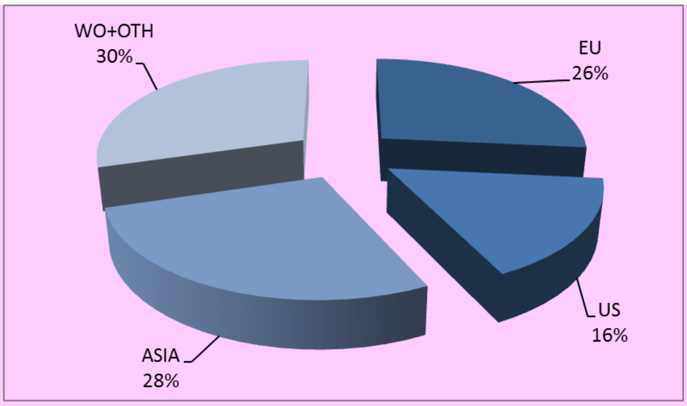
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	6
AM / MNE	1
AM / MNE / PhT	1
AM / PhT	1
AMS	52
AMS / PhT	1
MNE	17
MNE / PhT	7
PhT	8

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



Sub-domain: Systems and infrastructure for vehicle operation into traffic

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "Smart, green and integrated transport" societal challenge
- Contribute to the achievement of the EU Transport 2050 strategy (COM/2011/0144 final) objective of a 60% reduction of CO_2 emissions from transports
- Deliver safer and less congested travel as well as smoother and quicker journeys, as requested for the Trans European Transport Network (TEN-T) policy (Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 and repealing Decision No 661/2010/EU Text with EEA relevance)
- Achieve SESAR 2020 objectives for the European Air Traffic management, as regards environment (emissions and local nuisances), safety and ability to efficiently cope with growing traffic volumes
- Continuously enhance safety and resistance/resilience of vehicle operation all along end-to-end transport chains
- Support the Smart Vehicle initiative of the i2010 strategic framework on the innovation society (COM(2005) 229 final)
- Ensure operational implementation of European international transport agreements (as TRACECA, SEETO and NDPTL)

Demand-side requirements (stemming from market needs) addressed:

- Reduce traffic management direct (fees for operators) and indirect (such as costs of jams on citizen health, economy competitiveness, environment, etc.) operational costs
- Reduce or maintain numbers and rates of accidents in Europe at an acceptable number, whatever traffic growth
- Enable new transportation services dealing with changing mobility and transportation needs, changing trade patterns, citizen request for affordable, timely, seamless and ubiquitous transport services
- Support integration of lean global logistic chains taking advantage of communication and tracking technologies for preventing incidents and offering in-trip services

T.4.1: Information-rich operator position

Scope:

In the context where information capture is increased all over the transport chain (on-board vehicles, from the infrastructure or any other source), as well as multilateral communications (vehicle-to-vehicle, vehicle-to-infrastructure), the provision of the vehicle operator – pilot, driver, sailor, traffic controller, etc. – with full situational awareness and decision-making assistance is getting fundamental. Taking stock on advanced processing capabilities, advanced ergonomics and optimal human machine interfaces, the information-rich operator position supports safer, more efficient, more automated and foolproof vehicle operations.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

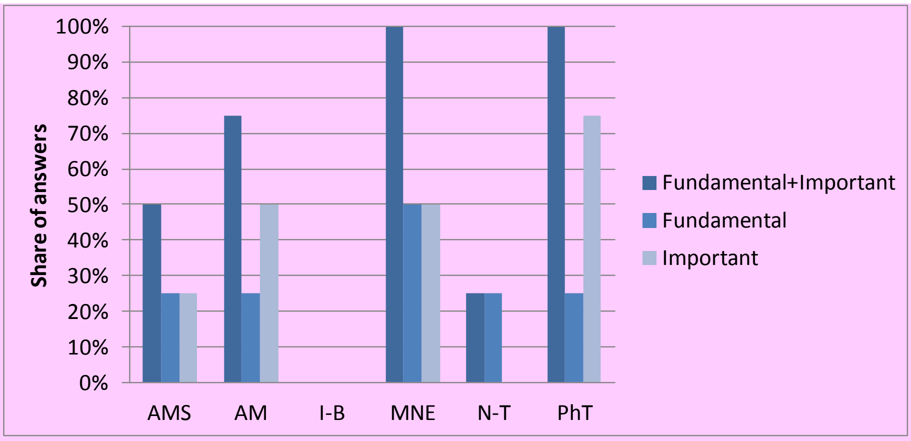
- Development of an open, scalable and resilient electronic architecture able to collect useful external and vehicle information and make it available to processing systems
- Improve and widely rely on vehicle-to-vehicle, vehicle-to-infrastructure and vehicle-to-road communication to optimize vehicle-infrastructure-user co-modal working
- Extension of the use of synthetic vision means merging com/nav information, visual and oral clues, vehicle status, load surveillance, etc. so as to provide operators with context-based operational assistance
- Spread use of glass displays for all sorts and sizes of vehicles and crews
- Integration of multi-channel HMI (audio, visual, olfactory, haptic) supported by an improved understanding of human behaviour and performance and the capability to adapt the interface to the particular user
- Increase of crew and staff situational awareness and event anticipation, and provide them with assisted decision-making systems
- Take advantage of cognitive and learning processes, sense & avoid capabilities and other artificial intelligence concepts to reduce requirements on unnecessary/routine human actions
- Reduction of crew workload through increased automation and virtualization
- Achievement of an effective level of operator's activity monitoring by detecting in real time overload, fatigue, stress, ill-health and other degradation of vigilance (including incapacitation due to breaches in security)
- Implementation of operational capability for minimization of human error and mitigation of the consequences
- Development of advanced low cost training systems for operators (simulators, etc.)
- Safely and efficiently provide personal / recreational vehicle operator with safety alarms, navigation and parking assistance, tourism information and other services based on context-awareness (including for behavioural change)
- Development of cheap foolproof and safe communication and identification equipment for recreational vehicles
- Progressive development and implementation of acceptable levels of automatic intervention on vehicle dynamics and controls according to its specific situation, location, events and/or operator status

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced solutions allowing the vehicle operator or the crew to have full situational awareness and decision-making assistance as well as a reduction of workload through increased automation and virtualization, taking stock on solutions such as enhanced human machine interfaces and open, scalable and resilient electronic architectures able to improve vehicle-to-vehicle, vehicle-to-infrastructure and vehicle-to-road communication and to detect in real time overload, fatigue, stress, ill-health and degradation of vigilance.

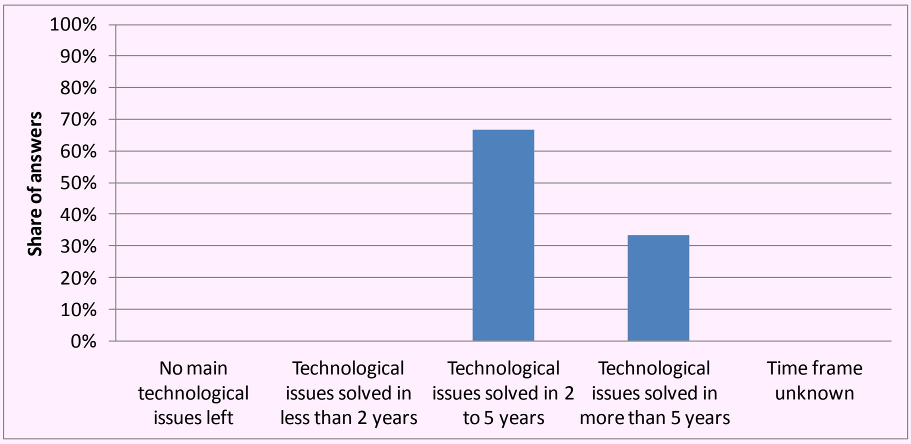
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet consensus by experts indicates also greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

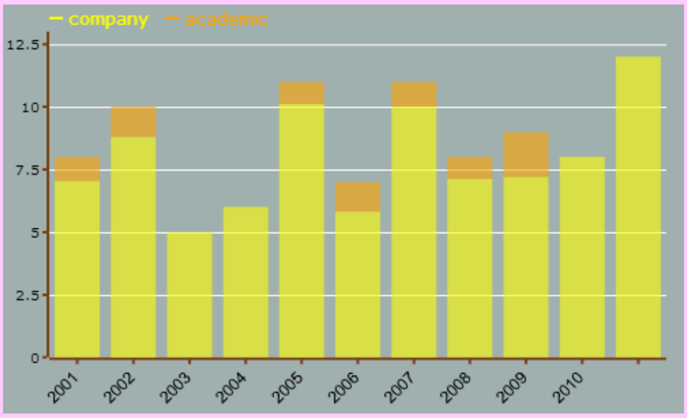
Additional information according to results of assessment:

- ***Impact assessment:***
  - In the defence sector, a strong development of autonomous vehicles has been going on in the past years, particularly to provide the operator with full situational awareness and decision-making assistance and support safe, efficient, automated and foolproof operations. Such capability could be useful also for many different civilian applications, thus it could be adapted for vehicle-to-vehicle or vehicle-to-infrastructure communications.
  - Most studies about transport accident reports consider that human errors contribute to around 80% of rail, air or waterborne transport, up to 90% for individual road transport. This seems quite stable in time, since the 1977 Treat & al. study already found that human error was the sole cause in 57% of all accidents and was a contributing factor in over 90%). Nevertheless just sticking to that share is already not automatic since traffic regularly grows in all modes of transport and machine failures are on a decreasing trend. Within a more and more complex operational environment, providing "operators" with more and better information is a key for reducing or keeping under control that human factor.
  - Better operator assistance is also of energetic, environmental and economic interest, as it can participate to traffic regulation, propose alternative paths to busy axes, promote an eco-responsible way of driving, inform on temporary regulations due to climate events or pollution peaks, deliver a warning in case of excessive speed, etc. Fuel-efficient driving can reduce consumption by as much as 6%.

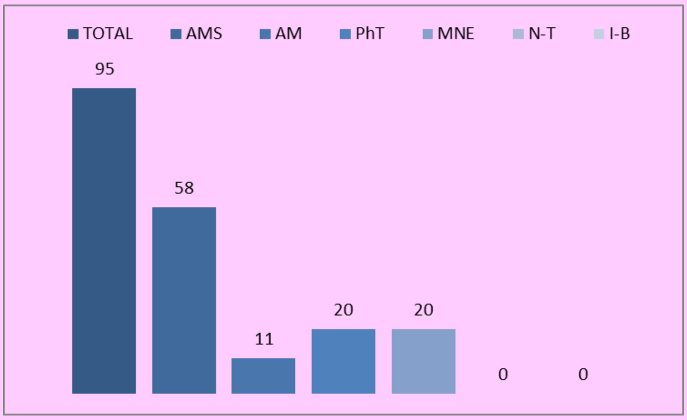
- An information-rich environment also has the potential to reduce vehicle crew workload, enabling better vigilance, better decision-making, better anticipation of possible events and feasibility of additional tasks related to new functionalities or services (e.g. preparing ground load/unload or maintenance activities while in cruise, communication with passengers, touristic or practical information research, etc.).
- Finally, the opportunity of further developing vehicle-to-operator interface is a step forward toward the longer-term autonomous human transport.

➢ ***Results of patents scenario analysis:***

- 95 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Stable or slightly increasing trend curve (number of patents per year)
- Highest share of industrial applicants:



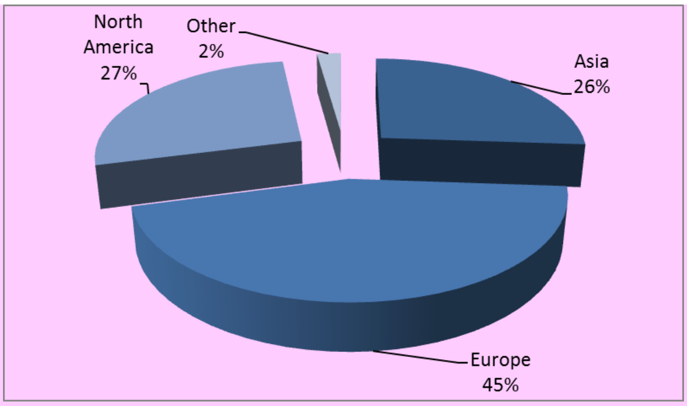
- Patents by KET(s):



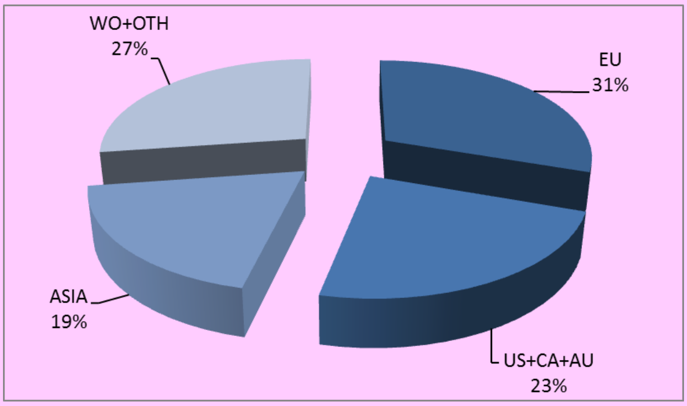
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	11
AMS	58
AMS / AM	1
AMS / MNE	4
AMS / MNE / PhT	1
AMS / PhT	1
MNE	20
MNE / PhT	9
PhT	20

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



T.4.2: Multimodal all cargo logistic chains and goods transport service

Scope:

To setup door-to-door, just-in-time and highly resource efficient lean logistic systems, serviced with streamlined multimodal chains that benefit from integrated information-based facilitators, specialized vehicles (as cargo vessels or airships) and highly dependable automated cargo and baggage handling systems, even to, or from, remote areas of Europe and the world.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

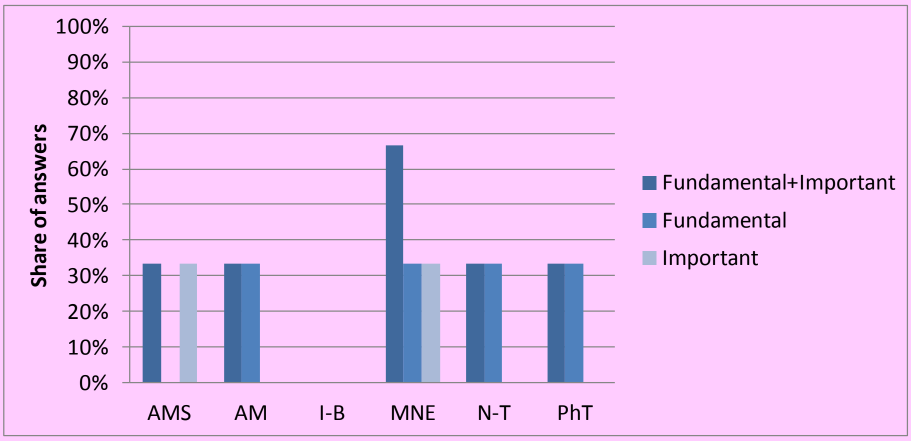
- Introduction of continued cargo (including luggage) tracking and based on indoor localization capability (relying on communication networks, wireless sensors, radio-frequency identification technology, etc.)
- Development of point to point heavy/large cargo transport means, with optimized ships and port infrastructure, high dependability airships or safe extra-large road transports
- Development of logistics planning tools supporting the integration of highly time-efficient and reliable end-to-end European supply chains
- Development of an integrated end-to-end logistic chain management system, dimensioned for end-to-end tracking of elements along the chain
- Development of logistics planning tools supporting the integrated monitoring of cargo movement along the supply chains
- Automation of luggage/cargo handling and lashing
- Increase of the adoption of unitized cargo containers along multimodal transport chains
- Ensure self-health monitoring / automated diagnostics of the system to trigger quick repair and guarantee high integrity of the system
- Enable dynamic, reliable and secure distribution of instructions down to any action / handling node of the chain
- Where security checks are mandatory, enable high-throughput and highly reliable check of luggage and cargo

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the set up of door-to-door, just-in-time and highly resource efficient lean logistic systems that benefit from integrated information-based facilitators, specialized vehicles (as cargo vessels or airships) and highly dependable automated cargo and baggage handling systems, building on solutions such as continued cargo (including luggage) tracking, indoor localization capability and integrated end-to-end logistic chain management systems, dimensioned for end-to-end tracking of elements along the chain.

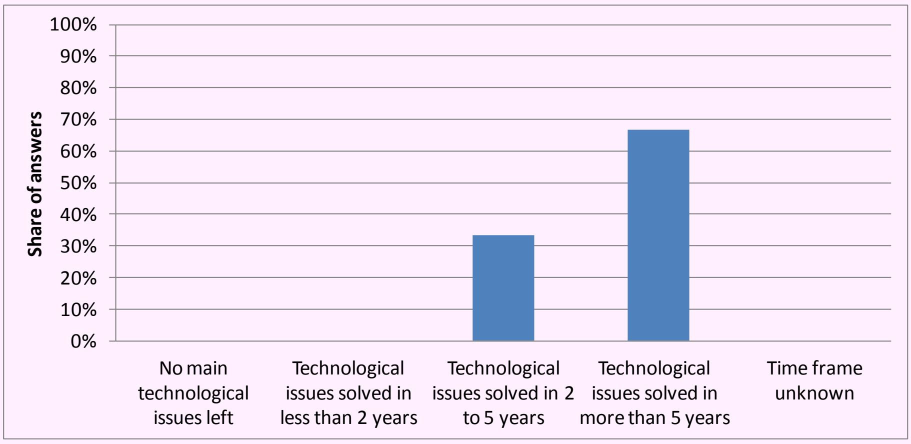
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Photonics (PhT)
- Advanced Manufacturing Systems (AMS)



Timing for implementation:

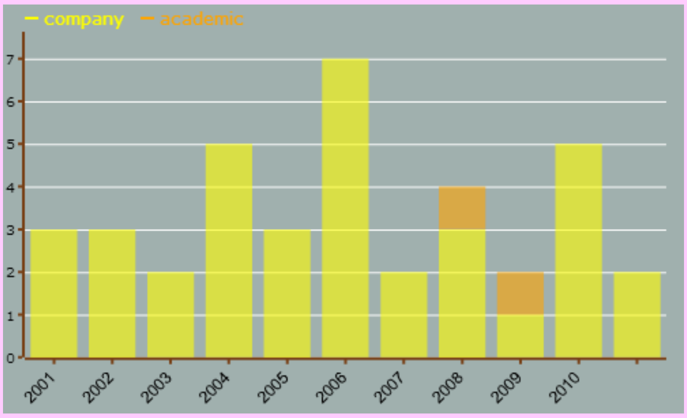
According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:



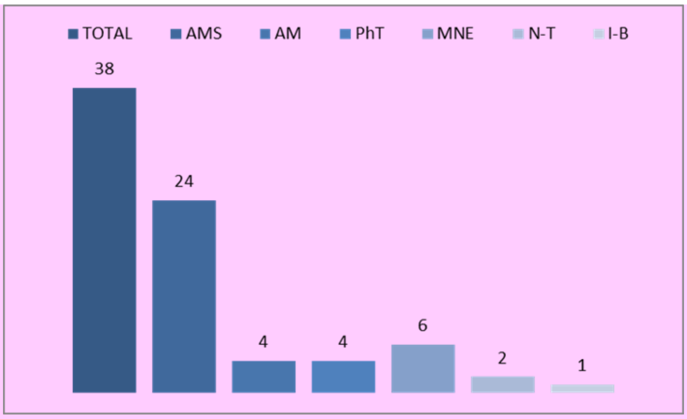
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - The SEALS 2008 study conducted for the DG Energy and Transport of the European Commission estimated the weight of logistics – i.e. weight transport and warehousing operations – around 900 billion Euro generated annually in EU27, half outsourced, totalizing about 5% of EU GDP and 7 million jobs. For the same year, the Alliance for European Logistics gives the figure of 950 billion Euro revenue, making it "the biggest industry sector in the EU".
  - On average, logistics costs account for a significant 10-15% share of the final cost of an average finished product (Source: 2006 Communication from the European Commission on the Freight Transport Logistics in Europe), so that well run and efficient supply chains play a major role on industry and services competitiveness, and EU logistics efficiency is a direct lever of EU economy competitiveness. Logistics efficiency is also a matter of environmental efficiency, as freight transportation is responsible for a large part of overall global and European emissions, CO_2 and other pollutants. It is finally a matter of society responsiveness and creativity (many innovative services emerge directly as a result of the opportunities created by new very quick or responsive supply channels, or on the contrary are suffocated by sub-efficient supplies).
  - Coordination efforts, at the EU level as well as nationally, are quite recent in that industry is recognized as highly fragmented. Developing more integrated, multimodal, door-to-door and information-based supply chains is the strategic priority of the overall logistic sector, as the main possible source for progress, in line with the strong industry concern for setting up lean production organisations. Although not measurable, the importance of high performance logistic chains was highlighted by several of the experts interviewed along the RO-cKETs project.
- ***Results of patents scenario analysis:***
  - 38 KETs-related patents were identified in the period 2001-2011 as directly relevant for the Innovation Field
  - Quite stable trend curve (number of patents per year), but the low number of patents makes it a weak signal
  - Highest share of industrial applicants, with no clear patterns within the top ones; the logistics sector fragmentation is visible from the patents scenario analysis, as there is no player in leading position and many non-technological service companies (e.g. postal service providers) are present. However, one point to mention is the good position of Europeans, with a 50% patent share:



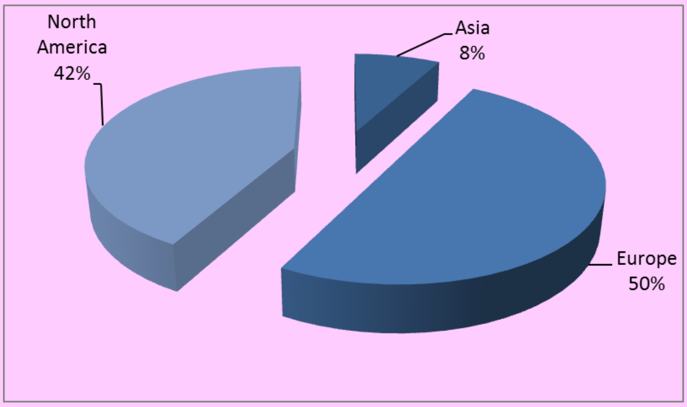
  - Patents by KET(s):



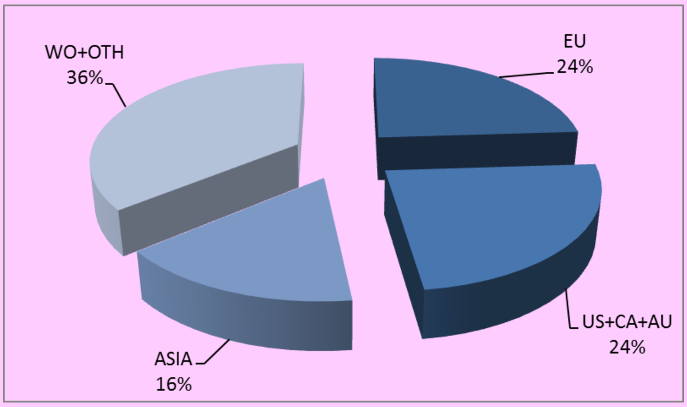
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	4
AM / N-T	1
AMS	24
AMS / MNE	1
IBT	1
MNE	6
MNE / PhT	1
N-T	2
PhT	4

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



T.4.3: Advanced embedded positioning and navigation

Scope:

To develop beacon-based, satellite-based or inertial systems, eventually coupled, able to deliver a highly precise and dependable positioning and navigation service, whatever the vehicle and operational conditions, cost-effectively and with low weight and cost-effective embedded systems.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

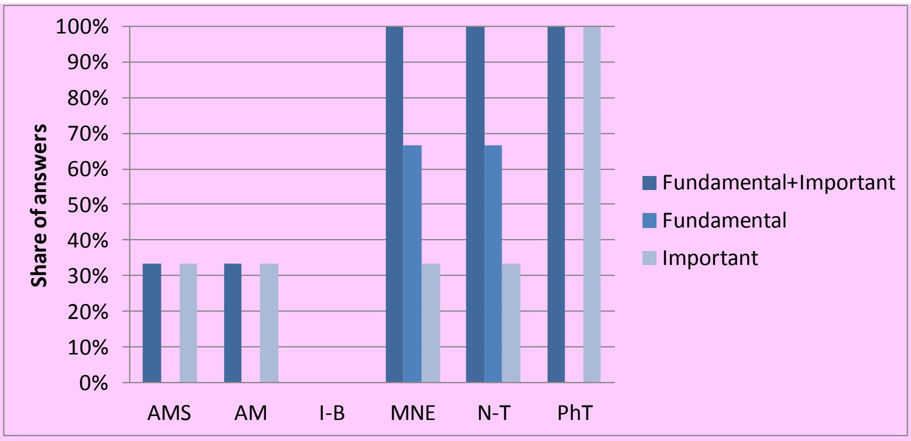
- Development of lightweight and low cost inertial systems able to provide highly precise positioning and pointing information over long journeys and whatever the operational conditions
- Take advantage of multi- global navigation satellite system (GNSS) systems reception capabilities (Global Positioning System (GPS), Galileo, Beidou, Glonass) to enable cost-effective but highly dependable satellite positioning
- Optimization of coupling of various navigation means (beacon-based, satellite-based and inertial) so as to increase precision, robustness (especially in urban areas / indoor or in other constrained environments) and dependability
- Minimization of external perturbations to the positioning equipment, such as radiation, vibrations, temperature shifts, etc.
- Development of active compensation high resolution Line Of Sight actuation control techniques (as with star trackers, sun sensors, magnetometers), mainly for spacecraft
- Implementation of compact, accurate, high stability and robustness time measurement solutions, from ion traps to optical atomic clocks
- Take advantage of improved positioning and navigation systems to improve models used for unmanned or highly automated operations (as flight models for autopilots)
- Build on advanced positioning capabilities to support innovative on-board services and/or provide accurate information to the traffic control services
- Make sure Galileo Public Regulated Service (PRS) is supported by relevant European ground receivers able to deliver the best possible related service

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced beacon-based, satellite-based or inertial systems, taking advantage of multi-GNSS systems reception capabilities (GPS, Galileo, Beidou, Glonass) to increase precision, robustness (especially in urban areas/indoor or in other constrained environments) and dependability, whatever the vehicle and operational conditions.

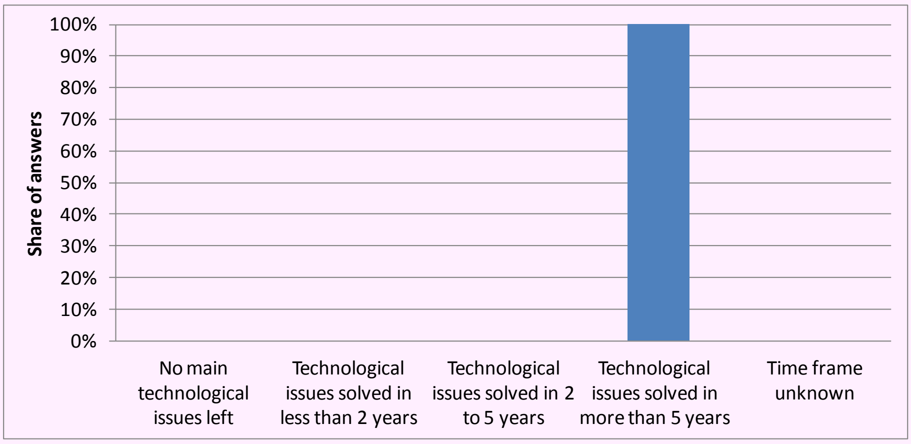
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Photonics (PhT)
- Advanced Manufacturing Systems (AMS)
- **Advanced Materials (AM)**



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:

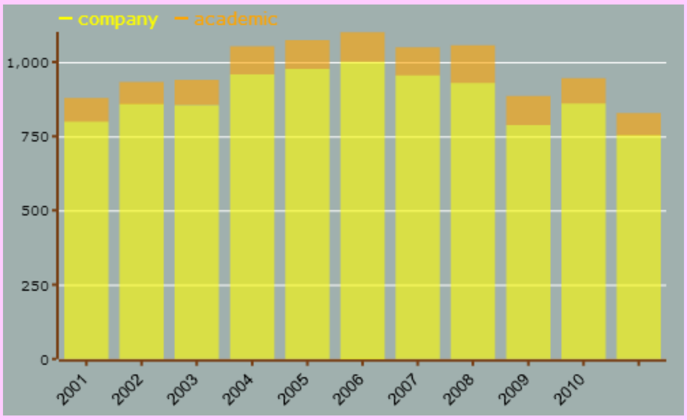


These technologies are actually following continuous improvement processes. Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

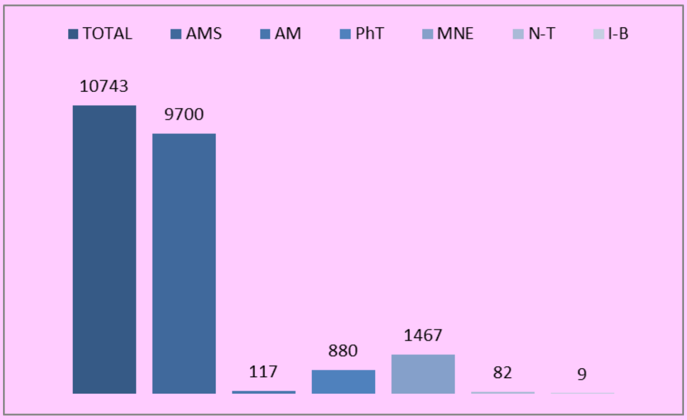
Additional information according to results of assessment:

- ***Impact assessment:***
  - Inertial or satellite-based navigation or positioning means are directly supporting safety improvements in air and seaborne transportation as well as in space ops. Precision is one aspect, but robustness whatever the weather conditions (Rio-Paris Air France crash in 2009 is considered due to weaknesses in the aircraft set of navigation instruments) or the geography, including near ground/near shore, is still to be improved.
  - Benefitting from aerospace developments, navigation and positioning systems are major enablers for advanced ground transportation services, including driver assistance, traffic management, jams avoidance or parking place detection, but also unmanned vehicle autonomous operations, stolen vehicle retrieval or even maybe upcoming capabilities such as collision avoidance.
  - KET-supported miniaturization – eventually integrated with indoor capabilities – enables integration of these precision positioning capabilities into mobile devices, supporting the emergence of many services of the innovation-based society.
  - By definition, the original Global Positioning System (GPS) was developed for military applications. Nowadays, it is well understood that the potential and further development of other similar systems are able to provide significant useful applications in civilian situations. Its dual use is therefore clearly established and implemented.
- ***Results of patents scenario analysis:***

- Considering the very effective identification of patents related to that dynamic innovation field, 10.743 relevant KETs related patents were identified in the period 2001-2011
- Stable trend curve (number of patents per year), starting a slight decrease in the recent years
- Highest share of industrial applicants:



- Patents by KET(s):

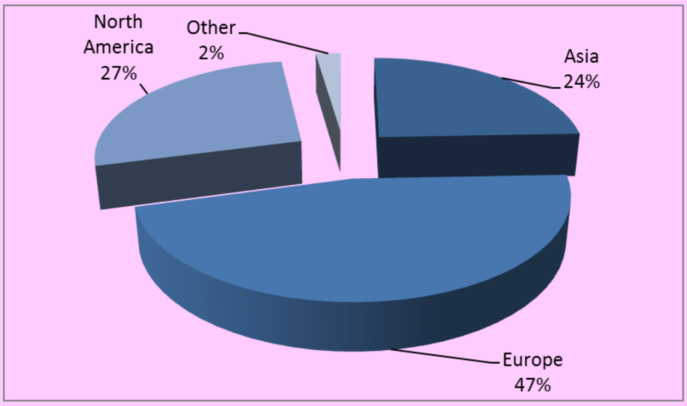


- Patents by KET(s) and relevant combinations of KETs:

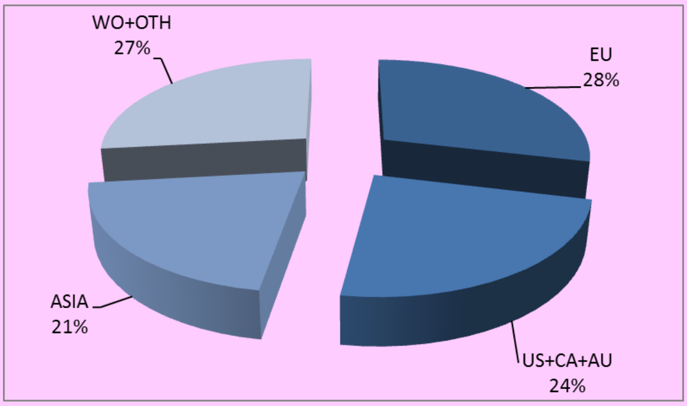
KET(s)	*Number of patents*
AM	117
AM / IBT	3
AM / IBT / MNE	1
AM / IBT / N-T	2
AM / MNE	23
AM / MNE / N-T	8
AM / MNE / N-T / PhT	1
AM / MNE / PhT	3
AM / N-T	19
AM / N-T / PhT	2
AM / PhT	8
AMS	9700
AMS / AM	54
AMS / AM / IBT	1
AMS / AM / IBT / N-T	1
AMS / AM / MNE	16
AMS / AM / MNE / N-T	7
AMS / AM / MNE / N-T / PhT	1
AMS / AM / MNE / PhT	1

AMS / AM / N-T	9
AMS / AM / N-T / PhT	1
AMS / AM / PhT	3
AMS / IBT	4
AMS / IBT / N-T	1
AMS / MNE	936
AMS / MNE / N-T	28
AMS / MNE / N-T / PhT	2
AMS / MNE / PhT	73
AMS / N-T	52
AMS / N-T / PhT	4
AMS / PhT	219
IBT	9
IBT / MNE	1
IBT / N-T	2
MNE	1467
MNE / N-T	38
MNE / N-T / PhT	6
MNE / PhT	285
N-T	82
N-T / PhT	13
PhT	880

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



T.4.4: Transportation system wide security and threat response

Scope:

To develop security systems with a holistic approach and with no breach all over the vehicle operation and infrastructure, integrating highly reliable and efficient check points for persons and goods designed to take into account the human factor and manage all sources of information in security and privacy, able to support decision-making and respond to all sort of threats, including with non-lethal neutralisation capabilities.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Increase of passengers and staff identity authentication capabilities
- Increase of checkpoint throughput with automation and passengers not required to devest
- Increase of large cargo/containers high throughput scanning
- Increase of detection capability whilst maintaining false alarm rate at operationally viable levels
- Development of sensors to detect prohibited articles and all sorts of present and future threats (as CBRN)
- Handling of data from various security related data sources (including capabilities for artificial intelligence, data mining, big data, data fusion and correlation, etc.)
- Guarantee integrity of information, systems and communication in case of any cyber-attack through non-disruptive information Technology (IT) infrastructure resilient to jamming, spoofing and other attacks (including for high volumes of unmanned vehicle operation)
- Introduction of time-efficient, non-repetitive, unpredictable measures in the verification process
- Identification of non-lethal on-board neutralization options for identified threats (cargo, passengers, crew), and regularly update it depending on piracy practices evolutions
- Evaluation of the opportunity to implement active defensive / threat detection measures (sea mine detection, anti-missile systems, etc.) on board civilian transport vehicles
- Optimization of operational systems and decision-making assistance so as to minimize or compensate occurrence of human error
- Equipment of urban areas with tamper-proof / theft-proof high autonomy sensing nodes and radio beacons able to deliver information on traffic, parking space availability, vehicle presence in parking lots and abnormal events
- Ensure trustworthy record, storage, transfer and usage of personal data, so as to prevent new types of attacks, privacy breaching or technology-induced safety risks
- Enable remote control of the vehicle when the crew is incapacitated or otherwise prevented from normally controlling the vehicle

Contribution by cross-cutting Key Enabling Technologies:

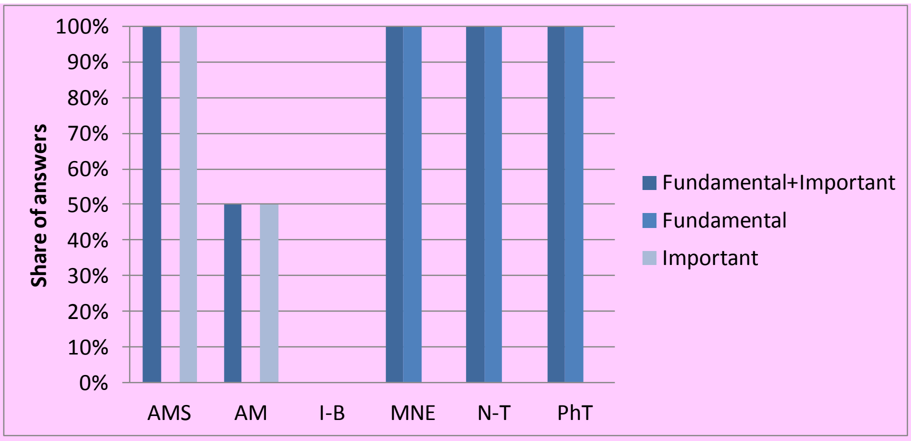
In respect to this Innovation Field, the integration of KETs could contribute to the development of holistic security systems with no breach all over vehicle operation and the infrastructure, thanks to integrating highly reliable and efficient checkpoints for persons and goods (including e.g. passengers and staff, prohibited articles and all sorts of present and future threats) with increased detection capability whilst low rate of false alarms.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Photonics (PhT)

and, to an important extent:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)

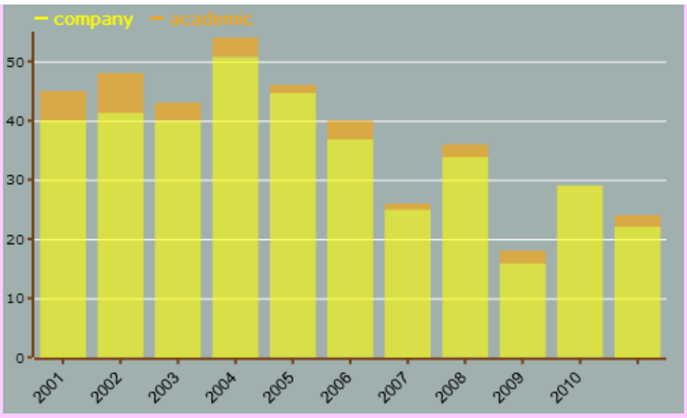


Timing for implementation:

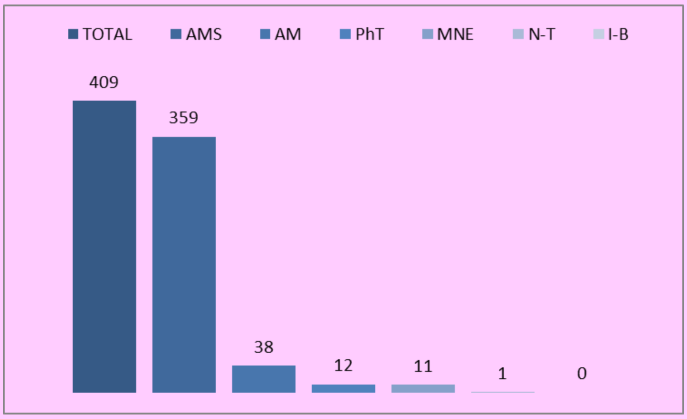
No consensual indication could be retrieved from KETs experts' opinions concerning the time frame required for solving the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field. However, considering the specific technical and/or industrial challenges and the maturity of technologies in this field, the provision of support in the short term is suggested within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - It is well known that the defence sector has long needed to cope with threat and emergency response, particularly in the last years, in order to cope with the most different threats that may arise, from biological to cyber security. This significant knowledge can prove useful to be further explored and implemented into stronger actions for safety and homeland security. This area is particularly related to dual use technologies.
  - As demonstrated by 9/11, Madrid or London attacks, transport chains have become a priority target for political terrorism and possibly any other form of malevolent action. Ensuring the protection of the transport systems is therefore a major contributor to the "*Secure societies - protecting freedom and security of Europe and its citizens*" societal challenge.
  - Security experts systematically underline the fact that "zero hijack" is not an achievable objective and security is to be seen through the concepts of risk and protective barriers. This is where the holistic approach is engaged, with considering that protection is to be built encompassing the entire transport system, or the risk would agglutinate on the unprotected – the weak – links.
  - If security – in the specific case physical security - is a human right and a social necessity, security technologies also have the potential for negative impacts, which are to be minimized. Air transport travel time advantage is notoriously diluted by time lost in transit, including time lost in airport checkpoints. In addition, the omnipresence of security clues has the paradox effect of creating more fears than confidence, feeding socio-political tensions. Developing security means that are highly protective but also smoother, less intrusive and stressful, respectful of privacy and democratic liberties is an absolute necessity for supporting the peaceful deployment of a secure and inclusive European standard society.
- ***Results of patents scenario analysis:***
  - 409 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Decreasing trend curve (number of patents per year):



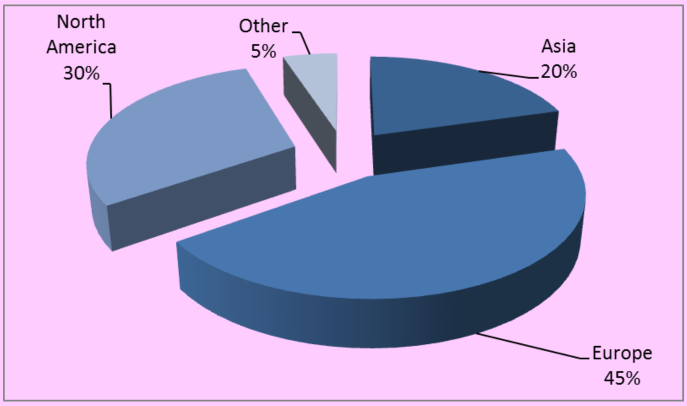
- Patents by KET(s):



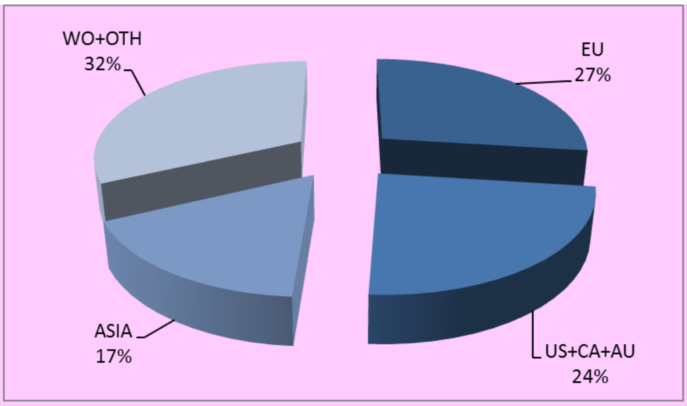
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	38
AM / MNE	1
AM / PhT	3
AMS	359
AMS / MNE	4
AMS / N-T	1
AMS / PhT	3
MNE	11
N-T	1
PhT	12

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:


WO+OTH
32%
EU
27%
ASIA
17%
US+CA+AU
24%

POTENTIAL AREAS OF INDUSTRIAL INTEREST RELEVANT FOR CROSS-CUTTING KETS IN THE CONSTRUCTION DOMAIN

Sub-domain: Advanced and/or functional construction and building materials and components

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "Climate action, resource efficiency and raw materials" societal challenge as well as the "Secure, clean and efficient energy" societal challenge in the first instance, thanks to lowering the amount of embodied energy in materials used during the construction process and the energy demand during the use-phase of buildings
- Contribute to achieve net zero-energy buildings in the future, serving as driver to boost the market for novel renewable energy applications in the residential sector (according to the Energy Performance of Buildings Directive (2010/31/EU))
- Contribute at the same time to the "Health, demographic change and wellbeing" societal challenge thanks to providing comfortable, well-designed, and energy efficient living spaces for all

Demand-side requirements (stemming from market needs) addressed:

- Enhance competitiveness of the construction sector
- Optimise the life-cycle cost of the built environment
- Provide comfortable, well-designed, energy efficient living spaces for people
- Reduce energy consumption (resulting in savings over the conventional energy purchase for private end-users and in the overall reduction of the energy demand on a global scale)
- Enhance the urban environment, creating a built environment that is accessible and usable for all
- Improve health, safety and security of the built environment
- Make construction activities more efficient, precise and with greater risk avoidance
- Improve health and safety conditions during construction processes

CS.1.1: Energy-efficient interconnected and versatile lighting

Scope:

To develop more energy-efficient interconnected and versatile lighting solutions (interoperable, adaptable, highly comfortable and customizable).

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development and cost-effective production of lighting equipment (following the "smart home" approach: interoperable, adaptable - in colour, hue, intensity, etc.)
- Design of low consumption highly comfortable and customizable lighting solutions

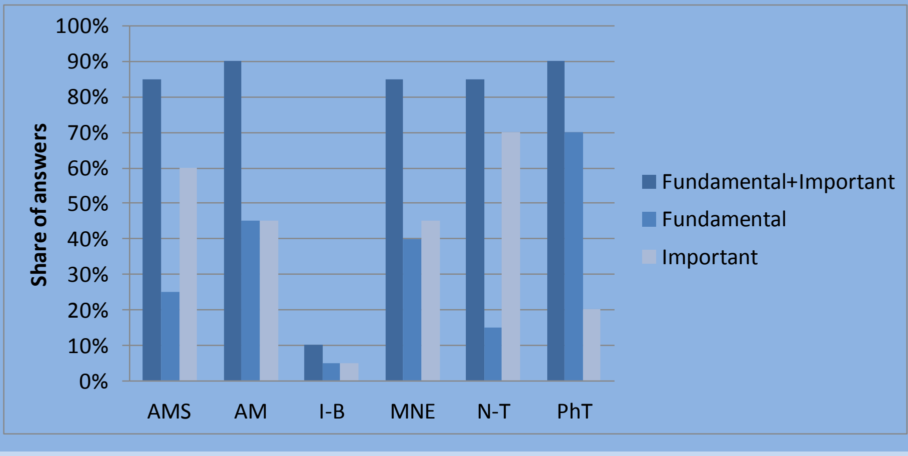
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of cost-effective, more advanced, low consumption, highly comfortable and customizable lighting solutions and related lighting equipment, and to the related production methods and processes.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

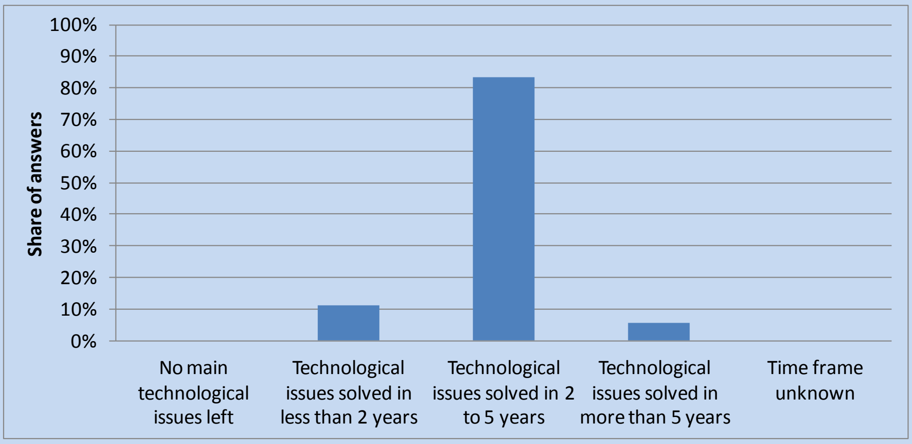
- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)

- Micro- and Nano-Electronics (MNE)
- Photonics (PhT)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

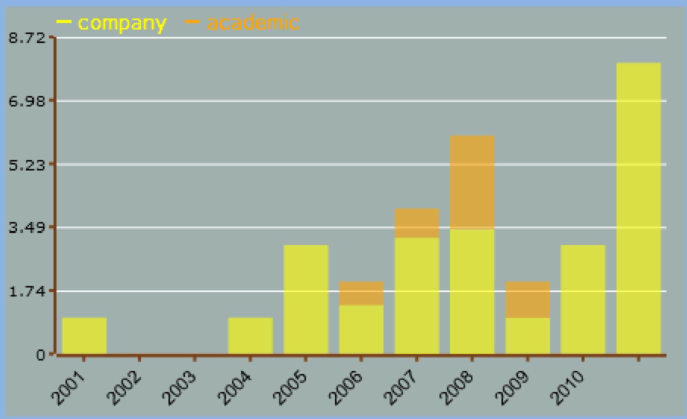
- ***Impact assessment:***
  - Approximately 85% of lamps currently in EU homes are energy inefficient.
  - Within this framework, significant growth is being driven in the European energy efficient lighting market primarily by European Union legislation to phase out incandescent lamps and other inefficient lighting technologies. There is a large push in fact by Europe to adopt energy efficient lighting (among other home appliances) in order to boost energy savings. All EU28 countries are required to use energy more efficiently at all stages of the energy chain – from the transformation of energy and its distribution to its final consumption. The new Energy Efficiency Directive will particularly help removing barriers and overcoming market failures that impede efficiency in the supply and use of energy and provides for the establishment of indicative national energy efficiency targets for 2020. The Directive on the Energy Performance of Buildings, moreover, which imposes certain energy efficiency standards on buildings, including lighting products, will play an important part in achieving the objective to phase out incandescent lamps and other inefficient light sources across Europe.
  - As a result of this strategy, the European energy-efficient lighting market is reported to have earned revenues of 0.8 billion Euro in 2011 and estimates this to reach 1.4 billion

Euro in 2018. While compact fluorescent lamps are currently the major product segment, the Light-Emitting Diodes (LED) segment is expected to grow rapidly as the technology improves and prices fall.

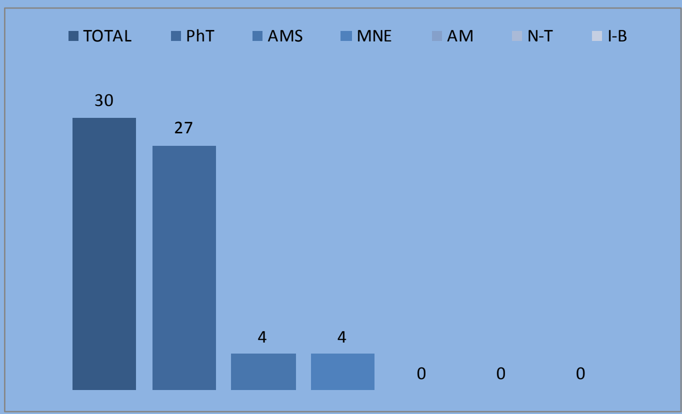
- Yet a switch to more efficient lighting in homes will require significant manufacturing changes within the lighting companies, which the lamp manufacturers are committed to manage in any case.
- Sources: The European lamp industry's strategy for domestic lighting, www.lightingeurope.org; European market energy-efficient lighting update, 2012, www.proudgreenhome.com

➢ ***Results of patents scenario analysis:***

- 30 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Growing trend curve (number of patents per year)
- Highest share of industrial applicants:



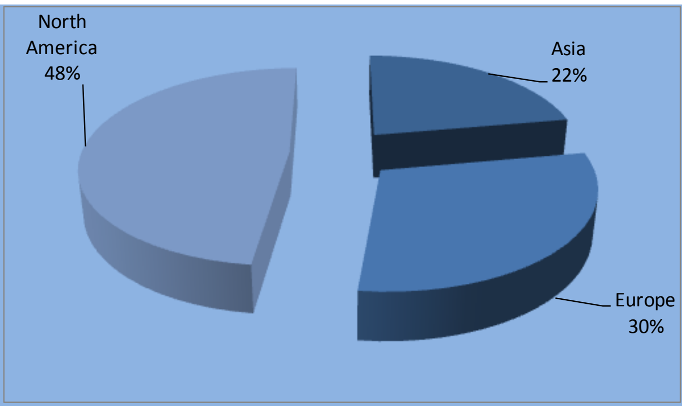
- Patents by KET(s):



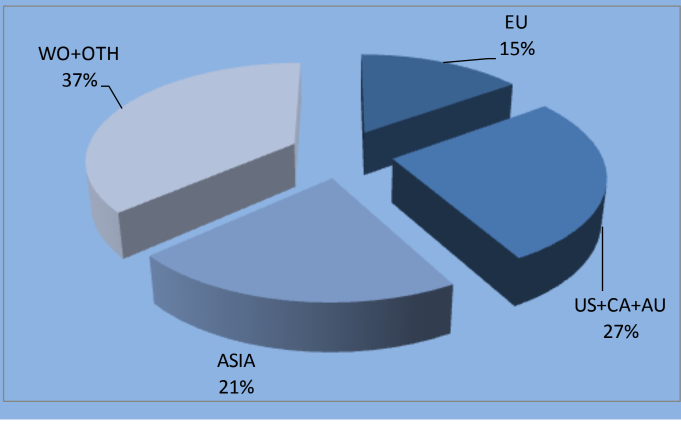
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AMS	4
AMS/PhT	1
MNE	4
MNE/PhT	4
PhT	27

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



CS.1.2: Insulating materials and components for the energetic improvement of the building envelope

Scope:

To develop cost-effective and environmentally sustainable insulating materials and components for the energetic improvement of the building envelope.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of new cost-effective energy efficient insulating materials from renewable sources or waste materials
- Development of low thickness high insulating and easy to install insulation materials for building refurbishment
- Improvement of thermally and / or acoustically insulating materials and foams providing enhanced thermal / acoustic insulation and a higher degree of energy conservation
- Development of materials with thermal conductivity $\lambda<0.03$ W/mK based on nano-foams, silica aerogels or mineral foams, capable to both retain and reflect heat from inside or outside or integrate other functions with solutions for both new buildings and for energetic improvement of existing ones
- Development of windows and other glass surfaces with a high insulating power and a low emissivity, whilst keeping high transparency performances and adaptive to different building structures and orientations
- Development of bio-based materials like natural fibres or foams for insulation with high durability
- Creation of innovative materials for barriers, pipes etc. for easy integration and reduction of thermal bridges
- Improvement of technical properties (e.g. fire resistance) of organic materials
- Development of chemical coupling agents and binders
- Development of new masonry based building components with integrated high-efficient insulation materials

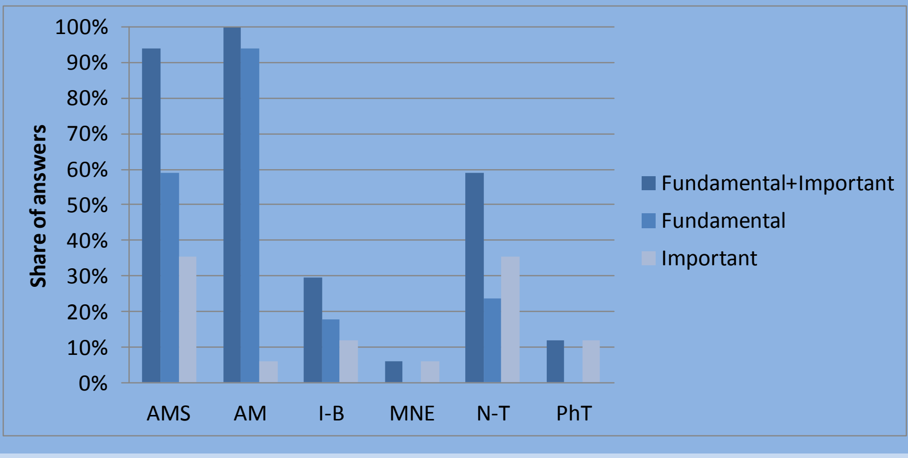
- Development of low-CO_2 advanced concrete available for durable building envelopes
- Development of basement insulation, moisture protecting systems and new building materials for draining

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of solutions such as more advanced insulating materials and components for the energetic improvement of the building envelope, including from renewable sources or waste materials, the improvement of thermally and/or acoustically insulating materials, and the development of windows and other glass surfaces with a high insulating power and low emissivity, whilst keeping high transparency performances.

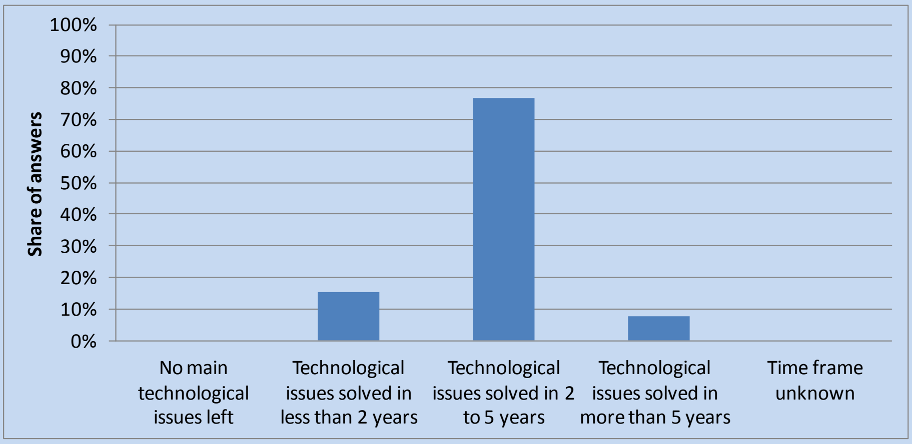
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - The construction of new buildings offers the best opportunity to deploy passive heating and cooling designs, which make use of energy-efficient building materials to minimise energy required for heating and cooling. Energy consumption for cooling is expected to increase sharply by 2050 – by almost 150% globally, and by 300% to 600% in developing countries. In hot climates, low-cost solutions such as reflective roofs and walls, exterior shades, and low-emissivity window coatings and films can curtail energy consumption for cooling. In cold climates, passive heating contributions can be increased by optimising building design and using advanced window and glazing systems (Source: Technology Roadmap – Energy efficient building envelopes; International Energy Agency (IEA), www.iea.org).
  - At the European level, the Energy Performance of Buildings Directive (Directive 2010/31/EU) is the central piece of regulation. This directive has far-reaching implications for home-owners and the construction sector. It has helped turn attention towards the energy efficiency of construction products, especially insulating products.
  - The insulation market is a mature market, with a large number of technologies available. However, innovative technologies represent a small share of the total turnover of the insulation market in the European Union (around 5%). Some Member States dominate the innovative market: these are particularly Nordic countries, Germany and Austria. With policy makers and civil society increasingly focusing on energy efficiency and the environmental impact of construction products, more innovative products are entering the market. Due to the highly competitive nature of the market, there is an innovation push for highly energy-efficient technologies. The new building business relies increasingly on green-oriented products, and the same process is starting in the retrofit sector – even though retrofit activities are less targeted by regulation. Potentially, the market for new high efficiency technologies in the insulation sector is unlimited. Even when taking into account the diversity of insulation needs across Europe (depending for instance on climate specificities), all individual homes, buildings and industries could be the target of these technologies. Growing environmental regulation is likely to provide producers with great opportunities to expand this market. Overall, the market opportunity for EU producers of new insulation technologies is high. With energy efficiency being a European flagship action in the EU 2020 strategy, awareness among producers and end users should rise, and drive the market to further take into account the environmental-related performance of the products (Source: EPEC, Detailed Assessment of the Market Potential, and Demand for an EU ETV Scheme, 2011).
- ***Results of patents scenario analysis:***
  - 14 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - No significant patent-related figures can be reported in this field

CS.1.3: Construction materials and components with low lifecycle carbon footprint

Scope:

To develop cost competitive and high performance construction materials and components with low lifecycle carbon footprint (such as green concrete, concrete using recycled aggregates, etc.).

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Demonstration of construction materials and components with low embodied carbon (e.g. green concrete, concrete using recycled aggregates, etc.) ensuring low lifecycle environmental impact
- Development of construction materials and components/elements (incl. prefabricate) containing a high level of recycled materials leading to CO_2 savings, energy savings and higher resource efficiency
- Ensuring of high and predictable durability and low lifecycle environmental impact of construction materials with low embodied carbon (e.g. green concrete, concrete using

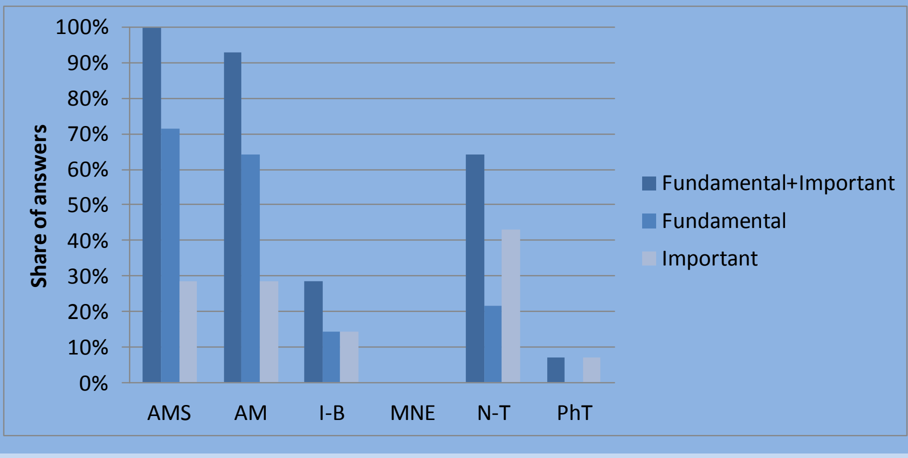
recycled aggregates, etc.)

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development and subsequent demonstration of solutions such as construction materials and components, including prefabricated ones, with low embodied carbon leading to CO_2 and energy savings, and to a global superior resource efficiency in the sector.

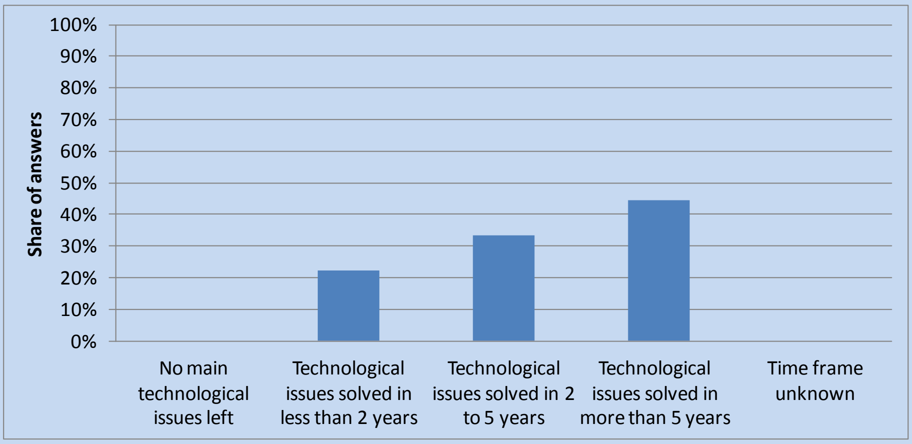
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Industrial Biotechnology (I-B) to a lower extent



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus by experts indicates also shorter periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

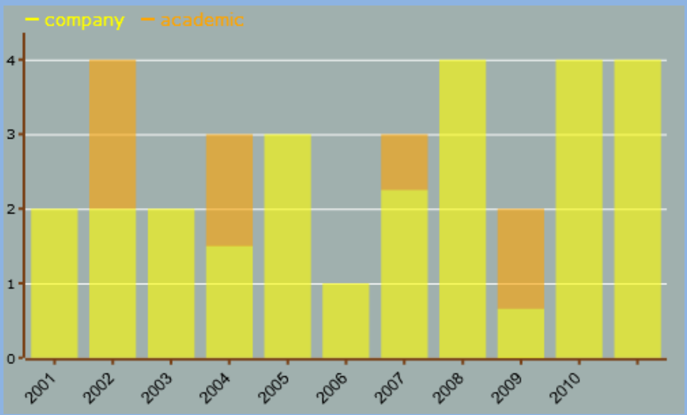
Additional information according to results of assessment:

- ***Impact assessment:***

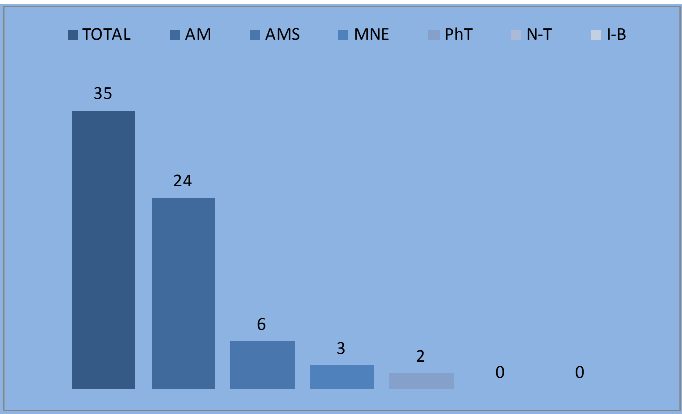
    - According to Eurostat data, construction production for EU28 was valued at 1550 billion Euro in 2011. Within this framework, the residential sector represents some 46% of the total EU production, the non-residential sector 31% and civil engineering 23%.
    - Construction production experienced a significant decrease in the last few years mainly resulted from the overall weak economic framework, high unemployment and low consumer confidence that reduced the potential in housing and non-residential construction, whereas public consolidation measures dampened civil engineering. Nonetheless, according to Euroconstruct, a positive trend is foreseen for the next 4 years. According to the Euroconstruct's outlook, during the course of the overall economic upswing, construction is expected to grow moderately by 0.9% in 2014, whereas a further more dynamic performance should follow in the forecast period 2015-2016, given a stable economic framework. Euroconstruct also foresees expansion in volume in all sectors (i.e. housing, non-residential construction and civil engineering), though such expansion has to cope with the fact that the growth path starts from low volumes of the previous years. Also as regards public works, necessary and often delayed infrastructure measures and investments will counter the public consolidation pressure.
    - Within this overall picture, driven by the need to perform more environmentally-friendly, the building and construction sector, which is a major consumer of both energy and resources, is moving toward the use of greener materials and methods. Environmentally-sustainable features are increasingly viewed by both buildings' and structures' owners and developers as a fundamental element, and attention to green building materials as well as to more sustainable construction methods is already considered a core competency, which is expected to grow in importance in the next future as the economy as a whole and the construction activity recover.
    - As environmental consciousness increases in the building and construction sector, green building standards and certifications are consequently also gaining in importance. There are several awarding programmes for certifying "green" buildings in Europe, the four most common which have gained importance are the LEED, BREEAM, DGNB, and HQE. Among these programmes, mainly certifying the energy performance of buildings, LEED also awards for the use of green building materials and the sustainable use of resources.
    - These argumentations, along with the need for energy intensive building and construction materials producing industries such as, among others, the cement and bricks producing industries to reduce the carbon footprint of their products, are at the basis of an increased interest toward cost competitive and high performance construction materials and components with low lifecycle carbon footprint (such as green concrete, concrete using recycled aggregates, etc.).
    - Source: Euroconstruct's outlook, 76th EUROCONSTRUCT Conference, Prague, 2013

- ***Results of patents scenario analysis:***

    - 32 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
    - Stable trend curve (number of patents per year)
    - Highest share of industrial applicants:



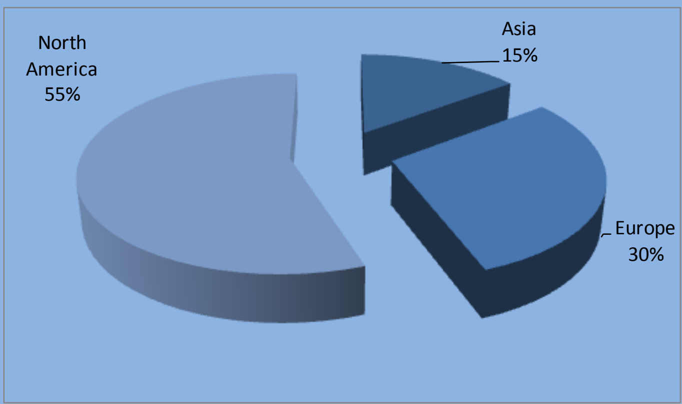
    - Patents by KET(s):



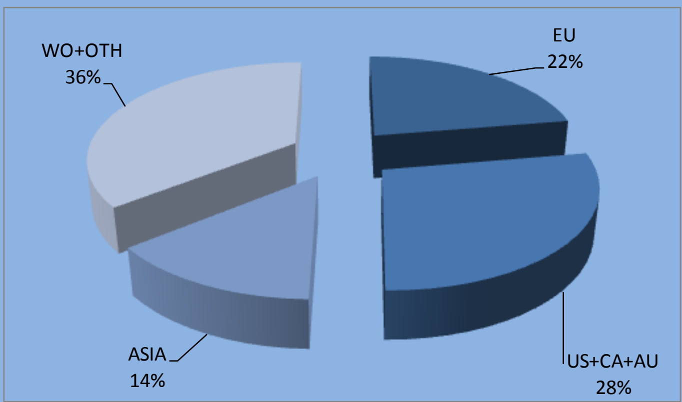
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	24
AMS	6
AMS / AM	1
MNE	3
MNE / PhT	2
PhT	2

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



CS.1.4: Lightweight structural beams and components

Scope:

To develop lightweight structural beams and components allowing completely new shapes, huge reductions in weight of the structure, besides easing construction towards higher performance works.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

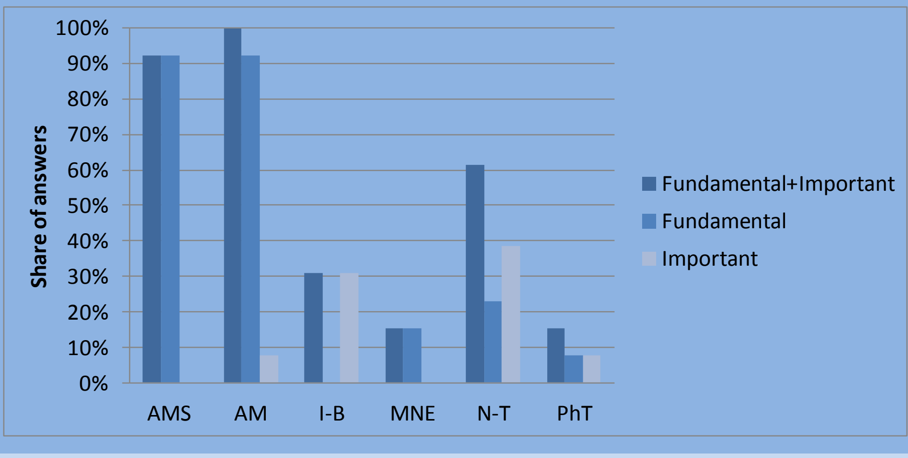
- Engineering of lightweight structural beams to ease construction towards higher performance works
- Engineering and development of automated manufacturing methods for large structures

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of lightweight structural beams and components for high performance construction, including based on high-strength/low-weight fibre-reinforced polymer composite materials or new material architectures, combined with automated manufacturing methods for large and very large structures.

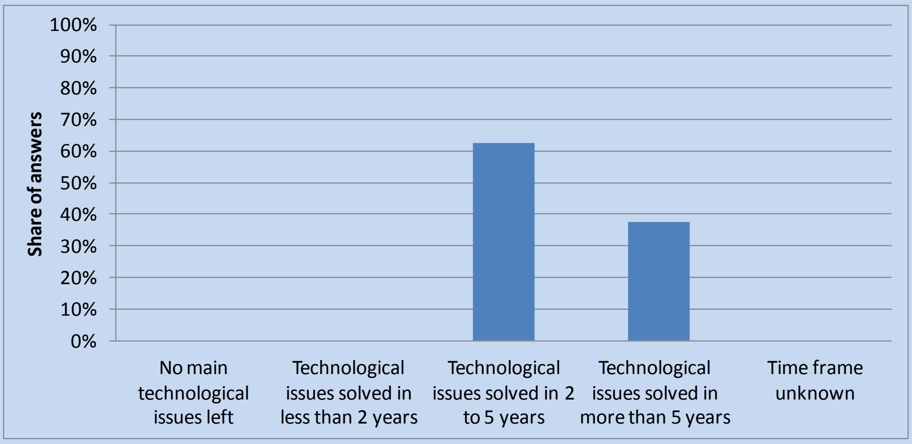
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also longer periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the

achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - The combined benefits of corrosion resistance and low weight of fibre-reinforced composites have proven attractive in many low stress applications in the construction sector. Decks for both pedestrian and vehicle bridges across waterways, railways and roadways are actually a commercial reality in both North America and Europe. An extension to the use of high performance fibre reinforced composites in primary structural applications, however, has been slower to gain acceptance although there is much development activity, with some pedestrian bridges being built entirely from composites. Composites present important opportunities to play increasing role as an alternate material to replace timber, steel, aluminium and concrete in buildings and civil infrastructure applications.
  - Fibre reinforced composites have greater strength capabilities and are less susceptible to environmental deterioration than steel. Fibre reinforced composites do not deteriorate in saline environment (which also includes areas that rely on the application of de-icing salts to maintain road access), which curtails the life of conventional structures. Additionally, fibre reinforced composites has strength to weight ratios of 50 times that of concrete and 18 times that of steel.
  - Bridges account for a major sector of the construction industry and have attracted strong interest for the utilization of high performance fibre reinforced composites, as the latter have been found quite suitable for repair, seismic retrofitting and upgrading of concrete bridges as a way to extend the service life of existing structures. Fibre reinforced composites are also being considered as a solution for new bridge structures. The commercial viability for repairs has been proven with hundreds of field applications in Europe, Japan and North America.
  - Advanced design approaches and increased manufacturing efficiencies developed for road bridge applications will benefit introduction of fibre-reinforced composites into a broader range of civil construction fields. Composites support beams are increasingly employed, with giant, pultruded carbon fibre beams now under test especially in the US for long span highway crossovers.
  - The ability to use composites to design lightweight, prefabricated modules brings about immediate cost savings by minimizing the disruption of traffic and commerce. Pre-fabricated sections can be transported to the job site, ready for installation. The lightweight composite modules can be then installed in a matter of hours instead of the days or weeks it takes to replace a deteriorated bridge parts with a conventional one.
  - The lightweight of composites is also especially valuable for the construction of waterway bridges incorporating a lift-up section to permit the passage of boats, and for ease of transportation and erection in remote areas without access to heavy lifting equipment. The composite deck has six to seven times the load capacity of a reinforced concrete deck with only 20% of the weight.
  - Source: S. Nangia, G. Srikanth, A. Mittal, S. Biswas, Composites in Civil Engineering, http://tifac.org.in
- ***Results of patents scenario analysis:***
  - No exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - No significant patent-related figures can be reported in this field

Sub-domain: Reliable and improved infrastructure management and operation

Demand-side requirements (stemming from Societal Challenges) addressed:

- Contribute to the “Smart, green and integrated transport” societal challenge

Demand-side requirements (stemming from market needs) addressed:

- Adapt infrastructures to innovative transport modes

- Maintain at a high level of efficiency and service the patrimony of the infrastructure systems
- Reduce impacts and nuisances related to urban infrastructure construction, upgrade and/or maintenance and operation
- Preserve the functional use of infrastructures in emergency episodes

CS.2.1: Solutions for adapting infrastructures to innovative transport means

Scope:

To develop solutions for adapting infrastructures to innovative transport means, such as solutions to make urban road and railroad infrastructures able to support operation of new sustainable energy sources vehicles.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

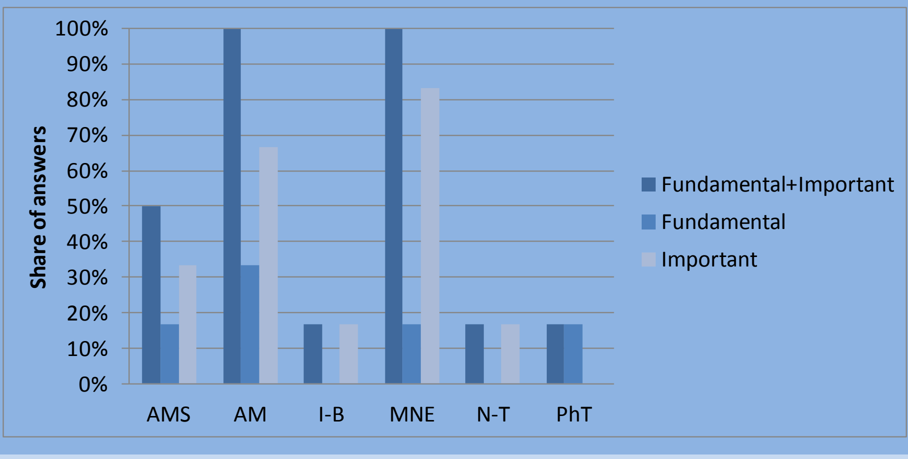
- Adaptation of existing and new infrastructure to new transport means (e.g. based on advanced technologies like magnetic levitation trains, automatic driving)
- Development of innovative means for adaptation of existing and new infrastructure to transport modes using new energy sources, needed in particular for the deployment of electric public urban transport systems
- Facilitation of dedicated road capacity for fully electric transport modes

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced solutions for adapting existing and new infrastructures to new transport means (e.g. based on advanced technologies like magnetic levitation, automatic driving, etc.) as well as to transport modes based on new energy sources (e.g. electric transport systems).

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

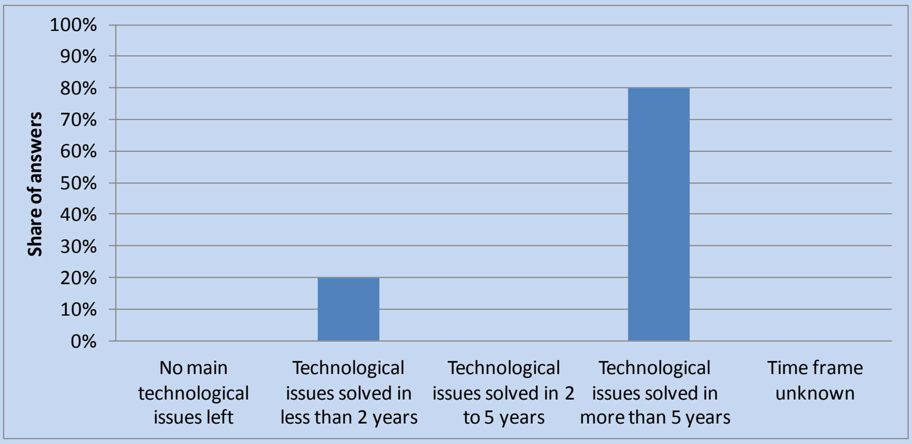
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Advanced Manufacturing Systems (AMS)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more

than 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - As an example of the adaptation of infrastructures, the market for Electric Vehicle charging stations is expected to grow rapidly from 7250 charging stations in 2012 to over 3.1 million by 2019 at a compound annual growth rate (CAGR) of 113.3% over the period 2012-2019. France, Germany, Norway and the United Kingdom are expected to lead the market due to the high adoption rates of EVs in these countries (Source: Strategic Technology and Market Analysis of Electric Vehicle Charging Infrastructure in Europe, www.frost.com).
- ***Results of patents scenario analysis:***
  - No exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - No significant patent-related figures can be reported in this field

Potential areas of industrial interest relevant for cross-cutting KETs in the Civil Security domain

Sub-domain: Contributions to Civil Security

Demand-side requirements (stemming from Societal Challenges) addressed:

- Contribute to achieving "inclusive, innovative and secure societies"

Demand-side requirements (stemming from market needs) addressed:

- Guarantee border security, considering land, maritime and country borders
- Guarantee security of people including of operators
- Guarantee privacy

SEC.1.1: Satellite- or drone-based wide area surveillance in air, land and water

Scope:

To develop multi-robot systems and drones for surveillance in air, land and water environments aimed at border security, including land, maritime and country borders or critical infrastructure and perimeter protection.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities:

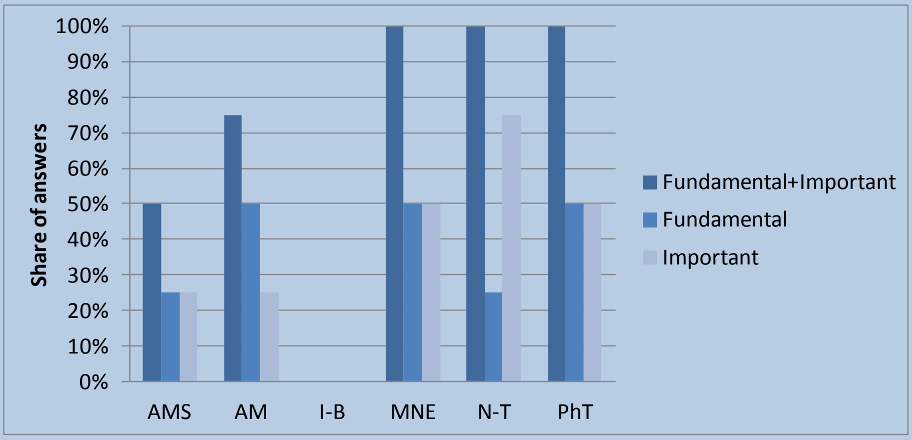
- Increase of the resolution and observation range of on-board observation sensors and sensing systems
- Enhancement of communicative interaction of robotic systems to other systems (including other robotic systems)
- Development of networked robotic architectures
- Development of improved cognitive and self-configuring software architectures
- Improvement of the (dynamic) models of physical, social and ecological environments validate sensor and motion performance
- Enhancement of user interfaces to improved human-machine interaction (two sided)
- Improvement of the robustness of robotic architectures by redundancy in hardware, software and design
- Further miniaturization and integration of actuators, sensors, control systems, energy systems and other physical manipulators
- Improvement of the efficiency of energy systems, including power management and enhanced efficiency of locomotion
- Further development of low weight power sources
- Enhancement of robot control systems, including self-learning, self-calibrating, fault tolerant, etc.
- Improvements in image recognition sensor systems, including environment assessment (objects, human emotions/behaviour, environments, etc.)
- Improvements in integrated sensory systems, including multi-sensors and high quality (bio, neuro, physical, environmental, chemical, motion, positioning, etc.)
- Development and integration of new light-weight, high strength materials
- Development of advanced integrated mechatronic systems
- Development of new concepts for distributed intelligence (e.g. swarms)
- Development of low cost robotic systems (sensors, control, locomotion, skelet, etc.)
- Improved navigation through enhanced mapping and localization (e.g. 3D, cooperative mapping, enhanced GPS or the Galileo system in the future, autonomous)

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced wide area surveillance systems based on satellites or drones, building on the increased resolution of on-board sensors and observation systems, the enhancement of the communicative interaction between robotic systems, improved user interfaces, the further miniaturization and integration of actuators, sensors, control and energy systems.

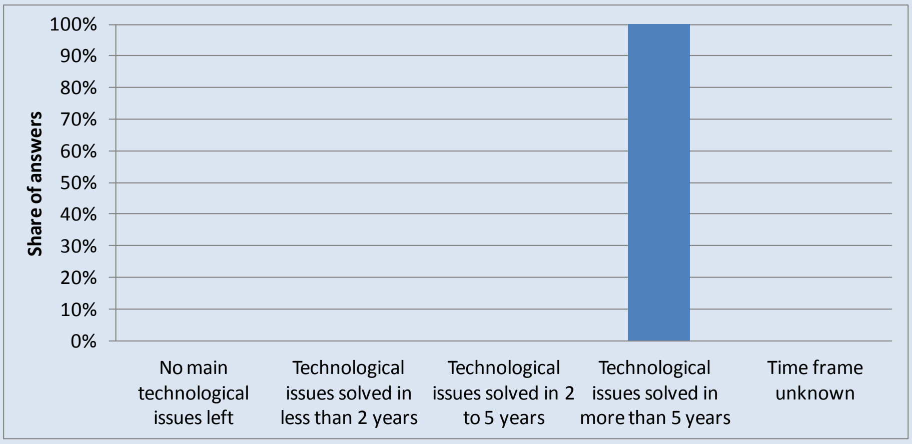
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Photonics (PhT)
- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Advanced Manufacturing Systems (AMS)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

- At least 16 out of the 28 EU Member States already own drones for military (combat and reconnaissance) or non-military (surveillance and detection) purposes. The design, development and production of more than 400 different unmanned aerial vehicle systems is now reportedly spread across at least 21 EU countries. The European Commission has long subsidised research, development and international cooperation among drone manufacturers. The European Defence Agency is moreover sponsoring pan-European research and development for both military and civilian drones. The European Space Agency is funding and undertaking research into the satellites and communications infrastructure used to fly drones. Frontex, the EU's border agency, is keen to deploy surveillance drones along and beyond the EU's borders to hunt for migrants and refugees (Source: B. Hayes, C.S. Jones, E. Töpfer, Eurodrones Inc.). This application, which has already been developed for defence sector, is clearly dual use and may be extended to the civilian segment.

- There are a number of critical technology areas in the development of UAVs in both the military and civilian sphere, including sense and avoid (S&A), secure datalinks, payloads and systems integration expertise, and the exploration of novel aerodynamic and propulsion solutions. These technologies are considered very challenging and are likely to be the ones which will provide more competitive advantages to whoever is interested in innovating them (Source: ENTR/2007/065, Study Analysing the Current Activities in the Field of UAV, 2007).

➢ ***Results of patents scenario analysis:***

- 10 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- No significant patent-related indicators can be reported in this field

SEC.1.2: Cyber security

Scope:

To develop tools and techniques for the cyber security including wireless security, cloud security and privacy, and autonomic network defence.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities:

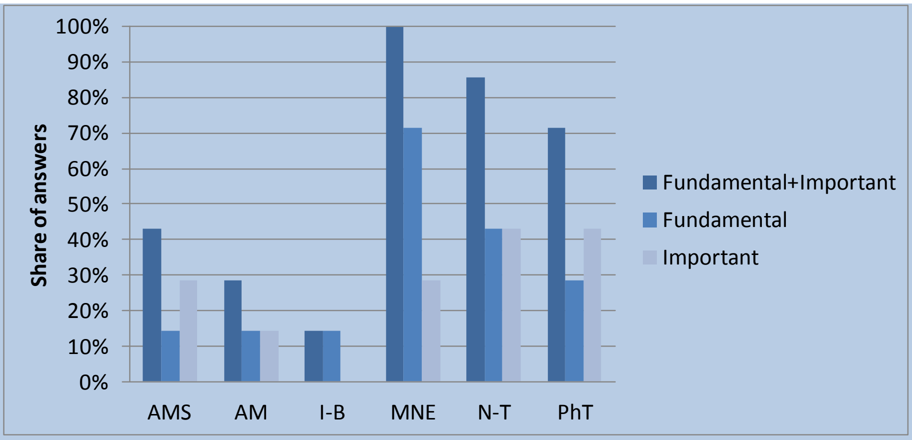
- Development of secure spectrum sharing techniques
- Development of secure operating systems for commercial cellular handsets
- Development of approaches to provide security and privacy for the growing enterprise cloud computing market
- Development of new tools and techniques to secure virtual machines
- Development of proactive network defences that can autonomically implement protective measures against identified attacks

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced tools and techniques for the cyber security, including wireless security, cloud security and privacy, and autonomic network defence, including low cost, low power, highly secure hardware-based cryptographic protection of networks, limitation of intrusion using near field communication, device-to-device communication, secure protocols and low power consumption integrity validity check.

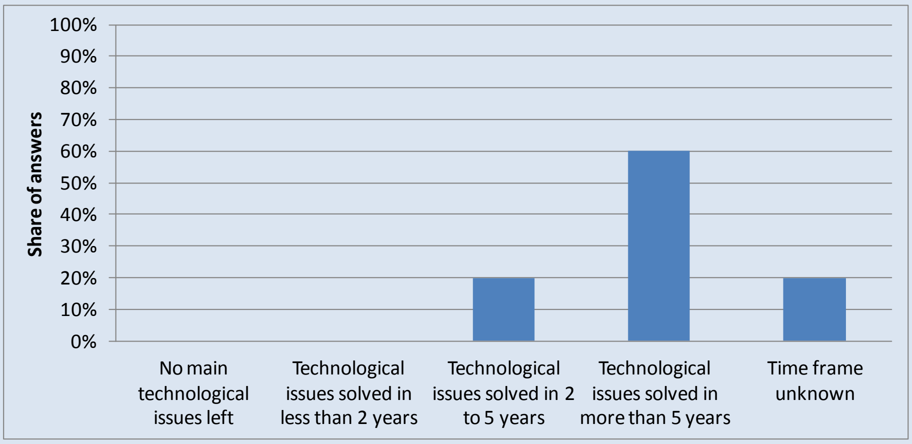
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Photonics (PhT)
- To a lesser extent, Advanced Manufacturing Systems (AMS) and Advanced Materials (AM)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Cyber security market is an amalgamation of various categories of technologies, and services, applied at various levels to protect an organization and user's personal and professional data from cyber threats. The dependence on information and communication technology is the prominent feature of today's modern and interconnected society and economy. The government, public utilities, and enterprises are dependent on internet, wireless and cloud-based services. With this dependency, cyber attacks have shown an exponential increase in the past few years and have generated the need for unified cyber security solutions to support the enhanced enterprise mobility and strict data disclosure laws. The market for security portfolios such as data encryption, authentication, security and vulnerability management, DDoS (Distributed Denial-of-Service) mitigation along with various others are experiencing a boom phase because of an increase in need for a secure and resilient cyberspace. The rapid adoption of cloud computing, data centres, and wireless communication, strict government compliances on data privacy, increasing threat in public utilities along with the rapid increase in sophistication of cyber attacks demand for integrated cyber solutions are expected to create extensive market opportunities for the cyber security solution vendors during the next years, with a market forecast to reach a value of 114 billion Euro by 2019.
  - Source: Markets and Markets, Cyber Security Market (IAM, Encryption, DLP, Risk and Compliance Management, IDS/IPS, UTM, Firewall, Antivirus/Antimalware, SVM/SIEM,

Disaster Recovery, DDoS Mitigation, Web Filtering, Security Services) - Global Advancements, Forecasts & Analysis (2014-2019), 2013, www.marketsandmarkets.com

- With a greater dependence on computer systems and a reliance on integrated networking, today's armed forces are faced with an ever-changing set of challenges in maintaining cyber security from the threat of attack. Rapid evolution in technology has forced governments and industry alike to continually develop secure systems that remain one step ahead of the enemy. As cyber systems become increasingly integrated the requirement for a multi-layered, adaptive and self-learning security system becomes imperative. This innovation field, on which the military and defence knowledge is already quite advanced, could prove useful for also civilian applications related to security, illustrating its dual use potential.

➢ ***Results of patents scenario analysis:***

- 1 patent identified in the period 2001-2011 for the specific Innovation Field in relation to KETs
- No significant patent-related indicators can be reported in this field

POTENTIAL AREAS OF INDUSTRIAL INTEREST RELEVANT FOR CROSS-CUTTING KETS IN THE MINING, QUARRYING AND EXTRACTION DOMAIN

Sub-domain: Enforcing efficient and environmentally friendly mining, quarrying and extraction

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "Climate action, resource efficiency and raw materials" societal challenge

Demand-side requirements (stemming from market needs) addressed:

- Secure the supply of raw materials and resources
- Reduce field operating costs while ensuring safety and decreasing environmental impacts
- Enable more efficient and sustainable resources utilisation
- Enhance productivity of mining, quarrying and other extractive activities
- Improve environmental management in mining, quarrying and other extractive activities
- Guarantee adequate waste management

MI.1.1: Non-invasive exploration technologies for cost-efficient underground resource detection and definition

Scope:

To develop improved non-invasive exploration technologies, such as ground penetrating radars, 3D and 4D seismic prospecting, hyperspectral imaging, Measuring While Drilling (MWD) techniques, and other geophysical technologies, are needed for more cost-efficient and environment-friendly exploration aimed at the detection and definition of underground resources (i.e. oil, gas, mineral as well as water resources).

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Improvement of non-destructive exploration technologies to detect underground resources, including ground penetrating radars, 3D and 4D seismic prospecting, hyperspectral imaging, and other geophysical technologies that make excavating not necessary
- Improvement of sensing while sampling techniques, e.g. Measuring While Drilling (MWD)

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of improved non-invasive exploration technologies, such as ground penetrating radars, 3D and 4D seismic prospecting, hyperspectral imaging, as well as sensing while sampling techniques.

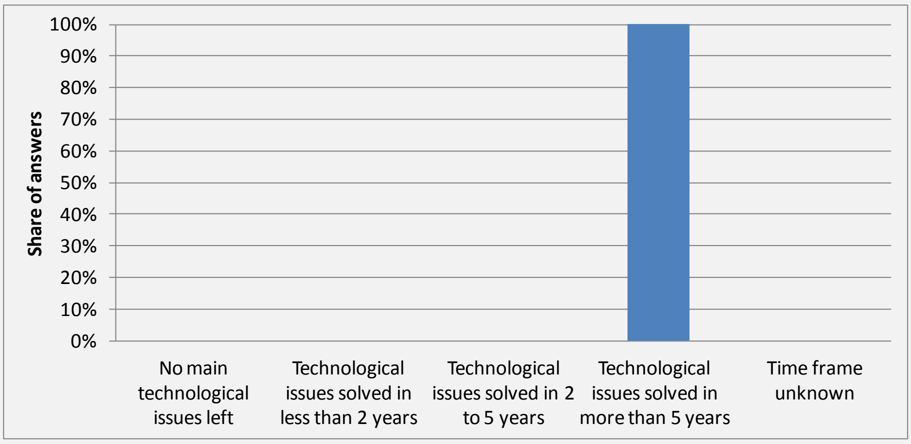
To this aim, the combination of KETs experts' opinions collected through the dedicated survey, the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)

Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting

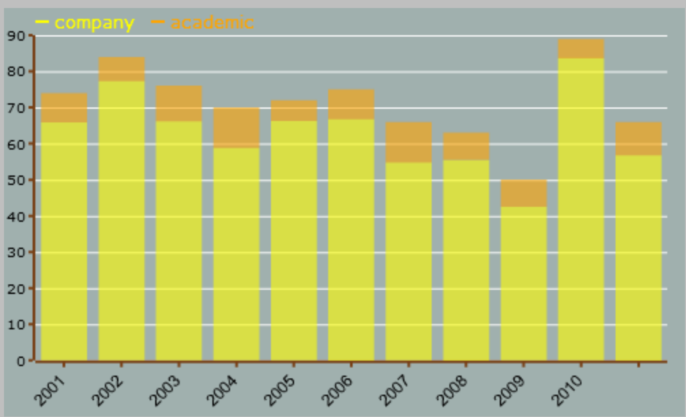
KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:



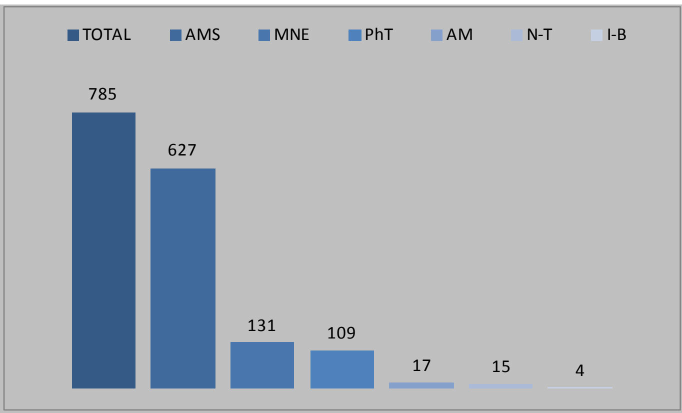
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - According to Frost & Sullivan, the demand for enhanced safety standards and for increased energy efficiency, together with technological improvements in monitoring and process control, will support growth in the European mining machinery market. The report 'Analysis of the European Mining Machinery Market' finds that the market earned revenues of 2 billion Euro in 2011, and estimates this to reach 2.5 billion Euro in 2016. The market research covers underground mining, surface mining and mineral processing equipment (Source: Frost & Sullivan, Analysis of the European Mining Machinery Market, 2012).
- ***Results of patents scenario analysis:***
  - 785 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Stable trend curve (number of patents per year)
  - Highest share of industrial applicants:



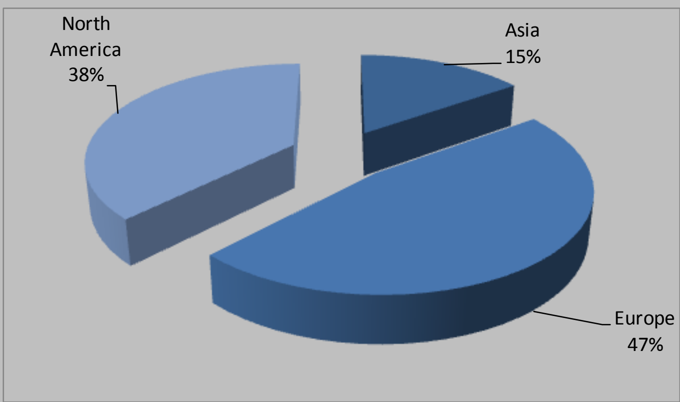
  - Patents by KET(s):



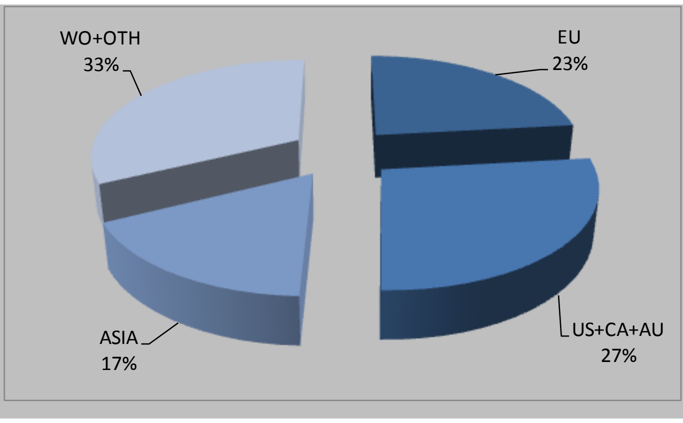
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	17
AM / MNE	1
AM / MNE / N-T	1
AM / MNE / N-T / PhT	1
AM / MNE / PhT	1
AM / N-T	1
AM / N-T / PhT	1
AM / PhT	1
AMS	627
AMS / AM	3
AMS / MNE	27
AMS / MNE / N-T	1
AMS / MNE / PhT	12
AMS / N-T	4
AMS / PhT	32
IBT	4
MNE	131
MNE / N-T	7
MNE / N-T / PhT	1
MNE / PhT	57
N-T	15
N-T / PhT	1
PhT	109

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



MI.1.2: Technologies for safe, profitable, energy- as well as cost-efficient mining and quarrying

Scope:

Improvements in technologies and processes to ensure safe as well as profitable mining or quarrying, with a focus on risk mitigation, cost reduction, productivity enhancement, energy efficiency, and environmental impact reduction.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

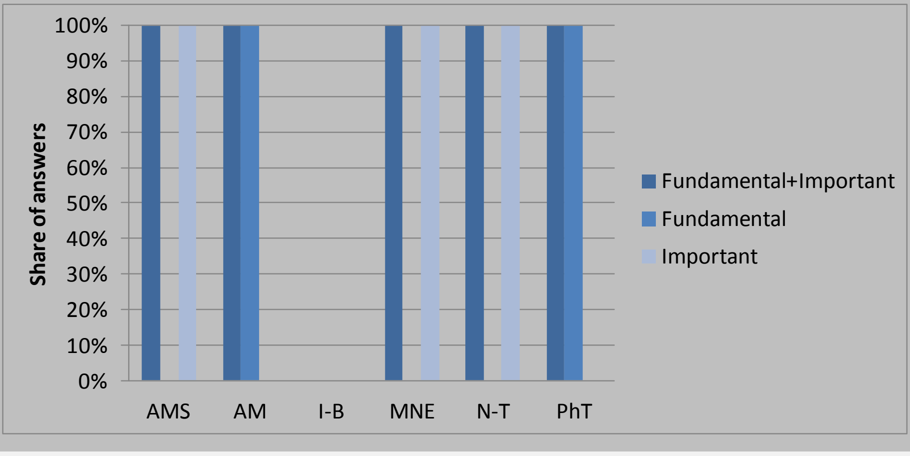
- Improvement of sensing while sampling techniques, e.g. Measuring While Drilling (MWD)
- Development of new technologies and processes to ensure safe, profitable mining or quarrying with a focus on risk mitigation, mechanized underground excavation or surface extraction, cost reduction, and productivity enhancement
- Technological improvements aimed at increasing energy efficiency in rock fragmentation as well as comminution (i.e. blasting, crushing, milling), excavation (e.g. by mechanical cutting, high-pressure water, microwaves, etc.), hauling and transportation
- Technological improvements in underground ventilation to decrease energy costs while ensuring the highest level of safety (e.g. through Ventilation of Demand)
- Development of fully automatic excavation as well as extraction technologies encompassing simulation, robotics, monitoring
- Development of more sustainable extraction methods capable to minimize mass transport, e.g. through maximization of in-situ processing, near-to-face beneficiation in mining, and the use of waste materials for backfilling
- Minimization of noise, dust, emissions and vibrations in drilling and blasting
- Optimization of tools and equipment used in aggregates production: drilling/blasting – loading/haulage – crushing/screening (including on-line size control of aggregates)
- Effective restoration of surface mining and quarrying sites
- Improvements in health and safety of workers including through enhanced communication as well as personal tracking devices, improved personal protection systems/equipment, gad detectors, etc.
- Improvements in rescue systems for the harsh environments
- Development of virtual reality-supported training modules for operators

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced technologies and processes to ensure safe, profitable mining or quarrying with a focus on risk mitigation, energy efficiency in rock fragmentation, excavation (e.g. by mechanical cutting, high-pressure water, microwaves, etc.), hauling and transportation.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Materials (AM)
- Photonics (PhT)
- Advanced Manufacturing Systems (AMS)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)

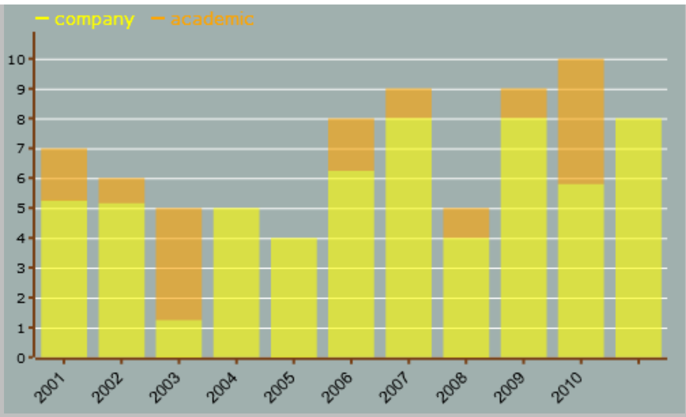


Timing for implementation:

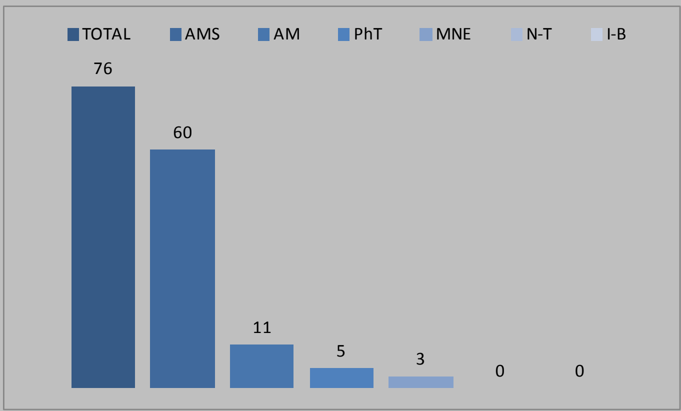
Depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
    - The EU-27's mining and quarrying sector is an industry that has been in decline for several decades. The average reduction in output during the period 1997-2007 equated to 2.2% per year. This was entirely due to a decrease in mining and quarrying activity for energy producing materials (average decline of 3.2% per annum), as the EU-27 index of production for mining and quarrying of non-energy producing materials rose, on average, by 2.0% per year over the period considered (Source: Eurostat).
    - The mining industry faces a confidence crisis. Low confidence in cost controls, return on capital and commodity prices are keeping industry leaders awake at night. To add to these concerns, the mining industry has recently stopped outperforming the broader equity markets—mining stocks fell nearly 20% in the first four months of 2013. In response, miners are trying to rebuild the market's confidence. Capital expenditures have been scaled back, hurdle rates are being increased and non-core assets are being disposed. There's a shift from maximizing value by increasing production volumes to maximising returns from existing operations from improved productivity and efficiencies (Source: http://www.pwc.com/gx/en/mining/).
- ***Results of patents scenario analysis:***
    - 76 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
    - Increasing trend curve (number of patents per year)
    - Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants, most probably standing for new technologies having been patented in the corresponding periods:



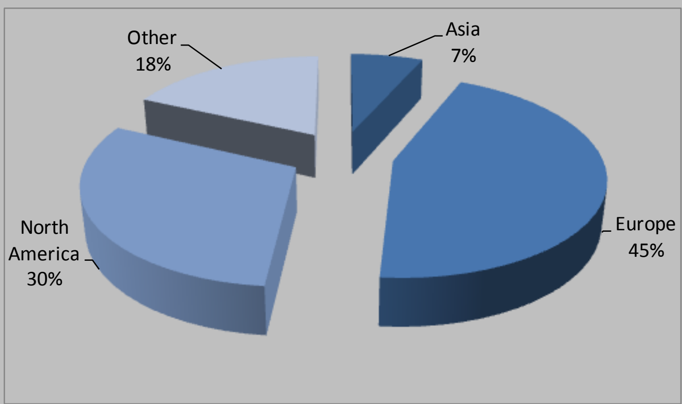
- Patents by KET(s):



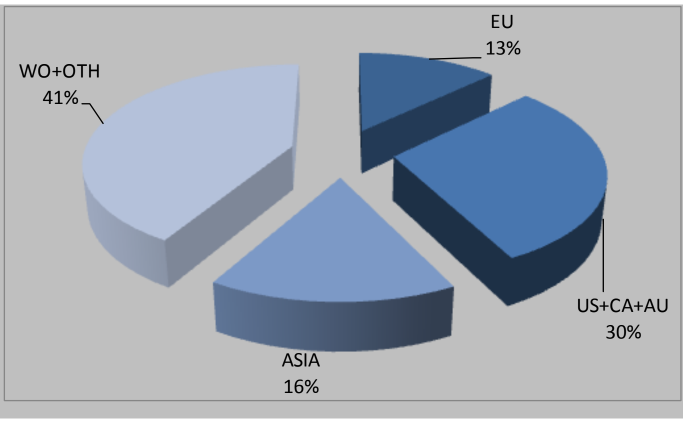
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	11
AMS	60
AMS / MNE	1
AMS / MNE / PhT	1
AMS / PhT	1
MNE	3
MNE / PhT	2
PhT	5

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



MI.1.3: Technologies and approaches for urban mining

Scope:

Metals, and other resources, can be widely found in structures, transportation, and the wide variety of products that are the hallmarks of modern life. Yet technological advances in dismantling, sorting, separation, recovery and processing of waste are needed in order to exploit this potential from urban waste.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

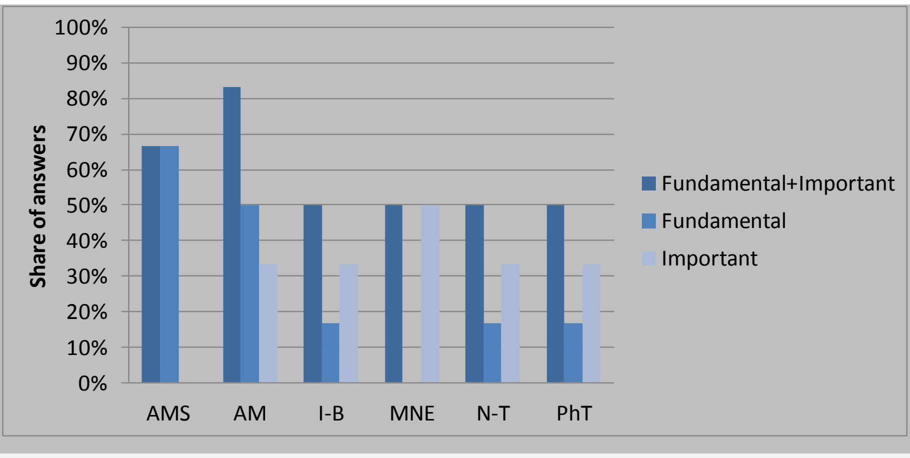
- Implementation of efficient and sustainable recovery operations (including logistics) for secondary raw materials
- Setting up of effective collection of obsolete and discarded equipment and assuring environmentally sound dismantling practices
- Technological advancements in dismantling, sorting, separation, recovery and processing of waste and scrap including Waste Electrical and Electronic Equipment (WEEE), end-of-life vehicles (ELV), batteries, structures, catalysts, slag, sludge and dusts

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to technological advances in dismantling, sorting, separation, recovery and processing of waste and the implementation of more sustainable collection and recovery of obsolete equipment.

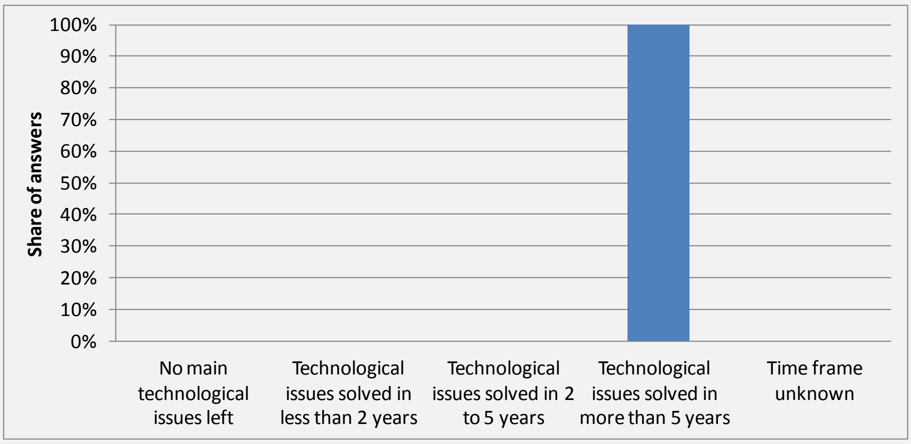
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Photonics (PhT)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Industrial Biotechnology (I-B)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

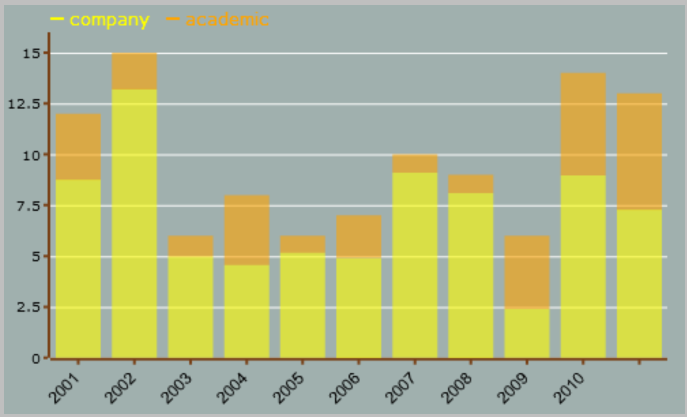
➢ ***Impact assessment:***

- According to the report by the analysts Frost & Sullivan titled "Global Opportunities in the Waste Electrical and Electronic Equipment (WEEE) Recycling Services Market," the global e-waste recycling (or urban mining) market was estimated to be worth 1 billion Euro in 2011. Moreover, the report predicts that the market will grow to 1.35 billion Euro by 2017 with a strong compound annual growth rate (CAGR) of 4%. That compound annual growth rate (CAGR) makes urban mining one of the fastest-growing sectors by volume within the global waste industry.
- Thanks to legislation, Europe is currently a world leader in urban mining. The EU's WEEE Directive requires all Member States to recover 45 tonnes of e-waste for every 100 tonnes of e-goods sold by 2016, with the recovery target increasing to 65% of sales by 2019 or 85% of all waste generated. Strong growth in the future is forecast as other global markets, mainly North America, are expected to grow aggressively to combat increasing waste volumes. Market momentum is maintained by a fast growth in e-waste volume, which is required to be appropriately managed as per evolving legislative targets (Source: Frost & Sullivan, Global Opportunities in the Waste Electrical and Electronic Equipment (WEEE) Recycling Services Market, 2012).

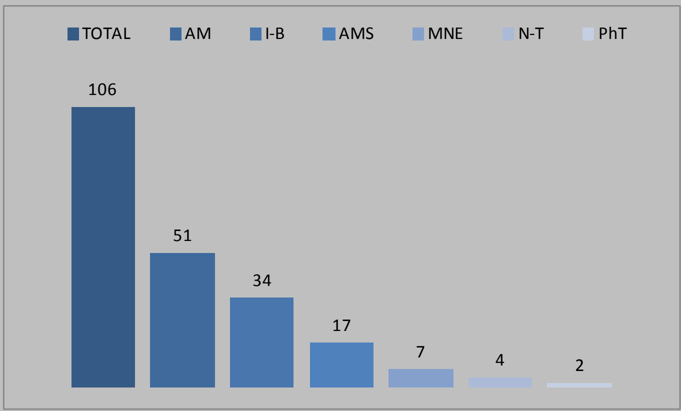
➢ ***Results of patents scenario analysis:***

- 106 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Increasing trend curve (number of patents per year)

- Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants, most probably standing for new technologies having been patented in the corresponding periods:



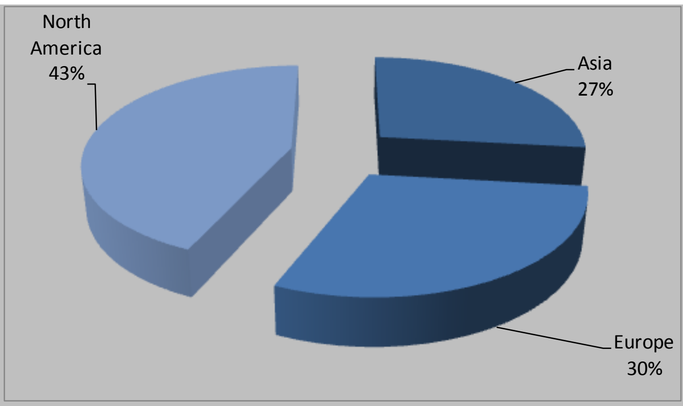
- Patents by KET(s):



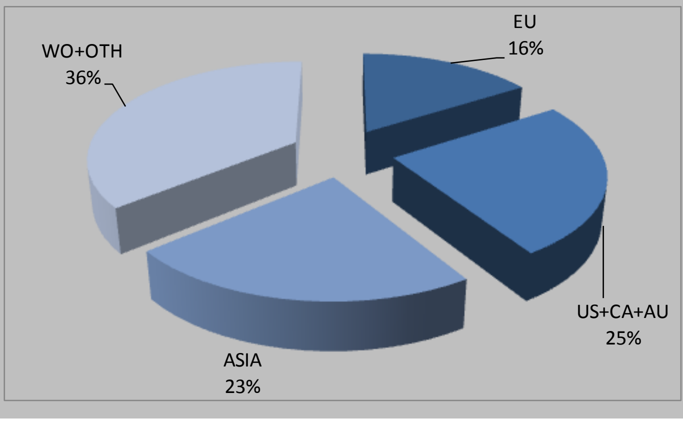
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	51
AM / IBT	2
AM / N-T	3
AM / PhT	1
AMS	17
AMS / AM	2
IBT	34
MNE	7
MNE / PhT	1
N-T	4
PhT	2

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



Potential areas of industrial interest relevant for cross-cutting KETs in the Environment domain

Sub-domain: Improved management of waste/wastewater or utilization of waste streams

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "climate action, resource efficiency and raw materials" challenge, indirectly also contributing to addressing challenges such as "food security, sustainable agriculture, marine and maritime research and the bio-economy" and "health, demographic change and wellbeing"

Demand-side requirements (stemming from market needs) addressed:

- Manage environmental hazards and pollution
- Reduce processing costs through recovery (of both energy and resources) in industrial activities
- Minimize waste thereby reducing related management costs

EV.1.1: Membrane filtration for municipal and industrial wastewater treatment

Scope:

To develop membrane filtration/separation processes (such as micro-filtration (MF), ultra-filtration (UF), nano-filtration (NF), reverse osmosis (RO)) including Membrane Bio-Reactors (MBR) for municipal and industrial wastewater treatment characterized by superior product water quality, reduced footprint at plant level and reduced energy consumption.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

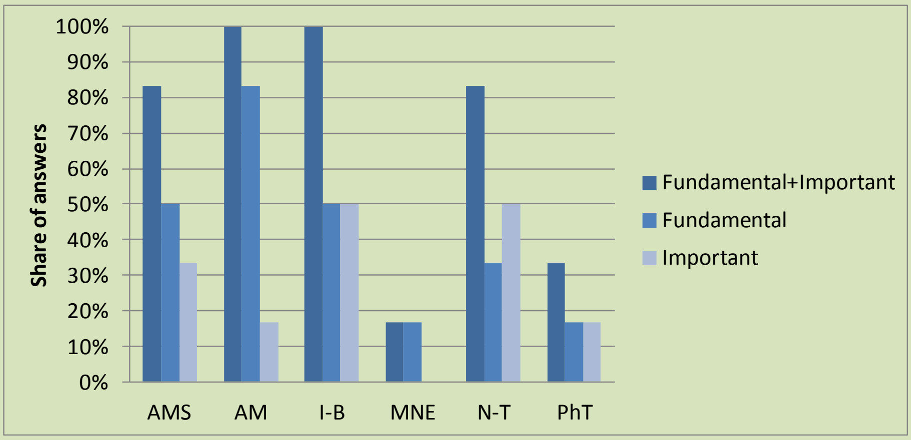
- Understanding of membrane microstructure and trans-membrane transport and tailoring of membrane microstructure and trans-membrane transport processes thanks to improved materials and precision manufacturing
- Engineering of membranes selectivity through design of pore size and selection of materials and related manufacturing
- Incorporation of membranes into housing modules designed to produce optimal hydrodynamic conditions for separation
- Development of the interfaces and control systems needed to integrate membrane modules into the various process configurations
- Cost reduction through membranes as well as process optimization
- General improvements in membrane filtration equipment to achieve increased performance and reduced operating as well as maintenance costs

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of higher performance membrane filtration/separation processes for municipal and industrial wastewater treatment, characterized by superior product water quality, reduced footprint at plant level and reduced energy consumption. The integration of KETs could particularly contribute to tailoring membrane microstructure and trans-membrane transport processes thanks to improved materials and precision manufacturing, along with general improvements in membrane filtration equipment to achieve increased performance and reduced operating as well as maintenance costs.

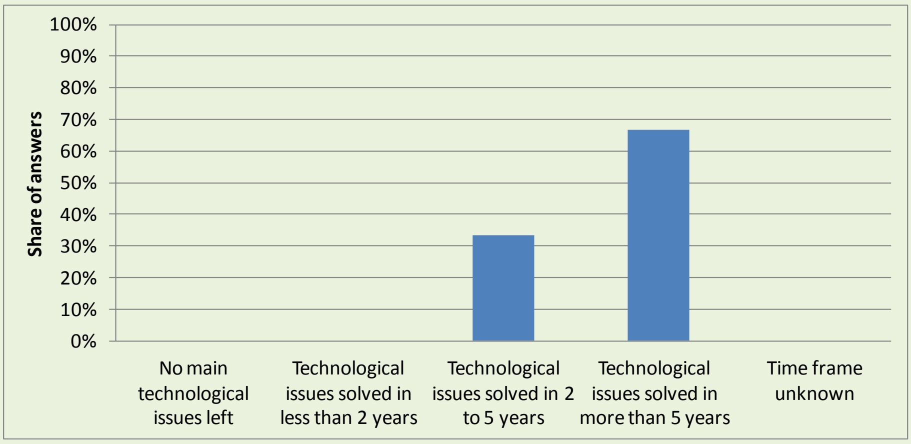
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Industrial Biotechnology (I-B)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus by experts indicates also shorter periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Market drivers for water and wastewater treatment are dominated by the implementation of stricter regulations and the need to reduce energy costs in treatment processes. Innovation is therefore focused on applications that will produce higher quality water at lower costs. Energy efficient treatment processes such as low pump rate membrane technologies are particularly suited to meeting these objectives. The waste and wastewater treatment industry is a mature industry that has been subject to decades of continuous tightening of water quality regulations. The scope for innovation is therefore incremental, although there remain opportunities to refine essentially mature technologies. There is also a need to move away from offsite laboratory testing to low cost and compact test kits that provide real time data analysis on site and which can be used by staff with minimal training (Source: EPEC, Detailed Assessment of the Market Potential, and Demand for an EU ETV Scheme, June 2011).
  - Within this framework, the majority of investments in this field are expected to take place in the rehabilitation of wastewater treatment plants. In Europe there are 60 000

wastewater facilities and most of them still need to comply with the EU treatment directives and be upgraded to perform nutrient removal. A priority for wastewater utilities is to comply with the Urban Wastewater Treatment directive by 2015. Frost & Sullivan estimate that most sewage purification plants partly need to be retrofitted by 2015 to meet stringent EU wastewater treatment legislation, requiring nutrient removal in sensitive areas. In parallel with rehabilitation investments necessary to address the Urban Waste Water Treatment Directive, wastewater utilities are also planning to introduce measures to improve operational performance and improve their economic efficiencies. According to the European Union, for sensitive areas "more stringent treatment is in place for 72% of the pollution load, with a compliance rate of 85%". Only the Netherlands, Germany and Austria are 100% compliant with the Directive. The other Member States are required to comply with this directive by 2015, thus new investments in tertiary and advanced treatment technologies are expected (Source: Frost & Sullivan, Analysis on Western European Water & Wastewater Utilities Market, 2011).

- In 2010, the total turnover of the EU water and wastewater treatment industry was 95 billion Euro. The EU was home to the top five utilities in the global market: Suez, Veolia, SAUR, Agbar and RWE. Together these industry giants, dominated by French and German utilities, accounted for 32% of the global market in 2010. As a result of many years of acquiring technology companies, the largest utilities such as French majors Veolia and Suez, have built up considerable technology capabilities across a diverse set of applications. This gives them unprecedented market strength and dominance (e.g. Suez acquiring Degrémont). Consequently, the largest utilities are both the leading water and wastewater treatment technology suppliers and users of such technologies (Source: EPEC, Detailed Assessment of the Market Potential, and Demand for an EU ETV Scheme, June 2011).
- Many of the other major suppliers in the sector are also multi-sector global technology giant OEMs such as Siemens (Germany) and GE (USA). To broaden their product portfolios, besides investing considerable proportions of their turnover in global R&D, these firms have also expanded through acquisition of innovative technology companies, particularly in the membrane market. Notable exemplars include Siemens' purchase of Memcor (Australia) and Inge Watertechnologies AG (Germany), and GE Power & Water's purchase of Zenon Environmental (Canada) (Source: EPEC, Detailed Assessment of the Market Potential, and Demand for an EU ETV Scheme, June 2011).
- Germany is the largest EU exporter of water technologies accounting for 33% of intra-EU and extra-EU exports. The next largest exporters are Italy and the Netherlands each with 10% of the EU export market (Source: EPEC, Detailed Assessment of the Market Potential, and Demand for an EU ETV Scheme, June 2011).

➢ ***Results of patents scenario analysis:***

- No significant patent-related indicators can be reported in this field

EV.1.2: Integrated water management aimed at water use minimization, reuse or recycling in industry

Scope:

Integrated water management aimed at water use minimization, water reuse or recycling especially aimed at water-intensive industrial activities, which exploits solutions for the reuse or recycle of process water in a closed-loop inside a factory or on a broader perimeter among different factories and/or solutions for optimizing water-energy coupling aimed in water cooling.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Development of solutions for the reuse or recycle of process water in a closed-loop inside a factory or on a broader perimeter, among different factories
- Development of solutions for optimizing water-energy coupling aimed in water cooling while reducing the use of fresh water including by improved water reclamation through water recirculation on site (e.g. treat and reuse cooling tower/coke quenching blowdown water for dust collection; use recovered waste heat to turn water into steam for power generation, etc.)
- Planning of stormwater containment and processing, including runoff water recovery

from coke ovens or coal stockpile

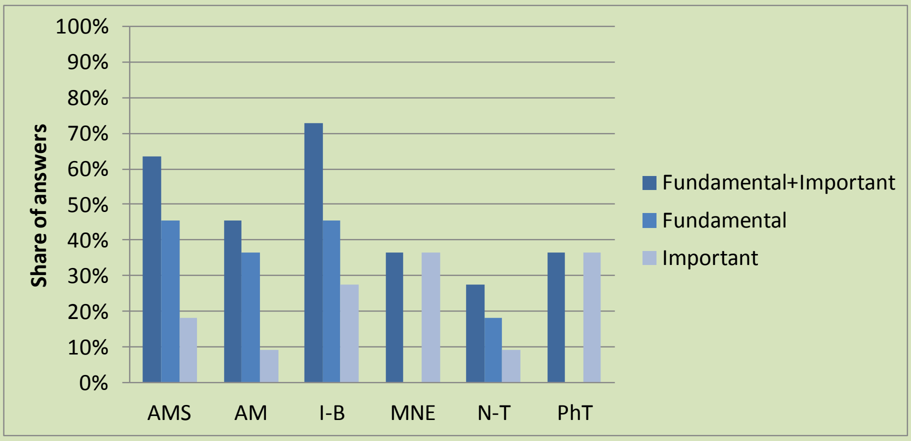
- Development of advanced filtration (such as micro-filtration (MF), ultra-filtration (UF) and nano-filtration (NF)) and reverse osmosis (RO) technologies to reduce the cost of effluent water post-processing and allow filtering out pollutions still hardly eliminated

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced integrated water management approaches aimed at water use minimization, water reuse or recycling especially aimed at water-intensive industrial activities.

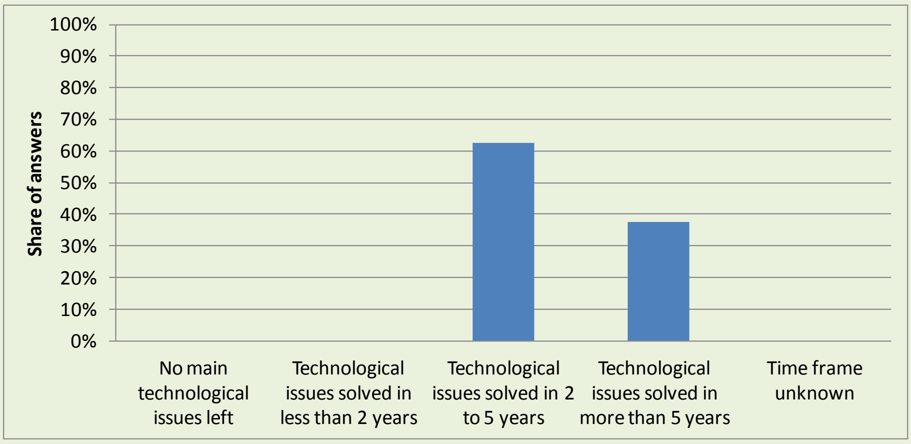
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Industrial Biotechnology (I-B)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also longer periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

- As in the case of urban water and wastewater treatment, industrial wastewater treatment market drivers are also dominated by the implementation of stricter regulations that are stimulating especially water-intensive industries in the take up of cost-effective integrated water and wastewater treatment solutions aimed at water use minimization and water reuse or recycling. This expanding practice exploits solutions for the reuse or recycle of process water in a closed-loop inside a factory or on a broader perimeter among different factories and/or solutions for optimizing water-energy coupling aimed in water cooling in order to recover the heat that is available in the water.
- Like in the case of urban water and wastewater treatment, also in the case of industrial wastewater treatment the need is to reduce energy costs.
- Within this framework, customized plant solutions and services are being offered by various companies that are providing the design and engineering, while in terms of technology suppliers these are often the same as for urban water and wastewater treatment solutions.

➢ ***Results of patents scenario analysis:***
- No significant patent-related indicators can be reported in this field

EV.1.3: Integrated heat management (including through waste heat utilization) in industry

Scope:

To develop integrated heat management approaches (including through waste heat utilization and industrial symbiosis) exploiting the integration of energy and effluents management systems at site and/or local environment scale, taking advantage of community consumption or production to optimize the overall energy balance of, especially, energy-intensive industries.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

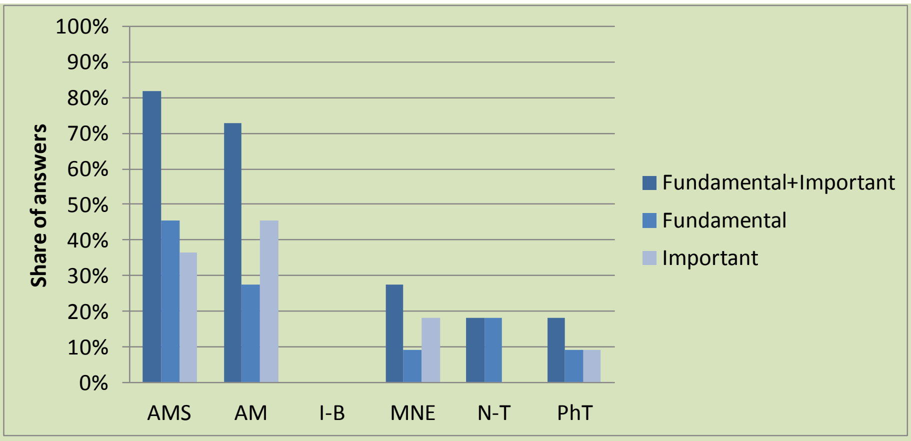
- Integration of energy and effluents management systems at site and/or local environment scale, taking advantage of community consumption or production to optimize the overall energy balance of the energy-intensive industries
- Reduction of processing costs through recovery (of both energy and resources) in industrial activities

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced integrated heat management approaches (including through waste heat utilization and industrial symbiosis) exploiting the integration of energy and effluents management systems at site and/or local environment scale, taking advantage of community consumption or production to optimize the overall energy balance of, especially, energy-intensive industries. To this end, the integration of KETs could particularly contribute to the development of enhanced materials addressing the important issues of durability, efficiency and cost of systems subject to the high temperatures, along with the development of specialized coatings improving heat transfer concepts.

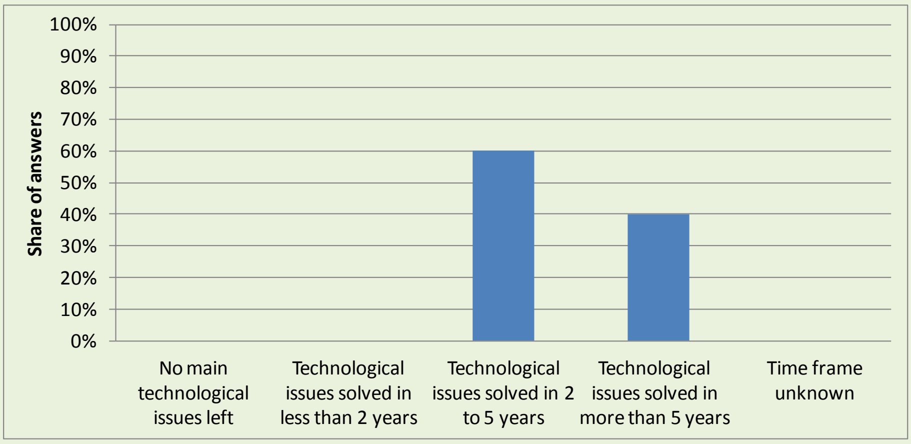
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also longer periods being necessary:



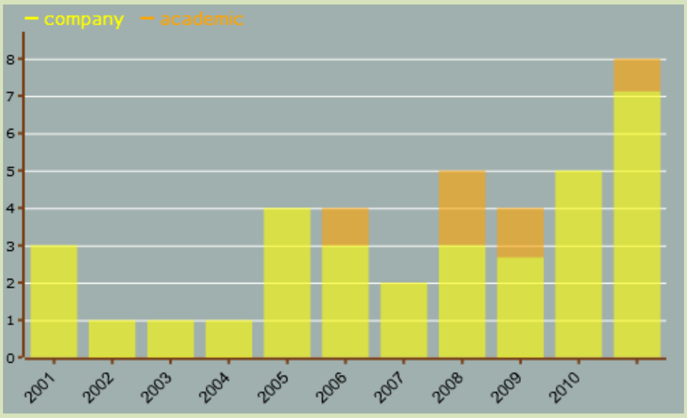
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

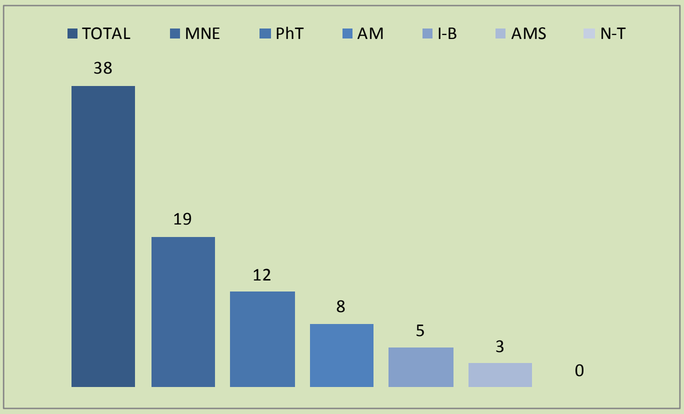
➢ ***Impact assessment:***

- The demand for waste heat recovery systems will continue to surge with the growing requirement for energy efficiency and rising environmental concerns regarding industrial waste heat emissions. Waste heat recovery is in fact being increasingly regarded by industry as offering energy savings thanks to effective utilization of the waste heat potential as a solution to the concerns over increasing energy and electricity prices. Technological improvement is as a major opportunity for the waste heat recovery systems market. The primary consideration in the R&D effort of this market lies in minimizing economic costs of waste heat recovery technologies.
- According to forecasts, the waste heat recovery market will reach 39 billion Euro by 2018. Europe dominates the market, accounting for a major share of about 38% in 2012. Asia-Pacific will experience highest growth rate of 9.7% in the next years from 2013-2018. Key regions in Asia-Pacific market are China and India, which will experience the highest installations of waste heat recovery systems.
- Source: Markets and Markets, Waste Heat Recovery Market by Application (Pre-heating, Steam Generation, Electricity & Others), and Industry (Petroleum Refining, Heavy Metal, Cement, Chemical, Natural Gas Compression, Pulp/Paper Industry & Others) - Global Trends & Forecast to 2018, 2014

- ***Results of patents scenario analysis:***
  - 38 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Increasing trend curve (number of patents per year)
  - Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants, most probably standing for new technologies having been patented in the corresponding periods:



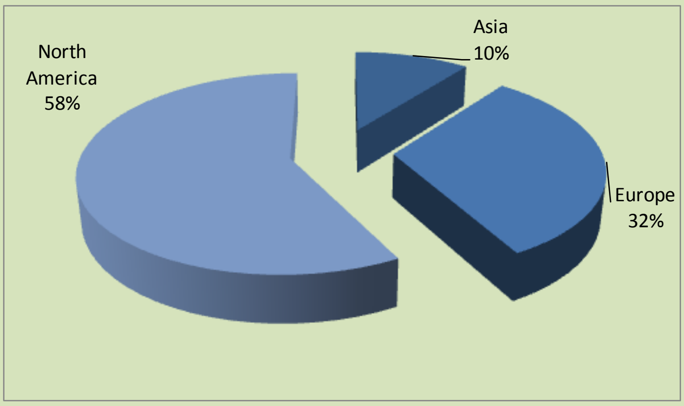
  - Patents by KET(s):



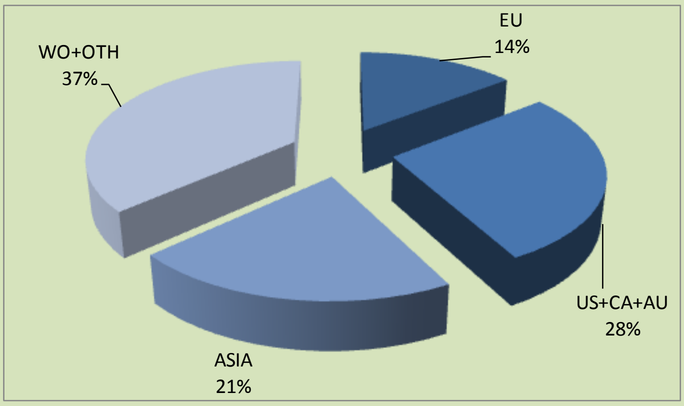
  - Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	8
AMS	3
IBT	5
MNE	19
MNE / PhT	9
PhT	12

  - Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



EV.1.4: Integrated gaseous effluents management aimed at emissions control, compounds and energy recovery

Scope:

To develop advanced integrated gaseous effluents management approaches aimed at both improved emissions control in industrial plants as well as transport means (e.g. ships), and compounds and energy recovery in industrial facilities.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Combination of optimized CCS technologies to allow carbon capture and storage (CCS) from carbon gas emissions all over the cokemaking, sintering, ironmaking and steelmaking processes (especially from blast furnace gas)
- Development of advanced filters and adsorbers, catalysis, plasma post-treatment and other ways for oven and furnace top gas recycling and dust emission control, so as to capture CO_2, filter out dust and pollutants (SO_x, NO_x and dioxins from sintering, heavy metals, etc.), extract calories and/or produce power (e.g. burn blast furnace and coke oven gases into an advanced combined cycle power plant)
- Integration of gas separation plants to blast furnace facilities so as to enable Top Gas Recycling (i.e. reuse useful components as Carbon Monoxide (CO) as a reducing agent into the furnace, reducing the need for coke, and inject Oxygen (O2) instead of preheated air, removing unwanted Nitrogen (N_2) and facilitating CCS)
- Integration of energy and effluents management systems at site and/or local environment scale, taking advantage of community consumption or production to optimize the overall energy balance of the energy-intensive industries
- Fuel quality improvement and integration of environmental protection measures into the transport and energy sectors

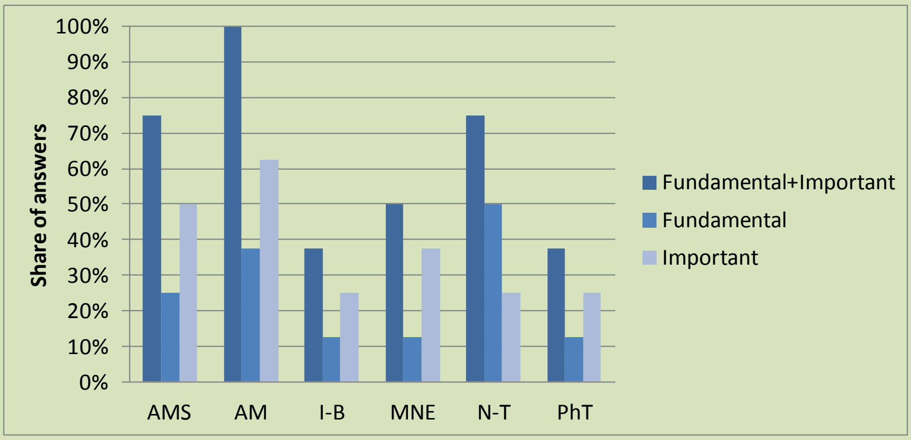
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced integrated gaseous effluents management approaches aimed at both improved emissions control in industrial plants as well as transport means, and compounds recovery in industrial facilities. The integration of KETs could particularly contribute to the development of solutions such as advanced filters and adsorbers, improved catalysts, plasma post-treatments and other ways for oven and furnace top gas recycling and dust emission control allowing to capture CO_2, filter out dust and pollutants, and recover materials.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

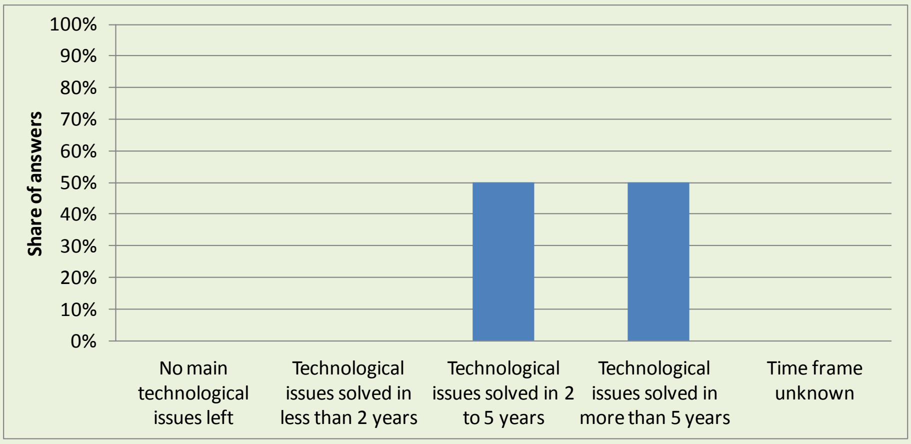
- Advanced Manufacturing Systems (AMS)

- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Micro- and Nano-Electronics (MNE)
- To a less important extent, Photonics (PhT) and Industrial Biotechnology (I-B)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of either 2 to 5 years or more than 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Drivers for gaseous effluents management and emissions control technologies are dominated by increasingly strict regulation in sectors where gaseous emissions are among the major issues, being mainly power generation, industrial processing, transport in its various forms (land, marine, air) and space heating.
  - The specific requirement for reducing air-polluting emissions represents hence the most significant driver for the European end-of-pipe emissions control equipment market. End-of-pipe emissions control equipment is installed in order to comply with legislative requirements, thus avoiding penalties.
  - As a result, the end-of-pipe emissions control equipment market in Europe has been estimated by Global Industry Analysts to reach 4 billion Euro by 2015.
  - In the longer term, developments in air pollution prevention strategies are moreover reported to be likely to displace conventional use of end-of-pipe pollution control equipment, which is traditionally expensive. This thereby will also open up opportunities for mitigation-at-source technologies. In addition to environmental performance, air pollution prevention technologies in this regard have the added advantage of being

economical in the long run in comparison with end-of-pipe technologies.

- ➢ Key players dominating the European market were reported to include AAF International, ALSTOM SA, A-TEC Industries AG, AE&E Lentjes GmbH, Balcke Duerr GmbH, Clyde Bergemann EEC, Donaldson Company Inc, EWK Umwelttechnik GmbH, Energomontaz-Polundine SA, Fabryka Elektrofiltrow “Elwo” SA, Impregilo Group, Fisia Babcock Environment GmbH, FLSmidth Airtech Company, Foster Wheeler Ltd, Fujian Environmental Protection Co. Ltd, Haldor Topsoe A/S, Hamon Group, Hitachi Zosen Corporation, Hosokawa Micron Group, Johnson Matthey, Mitusi Mining Company Limited, Polimex-Mostostal SA, Rafako SA, Termokimik Corporation, Wahlco Inc. ZVVZ AS, and ZVVZ-Enven Engineering AS, among others.
- ➢ Source: Global Industry Analysts Inc., End-of-Pipe Air Pollution Control Equipment: A European Market Report, 2009

➢ ***Results of patents scenario analysis:***

- ➢ No significant patent-related indicators can be reported in this field

EV.1.5: Use of waste as a resource enabled by advanced sorting, separation and treatment technologies

Scope:

To provide for an increased use of waste as a resource enabled by advanced sorting technologies capable of recognizing various waste types in a more effective way, advanced separation approaches capable of separating waste into the various recoverable waste streams, and advanced treatment technologies capable of treating the various waste streams, towards a circular economy.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

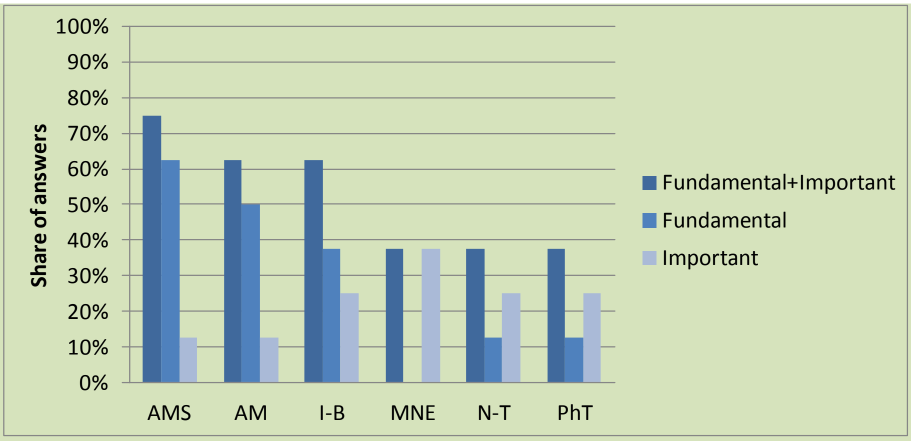
- Development of advanced sorting technologies capable to recognize various waste types in a more effective way
- Development of advanced separation approaches capable to separate waste into the various recoverable waste streams
- Development of advanced treatment technologies capable of treating the various waste streams

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced solutions aimed at an increased use of waste as a resource towards the circular economy, thanks to the development of more advanced sorting, separation and treatment technologies that are able to sort and separate waste more effectively into the various recoverable waste fractions and treat them accordingly toward effective recovery. Among technologies, one should mention sensors, a diverse range of which (based on e.g. optical, X-ray, electromagnetic, conductive, thermal technologies) allows to recognize the various materials within waste streams, as combined with effective separation methods (based on e.g. grasping, ejection using compressed air, etc.) or treatment technologies.

To this aim, the combination of KETs experts’ opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Photonics (PhT)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Industrial Biotechnology (I-B)



Timing for implementation:

Waste sorting, separation and treatment technologies are actually already widely applied in industrial practice. Although this Innovation Field has been assessed by KETs experts as still entailing some R&D issues that require more than 5 years for being solved (especially referring to advanced sorting technologies), innovation in this field is actually of the incremental type, for which support can in principle be foreseen throughout time. Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Waste sorting, separation and treatment technologies are already widely applied in industrial practice, although potentials for improvement through the implementation of more advanced solutions are high.
  - One of the key features of companies leading the market is the ability to sort the increasingly diverse range of materials coming through, and deal with them appropriately. TOMRA Sorting Solutions, a global market leader in sensor-based sorting solutions with its headquarters in Norway, provides technology for the recycling, mining and food industries under the product names TITECH, CommodasUltrasort and Odenberg respectively, has long been aware of this issue and has been spearheading technologies which have now been adopted across the industry. The company provides technologies and complete equipment for sorting a huge range of materials, from plastic bottles and WEEE to construction and industrial waste (Source: Waste sorting, A look at the separation and sorting techniques in today's European market, www.waste-management-world.com; Press Release by TOMRA, 2012, www.tomra.com).
  - Among technologies, one should mention sensors, a diverse range of which (based on e.g. optical, X-ray, electromagnetic, conductive, thermal technologies) allows to recognize the various materials within waste streams, as combined with effective separation methods (based on e.g. grasping, ejection using compressed air, etc.) and subsequent treatment technologies enabling recovery of the various waste streams.
  - As an example, Waste Electrical and Electronic Equipment (WEEE) is currently considered to be one of the fastest growing waste streams in the EU, growing at 3-5% per year. WEEE contains diverse substances that pose considerable environmental and health risks if treated inadequately. On the other hand, the recycling of WEEE offers substantial opportunities in terms of making secondary raw materials available on the market. EU legislation promoting the collection and recycling of such equipment (Directive 2002/96/EC on WEEE) has been in force since February 2003. The legislation provides for the creation of collection schemes where consumers return their used waste equipment free of charge. Yet, separation still largely relies on manual work (Sources: Eurostat, http://epp.eurostat.ec.europa.eu).
- ***Results of patents scenario analysis:***
  - No significant patent-related indicators can be reported in this field

Sub-domain: Earth observation for environment monitoring

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "climate action, resource efficiency and raw materials" challenge, indirectly also contributing to address challenges such as "food security, sustainable agriculture, marine and maritime research and the bio-economy" and "health, demographic change and wellbeing"

Demand-side requirements (stemming from market needs) addressed:

- Manage environmental hazards and pollution
- Ensure health and safety of people including through managing environmental pollution
- Ensure health and safety of people including through managing environmental hazards

EV.2.1: Satellite- or drone-based Earth observation for meteorology, environment monitoring and other wide area services

Scope:

Satellite or drone-based Earth observation systems for meteorology, environment monitoring, land exploration and other wide area services including homeland surveillance.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

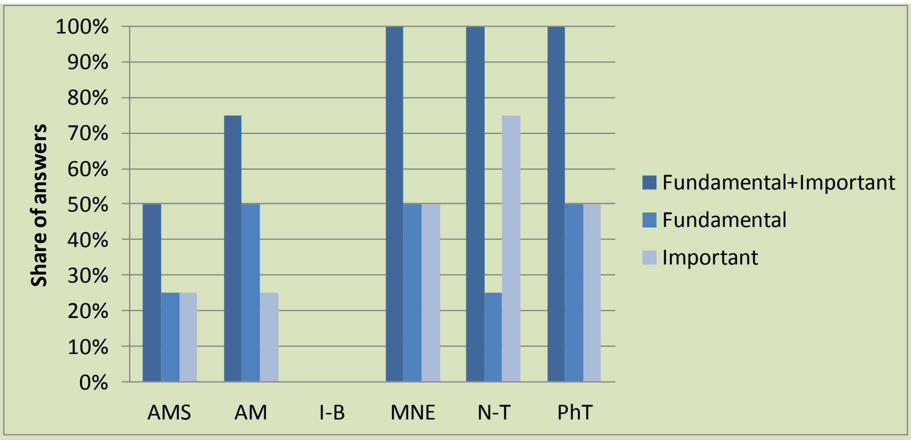
- Increase of the resolution and observation range of on-board Earth observation sensors and sensing systems
- Optimization of data chains, from generation to processing, compression, storage and transmission, so as to reduce resource use and increase security and dependability
- Setup of cost-effective versatile satellite and constellation architectures adapted to changing missions
- Development of enablers for Earth Observation satellite constellation, including launching, positioning and station keeping capabilities, inter-satellite links and related ground segment facilities
- Enabling of simulations and data processing by supercomputing
- Especially for drone-based observation systems, improvement of human-machine interfaces, improvement of the robustness of robotic systems and architectures (including through the development and integration of lightweight, high strength materials and the development of advanced integrated mechatronic systems), improvement of energy systems (including through the development of low weight power sources and through improved power management solutions), enhancement of locomotion efficiency,

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced wide area observation systems based on satellites or drones, building on the increased resolution of on-board sensors and observation systems, the enhancement of the communicative interaction between robotic systems, improved user interfaces, the further miniaturization and integration of actuators, sensors, control and energy systems.

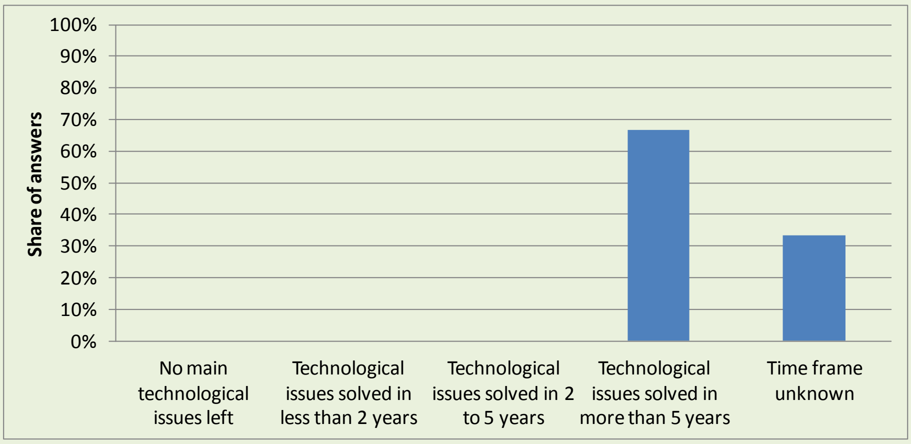
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Photonics (PhT)
- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Advanced Manufacturing Systems (AMS)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - The Global Satellite-based Earth Observation market will grow at a compound annual growth rate (CAGR) of 11.34% over the period 2013-2018. One of the major trends witnessed in the market is the formation of the GEOSS. GEOSS is an internet-based platform that allows users of Earth observation data to access, search, and use the data, information, tools, and services for their needs. GEOSS is mainly used to develop a data-driven system to investigate the Earth's past, present, and future scenarios and models. In addition, GEOSS is expected to address societal benefit areas of critical importance such as disaster, climate, water, weather, ecosystem, agriculture, biodiversity, health, and energy. GEOSS was developed by the GEO, a voluntary partnership of governments and international organizations, to utilize the growing potential of Earth observation. The GEO has been coordinating efforts to build GEOSS on the basis of a 10-year implementation plan. The GEOSS system is expected to be completed by 2015. Therefore, the formation of GEOSS is an emerging trend that is expected to have a positive influence on the growth of the market during the forecast period.
  - According to the report *"Global Satellite-based Earth Observation Market 2014-2018"*, one of the main drivers in this market is the increasing number of Earth observation satellites being launched. Seven Earth observation satellites were launched between January 2013 and October 2013. In addition, almost 30 Earth observation satellite missions are expected to be launched November 2013-December 2014, and almost 258

Earth observation satellites are expected to be launched during 2014-2029.

- Further, the report states that one of the major challenges in the market is the increasing adoption of UAV-based Earth observation. Many defence organizations as well as natural resources and biodiversity researchers, are using UAVs to gather information and imagery, because the UAVs provide more flexibility and hyper-spatial data compared to the satellite-based Earth Observation data.
- Source: Research and Markets, Global Satellite-based Earth Observation Market 2014-2018, 2014

➢ ***Results of patents scenario analysis:***

- No significant patent-related indicators can be reported in this field

Potential areas of industrial interest relevant for cross-cutting KETs in the Health and Healthcare domain

Sub-domain: Devices and systems for targeted diagnostics and personalized medicine

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "health, demographic change and wellbeing" societal challenge

Demand-side requirements (stemming from market needs) addressed:

- Improved quality (increased sensitivity and speed) of diagnostics approaches
- Early detection of diseases
- Increased safety for patients

H.1.1: Targeted molecular imaging diagnostics and/or focussed therapy

Scope:

To develop cost-effective techniques for higher efficiency and more biocompatible targeted molecular imaging for in vivo diagnostics eventually combined with focussed therapy (theranostics).

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

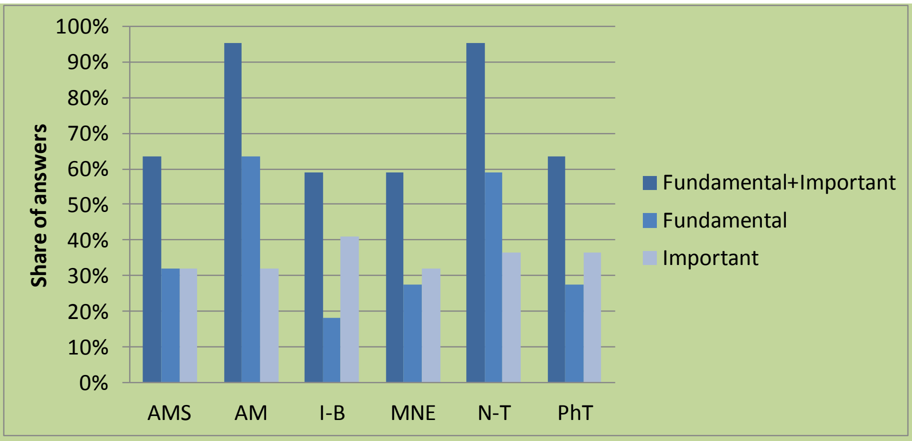
- Development of targeted molecular imaging techniques
- Development of new and innovative tracers or contrast agents for in vivo (imaging) diagnostics
- Improvement of tracers or agents efficiency of targeting
- Improvement of tracers or agents biocompatibility

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced cost-effective techniques for higher efficiency and more biocompatible targeted molecular imaging for in vivo diagnostics, eventually combined with focussed therapy (theranostics), including thanks to the development of targeted molecular imaging techniques and new and innovative tracers or contrast agents with improved biocompatibility.

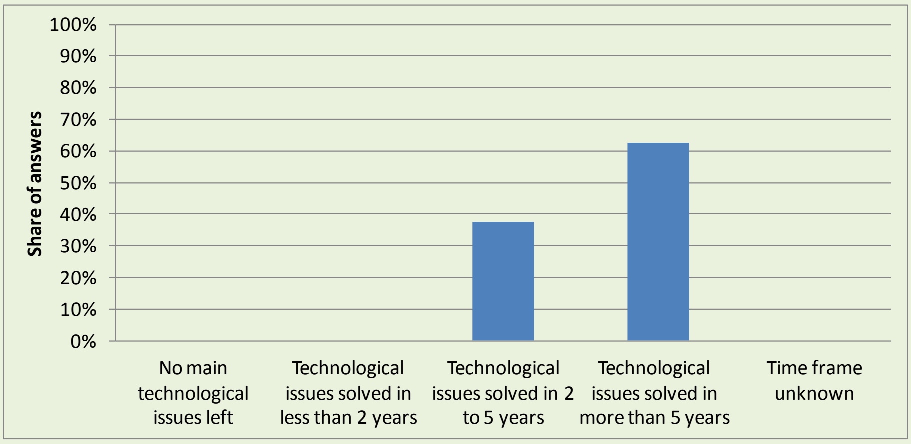
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Photonics (PhT)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Industrial Biotechnology (I-B)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus by experts indicates also shorter periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - The global molecular diagnostics market is witnessing a period of profound growth, coming from different regions and markets. The next years will witness significant developments in molecular diagnostics such as automation, as well as introduction of a wide range of new products. Molecular diagnostics involves multiple technologies to identify genetic variations and cancer development in individual patients. These technologies include PCR, FISH, hybrid capture, sequencing and microarrays. The increase in the ageing population and incidences of various chronic diseases are driving the demand of molecular diagnostics world over. The industry is getting a push from every side and many factors collectively are fuelling the growth in this industry. Growing with a compound annual growth rate (CAGR) of 14.64% global molecular diagnostics market is expected to double its size in 2017 from 2012 (Source: Renub Research, Molecular Diagnostics Market & forecast (by application, technology, countries, companies & clinical Trials) to 2017: Global analysis, April 2013).
  - On the other hand, theranostics is the fusion of drug therapy and diagnostics to optimize effectiveness, safety, and streamline drug development. Combination of medical drugs with diagnostic tests is also known as integrated medicine, pharmaco-diagnostics, companion diagnostics, and Dx/Rx partnering. The theranostics market is an emerging field which is generating strong interest from healthcare industry and

regulatory bodies. It is an emerging clinical diagnostics field that focuses on developing specific analysis to predict the use of the most significant drug for the patient. This technique uses molecular assays to determine optimum dose of drug necessary for the patient. Cost and regulatory timelines are some of the important challenges faced by this market. Improved cooperation between drug and diagnostics companies will boost the success of the theranostics industry. Effective communication with physicians to understand theranostics penetration in the market will lead to commercialization of this field. Companies focusing on theranostics with licensed drugs are expected to play a major role in reaching larger pharmaceutical companies (Source: Market Research, Theranostics Market - Global Industry Size, Market Share, Trends, Analysis And Forecasts 2012-2018, 2011).

- ***Results of patents scenario analysis:***
  - 16 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Hence, no significant patent-related indicators can be reported in this field

H.1.2: Minimally-/non-invasive devices for diagnostics and/or focussed therapy or surgery

Scope:

To develop minimally invasive endoscopic instrumentation and devices for in vivo medical diagnostics/imaging eventually combined with focussed therapy or surgery (e.g. endoscopic instruments eventually integrating multiple functionalities such as for example imaging guided surgery).

Demand-side requirements (stemming from market needs) addressed:

- Decreased patients' pain during medical, diagnostic and treatment activities

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

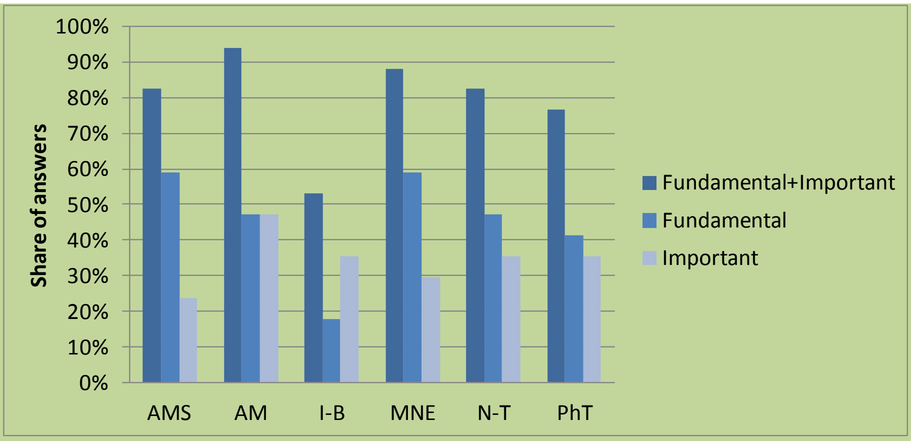
- Miniaturisation for lower invasiveness
- Surface functionalization and "biologicalization" of instruments to increase biocompatibility

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced minimally or non-invasive endoscopic instrumentation and devices for in vivo medical diagnostics/imaging, eventually combined with focused therapy or surgery, further contributing to the miniaturization and to surface functionalization of the instruments and devices to increase biocompatibility.

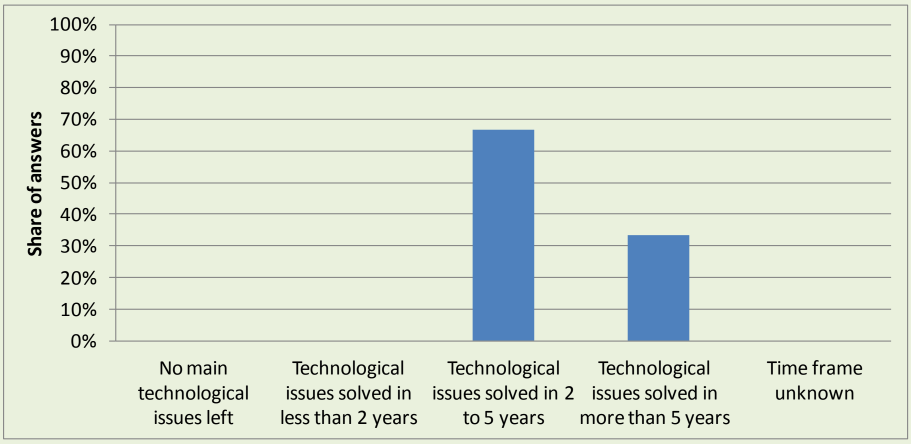
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Photonics (PhT)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Industrial Biotechnology (I-B) to a lower extent



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also longer periods being necessary:

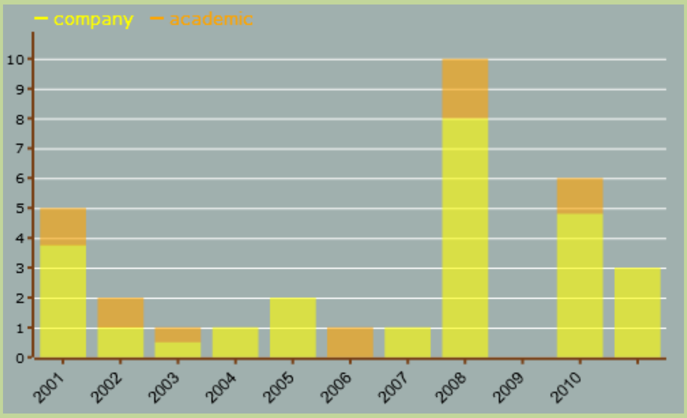


Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

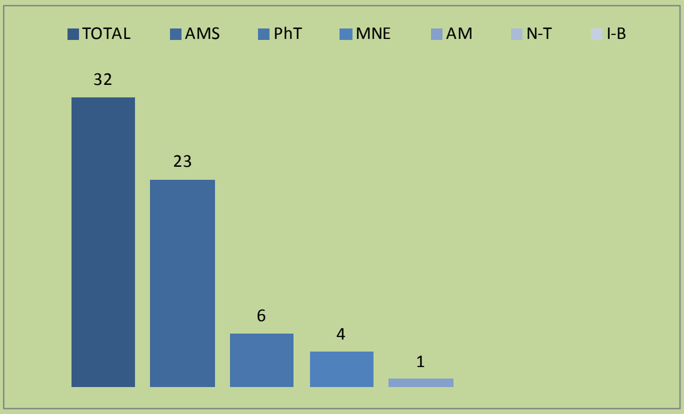
Additional information according to results of assessment:

- ***Impact assessment:***
  - Endoscopic instrumentation and devices are applied either to in vivo medical diagnostics / imaging or also to focussed therapy or surgery. Endoscopic instruments also exist that eventually integrate multiple functionalities such as, for example, imaging guided surgery. These instrumentation and devices are designed to be minimally invasive in order to provide fewer risks as well as less pain and quicker recovery to patients. This instrumentation is increasingly being applied in almost any surgical field. The approach can in fact allow for small incisions and smooth introduction within the body's lumens and cavities, thus resulting in quicker recovery and fewer side effects to the patient besides enabling a greater number of outpatient procedures, resulting in lower overhead costs for national healthcare systems. Minimally invasive instrumentation for either medical diagnostics or therapy/surgery, which was introduced in the late 1980s, has actually significantly changed the standards of operations and interventions.
- ***Results of patents scenario analysis:***
  - 32 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Significantly scattered trend curve (number of patents per year)
  - Unpredictable share between industrial and academic applicants with intermittent relevant patenting activity by academic applicants, most probably standing for new

technologies having been patented in the corresponding periods:



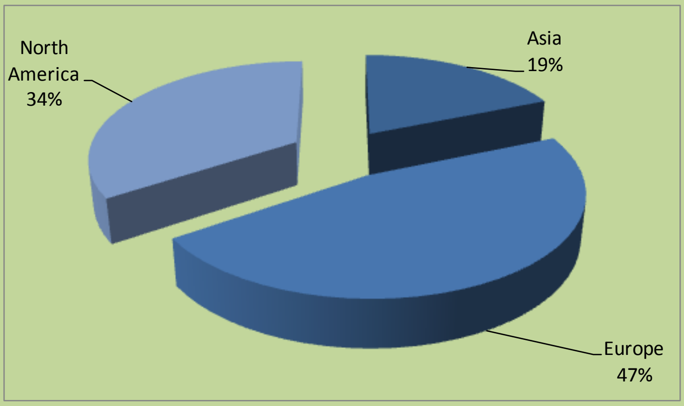
- Patents by KET(s):



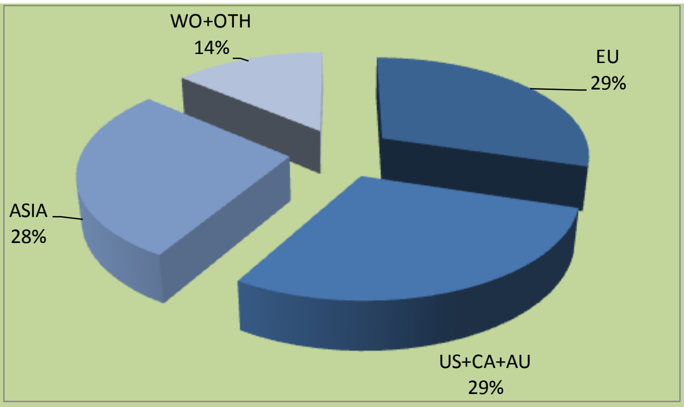
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	1
AMS	23
AMS / MNE	1
AMS / PhT	1
MNE	4
PhT	6

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



H.1.3: Technologies to identify and validate biomarkers for diagnostics and predictive personalized medicine

Scope:

To develop technologies able to identify and validate more accurate and informative biomarkers for diagnostics e.g. better than PSA in prostate cancer, including epigenetic methilation profiles; including predictive biomarkers as short DNA repeats for preventing/anticipating disease susceptibility.

Demand-side requirements (stemming from market needs) addressed:

- Individualised / personalized health care

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

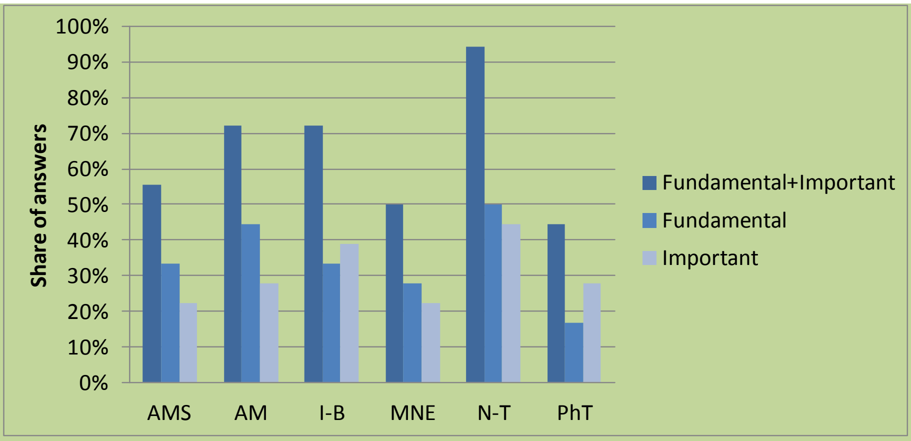
- Identification of new diagnostic markers specific to diseases

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced technologies able to identify and validate biomarkers for diagnostics, e.g. better than PSA in prostate cancer, including epigenetic methilation profiles, or including predictive biomarkers as short DNA repeats for preventing/anticipating disease susceptibility.

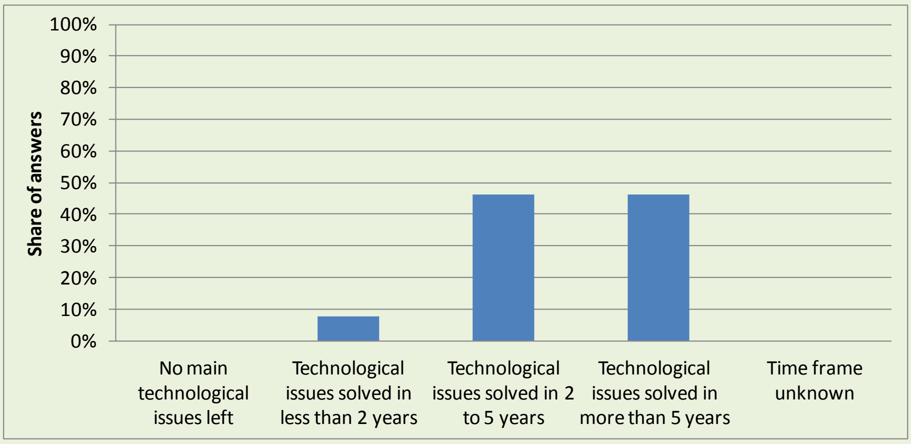
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Industrial Biotechnology (I-B)
- Advanced Manufacturing Systems (AMS)
- Micro- and Nano-Electronics (MNE)
- Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of either 2 to 5 years or more than 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework. Particularly, while short term support could be useful to further R&D development in this field, longer term support will be needed in order to enable validation in more complex environments including, ultimately, through clinical trials.

Additional information according to results of assessment:

➢ ***Impact assessment:***

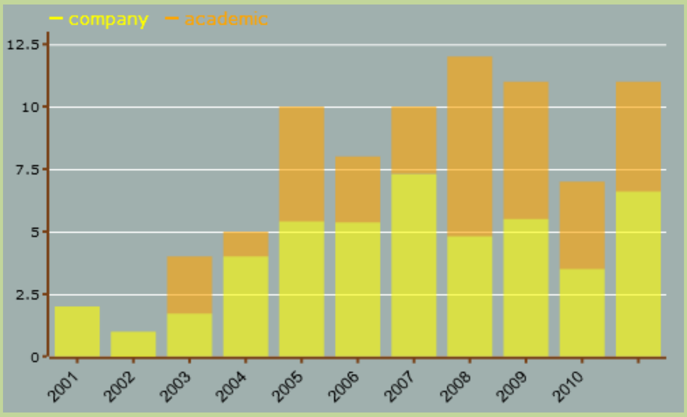
- The global biomarkers market showcases high growth potential in the near future with an estimated compound annual growth rate (CAGR) of 18.5% from 2013 to 2018, to reach 30 billion Euro by 2018. Current industry trends such as advancements in discovery technologies, government initiatives, and grants for biomarker research activities, and the rising demand for personalized medicine are the key factors that contribute to the growth of this market. However, the need for high capital investment for biomarker discovery, low benefit-cost ratio, a cumbersome biomarker validation, and testing process are a few of the critical factors that restrain the growth of the market.
- The omics technology segment holds the largest share of ~75% of the biomarker discovery market, primarily due to the increase in adoption of proteomics and genomics technologies, globally. The emerging Asia-Pacific region exhibits high growth opportunities for industry participants. Growing economies such as China and India are experiencing an increasing rate of biomarkers research activities. This is attributed to the rising number of contract research organizations and the low cost of conducting clinical trials in Asia-Pacific nations when compared to developed countries.
- Increasing popularity of personalized medicine and the growing importance of companion diagnostics are further opening new growth opportunities for the

development of novel biomarkers.

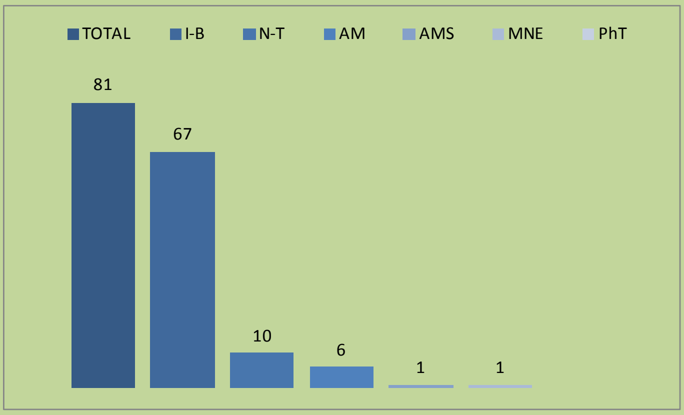
- Source: Market and Markets, Biomarkers Market, ([Discovery Technologies - Proteomics, Genomics, Imaging, Bioinformatics], Validation Services, Applications [drug development, personalized medicine], Diseases [Oncology, Cardiology, Neurology]) - Global Trends & Forecasts (2013 – 2018), 2012)

➢ ***Results of patents scenario analysis:***

- 81 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Growing trend curve (number of patents per year)
- Significant participation of academic applicants in the patenting activity:



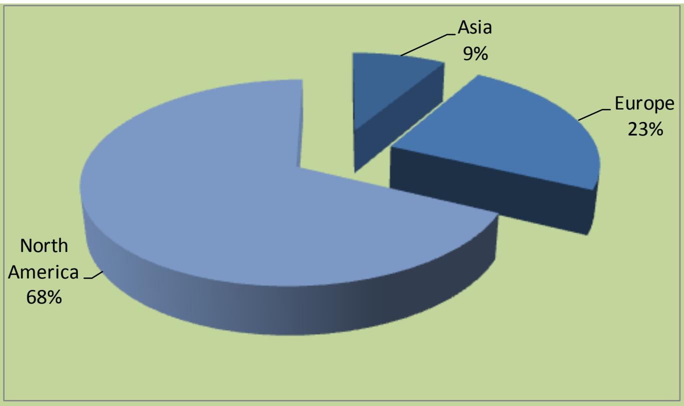
- Patents by KET(s):



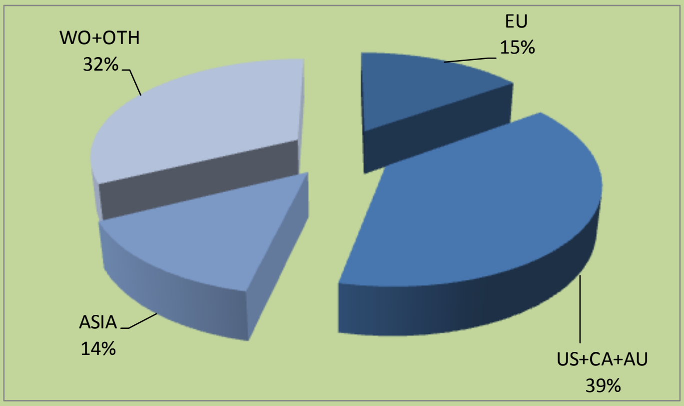
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	6
AM / N-T	4
AMS	1
IBT	67
MNE	1
N-T	10

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



H.1.4: Portable Point-of-Care (POC) devices and test kits for instant diagnosis based on microfluidics, bionsensors and/or arrays

Scope:

To develop rapid, safe and cheap diagnostics, portable and miniaturized devices or easy kits for diagnosis or treatment monitoring at home (capable of data collection and communication with the medical doctor).

Demand-side requirements (stemming from market needs) addressed:

- Individualised / personalized health care
- Reduced discomfort to patients associated with sampling aimed at in vitro diagnostics
- Improved quality (increased sensitivity and speed) of in vitro diagnostics

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Substitution of analytical labs by point-of-care in vitro diagnostic tests

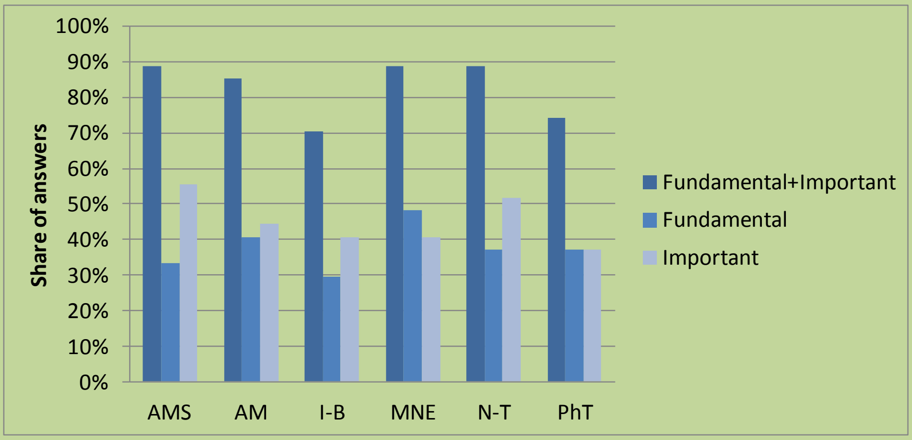
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced portable Point-of-Care (POC) devices and test kits for instant diagnoses based on microfluidics, miniaturized multi-parameter measuring devices, bio-sensors and/or arrays, etc.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

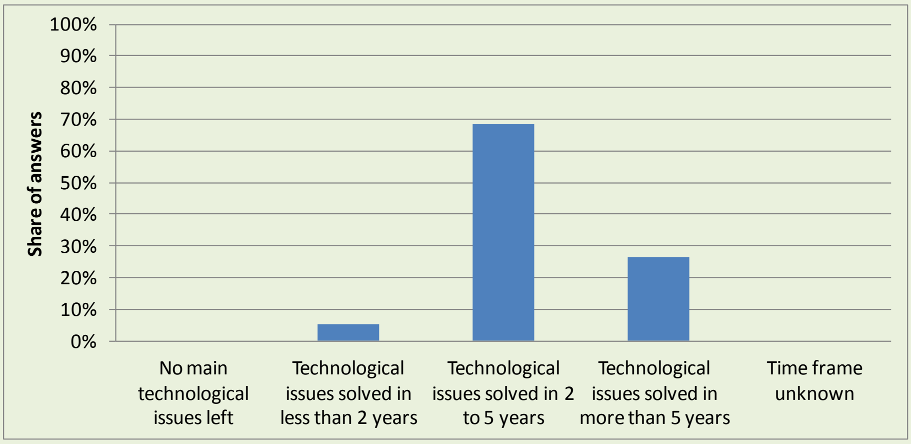
- Advanced Manufacturing Systems (AMS)

- Advanced Materials (AM)
- Photonics (PhT)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Industrial Biotechnology (I-B)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

- The European POCT market is a robust and dynamic market which has evolved into one of the largest sub-segments of the global medical equipment market. Significant and major technological advances and developments have occurred over the last couple of decades, which have helped stimulate and acted as a major driver of the market. The major suppliers have progressively introduced new products which have increased the number and range of diagnostic applications and indications whilst supporting the healthcare professionals by improving the quality of patient care. The introduction of these new and innovative technologies has also helped to rejuvenate the market, retain and gain market share and improve their return on Investments (ROI) (Source: Trimark Publications, European Point of Care Diagnostic Testing Markets, September 2011).

➢ ***Results of patents scenario analysis:***

- Only 11 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field

- Hence, no significant patent-related indicators can be reported in this field

H.1.5: Multiplexing devices for in vitro diagnostics

Scope:

To develop multi-parameter measuring devices for fast, accurate, easy medical laboratories analyses.

Demand-side requirements (stemming from market needs) addressed:

- Secure, fast and user friendly sample preparation by laboratory personnel
- Reduced discomfort to patients associated with sampling aimed at in vitro diagnostics
- Reduced discomfort to patients associated with sampling aimed at in vitro diagnostics

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

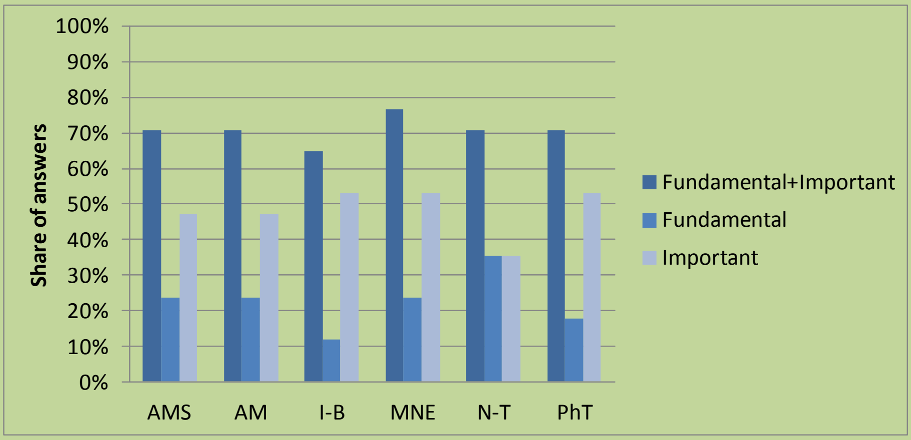
- Design and development of integrated multifunctional devices with a broad range of applications for improving in vitro diagnostics
- Development of reliable, cheap, fast and multiplexed highly sensitive detectors providing high content results from a single sample
- Identification of new diagnostic markers specific to diseases

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of integrated multi-functional multi-parameter devices, building on reliable, cheap, fast and multiplexed highly sensitive detectors providing high content results from a single sample and the identification and validation of new disease-specific diagnostic markers.

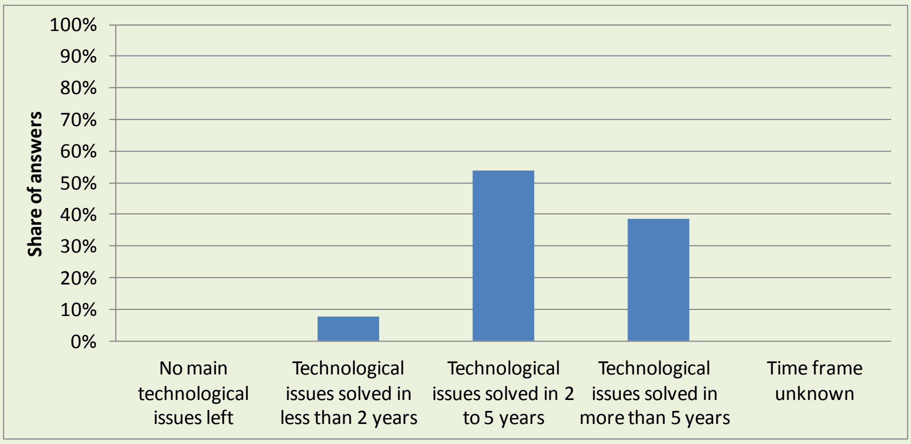
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Photonics (PhT)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Industrial Biotechnology (I-B)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also longer periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

- On the whole, the multiplexed diagnostics market is expected to tip in favour of continued rapid growth, reaching almost 4.2 billion Euro in 2015, according to a report, Multiplexed Diagnostics 2010, published by Select Biosciences and written by BioPerspectives and Bachmann Consulting (Source: BioPerspectives and Bachmann Consulting , Multiplexed Diagnostics 2010 Market Report, 2011).
- Oligonucleotide arrays, phage display, bacterial artificial chromosome arrays, protein arrays, bead-based arrays, antibody arrays, reverse arrays, mass spectrometry, quantitative PCR bead-based and microplate assays and next-generation sequencing are included in this market. Further, this market is also segmented on the basis of several application areas of multiplexed diagnostics, namely, infectious disease diagnosis, oncology, autoimmune diseases, cardiac conditions, allergies and others (Alzheimer's disease, diabetes, kidney toxicity and HIV).
- The global multiplexed diagnostics market has phenomenally increased the volume and quality of diagnostic procedures by reducing the turnaround time and analyzing multiple analytes in a single cycle and thereby resulting in rapid adoption of such techniques. The stakeholders in this market include market players who provide multiplexed diagnostic assay kits, reagents, solutions and systems (Source: Multiplexed Diagnostics Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013-2019).

➢ ***Results of patents scenario analysis:***

- No exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- No significant patent-related indicators can be reported in this field

Sub-domain: More efficient and less invasive drugs and therapies

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "health, demographic change and wellbeing" societal challenge

Demand-side requirements (stemming from market needs) addressed:

- Targeted treatment of diseases
- Assistance to living functions
- Individualised / personalized health care

H.2.1: Implantable devices for medicine

Scope:

To develop new and improved devices for assisting vital functions or controlled drug delivery (e.g. heart assisting devices, devices for drugs on demand delivery, pain therapy and management).

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

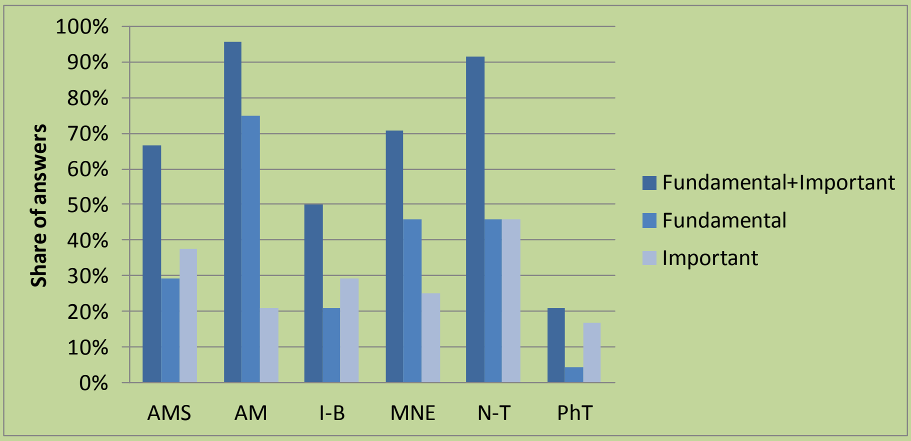
- Miniaturisation for lower invasiveness
- Surface functionalisation and 'biologicalisation' of instruments to increase biocompatibility
- Delivery of macro (bio) molecules
- Development of nano- or micro-scale devices for drug delivery (e.g. micropumps)

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of new and improved devices for assisting vital functions or controlled drug delivery, thanks to further miniaturization to achieve lower invasiveness, surface functionalization and "biologicalization" to increase biocompatibility, or the development of nano- or micro-scale devices for drug delivery.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

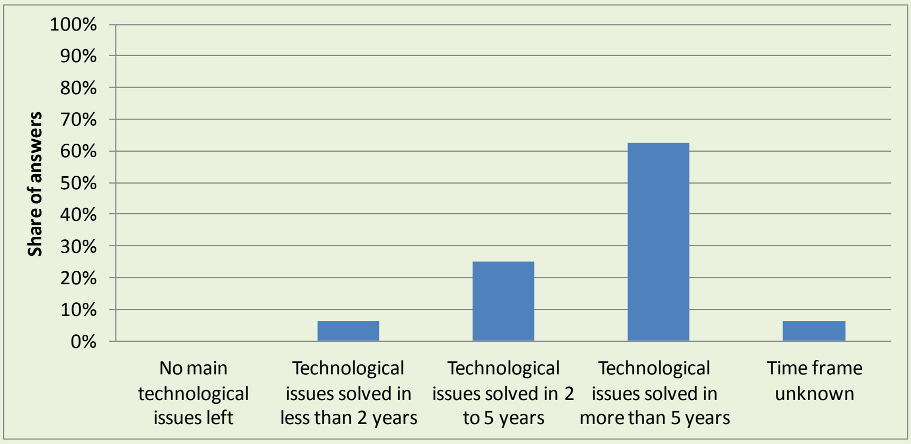
- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more

than 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

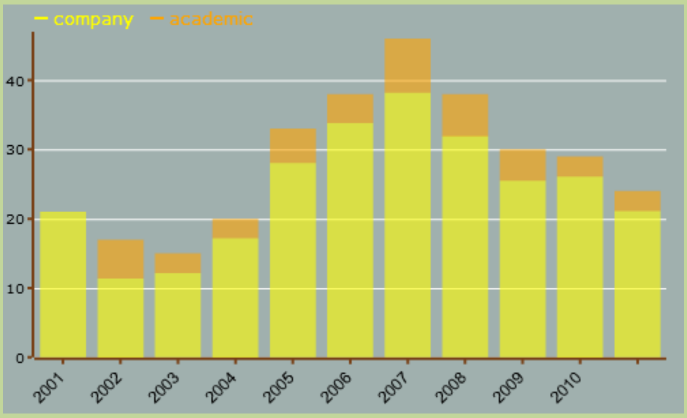
Additional information according to results of assessment:

➢ ***Impact assessment:***

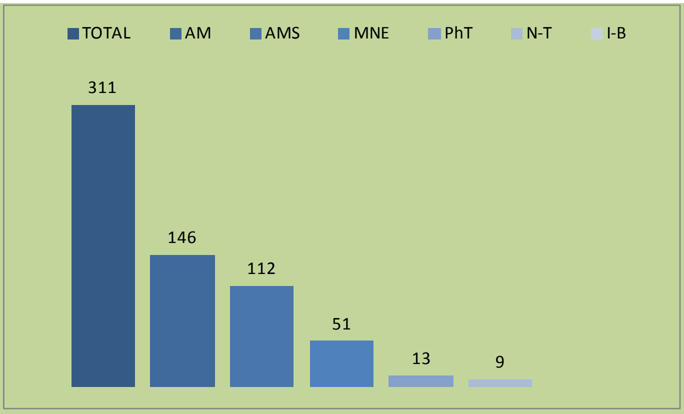
- Demand for implantable medical devices is expected to increase significantly. These products have benefited from technological advances, and growth is expected to be strong over the next years. Next generation devices have increased confidence in orthopaedic, cardiovascular and other implants. Demand will also benefit from the lack of alternative treatments for many chronic disorders and injuries. The ability of medical implants to reduce overall treatment cost for many conditions, including osteoarthritis and chronic heart failure, will work in favour of growth for these products. (Source: Implantable Medical Devices Market, March 2012).
- Implantable medical devices can be classified into active and non-active. Both classes, but especially the Active Implantable Medical Devices (AIMDs) are subject to strict standards and definitions before they can reach the market. Directive 90/385/EEC of the European Union (EU) specifies the Essential Requirements manufacturers and importers must meet to apply the CE Mark and legally market or sell AIMDs in the EU.

➢ ***Results of patents scenario analysis:***

- 311 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Stable trend curve (number of patents per year)
- Highest share of industrial applicants:



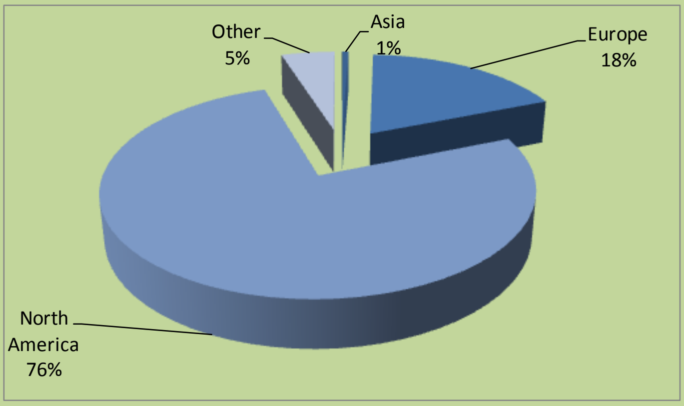
- Patents by KET(s):



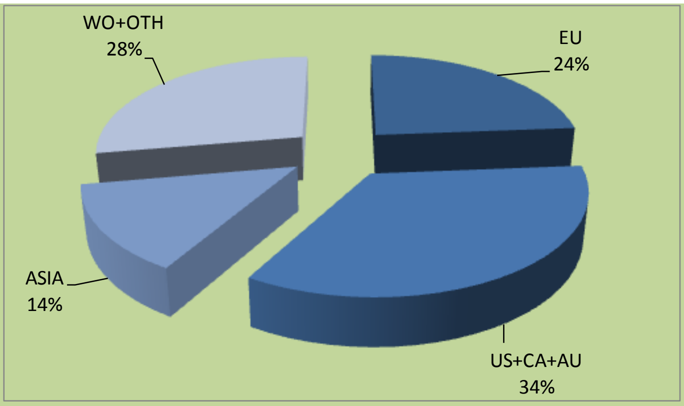
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	146
AM / MNE	1
AM / N-T	5
AM / PhT	2
AMS	112
AMS / AM	2
AMS / AM / N-T	1
AMS / MNE	3
AMS / N-T	1
AMS / PhT	1
MNE	51
MNE / PhT	6
N-T	9
PhT	13

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



H.2.2: Improved delivery systems, surface coatings and coating techniques for drugs

Scope:

To develop new and improved delivery systems and surface coatings for conventionally fabricated tablets.

Demand-side requirements (stemming from market needs) addressed:

- Improved efficacy of therapies

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

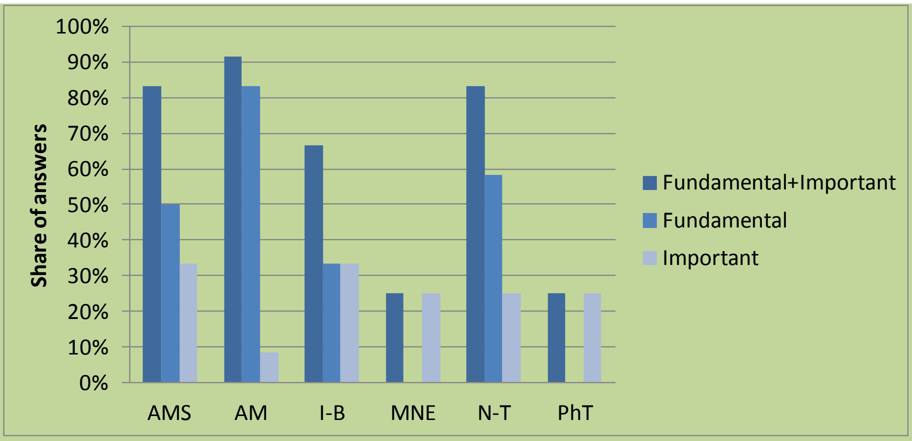
- Improvement of conventionally fabricated tablets by new delivery systems as well as surface coatings and coating techniques achieved through optimised formulation research

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more efficient drugs delivery systems, surface coatings and coating techniques for drugs, building on improved drugs formulation and the incorporation of drug molecules into new delivery systems.

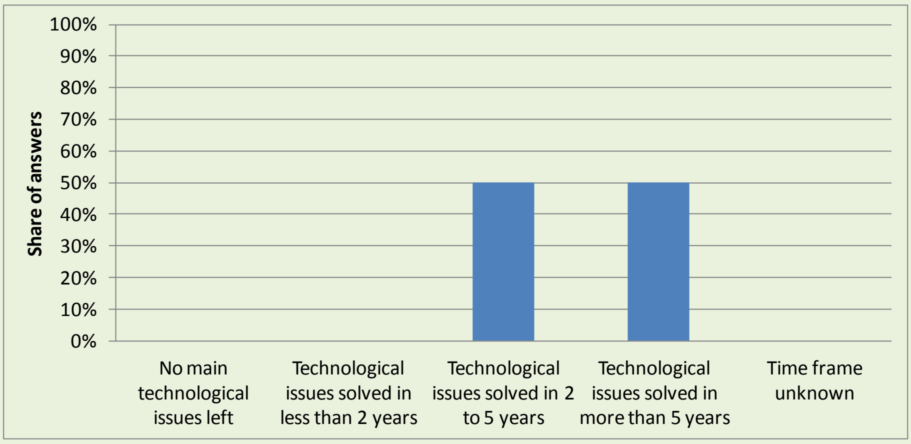
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Industrial Biotechnology (I-B)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of either 2 to 5 years or more than 5 years:



Hence, considering the fact that research in this field is of the incremental type, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

- The market for drug delivery systems, which include several product types (among which oral, parenteral, inhalation, implantable, transdermal) will continue to grow at a high rate along with an increasingly aging population in Europe.
- Today's drug delivery technologies enable the incorporation of drug molecules into new delivery systems, thus providing numerous therapeutic and commercial advantages. A large number of companies are involved in the development of new drug delivery systems, which is evident by an increased number of products in the market.
- Today, drugs formulation is more challenging in terms of the development of improved delivery systems than in terms of formulation itself. Fast disintegrating or dissolving tablets, which are tablets that dissolve or disintegrate in the mouth in the absence of additional water upon introduction into the mouth, for easier administration of active pharmaceutical ingredients responding to today's lifestyles, are a clear example thereof, having received ever-increasing demand during the last decade so that the field has become a rapidly growing area in the pharmaceutical industry (Source: Fast disintegrating tablets: V. Parkash et al., Opportunity in drug delivery system, Journal of Advanced Pharmaceutical Technology and Research, 2011 October-December; 2(4): 223–235).
- Oral drug delivery remains the preferred route for administration of various drugs with a huge market that is expected to grow.

➢ ***Results of patents scenario analysis:***

- 1 KETs-related patent identified in the period 2001-2011 for the specific Innovation Field
- Hence, no significant patent-related indicators can be reported in this field

H.2.3: Bioengineered tissues (including organs) for regenerative therapies (and for autologous transplantation in case of organs)

Scope:

To develop new and improved techniques for tissues (or organs) regeneration, such as for example engineering of skin, cartilage and bone for autologous implantation or engineering of organs for autologous transplantation.

Demand-side requirements (stemming from market needs) addressed:

- Introduction into the market of alternative therapeutic approaches

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

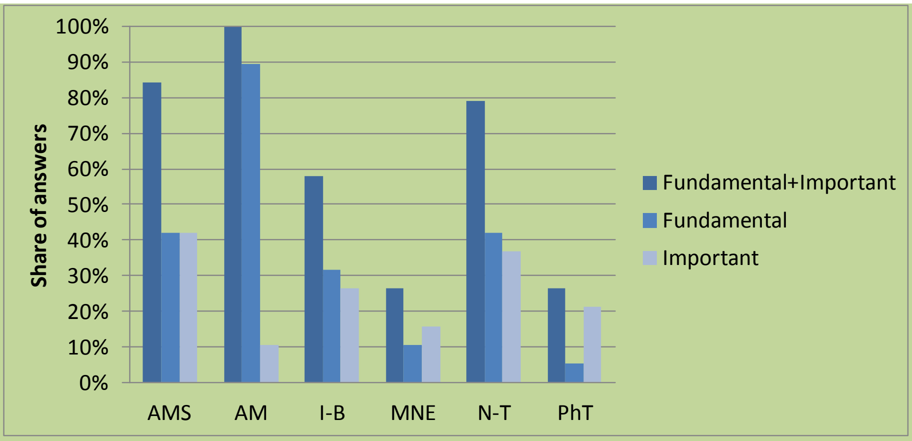
- Development of novel cell culture techniques
- Development of targeted drugs to trigger and control stem cell differentiation
- Use of biomaterials as carriers for ligands stimulating cell membrane receptors and on controlled release of bioactive compounds
- Chemical modification of existing biomaterials to obtain new generation of healing dressings
- Chemical modification of existing biomaterials to obtain scaffolds for in-vitro cell culture or tissue engineering
- Validation of product manufacturing processes in regenerative medicine, including scale-up and manufacturing (process optimization)
- Proof of long term efficacy and safety in regenerative medicine

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of novel cell culture techniques, targeted drugs to trigger and control stem cell differentiation, bio-materials to be used as carriers for ligands and controlled release of bio-active compounds, the modification of existing bio-materials to obtain new generation of healing dressings as well as scaffolds for in-vitro cell culture or tissue engineering.

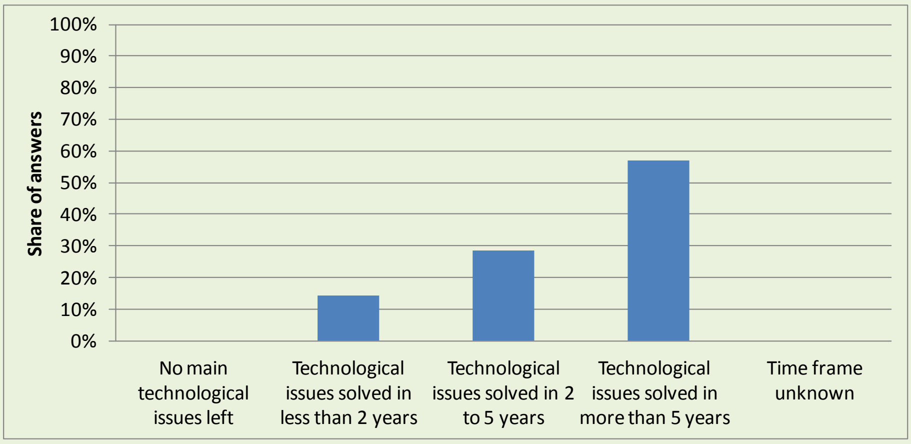
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Industrial Biotechnology (I-B)



Timing for implementation:

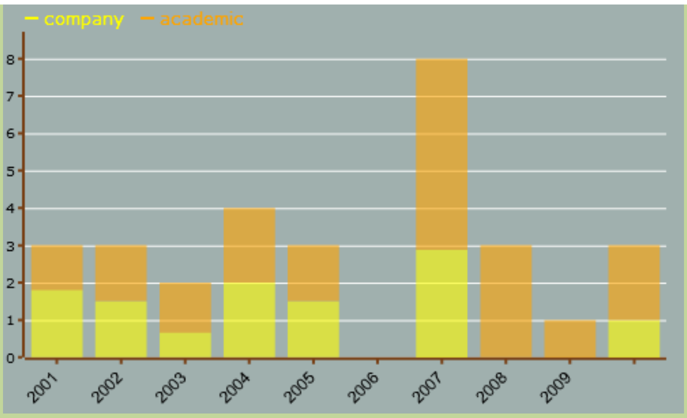
According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:



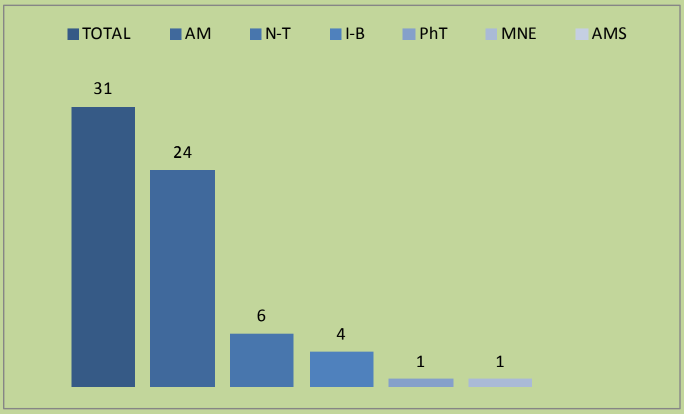
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Human tissue engineering and regenerative medicine in general (e.g. the use of "smart" biomaterials that promote self-repair of damaged tissues) offer tremendous promise for improved patient treatment, faster recovery, improved prognosis and a more biologically favourable situation where the body can be stimulated to heal itself. There is a huge amount of research being undertaken worldwide in all areas mentioned in this overview (and others) and a huge interest in the potential of tissue engineering/regenerative medicine. However, there is still currently a lack of an effective regulatory framework on a European basis. (Source: European Medical Technology Industry Association, Innovations in Medical Technology, Regenerative medicine and human tissue engineering, 2007).
- ***Results of patents scenario analysis:***
  - 31 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Almost stable trend curve (number of patents per year), despite a peak in 2007, with a generally low patenting activity per year
  - The intellectual property ownership is shared between academia and industry:



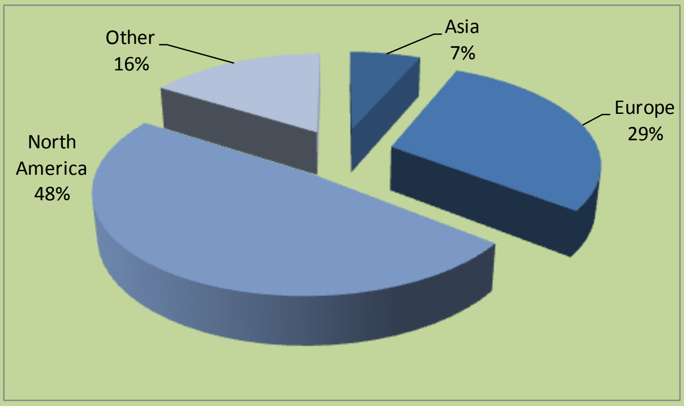
- Patents by KET(s):



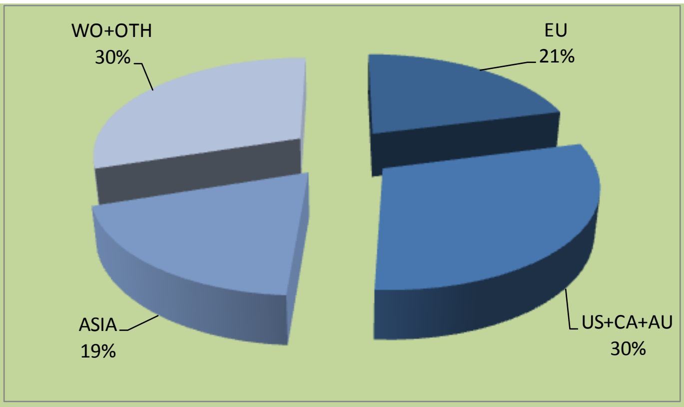
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	24
AM / N-T	4
IBT	4
MNE	1
MNE / PhT	1
N-T	6
PhT	1

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



Sub-domain: Smart systems and robots for healthcare services

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "health, demographic change and wellbeing" societal challenge

Demand-side requirements (stemming from market needs) addressed:

- Decrease costs of care provision or paramedic tasks

H.3.1: Robots supporting professional care

Scope:

To develop improved robotic systems supporting healthcare workers either within the setting of a hospital or a patient's home in patients' monitoring and care activities (e.g. logistical robotized aids for nurses, robotized patient monitoring systems, automated medicine delivery to patients, and other robotized physical tasks in care provision or paramedic tasks).

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Creation of robotic platform technologies to enhance standardization and cooperation
- Creation of open design and simulation systems to jointly develop new robotic systems
- Enhancement of communicative interaction of robotic systems to other systems (including other robotic systems)
- Development of networked robotic architectures
- Creation of open source software architectures
- Development of improved cognitive and self-configuring software architectures
- Improvement of the (dynamic) models of physical, social and ecological environments validate sensor and motion performance
- Enhancement of user interfaces to improved human-machine interaction (two sided)
- Improvement of (real-time) dynamic models for robotic structures
- Improvement of the robustness of robotic architectures by redundancy in hardware, software and design
- Improvement of robotic safety through software (prediction and reaction), as well as physical systems
- Further miniaturisation and integration of actuators, sensors, control systems, energy systems and other physical manipulators
- Improved efficiency of energy systems, including power management and enhanced efficiency of locomotion
- Further development of low weight power sources
- Creation of efficient wireless power transmission systems
- Enhanced robot control systems, including self-learning, self-calibrating, fault tolerant,

etc.

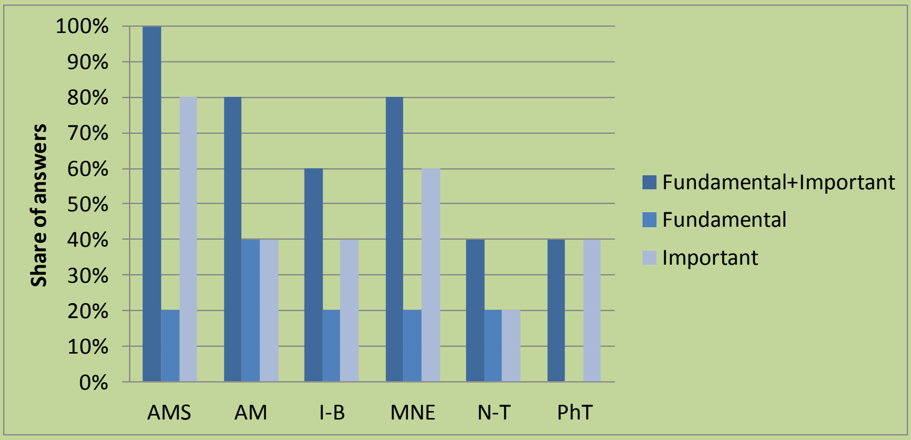
- Improved image recognition sensor systems, including environment assessment (objects, human emotions/behaviour, environments, etc.)
- Improved task, grasp, motion and distributed planning for robotic systems (interactive and intelligent planning, programming and scheduling)
- Improved integrated sensory systems, including multi-sensors and high quality (bio, neuro, physical, environmental, chemical, motion, positioning, etc.)
- New light-weight, high strength materials
- Advanced integrated mechatronic systems
- Advanced locomotion, including movement and grasping
- New concepts for distributed intelligence (e.g. swarms)
- Low cost robotic systems (sensors, control, locomotion, skelet, etc.)
- Enhancing the cognitive human reaction of robots
- Improved navigation through enhanced mapping and localisation (e.g. 3D, cooperative mapping, enhanced GPS, autonomous)

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of improved robotic systems capable of supporting healthcare workers in patients' monitoring and care activities, building on pervasive sensing systems, enhancement of robotic communication, user interfaces, miniaturization and integration of actuators, sensors, control systems, energy systems, etc., power management, enhanced efficiency of locomotion, and new light-weight, high strength materials.

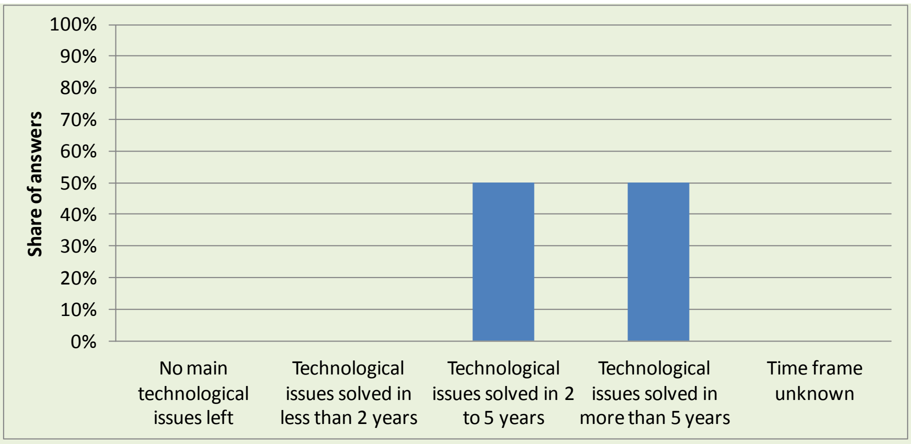
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of either 2 to 5 years or more than 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Robotics for healthcare is an emerging field which is expected to grow in the face of demographic change (ageing), expected shortages of healthcare personnel, calls for improving quality of life for the elderly and disabled, and the need for even higher quality care. All these factors stimulate innovation in the domain of robotics for healthcare. Several programs and networks dedicated to research on robotics are already focusing part of their efforts on applications in healthcare (Source: EC-robotics for healthcare, Final Report, 2008).
  - Actually, in the health and healthcare domain, robots have been applied since quite some time especially in aided surgery, where the Da Vinci surgical assistant is playing a significant role, having conducted more than 20 000 surgeries and having paved the way for robotic advancements in healthcare.
  - Yet the market of robots performing or supporting surgery is highly dominated by the US.
  - Within this framework, according to interviews and opinions collected at the workshops organized within the framework of the study, and as evidenced throughout desk research, one of the segments expected to grow in Europe is instead represented by robots supporting professional care to patients in the healthcare domain. This products category today already includes automated robotic delivery system that transport scheduled and on-demand deliveries of meals or medications in hospitals, at home and between ancillary, support, and patient care units.
  - Demographic changes such as population ageing are the main driving force behind assistive technologies. Although many prerequisites in regard to these technologies, such as safe operation near humans, human-robot interaction, building intelligent robots, robots that learn while operating have not yet been fully met, automated and robotized systems are being increasingly introduced in healthcare. Robotic assistive technologies are a new market segment that will offer many business opportunities and jobs. When they are used to assist older persons, they will also redefine the care sector and upgrade the image of care work. In the long run, assistive technologies will ease the financial burden on the care system and facilitate the work of caregivers. Enabling older people to lead an independent life at home is one of the most important positive aspects. However, it should also be mentioned that many technological hurdles still have to be overcome before robots will become a standard device in older people's homes (Source: P. Flandorfer, Drivers, Barriers and long-term Requirements of assistive Technologies supporting older Persons in living longer independently at Home: A systematic Review of European, US-American and Japanese Policy Papers and Assessment Studies, 2012).
- ***Results of patents scenario analysis:***
  - 2 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Hence, no significant patent-related indicators can be reported in this field

H.3.2: Robotized systems capable to assist patients' mobility or other living functions

Scope:

To develop passive robotized systems (including intelligent prostheses) capable to assist patients' mobility or other living functions (e.g. exoskeletons for disabled patients).

Demand-side requirements (stemming from market needs) addressed:

- Assistance to living functions
- Improved quality of life

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Creation of robotic platform technologies to enhance standardization and cooperation
- Creation of open design and simulation systems to jointly develop new robotic systems
- Enhancement of communicative interaction of robotic systems to other systems (including other robotic systems)
- Development of networked robotic architectures
- Creation of open source software architectures
- Development of improved cognitive and self-configuring software architectures
- Improvement of the (dynamic) models of physical, social and ecological environments validate sensor and motion performance
- Enhancement of user interfaces to improved human-machine interaction (two sided)
- Improvement of (real-time) dynamic models for robotic structures
- Improvement of the robustness of robotic architectures by redundancy in hardware, software and design
- Improvement of robotic safety through software (prediction and reaction), as well as physical systems
- Further miniaturisation and integration of actuators, sensors, control systems, energy systems and other physical manipulators
- Improved efficiency of energy systems, including power management and enhanced efficiency of locomotion
- Further development of low weight power sources
- Creation of efficient wireless power transmission systems
- Enhanced robot control systems, including self-learning, self-calibrating, fault tolerant, etc.
- Improved image recognition sensor systems, including environment assessment (objects, human emotions/behaviour, environments, etc.)
- Improved task, grasp, motion and distributed planning for robotic systems (interactive and intelligent planning, programming and scheduling)
- Improved integrated sensory systems, including multi-sensors and high quality (bio, neuro, physical, environmental, chemical, motion, positioning, etc.)
- New light-weight, high strength materials
- Advanced integrated mechatronic systems
- Advanced locomotion, including movement and grasping
- New concepts for distributed intelligence (e.g. swarms)
- Low cost robotic systems (sensors, control, locomotion, skelet, etc.)
- Enhancing the cognitive human reaction of robots
- Improved navigation through enhanced mapping and localisation (e.g. 3D, cooperative mapping, enhanced GPS, autonomous)

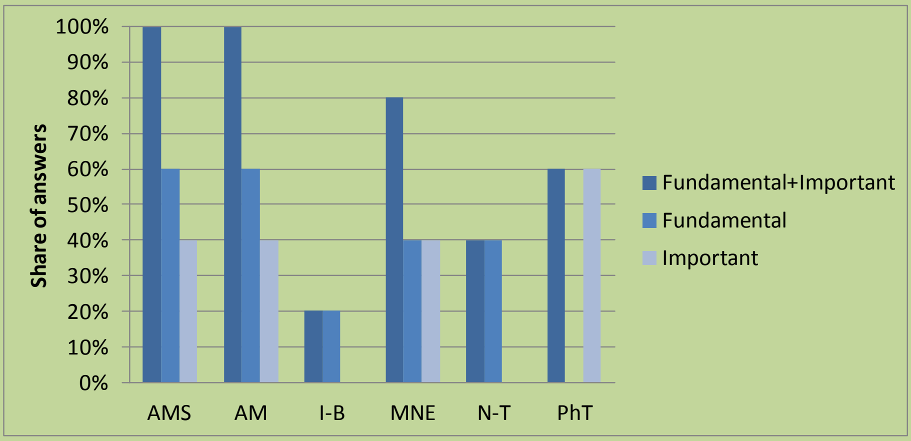
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced passive robotized systems including intelligent prostheses, building on the development and integration of new light-weight, high-strength materials, advanced integrated mechatronics, communicative interaction, user interfaces, miniaturization and integration of actuators, sensors, control and energy systems.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting

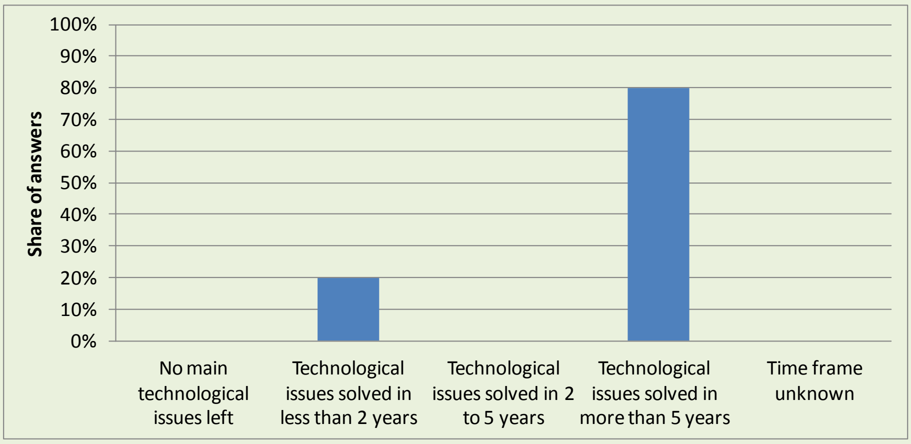
activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

- Increasing the autonomy of people with disabilities (including of people having experienced stroke or amputations) through robot-assisted mobility and advanced prostheses has the potential of facilitating these people's mobility besides their social development as a consequence, as well as reducing the burden of caring for such populations in both inpatient and outpatient settings. While techniques for task-specific assistance exist, they are largely focused on satisfying short-term goals (e.g. rehabilitation treatment and locomotion training) (Source: Y. Demiris and T. Carlson, Lifelong robot-assisted mobility: Models, Tools, and Challenges, In Proc. of IET Assisted Living Conference, London, March 2009).
- For lifelong disabled users, however, fewer opportunities exist, despite the market of robot-assistive mobility is gaining much attraction as robotic and bionic systems evolve.
- As a result of the evolving technologies and the consequent reductions in costs, these devices are even being moved considerably closer to everyday use. Examples thereof

are constituted by the exoskeletons that Honda has begun leasing as Walking Assist Devices to hospitals in Japan so that the company can monitor and validate their usefulness in the real world. Other robot-assistive mobility devices, which are all at or close to market, are Panasonic's Activelink Powerloader, Cyberdyne's HAL, Argo Medical Technologies' Rewalk, Rex Bionics' REX, Ekso Bionics EKSO, Raytheon's XOS2, RB3D's Hercule and Lockheed Martin's HULC exoskeletons (Sources: www.corporate.honda.com; www.innovationtoronto.com).
- Exoskeletons have been developed by the defence industries for applications in soldier and ground fields. Such knowledge and development capability can be transferred into the civilian sector for other medical applications that could significantly benefit from this previous development.

➢ ***Results of patents scenario analysis:***
- 4 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Hence, no significant patent-related indicators can be reported in this field

H.3.3: Connected systems for ambient assisted living

Scope:

To develop improved connected systems for ambient assisted living, i.e. integrated solutions for various (home) care support applications enabling health and disease monitoring as well as assisted living (e.g. assistance to disabilities and/or chronic diseases, rehabilitation monitoring, personalized fitness or nutrition assistance, etc.).

Demand-side requirements (stemming from market needs) addressed:

- Improved quality of life
- Prompt medical or paramedical response and assistance

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Decrease of energy consumption of mobile electronics devices
- Development of novel materials for better design ("look&feel") with better properties (e.g. more wear resistant, lightweight)
- Development of wearable electronics
- Establishment of an independent Machine-2-Machine network (e.g. measuring biological parameters and transfer to healthcare monitoring system)
- Automation of decision making based on collected data
- Adaptation of remote power supply/storage to specific requirements of application (e.g. very long lifetime without recharging)
- Specialization of networks according to specific needs (e.g. low data transfer but precise timing)
- Improvement of self-organization and collective intelligence (cognition, cooperation, coordination)
- Further miniaturization of electronics
- Development of large area sensors/actuators
- Improvement of printed electronics for ubiquitous and flexible electronics (packaging, disposable electronics, textile)
- Design of integrated solutions for various home care support applications (non-invasive health monitoring, assistance to disabilities and/or chronic diseases, rehabilitation monitoring, personalized fitness or nutrition assistance, etc.)
- Development of wearable smart wireless communicating devices with low weight, ergonomic and high autonomy sensing and monitoring capabilities (own ultrasonic imaging, breath analysis, cerebral diagnosis, cardiac risk assessment, integrated sample preparation and sensing, etc.)
- Use trends from robotics and artificial intelligence on automated analytics on environment information/measurement to develop information-based interactive assistance platforms, in particular for supporting independent living of ageing or disabled persons
- Build on specific patient capabilities to setup user-friendly platform human machine

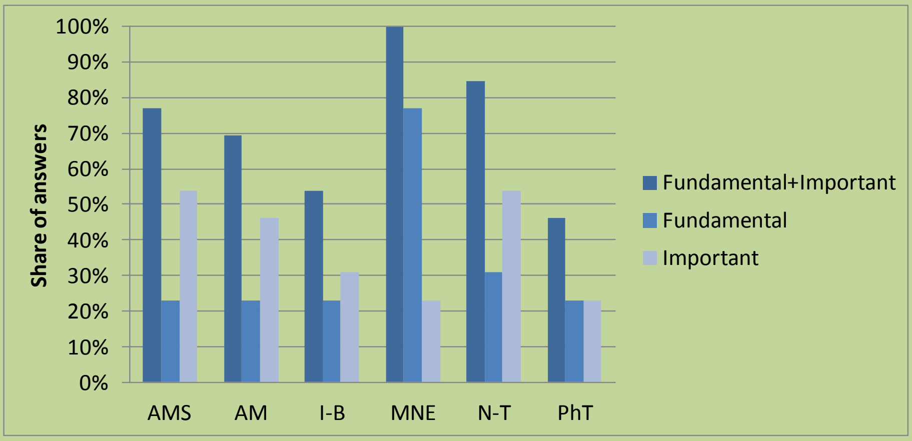
interface, adapted to be used by non-computer-literate users
- Achievement of broadband data transmission with high standards of reliability, scalability, interoperability and configurability, as well as controlled levels of electro-magnetic radiation in confined environment
- Development of device low power indoor localization capability based on communication networks
- Ensure trustworthy record, storage, transfer and usage of personal and medical data, so as to prevent new types of attacks or privacy breaching

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced connected e-health home systems, enabling home care support, health monitoring as well as assisted living, building on improved mobile systems or wearable devices.

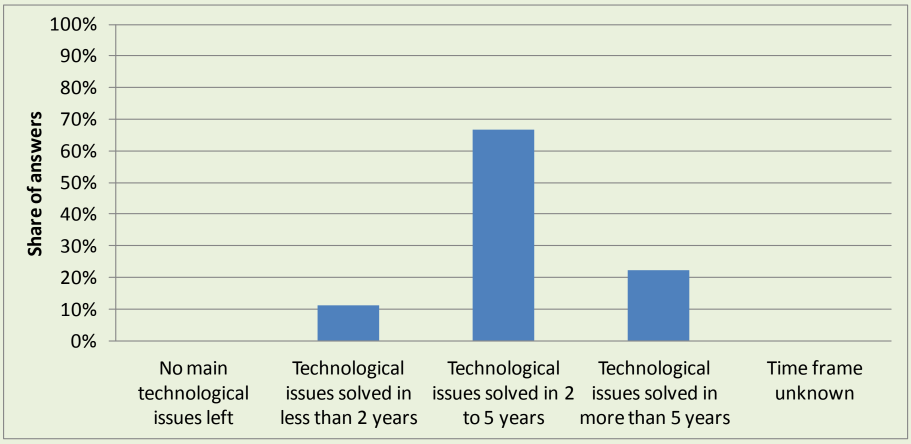
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - While society ages, connected systems for ambient assisted living are gaining much attraction. Being strictly related to domotic systems but offering in addition advanced functionalities and connectivity, these systems offer the opportunity especially to elderly people to remain autonomous for longer, while being assisted from remotely from their relatives (with solutions expected to gain attraction in the shorter term), or from their medical doctor (in the longer run).
  - This trend is benefitting much from new technologies in mobile electronics devices as well as the smartification of the environment where we live.
  - Wearable textiles are also expected to gain attraction in this field for monitoring vital functions, with prototypes having been already developed and validated in reduced complexity environments.
  - Many of the latest solutions being devised in this field are increasingly sophisticated, with some deployed in assisted living environments, such as nursing homes. In industrialized countries, work focuses as well on the use of intelligent and highly interactive systems (including appliances, as evidenced during interviews conducted throughout the study) for improving quality of life (Source: Special Issue on Ambient Assisted Living and Robotics, www.computer.org).
- ***Results of patents scenario analysis:***
  - No KETs-related patent identified in the period 2001-2011 for the specific Innovation Field
  - Hence, no significant patent-related indicators can be reported in this field

POTENTIAL AREAS OF INDUSTRIAL INTEREST RELEVANT FOR CROSS-CUTTING KETS IN THE TRAINING, EDUCATION AND EDUTAINMENT DOMAIN

Sub-domain: Advanced interfaces for training, education and edutainment

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "Inclusive, innovative and secure societies" societal challenge

Demand-side requirements (stemming from market needs) addressed:

- Reliably detect and track human motion for higher-level applications that rely on visual input (such as automatic motion capture for film and television, human-computer interaction, robotics, industrial machine vision, navigation, events detection, surveillance, etc.)
- Interaction with humans and understanding of their activities as the core of many problems in intelligent systems

EDU.1.1: Characteristic (e.g. human) motion detection in computer vision

Scope:

To develop characteristic (e.g. human) motion detection in computer vision characterized by real-time performance, insensitivity to background clutter and movement, and a modular design that can be generalized to other types of motion aimed at various higher-level applications (including automatic motion capture for film and television, human-computer interaction, robotics, industrial machine vision, navigation, events detection, surveillance, etc.).

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities:

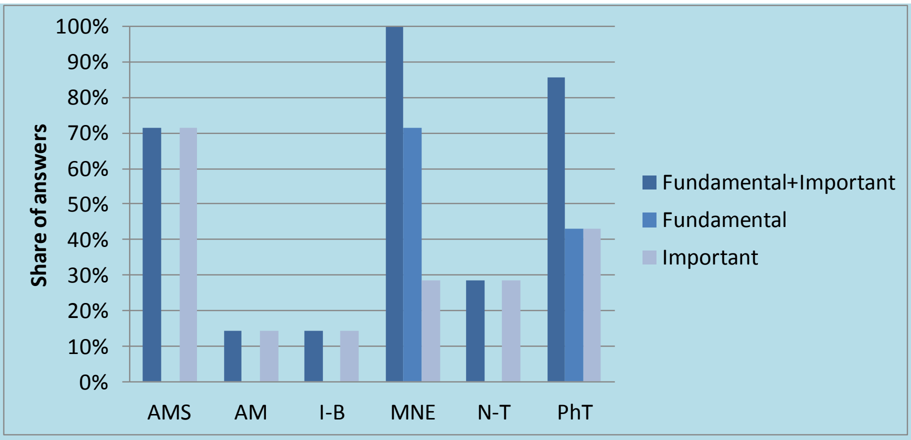
- Development of accurate algorithms for human motion tracking and detection which can digest high-bandwidth video into a compact description of the human presence in a scene
- Development of a model of motion that accurately represents human motion
- Use motion to obtaining other characteristics such as, for instance, object shape, speed or trajectory, which are meaningful for detection and recognition
- Development of whole computer programs to capture and convert movements of arbitrary objects (which can be a human mounted with positioning labels) into quantitative parameters (e.g. point-to-point distance and joint orientation)
- Feature extraction of the acquired images using image processing techniques
- Reconstruct the human gestures based on a sufficient number of feature points

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced characteristic (e.g. human) motion detection systems for computer vision, building on more advanced, high-performance motion sensors characterized by real-time detection and high accuracy.

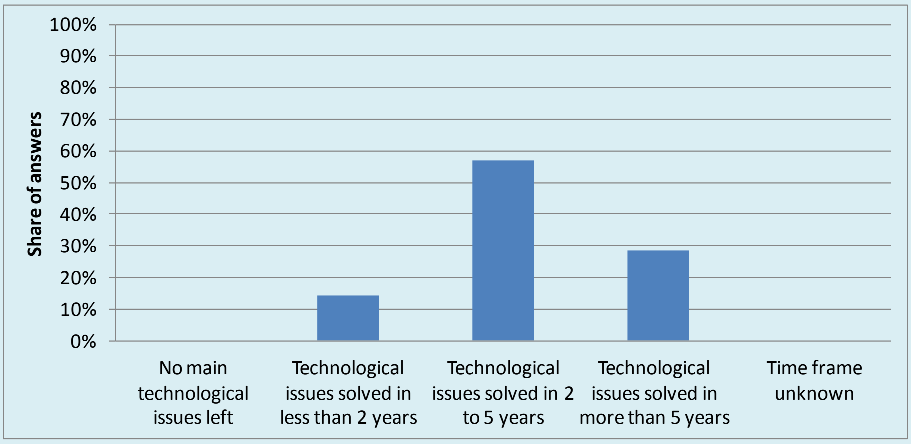
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Micro- and Nano-Electronics (MNE)
- Photonics (PhT)
- Advanced Manufacturing Systems (AMS)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:

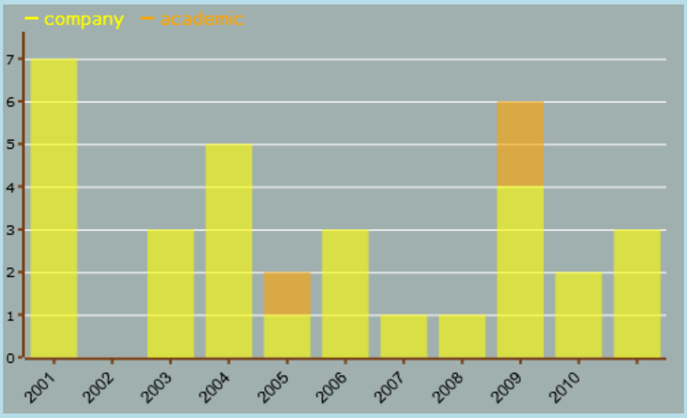


Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

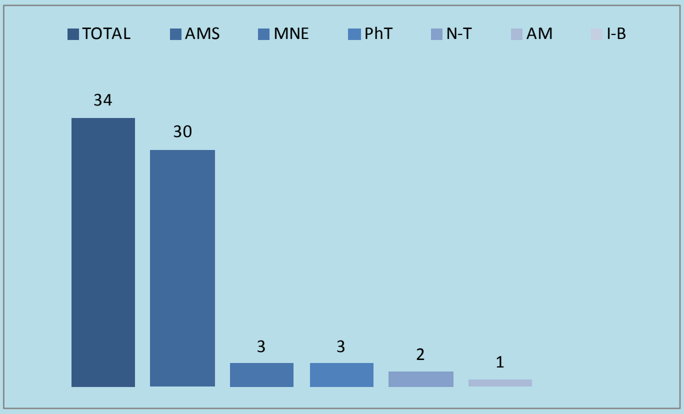
Additional information according to results of assessment:

- ***Impact assessment:***
  - Innovative researches are ongoing towards new directions which can link to contactless interactive educational learning. Events of experiencing the human body through responding to various real-time motion gestures of audiences were applied, and it was manufactured as a system of human body being a one whole interface. By reproducing the roles and states of actual organs in the form of active simulation, a maximization of the experience learning effect can be reached. This user-based interactive education contents will propose ways of participation in edutainment design and new ways to educational learning. This will not be just a simple interaction, but play a role of expanding the field of education (Source: S. Hong, H. Yi Jung, U. Kim, Research on Real-Time Contents for Human Body Experience Edutainment, Advanced Science and Technology Letters Vol.46 (Games and Graphics 2014), pp.285-291).
  - The defence sector is the leader in development of high-performance sensors and systems. Military innovations are increasingly being industrialised for the consumer applications. CBRNE (Chemical, Biological, Radiological, Nuclear, Explosive) sensor development is transferring military technology to civilian security applications. In return, defence benefits from the technology progress in silicon-based components supported by the consumer market. This virtuous circle is a key element in the sustained growth of photonic sensors (European Photonics Industry Consortium – Vision paper photonic sensors).
- ***Results of patents scenario analysis:***

- 34 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Almost stable trend curve (number of patents per year) with peaks and a generally low patenting activity per year
- Highest share of industrial applicants:



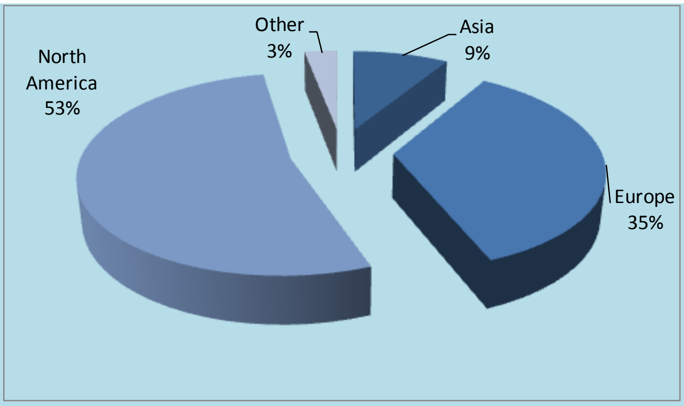
- Patents by KET(s):



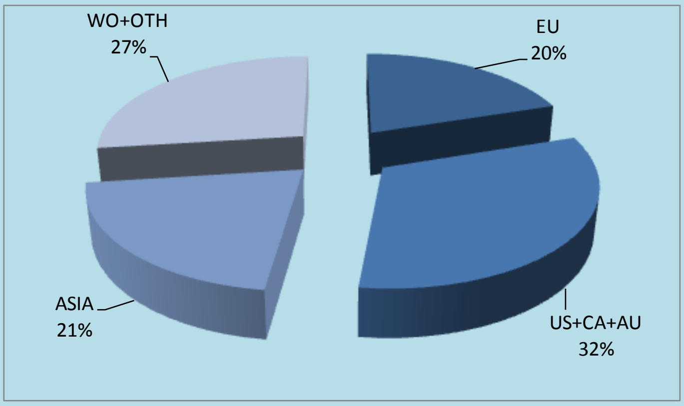
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	1
AM / N-T	1
AMS	30
AMS / MNE	2
AMS / PhT	1
MNE	3
MNE / PhT	1
N-T	2
PhT	3

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



POTENTIAL AREAS OF INDUSTRIAL INTEREST RELEVANT FOR CROSS-CUTTING KETS IN THE TEXTILES DOMAIN

Sub-domain: Novel functional and high performance fibres and fabrics

Demand-side requirements (stemming from Societal Challenges) addressed:

Depending on the application or the type of feedstocks or processes used for production, textiles can contribute to tackle the following societal challenges:

- Health, demographic change and wellbeing
- Inclusive, innovative and secure societies
- Climate action, resource efficiency and raw materials
- Secure, clean and efficient energy

TX.1.1: Textiles with enhanced care (cleaning, washing, etc.) properties

Scope:

To develop textiles and textile products with enhanced care (cleaning, washing, etc.) properties.

Demand-side requirements (stemming from market needs) addressed:

- Increase products' usage flexibility in order to cope with today's lifestyles
- Address individual customer needs and use scenarios

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

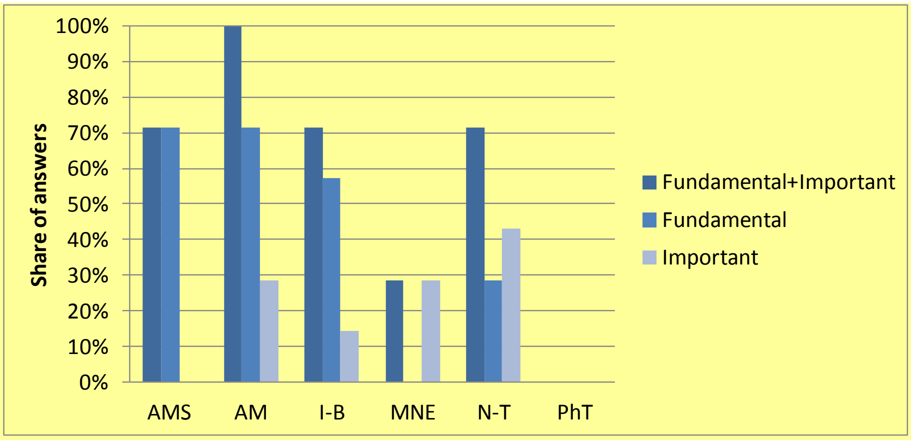
- Development of enhanced surface treatments and coatings to provide effective anti-stain, anti-dust and other properties to the textile

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of enhanced surface treatments and coatings to provide anti-stain, anti-dust and other functionalities to textiles, building on new formulations for coatings or advanced surface treatments, such as plasma treatment, enzymatic processes, etc.

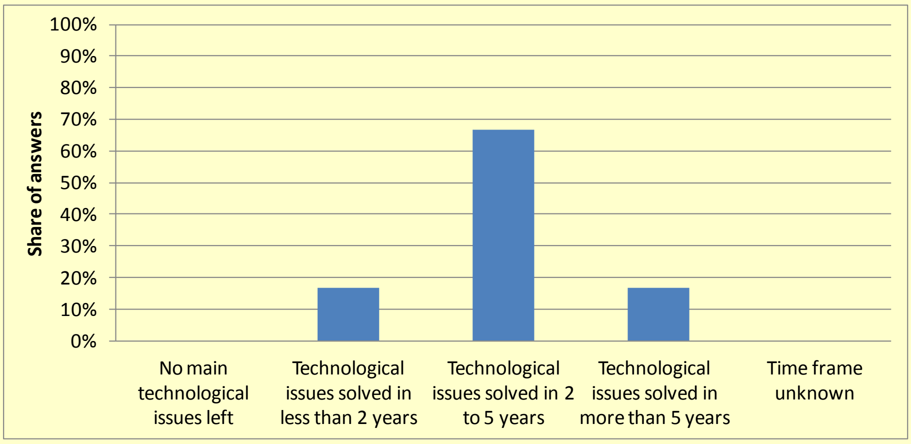
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Industrial Biotechnology (I-B)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

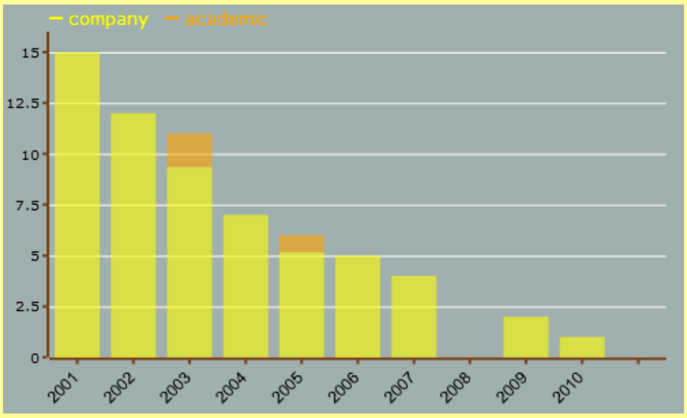
➢ ***Impact assessment:***

- The textile industry is living a period of changes in the supply chain, in the end markets and business models. The major long-term industry trends for the textile and clothing sector are well identified by the European Technology Platform for Textiles and Clothing. Among others, the textile industry is experiencing a change from providing commodities to providing specialty products by applying high-tech processes, fibres, filaments, fabrics and final products with highly functional, purpose-targeted properties (Source: In-depth assessment of the situation of the T&C sector in the EU and prospects, Task 7: Synthesis report for the European textile and clothing sector, December 2012).
- Within this framework, one of the earliest functional products introduced in the market by the textile industry are textiles with anti-stain properties imparted thanks to surface treatments (e.g. plasma treatment, enzymatic processes) and coatings. Yet, the industry is still developing enhanced surface treatments and coatings to provide effective anti-stain, anti-dust but also other properties to the textile so to facilitate care (cleaning, washing, etc.) in order to respond to market needs calling for increased products' usage flexibility, which is especially the case in the home textiles market segment, in order to cope with today's lifestyles.

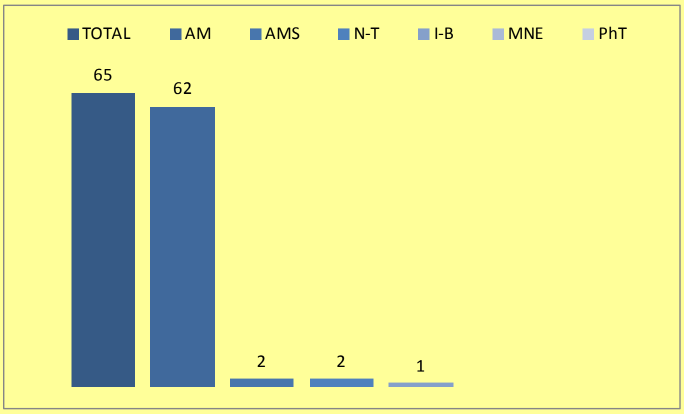
➢ ***Results of patents scenario analysis:***

- 65 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Decreasing trend curve (number of patents per year)

- Highest almost exclusive share of industrial applicants:



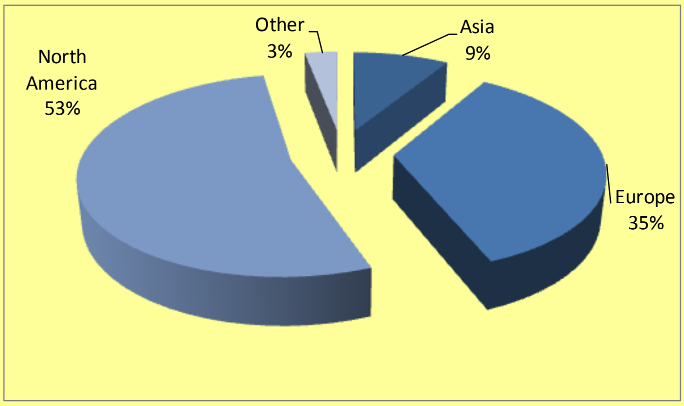
- Patents by KET:



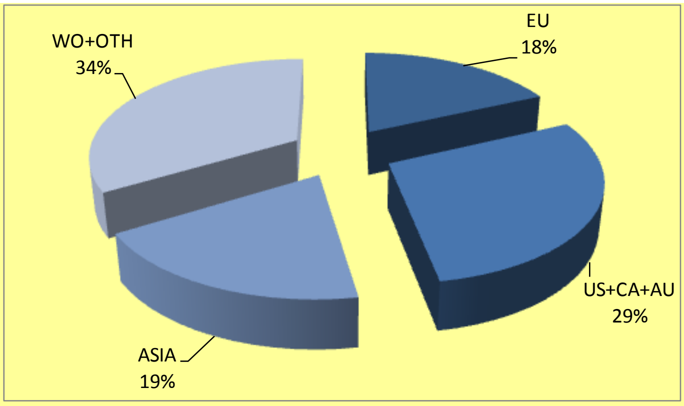
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	62
AM / N-T	2
AMS	2
IBT	1
N-T	2

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



TX.1.2: Bio-based fibres with tailored properties

Scope:

To develop bio-based fibres with tailored properties intended for biomedical, textile and technical textile applications to move away from refined-oil based products.

Demand-side requirements (stemming from market needs) addressed:

- Decrease dependency of chemical production from oil by shifting the feedstock base towards alternative feedstocks
- Improve environmental performance of products

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

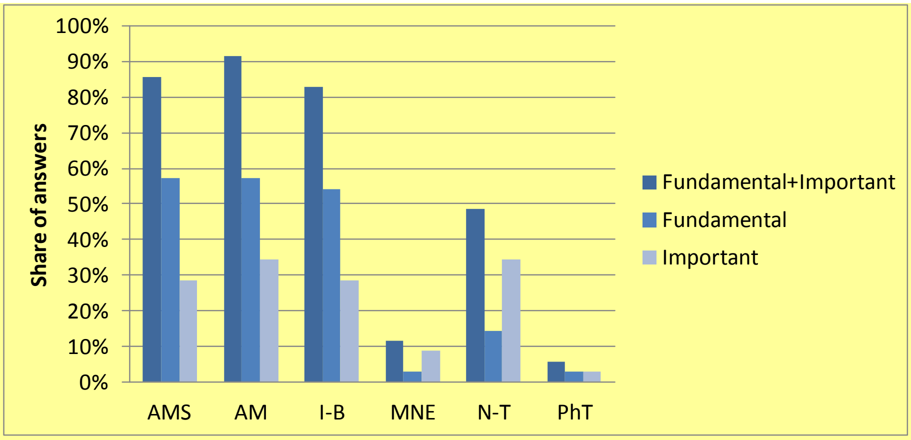
- Production of bio-based textile fibres with tailored properties to move away from refined-oil based products
- Development of improved machines allowing for the processing of these fibres
- Development of natural fibres with improved and tailored performances

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of bio-based fibres with tailored properties intended for biomedical and technical textile applications, reducing the dependency from fossil-based resources; results are expected to overcome most bio-polymers' limitations in regard to textile processing.

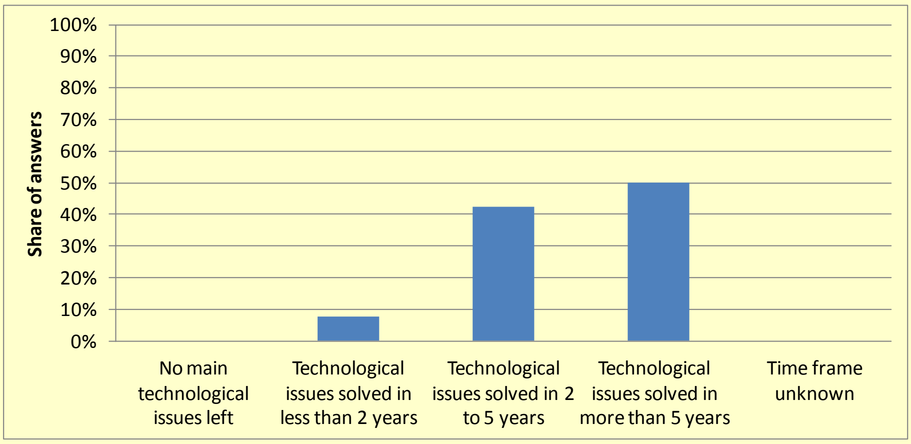
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Industrial Biotechnology (I-B)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus by experts indicates also shorter periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

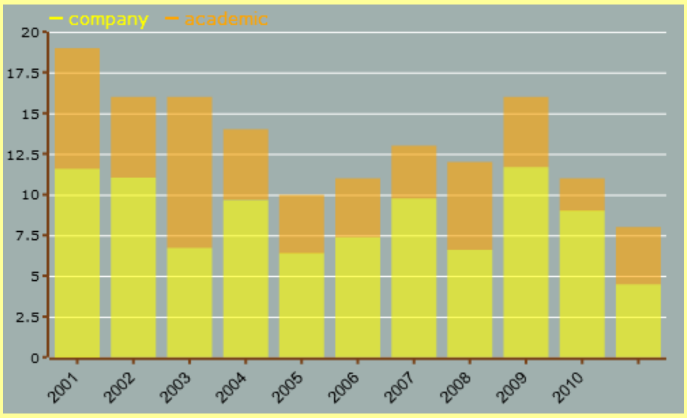
- There are two opportunities for bio-based products to penetrate the textiles market. First, bio-based fibres derived from either agricultural crops or forestry waste can be processed and developed to replace or blend with existing natural fibres. On the other hand, bio-based chemicals can be used to manufacture polymeric materials that, depending on their characteristics, can be spun into fibre for use in textiles (Source: Bio Based Textiles, http://fibreroadmap.wikispaces.com).
- Bio-based chemicals have the potential to be used for the manufacture of polyesters and nylons, which will probably occur as soon as bio-based chemicals that can be polymerized become available at competitive pricing.
- On the natural fibre side, cellulose has been used for fibre manufacture for many years via simple chemical processing that produces Rayon®. Addition of carbon disulfide, altered the properties of the cellulose fibre so that it could be spun into filament, known as generically as the viscose process. Subsequently, a process where cellulose is treated with amine oxide has been used to produce a slightly different cellulosic fibre. This material is known as lyocell, and is manufactured by Lenzing under the tradename Tencel® using cellulosic material sourced mainly from beech wood, but flax, and hemp fibres have also been utilized. The resulting textiles are known by a number of names, including polynosics, Modal, and Tencel. Other efforts in natural fibre utilization involve

plant genetics, particularly for flax and hemp, in order to produce plant fibre that has properties more closely related to that of cotton (Source: Bio Based Textiles, http://fibreroadmap.wikispaces.com).

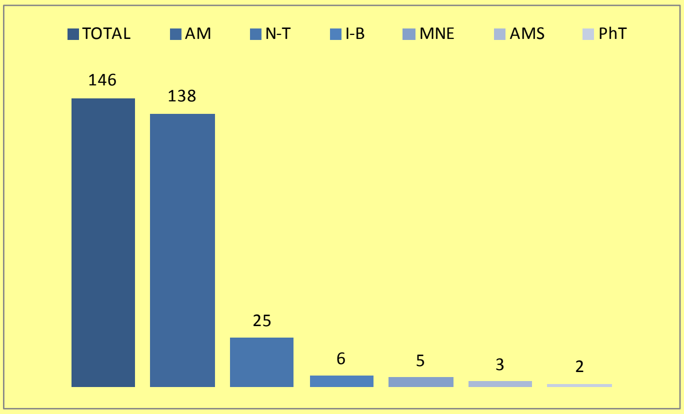
- As regards technical applications, in construction for example, the cost of natural fibres is 3-4 times higher than that of mineral wools but natural fibres have good mechanical properties (impact resistance, acoustic qualities, and strongly reduced weight). Benefits in cars are as well related to lightweight advantages over conventional glass fibre compounds and partly to cost advantages over PUR foam based products. Natural fibres also allow for better waste management: materials containing vegetable fibres are easier to recycle or burn than the materials containing fibreglass fibres (Source: Accelerating the Development of the Market for Bio-based Products in Europe, Report of the Taskforce on Bio-Based Products Composed in preparation of the Communication "A Lead Market Initiative for Europe").

➢ ***Results of patents scenario analysis:***

- 146 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Oscillating but almost stable trend curve (number of patents per year)
- Shared between industrial and academic applicants:



- Patents by KET:

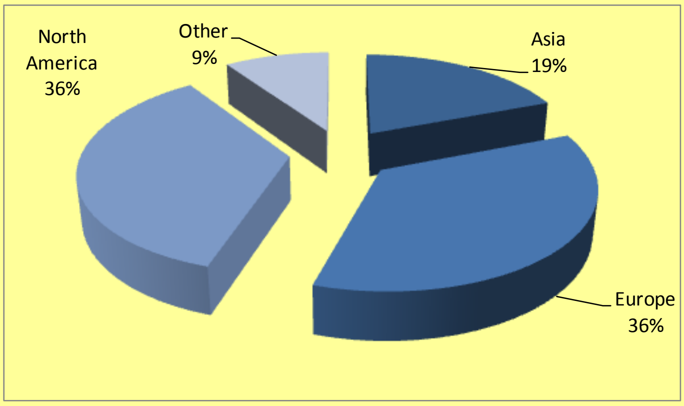


- Patents by KET(s) and relevant combinations of KETs:

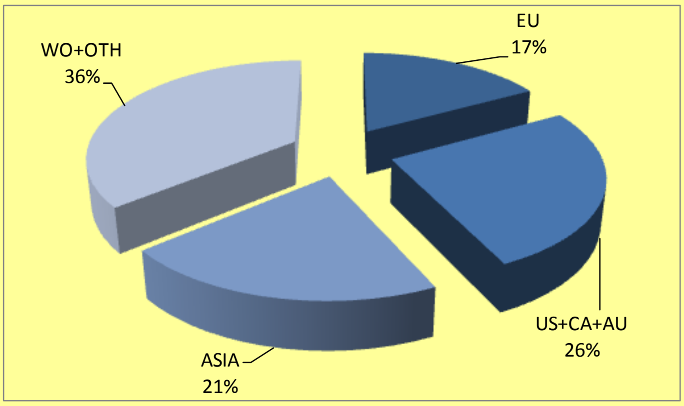
KET(s)	*Number of patents*
AM	138
AM / IBT	4
AM / IBT / N-T	1
AM / MNE	3
AM / MNE / N-T	3
AM / N-T	20
AM / PhT	2
AMS	3
AMS / AM	2
AMS / AM / N-T	2

AMS / N-T	2
IBT	6
IBT / N-T	1
MNE	5
MNE / N-T	5
N-T	25
PhT	2

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



TX.1.3: Biodegradable fibres and textiles for increased environmental sustainability

Scope:

To develop biodegradable fibres and textiles for increased environmental sustainability.

Demand-side requirements (stemming from market needs) addressed:

- Decrease dependency of chemical production from oil by shifting the feedstock base towards alternative feedstocks
- Improve environmental performance of products

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

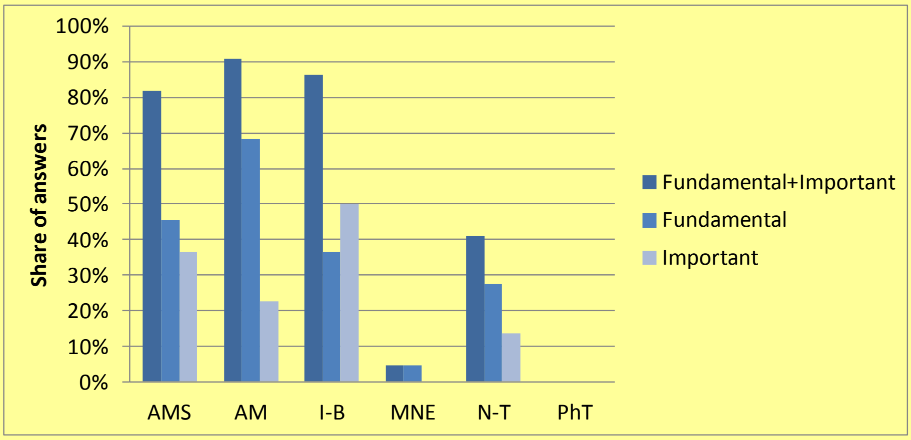
- Development of fully biodegradable materials for fibres and textiles

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of biodegradable fibres and fabrics for increased environmental sustainability, thanks to fully biodegradable materials, building on innovative material formulations or on the modification of the starting material (e.g. by alloying, incorporation of nano-additives, etc.), which may originate from renewable sources.

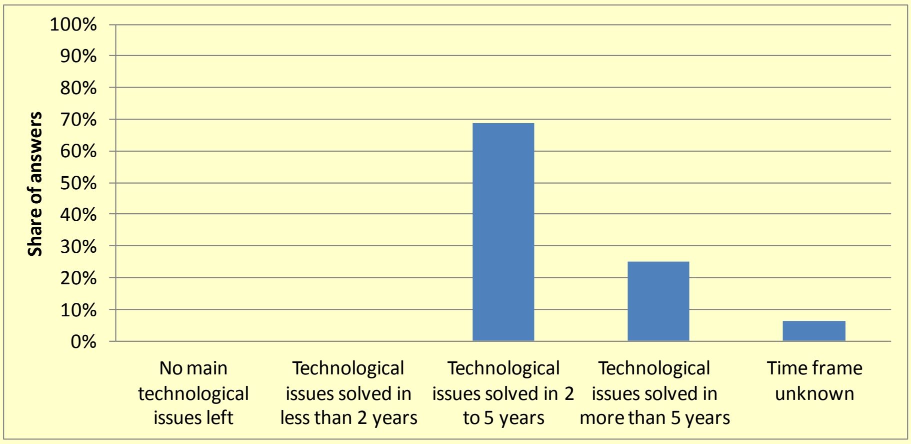
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Industrial Biotechnology (I-B)
- Nanotechnologies (N-T)



Timing for implementation:

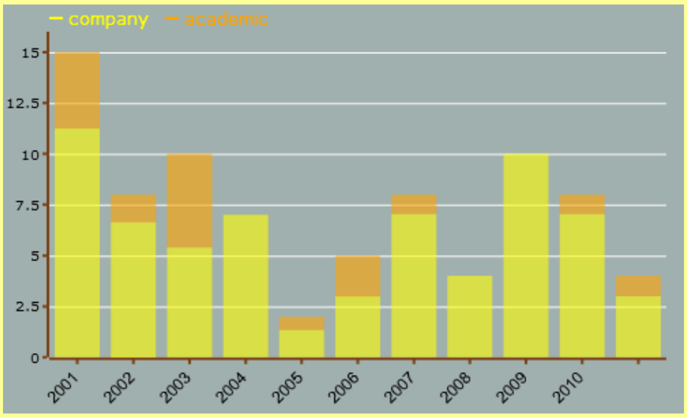
According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



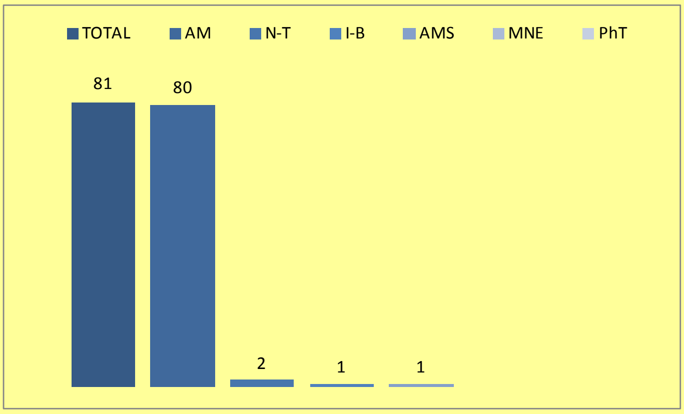
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Fibres obtained from fossil resources have replaced fibres based on biodegradable natural polymers in all markets over the last century. Yet, today, there is an increasing expressed consumer preference for "environmentally friendly" products, which finds its highest expression in the disposables area.
  - The largest and most potentially environmentally sensitive market where biodegradable fibres and textiles such as particularly nonwovens could have a major impact is probably the market of disposable diapers and sanitary napkins, where biodegradable products are still limited. In this field, opportunities for using biodegradable fibres possibly obtained from renewable resources are significant.
  - Other areas in which biodegradable fibres and textiles are already applied in a certain instance but could offer even higher opportunities are medical products, disposable filters, agricultural products (e.g. mulch covers), and packaging to materials used in the automotive industry, interior designs and the building industry.
- ***Results of patents scenario analysis:***
  - 81 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Oscillating almost stable trend curve (number of patents per year)
  - Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants especially in the early part of the period, most probably standing for new technologies having been patented in the corresponding periods:



  - Patents by KET:

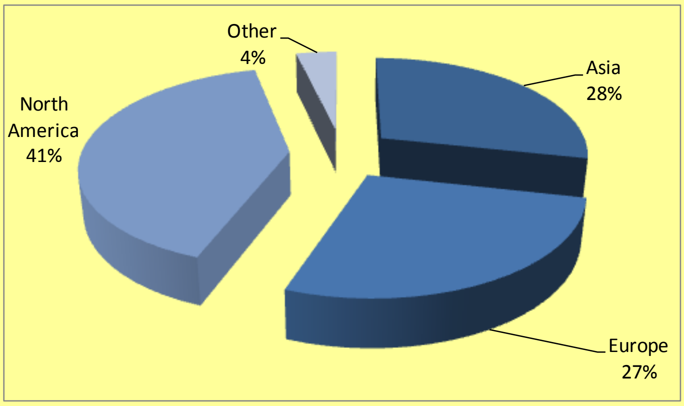


  - Patents by KET(s) and relevant combinations of KETs:

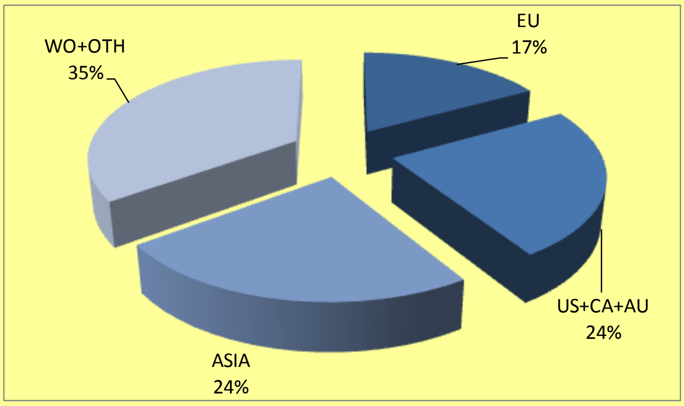
KET(s)	*Number of patents*
AM	80
AM / N-T	2
AMS	1
AMS / AM	1
IBT	1

N-T	2

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



Sub-domain: Improved functional textile based products

Demand-side requirements (stemming from Societal Challenges) addressed:

Depending from the application or the type of feedstocks or processes used for production, textiles can contribute to tackle the following societal challenges:

- Health, demographic change and wellbeing
- Inclusive, innovative and secure societies
- Climate action, resource efficiency and raw materials
- Secure, clean and efficient energy

TX.2.1: Wearable active textiles and clothing for improved human performance aimed at human safety and protection

Scope:

To develop wearable textiles and clothing capable to measure and communicate human living functions (including through integrating sensors, flexible screens, embedded energy storage or harvesting devices) and/or react autonomously to changing activities or conditions of the wearer in order to optimise the wearer's comfort and safety at every moment.

Demand-side requirements (stemming from market needs) addressed:

- Provide for personal protection and safety
- Address individual customer needs and use scenarios

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

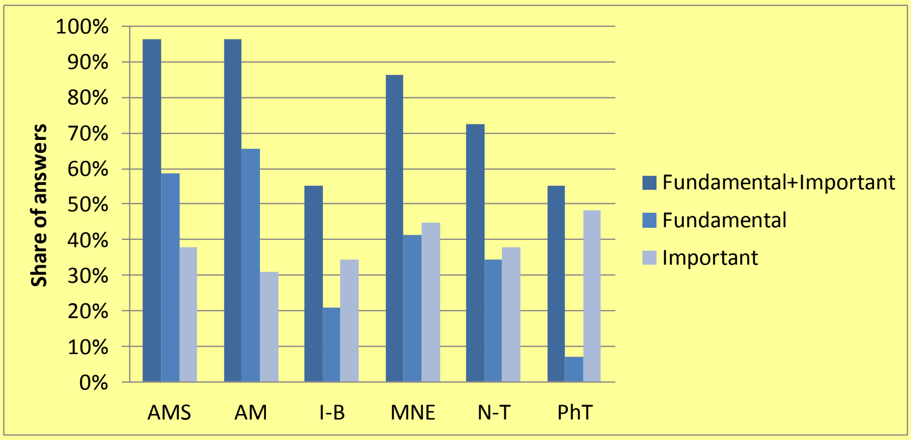
- Development of active textiles, which react autonomously or actively to the changing activities or conditions of the wearer in order to optimise comfort and safety at every moment
- Integration of smart textile materials and built in electronics (such as miniaturized embedded sensors, flexible screens, embedded energy storage or harvesting devices) in order to achieve intelligent and functional textiles and clothing capable to measure parameters and react autonomously to the changing conditions of the wearer

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of wearable textiles and clothing capable to measure and communicate human living functions and/or react autonomously to changing activities or conditions of the wearer thanks to incorporating smart textile materials and/or built in electronics.

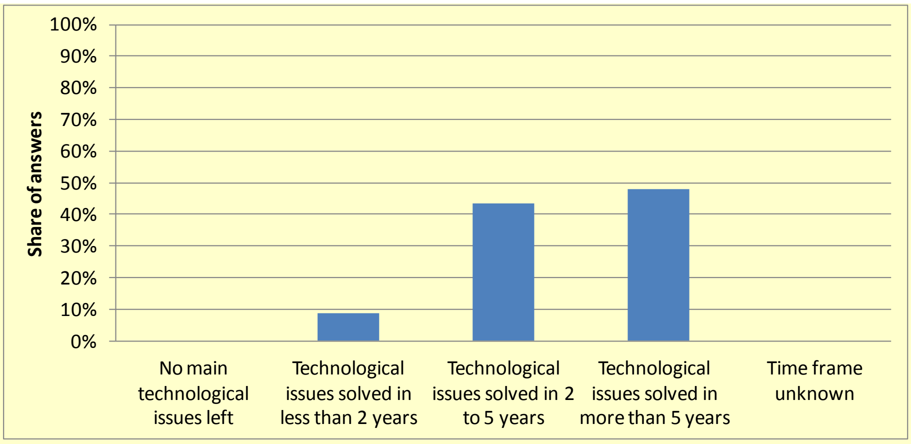
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)



Timing for implementation:

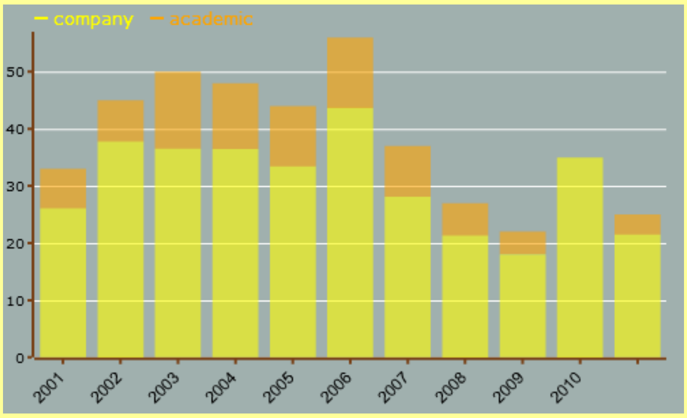
According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus by experts indicates also shorter periods being necessary:



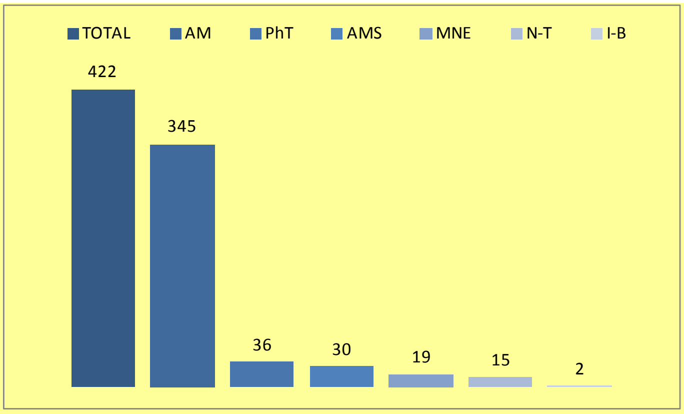
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - Smart textiles represent the next generation of textiles affiliated in both research and commercial activities. There has already been an introduction of smart textiles in fashion, however the efforts of introducing smart textiles in other wearable textiles areas still dominate research activities. There is surely a difference between application of smart textiles in health care or for workwear and in their application for fashion purposes. In health care and workwear the applications are focused on monitoring the wearer's health and conditions or to facilitate communication. In fashion the applications are more focused on visual or tactile feedback from the wearer. Most of the market analyses and roadmaps on smart textiles point out potential of other areas than fashion and the funding of research projects also proves that there is a focus on technical aspects of clothing rather than fashion (Source: Berglin, Smart Textiles and Wearable Technology - A study of smart textiles in fashion and clothing, Report within the Baltic Fashion Project, published by the Swedish School of Textiles, University of Borås, November 2013).
  - This Innovation Field is highly interesting also for dual use applications as some interactive wearable textiles for warrior systems already exist that may be applied to civilian applications.
- ***Results of patents scenario analysis:***
  - 422 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Stable-decreasing trend curve (number of patents per year)
  - Highest share of industrial applicants with relevant patenting activity by academic applicants especially in the early part of the period:



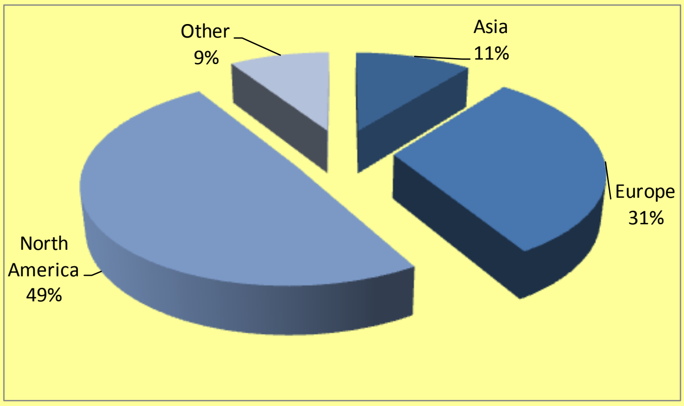
  - Patents by KET:



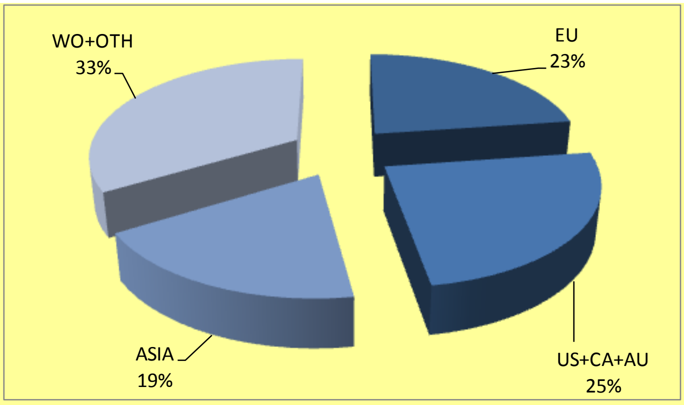
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	345
AM / MNE	4
AM / MNE / N-T	1
AM / N-T	7
AM / PhT	1
AMS	30
AMS / AM	2
AMS / MNE	1
AMS / PhT	1
IBT	2
MNE	19
MNE / N-T	2
MNE / N-T / PhT	1
MNE / PhT	8
N-T	15
N-T / PhT	1
PhT	36

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



TX.2.2: Active textiles with embedded sensing capabilities for "large area" applications

Scope:

To develop textile products reacting autonomously or actively to the changing conditions of the environment (e.g. geotextiles with built in sensing functionalities capable of monitoring slopes) for environmental protection and climate-related environmental risks mitigation.

Demand-side requirements (stemming from market needs) addressed:

- Provide for environmental protection and environmental risks mitigation

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

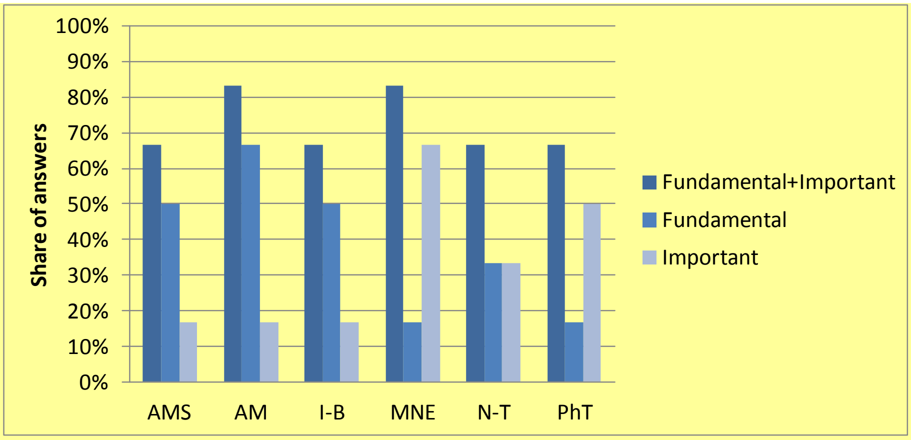
- Development of active textiles, which react autonomously or actively to the changing activities or conditions of the environment
- Development of enhanced manufacturing methods that can effectively build sensors into the textile structure

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of active textiles with embedded "large area" sensing capabilitiesfor environmental protection and risks mitigation, thanks to incorporating smart textile materials and/or built in electronics, optical fibres, or any other sensing element.

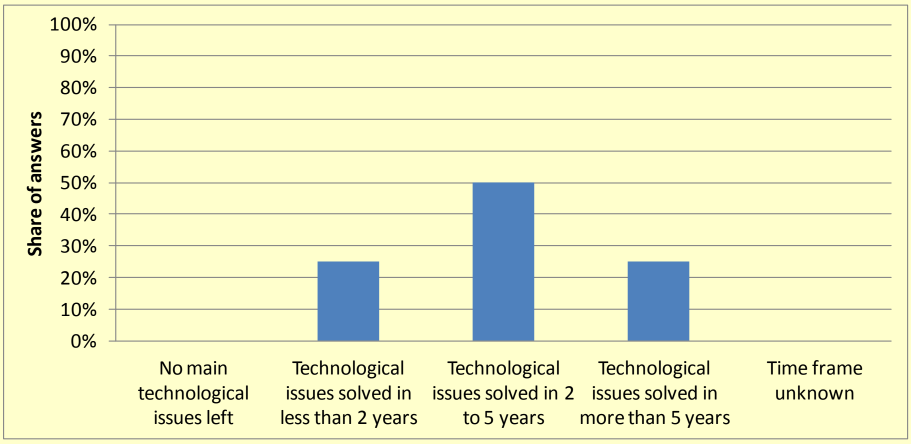
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Photonics (PhT)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Industrial Biotechnology (I-B)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short term should be taken into consideration within this framework.

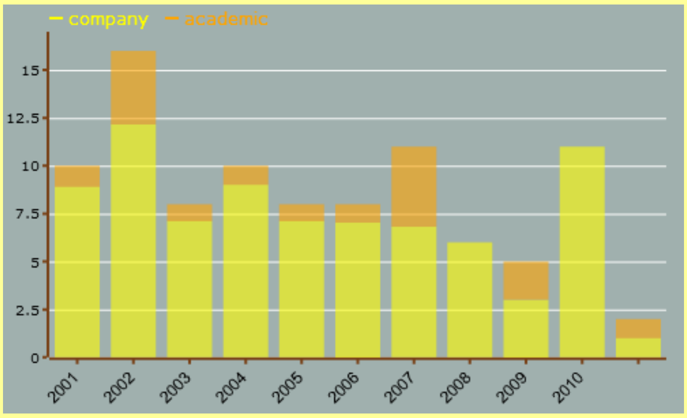
Additional information according to results of assessment:

➢ ***Impact assessment:***

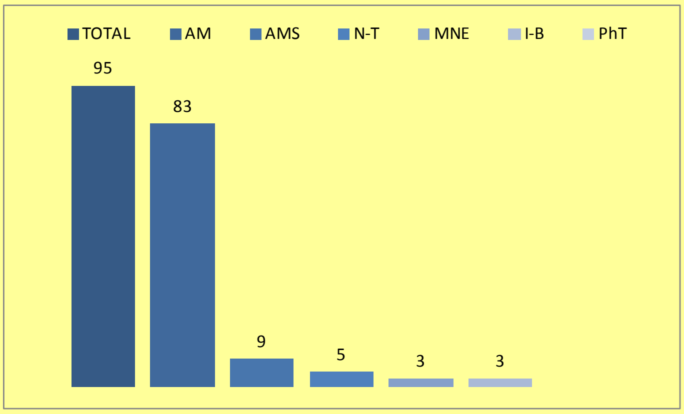
- Geotextiles are gaining importance due to large scale infrastructural development at a global level. The geotextiles performs several functions which include separation, filtration, reinforcement, protection, and draining. The major applications for geotextiles are road industry, erosion control, waste management and pavement repair. The emerging economies have large number of projects which are currently being developed. Countries such as China, India, and other Asian economies are growing markets for the geotextiles industry. As a result, the global geotextiles market is forecast to reach a value of 4.6 billion Euro by 2017.
- Major players in the field of geotextiles in Europe include TenCate, NAUE, and Huesker Synthetic. Within Europe, most of the major market players are situated in countries such as UK, Germany, Denmark, The Netherlands, and Italy.
- Considering regional markets, Asia dominates the global geotextiles industry. It is estimated to reach 1.8 billion Euro by 2017. The growth of Asian market is expected to be highest among all regions. North American region is the second largest market of geotextiles and is estimated to reach a value of 1.2 billion Euro by 2017.
- Source: Markets and Markets, Geotextiles Market by Types (Woven, Nonwoven, Knitted), Materials (Polypropylene, Polyester, Polyethylene) and Applications (Road Industry, Pavement Repair, Erosion Control, Waste Containment, Railroad Stabilization) - Global Trends and Forecasts to 2017, 2013
- This Innovation Field is highly interesting also for dual use applications. The defence

sector already uses this kind of advanced geotextiles and active textiles for specific applications, such as in the marine domain. This wide background of knowledge can be transferred into the civil domain, thus strengthening the potential of duality.

- ***Results of patents scenario analysis:***
  - 95 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Stable-decreasing trend curve (number of patents per year)
  - Highest share of industrial applicants:



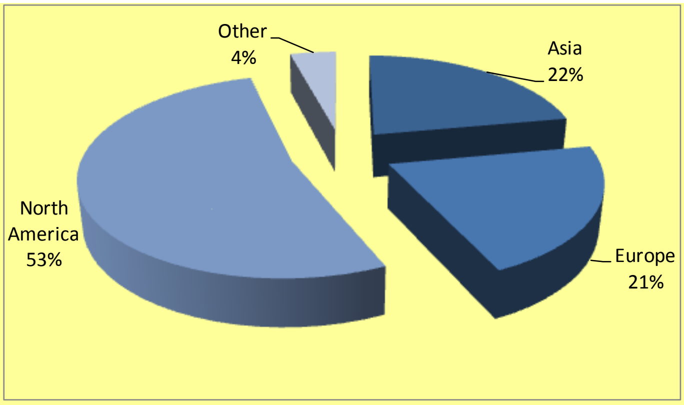
  - Patents by KET:



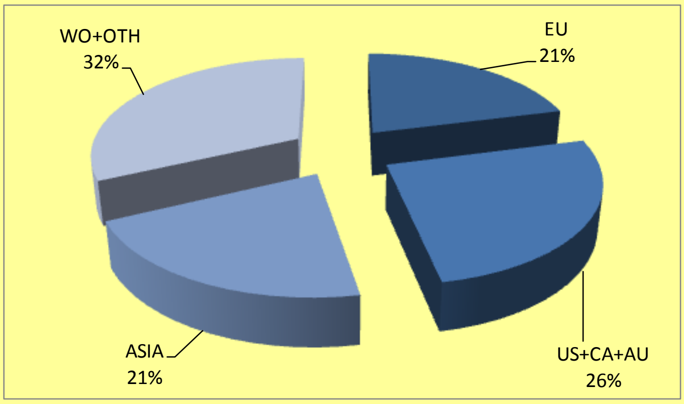
  - Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	83
AM / MNE	1
AM / N-T	4
AMS	9
AMS / AM	2
AMS / MNE	1
IBT	3
MNE	3
N-T	5

  - Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



TX.2.3: Functionalized textile products for better health, wellbeing, comfort and aesthetics

Scope:

To develop functionalized textile products with enhanced functionalities and performance for better health, wellbeing, comfort characteristics and aesthetics.

Demand-side requirements (stemming from market needs) addressed:

- Optimize the wearer's comfort and safety at every moment

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

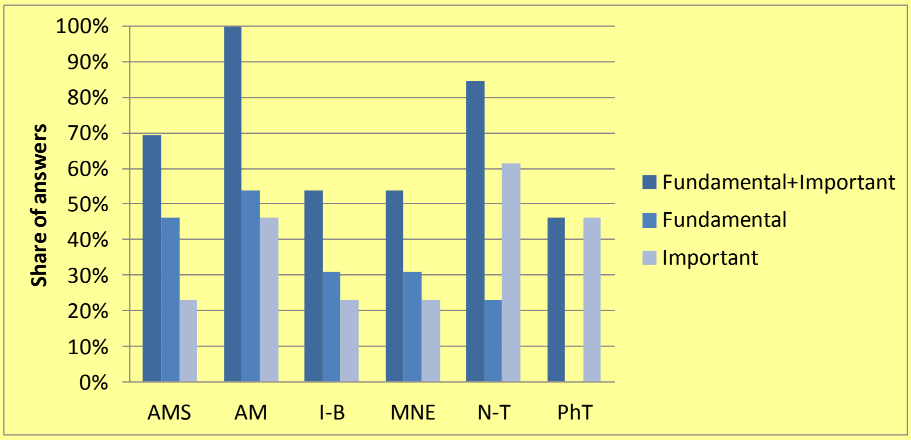
- Development of fibres and textiles with enhanced functionalities and performances for better health, wellbeing and comfort characteristics
- Development of active textiles, which react autonomously or actively to the changing activities or conditions of the wearer in order to optimize comfort and safety at every moment
- Development of surface functionalization methods and processes for the production of fibres and textiles with enhanced performance

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced functionalized textile products with enhanced functionalities and performance for better health, wellbeing, comfort and aesthetics, building on solutions such as innovative material formulations or the modification of the starting material, surface functionalization, and integration of smart textile materials and/or built in electronics.

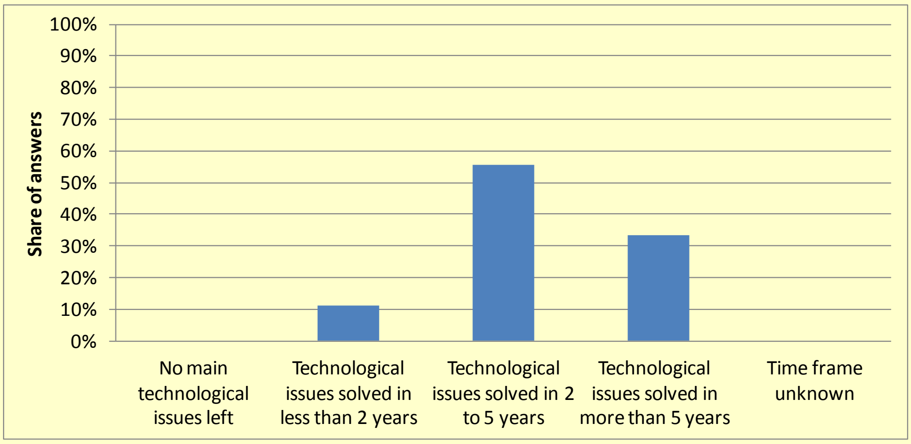
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Industrial Biotechnology (I-B)
- Micro- and Nano-Electronics (MNE), evenatually, if embedded electronics would be involved



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also greater periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

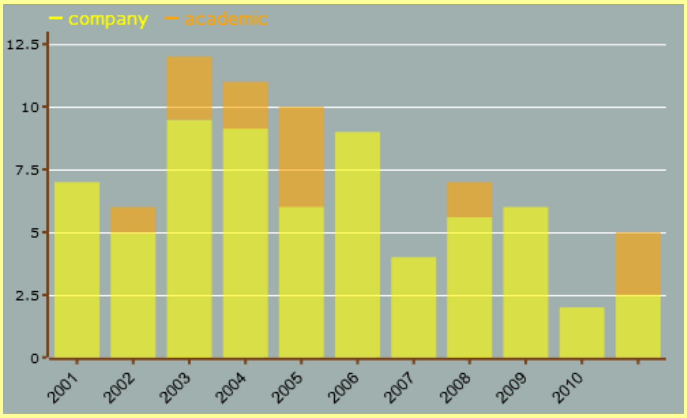
- As introduced in relation to other Innovation Fields, the textile industry is experiencing a period of change in the supply chain, in the end markets and business models. The major long-term industry trends for the textile and clothing sector are well identified by the European Technology Platform for Textiles and Clothing. Among others, the textile industry is experiencing a change from providing commodities to providing specialty products by applying high-tech processes, fibres, filaments, fabrics and final products with highly functional, purpose-targeted properties.
- Especially in sport and workwear, end-users demand materials with a broad range of functionalities. Within this framework, the application of technical finishes, as well as multilayer coating and lamination, is an area of substantial innovation. Textiles with

antimicrobial properties have been one of the earliest functional products introduced in the market segment of sport and workwear by the textile industry. Yet to date only a few possibilities have been explored and commercialized. A new generation of finishes based on nanotechnology (e.g. the lotus effect) is also at a level of market introduction. Biotechnology-based functionalities such as enzymes, plant extracts are being researched and developed. Alternative, more sustainable finishing processes based on digital technology, plasma or supercritical CO2 are being explored and tested. Several of these methods are essentially oriented to functional properties, but especially Italian finishers are also exploring the aesthetic potential of new finishes and finishing technologies.

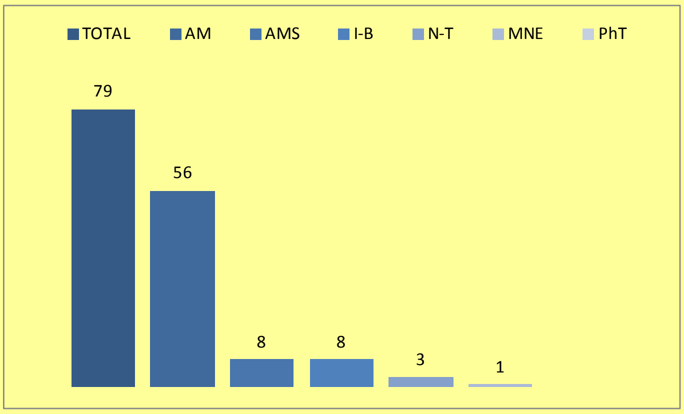
- Europe still has a commanding position in textile finishing worldwide. Finishing is where most of the functionalization towards special properties can be applied, and therefore plays a key role when it comes to incorporate innovative properties to a textile product. It is also the first mover in new technologies such as digital printing.
- Source: In-depth assessment of the situation of the T&C sector in the EU and prospects, Task 7: Synthesis report for the European textile and clothing sector, December 2012

➢ ***Results of patents scenario analysis:***

- 79 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Stable-decreasing trend curve (number of patents per year)
- Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants, most probably standing for new technologies having been patented in the corresponding periods:



- Patents by KET:

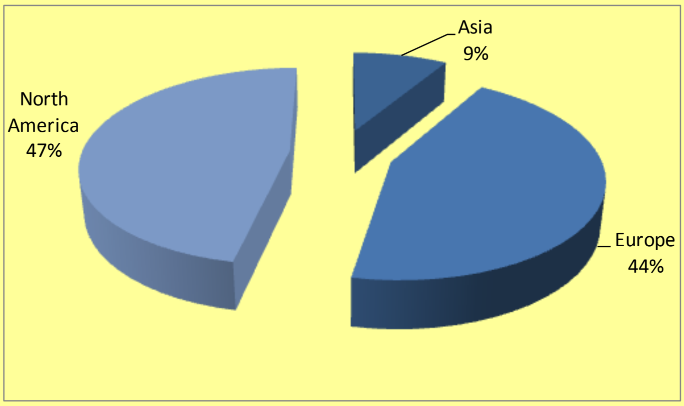


- Patents by KET(s) and relevant combinations of KETs:

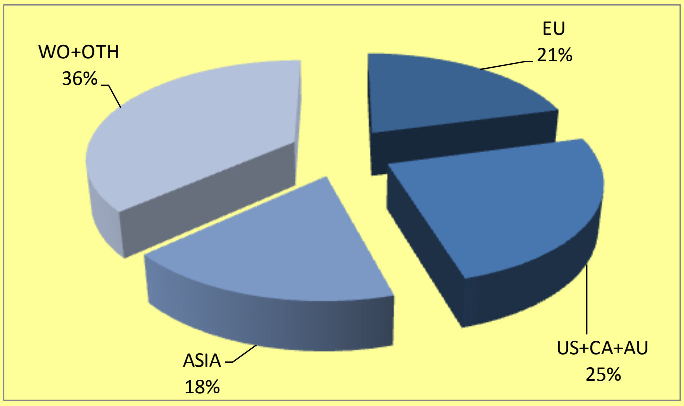
KET(s)	*Number of patents*
AM	56
AM / MNE	1
AMS	8
AMS / MNE	1
IBT	1
MNE	10

MNE / PhT	5
N-T	3
PhT	8

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



TX.2.4: Functional (para-) medical textiles

Scope:

To develop functional (para-) medical textiles and textile-based products (e.g. bandages) with built in functionalities such as the release of drugs or active components, etc.

Demand-side requirements (stemming from market needs) addressed:

- Demand for high performing materials with improved functionalities

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

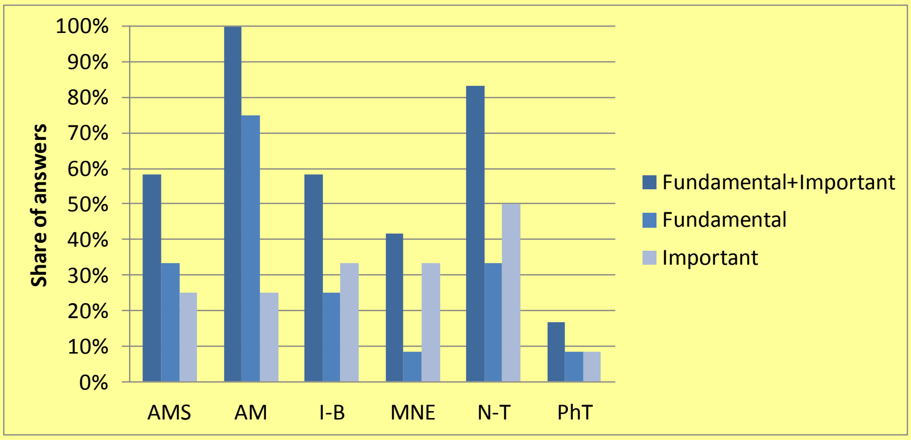
- Development of fibres and textiles as medium for targeted release / delivery mechanisms (e.g. slow release of pharmaceuticals)
- Tailoring of controllable biomedical properties of fibres and textiles
- Development of functional textiles to be used for targeted drug release, tissue scaffolds and intelligent textile implants

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more advanced functional (para-) medical textiles and textile-based products (e.g. bandages) with built-in care functionalities, building on solutions such as fibres and textiles applied as media for the targeted release/delivery of components, biocompatible functional textiles such as tissue scaffolds and implants, and the related manufacturing processes.

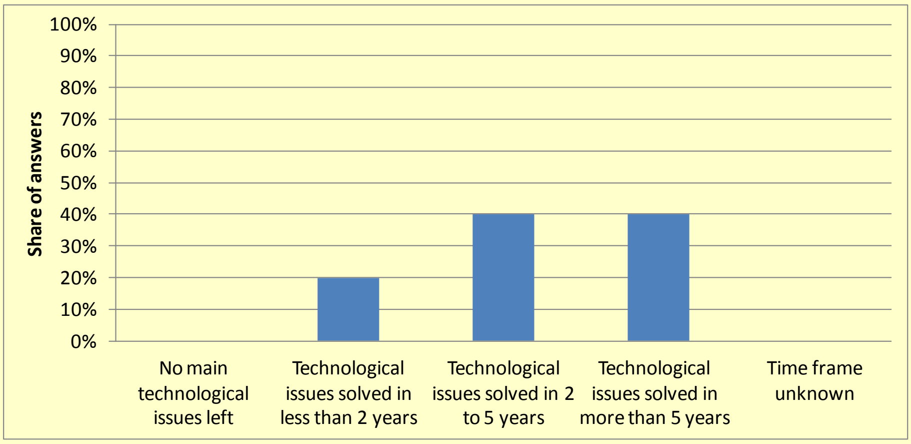
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)
- Industrial Biotechnology (I-B)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of either 2 to 5 years or more than 5 years:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

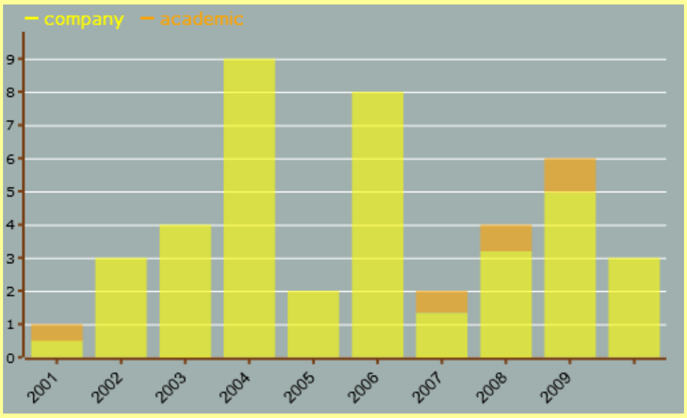
Additional information according to results of assessment:

➢ ***Impact assessment:***

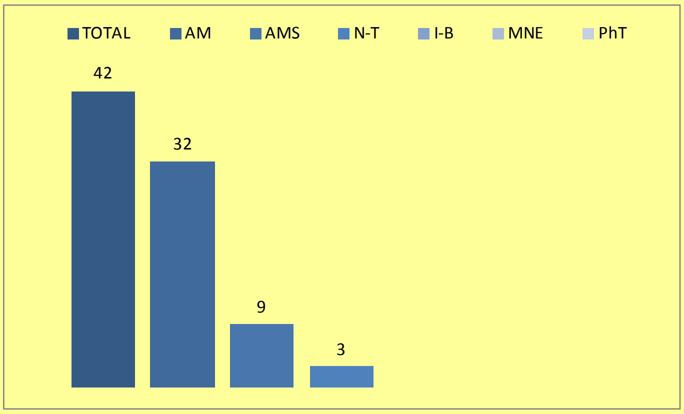
- In Europe, four countries consume about half of the technical textiles in terms of value: Germany, France, the UK and Italy. The technical textiles industry in Germany represents 45% of the European textile industry, followed by France, UK and Italy. Medical textiles are one of the faster growing sectors of the global technical textiles industry. The global market for medical textiles was about 5 billion Euro in 2007. Every year this niche market becomes more relevant and its importance will increase even more in the future (Source: F. Conicella, A. Dayon, Health care: trends, priorities and relations with textiles, Presentation Piemonte Innovation Cluster, 2013).

➢ ***Results of patents scenario analysis:***

- 42 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Scattered trend curve (number of patents per year)
- Highest share of industrial applicants:



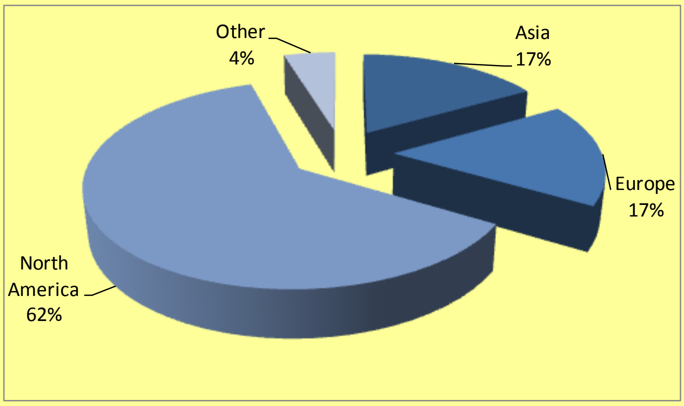
- Patents by KET:



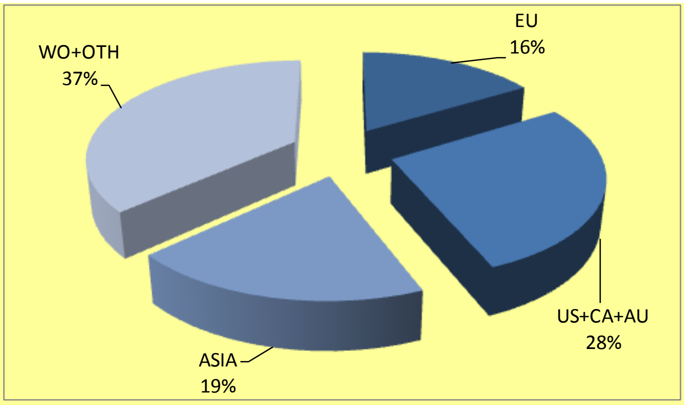
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	32
AM / N-T	2
AMS	9
N-T	3

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



TX.2.5: Technical textiles and textile products for specialized industrial applications

Scope:

To develop technical textiles for specialized industrial applications with improved functionalities and performance (e.g. textile-based filters with high filtration efficiencies; lightweight, non-flammable and scratch-resistant technical textiles for mobile applications, including for seats and in-vehicle garments, etc.).

Demand-side requirements (stemming from market needs) addressed:

- Demand for high performing materials with improved functionalities

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

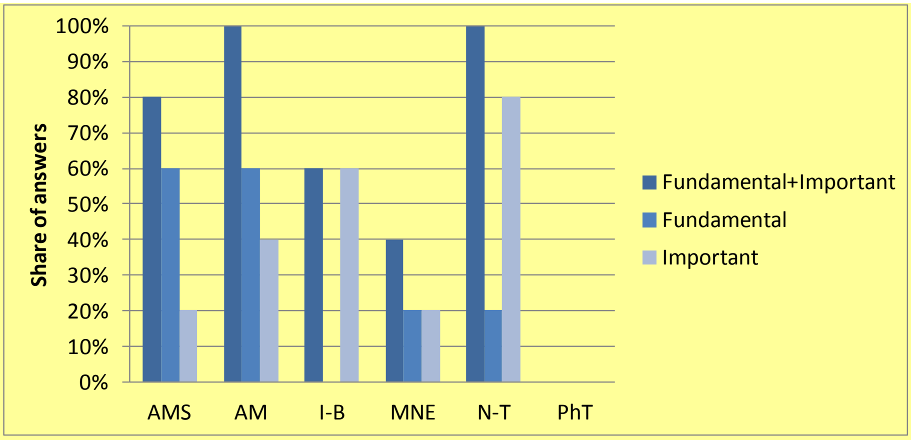
- Development of fibres and textiles with enhanced functionalities and performances (e.g. high strength, scrap resistance, high modulus, hydrophilic or hydrophobic, etc.)
- Development of surface functionalization methods and processes for the production of fibres and textiles with enhanced performance

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced technical textiles for specialized industrial applications, thanks to solutions such as fibres and textiles with enhanced functionalities and performance (e.g. high strength, cut and puncture resistance, high modulus, hydrophilic or hydrophobic, non-flammable, lightweight properties, etc.), along with functionalization methods and processes.

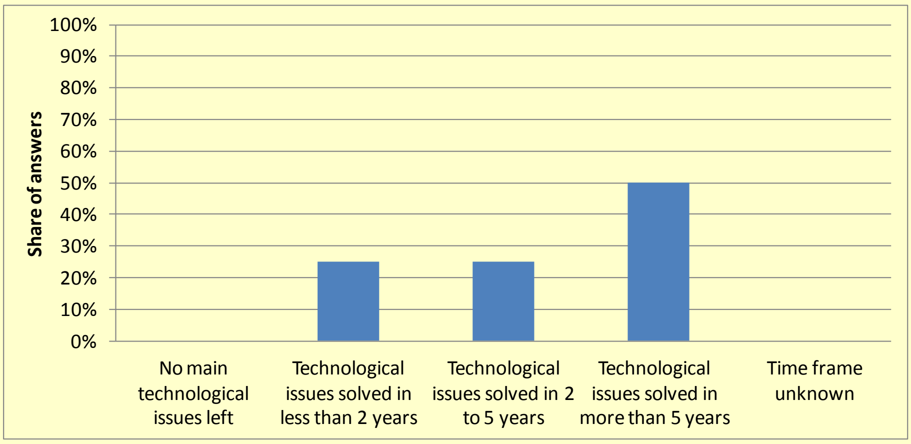
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus by experts indicates also shorter periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

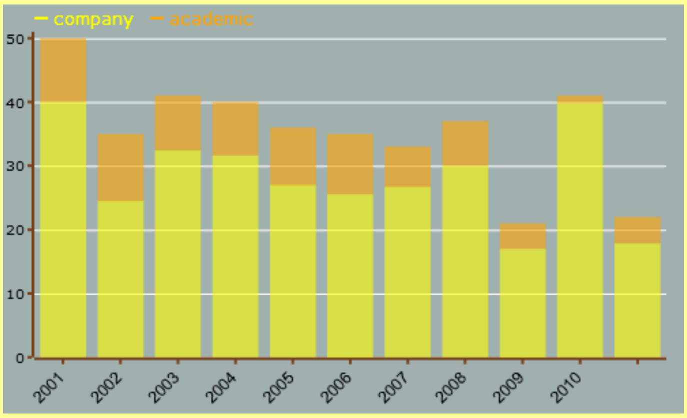
Additional information according to results of assessment:

- ***Impact assessment:***
  - While fashion and home apparel remains to date the main part of the EU industry and will continue to be important, a closer look at the EU textiles and clothing industry structure shows that technical textiles have become an increasingly vital part of the European textiles and clothing industry. The sub-sector of technical textiles is one of the most dynamic sub-sectors, accounting for an increasing share in EU production. In l998 technical textiles accounted for approximately 25% in total EU textile production. A percentage that has increased and where estimates suggest that technical textiles account today for 33 to 36% of EU textiles and clothing turnover.
  - Technical textiles are as well the section of the industry with most interest for research, with most skills in planning research and protecting intellectual property. As a result, 85% of all patents in textiles are in technical textiles, and this contributes to the global leadership Europe has in this segment.
  - The technical textiles segment is organized in rather large companies, with a high level of organization and the necessary skills to compete worldwide. For universities and research centres, this industry offers a stable source of funding for programmatic research or for commercial services. In addition, research into technical textiles enables the publishing of articles in journals with a high impact and thus a contribution to excellence.

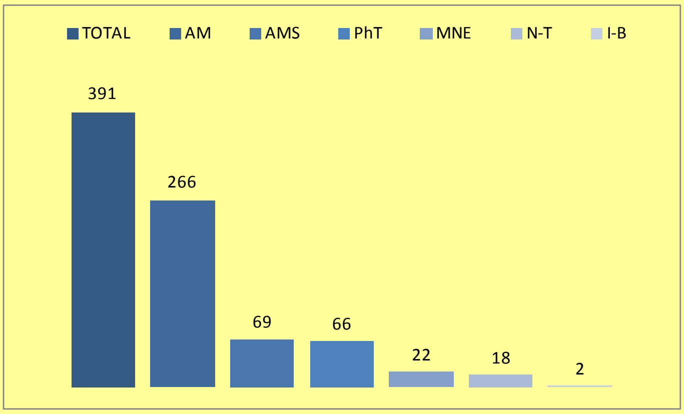
- Commercial research from companies have also a considerable role and especially applies to technical fibres, such as aramides that were developed in the 1970s by Dupont (US) and Akzo (The Netherlands) as well as other strong fibres developed by Rhone-Poulenc (France) and DSM (The Netherlands). These companies have also been active in fostering the applications of these fibres in the value chain and have adopted dynamic technical marketing. The application of technical fibres has been promoted by higher security needs (e.g. in personal protective equipment) or regulation in fuel-efficient mobility.
- Public procurement is also an important element in market adoption of technical textiles. Hence public authorities have been rather present, but more in a regulatory than in a funding role. The same applies to composites, geotextiles, filtration materials for which innovation is largely driven by higher regulatory demands.
- Sources: Sectoral Study, Textile Industry in European Union-Bringing together the EEN to improve environmental management in the leather, paper, chemicals and textiles sectors; Source: In-depth assessment of the situation of the T&C sector in the EU and prospects, Task 7: Synthesis report for the European textile and clothing sector, December 2012

➢ ***Results of patents scenario analysis:***

- 391 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Almost stable slightly decreasing trend curve (number of patents per year)
- Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants especially in the early part of the period, most probably standing for new technologies having been patented in the corresponding periods:



- Patents by KET:

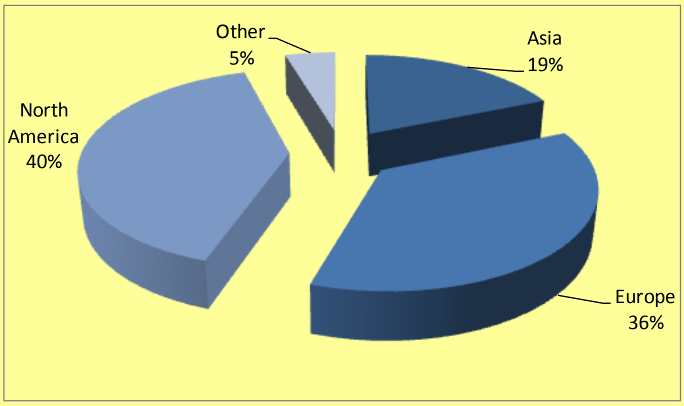


- Patents by KET(s) and relevant combinations of KETs:

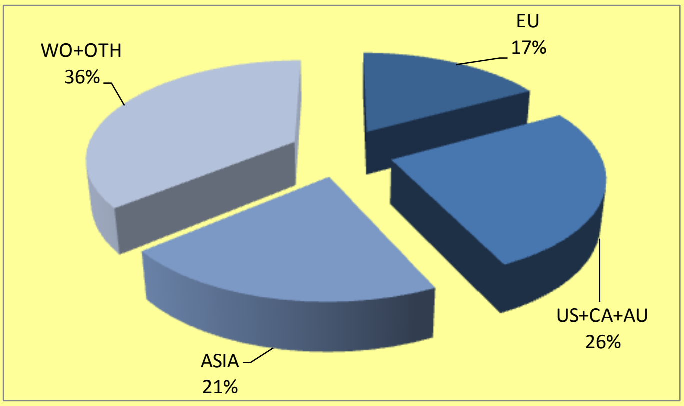
KET(s)	*Number of patents*
AM	266
AM / MNE	5
AM / MNE / N-T	1
AM / MNE / N-T / PhT	1
AM / MNE / PhT	4

AM / N-T	10
AM / N-T / PhT	1
AM / PhT	10
AMS	69
AMS / AM	10
AMS / AM / N-T	1
AMS / MNE	1
AMS / N-T	1
AMS / PhT	4
IBT	2
MNE	22
MNE / N-T	1
MNE / N-T / PhT	1
MNE / PhT	15
N-T	18
N-T / PhT	2
PhT	66

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



POTENTIAL AREAS OF INDUSTRIAL INTEREST RELEVANT FOR CROSS-CUTTING KETS IN THE AGRO-FOOD DOMAIN

Sub-domain: Cost-efficient and safe food and food processing

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "Food security, sustainable agriculture, marine and maritime research and the bio-economy" societal challenge
- Contribute at the same time to the "Climate action, resource efficiency and raw materials" challenge as well as the "Health, demographic change and wellbeing" challenge

Demand-side requirements (stemming from market needs) addressed:

- Improve health, well-being and longevity by food products
- Improve food chain management
- Improve food safety

AF.1.1: Functional and lifestyle foods to meet diversifying dietary requirements of consumers

Scope:

To develop functional foods aimed at meeting diversifying dietary requirements of consumers of different age groups, life styles and health conditions. This can mean combining several functionalities in one food product, such as proper textures, high nutritional quality and ease of use in case of savoury foods.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities:

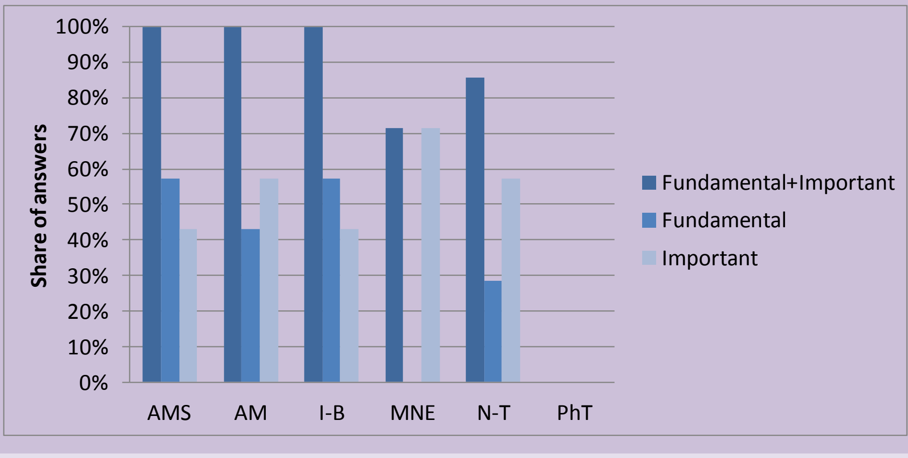
- Improving food products to fulfil nutritional, sensory and textural needs of the elderly and other consumer groups through bioactive ingredients incorporation in new structures
- Development of food structures with physiological beneficial impact, via gastro intestinal modelling approaches for digestion and metabolism-relevant processing (including probiotics, prebiotics, and gut microbiota characteristics)
- Development of tailor-made products for gut microbiota (e.g. effect of the food matrix structure on the functionality of foods modulating the gut microbiota)
- Improving effects of diet/dietary constituents in delaying/preventing the decline of cognitive functions in the aging human brain
- Improving the understanding of the variation in human metabolic energy efficiency - including the contribution of the gut microbiota to energy homeostasis
- Improving understanding on the role of diet in pregnancy on the outcome of offspring, preventing cognitive decline, treatment of low-grade inflammation, drug delivery, etc.
- Development of food-grade nano-formulations for effective nutrient delivery
- Development of food processing technologies for functionality and nutrient security
- Development of logistics and e-commerce solutions needed for life style food products

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of solutions to the challenges listed above, such as the modulation of the nutrients' composition as well as structure in food to be achieved thanks to the development of food-grade nano-formulations for effective nutrient delivery along with the development of food processing technologies, which may help in introducing more desirable traits in food by altering the food's structure or nutrients content.

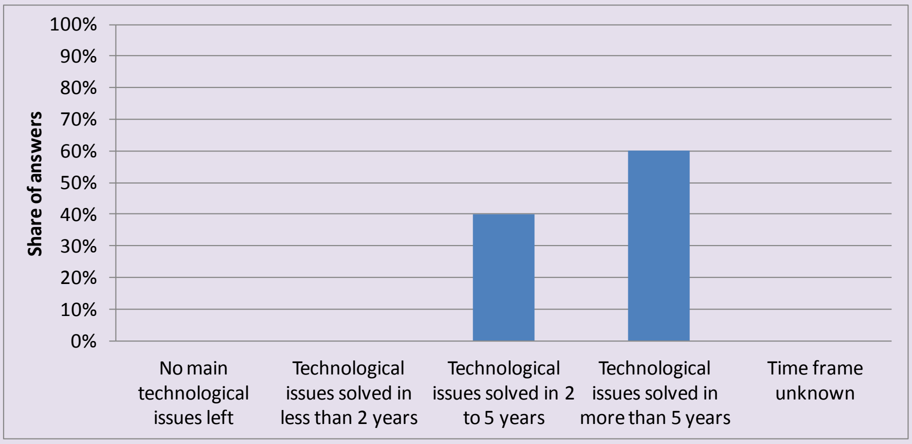
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Industrial Biotechnology (I-B)
- Nanotechnologies (N-T)
- Micro- and Nano-Electronics (MNE)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus by experts indicates also shorter periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

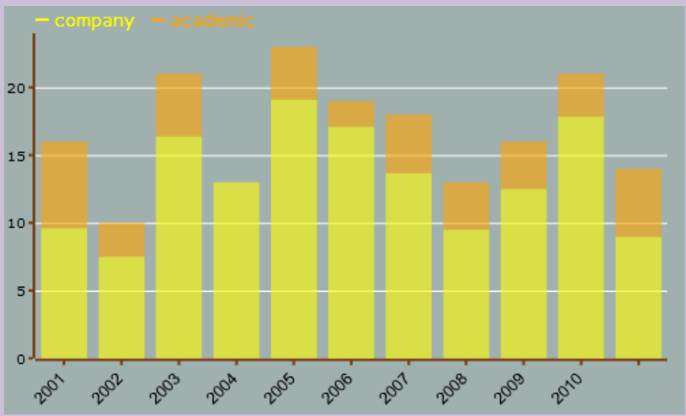
- The food sector is one of the largest and most important manufacturing sectors in Europe. It is the second largest (after metal) in the manufacturing industry, with 14.5% of total manufacturing turnover (917 billion Euro for the EU27) (Source: http://ec.europa.eu).
- The employment in the food industry represents about 14% of the total manufacturing sector. However, the food industry is characterised by fragmentation. There are few European multinational companies competing worldwide with a wide variety of products, but 99% of all enterprises in the food sector are micro, small and medium-sized enterprises (SMEs) (Source: Accelerating regional competitiveness and sector-based excellence through innovation management tools and techniques; www.central-

access.eu).

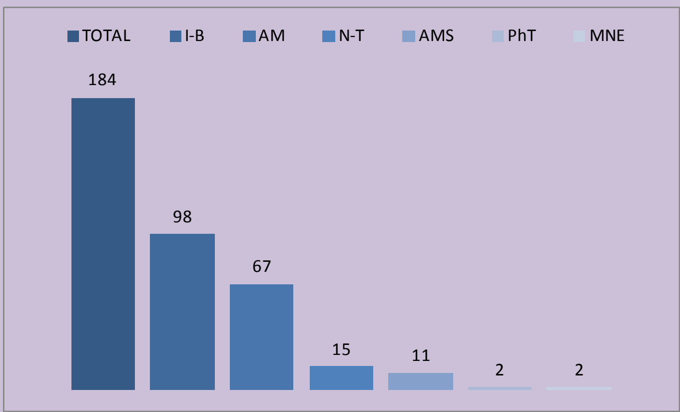
- One of the emerging trends in the modern food industry is represented by functional and lifestyle foods designed to meet diversifying dietary requirements of consumers. In 2013 the global market for functional foods and beverages was reported to be on track to reach 130 billion Euro, accounting for 5% of the overall food market. As a result, the booming market for functional foods and beverages was reported to drive growth for the food industry as a whole (Source: www.nutraingredients-usa.com).

➢ ***Results of patents scenario analysis:***

- 184 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Stable trend curve (number of patents per year)
- Shared between industrial and academic applicants:



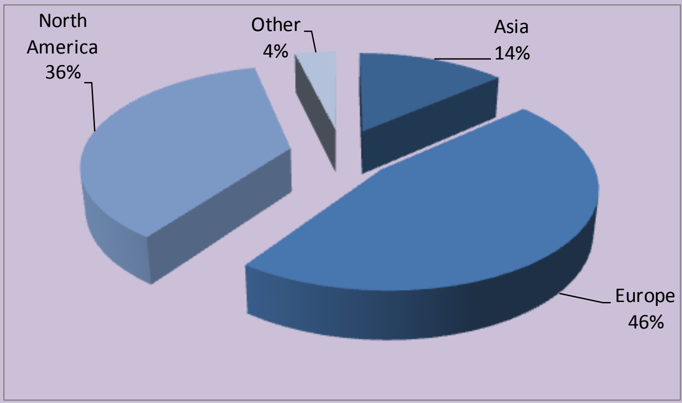
- Patents by KET(s):



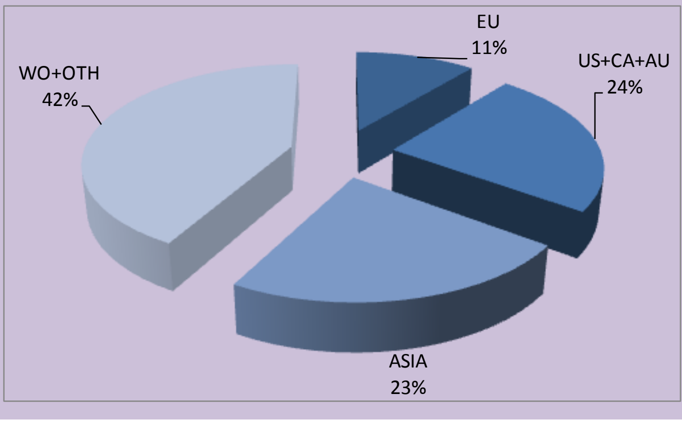
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	67
AM / IBT	5
AM / N-T	2
AMS	11
AMS / AM	1
AMS / MNE	1
IBT	98
IBT / MNE	1
IBT / MNE / PhT	1
IBT / PhT	1
MNE	2
MNE / PhT	1
N-T	15
PhT	2

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



AF.1.2: Assessment and prevention tools to ensure safety of food products and the food chain

Scope:

To develop assessment and prevention tools (including sensors) aimed at diminishing the risk of biological contamination, chemical hazards (toxins), undesirable components (allergens) or fake components (fake meat) of food products including all along the food chain, thus ensuring safety of food products. These include solutions aimed at the traceability of foodstuff and at the identification of potentially risky events along the food chain. Product examples include, e.g. stable isotope labelling of foodstuff, monitoring systems for the real-time in-line process control for hygiene in food processing, etc.

In order to ensure safety of food products, not only devices, but also versatile and affordable sensors for the control of critical quality and performance attributes for food industries are required. The European food industry needs to integrate advanced technologies into food production, jointly with high-tech and eco-efficient processing systems and smart control applications. Sensors in food processing operations play a key role: they can enable systematic preventive approaches such as Hazard Analysis and Critical Control Point (HACCP) method, practical decision-making tools and early warning systems.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities:

- Development of real-time, rapid and reliable methods as well as devices (including sensors) for detection and monitoring of contaminants in relation to foods
- Development of monitoring systems that also include in-line sensing capabilities for the real-time in-line process control for hygiene
- Identification and validation of biomarkers of exposure and susceptibility to key hazards
- Probabilistic modeling of intakes
- Understanding of toxicological thresholds

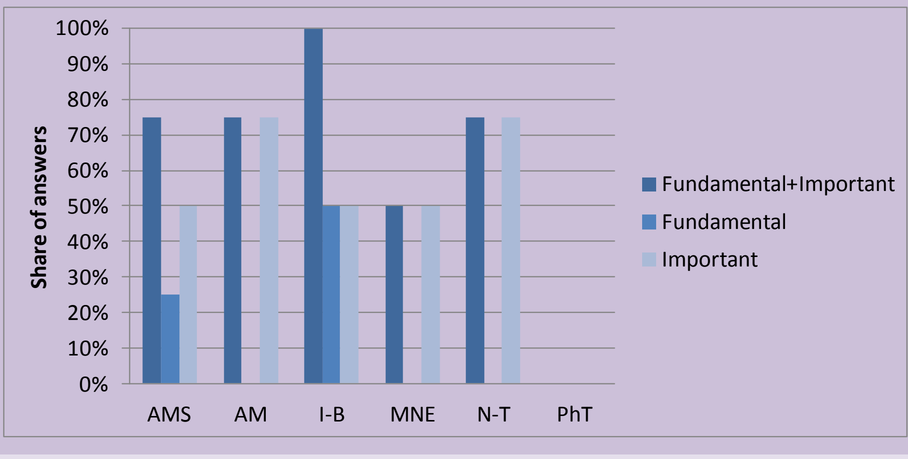
- Refinement and improvement of (quantitative) risk assessment procedures based on scientific understanding to address setting appropriate, robust and consistent standards that enhance safety and foster innovative food product design
- Development of decision support tools for the industry based on predictive microbiological models and models on occurrence, development, migration of chemical contaminants
- Preventing chemical hazards including toxins of biological origin through effective control procedures and traceability of foodstuff
- Development of stable isotope labelling of food products
- Development of modified atmosphere technologies
- Development of in-package food processing techniques
- Reduction methods of “anti-nutritive” components in food, such as allergens

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of solutions to the challenges listed above, such as versatile and affordable sensors for the control of critical quality and performance attributes of food, systems allowing the traceability of foodstuff or the identification of potentially risky events along the food chain.

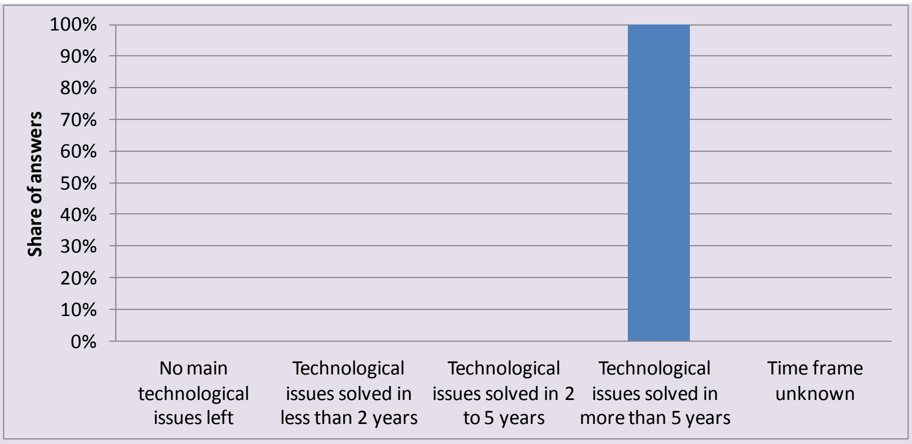
To this aim, the combination of KETs experts’ opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Industrial Biotechnology (I-B)
- Nanotechnologies (N-T)
- Micro- and Nano-Electronics (MNE)



Timing for implementation:

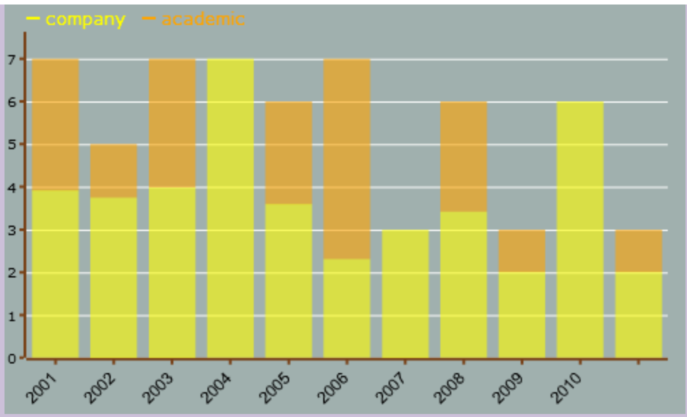
According to the majority of KETs experts’ opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years:



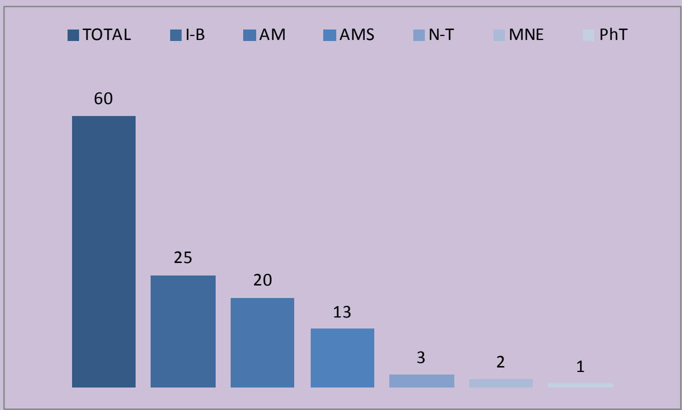
Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - The global food safety market has been growing, pulled by relevant regulation, norms and standards regarding food safety and hygiene. The factors responsible for food contamination include improper handling of food, contaminated input food materials, inadequate treatment/processing of food to destroy the contaminants, etc. Many outbreaks of foodborne illness have been reported due to pathogens in the food.
  - Within this framework, the global food testing market, which includes the food safety testing market, is expected to grow at a healthy growth rate of around 6% during the period 2013-2018 to reach 3.4 billion Euro in 2018 from 2. 4 billion Euro in 2013. The food testing equipment market on the other hand is worth 3 billion Euro with IR type of instruments occupying the highest share in-terms of technology. Competition from local companies with respect to instruments OEMs is the major challenge for the market (Source: Markets and Markets, Food Safety Testing Market By Contaminants, Technology, Food Types & Geography - Global Trends Forecast to 2018, 2013, www.marketsandmarkets.com).
  - As regards Europe, the need to prevent foodborne illnesses and poisoning risks have resulted in strict food safety regulations, which specify maximum permitted levels of any contaminant in food and that the food manufacturers are responsible for safety of food. Therefore, food safety testing has to be implemented during all stages of food production to ensure the absence of contaminations and to prevent any potential health risks on consumption of contaminated food. The regulatory bodies in Europe have been implementing Hazard Analysis Critical Control Point (HACCP) systems to ensure food safety. Implementation of these food safety regulations has been driving the food safety testing market. Globalization of food supply and demand of the consumer for food safety and information has further helped the market to grow.
  - As a result, the European food safety testing market is projected to grow **at a compound annual growth rate (CAGR) of** 6.5% by 2018. In 2011, foodborne related occurrences in Germany resulted in rigorous implementation of food safety regulations. In 2012, Germany dominated the food safety testing market and is projected to be the fastest growing food safety testing market in Europe. Moreover, the European Food Safety Authority (EFSA) have been strictly supervising the implementation of Hazard Analysis Critical Control Point (HACCP) systems by food manufacturers. The market has been driven by the testing of food material during every stage of food production and processing (Source: European Food Safety Testing Market By Contaminant, Technology, Food Type & Country - Trends & Forecast To 2018, www.marketsandmarkets.com).
- ***Results of patents scenario analysis:***
  - 60 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
  - Stable-decreasing trend curve (number of patents per year)
  - Shared between industrial and academic applicants:



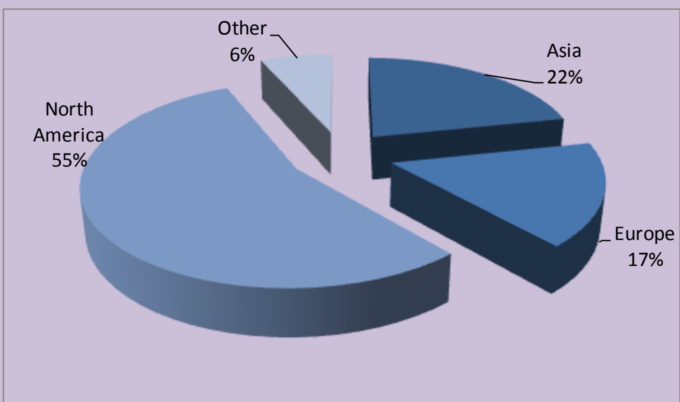
- Patents by KET(s):



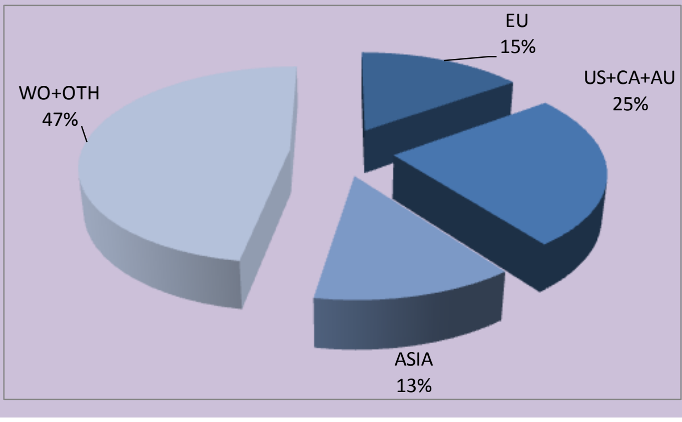
- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	20
AM / IBT	1
AM / IBT / N-T	1
AM / N-T	1
AMS	13
AMS / AM	1
IBT	25
IBT / N-T	1
MNE	2
MNE / N-T	1
N-T	3
PhT	1

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection:



Sub-domain: Safe, sustainable and functional food packaging

Demand-side requirements (stemming from Societal Challenges) addressed:

- Tackle the "Food security, sustainable agriculture, marine and maritime research and the bio-economy" societal challenge
- Contribute at the same time to the "Climate action, resource efficiency and raw materials" challenge as well as the "Health, demographic change and wellbeing" challenge

Demand-side requirements (stemming from market needs) addressed:

- Improve food chain management
- Improve food safety
- Improve food shelf life

AF.2.1: Food packaging systems for preserving food from microbial contamination and for improving shelf life

Scope:

Long food chains and storage times call for intelligent/communicative or functionalized packaging materials and/or coatings that improve food safety (e.g. through alerting risky events which may have occurred during distribution and/or storage), reduce the need of cold chain use and enable in-package food processing.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities:

- Development of active food packaging materials (e.g. packages modified by the entrapment of biomolecules or useful micro-organisms)
- Development of multi-functional food packaging materials and coatings (e.g. packages coated or modified by the entrapment of (nano)particles)
- Development of smart intelligent/communicative packaging solutions

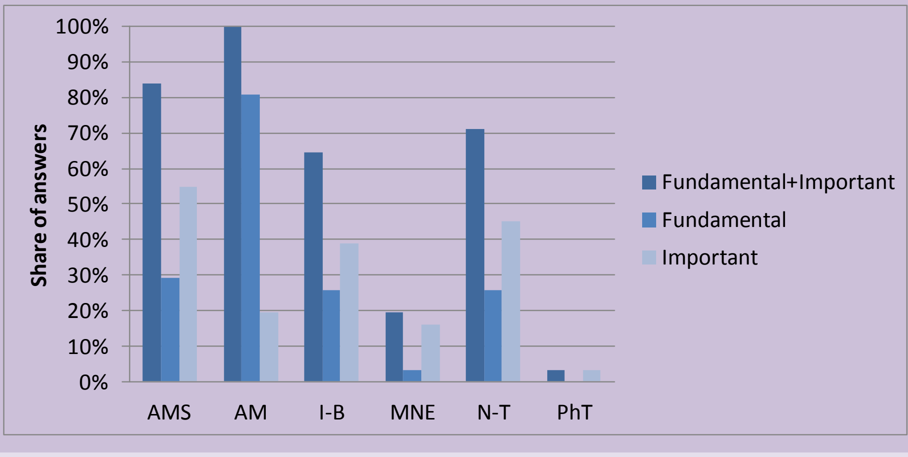
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of solutions to the challenges listed above, such as active food packaging materials, of multi-functional food packaging materials and coatings, of intelligent/communicative packaging solutions that are able to alert the consumer regarding risky events occurred during distribution and/or storage, etc.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting

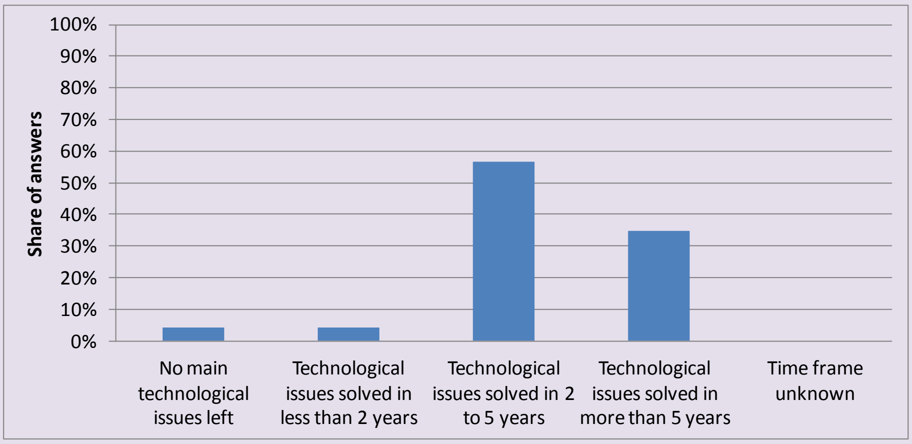
activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Industrial Biotechnology (I-B)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also longer periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

- Packaged, frozen, and ready-to-eat food has witnessed a significant surge in demand in recent times. With supply of exotic fruits and vegetables, meat products and frozen foods transcending geographical boundaries, the packaging industry has been focusing on development of solutions that provide maximum food safety, while maintaining nutritional value, at competitive prices. Out of the total market for the global advanced packaging, the contribution of the food sector is 51%, while that of beverage is 19%. Active packaging is mainly used for food packaging, which enhances the food quality with flavour, taste, colour. Intelligent packaging is used for both food and beverage packaging. New technologies such as intelligent packaging, smart packaging, active, and modified atmosphere packaging are replacing traditional methods such as canning. The industry is expected to witness significant growth in the years to come. Similar to the other aspects in the food industry, this market is also highly regulated with strict guidelines for packaging materials, testing, and labelling.

- Another emerging technology in the market is nanotechnology. Nanomaterials have various applications both in active and intelligent packaging. In active packaging, the nanostructures that can enhance the vapour permeability of plastics are used. They have various applications such as fruits and vegetables packaging. The nanosensors categorized under intelligent packaging can help in detecting pathogens, toxins, and chemicals. With nanosensors incorporated inside the packaging, the consumer can easily know the status of food inside, which means these sensors can inform the consumers about the food's freshness level and nutrition status.
- As a result of these trends, in 2010, the active and intelligent packaging technology held the highest growth rate in the food and beverages packaging market. Modified atmosphere technology accounted for the largest share (approximately 54%) of the total market in advanced packaging technology. The global advanced packaging technology was estimated to grow at a compound annual growth rate (CAGR) of 8.2% from 2010 to 2015. The value of the global active, intelligent and smart food and drink packaging market was reported, in 2010, to reach 9 billion Euro in 2012. The largest market for active and intelligent packaging was forecast to be the US, with Japan and Australia ranking second and third respectively. Yet, in Europe, UK was considered to be a gradually emerging market, forecast to reach a value of 0.9 billion Euro in 2021, while Germany was predicted to jump from about 450 million Euro in 2011 to 1 billion Euro in 2021.
- Sources: Markets and Markets, Global Active, Smart and Intelligent Packaging Market By Products, Applications, Trends and Forecasts (2010-2015), www.marketsandmarkets.com; Visiongain, Active, Intelligent & Smart Food & Drink Packaging Market 2012-2022, 2011
- Actually, solutions that would allow the consumer to identify the safety of a given foodstuff might also reduce unnecessary food waste. Currently, a significant share of food discards consists in food that approaches or has passed its use-by or best-before date. By law, the producer has to indicate those dates on food packaging at time of production, usually with a margin that takes into account uncertainties on the way the product will be managed after production. Smart packaging and sensor-based technologies could pave the way for alternative approaches that might contribute to reducing food waste volumes in the future, in line with the legal proposal of the Commission amending the waste framework directive, which includes a new aspirational objective to cut food waste by 30% by 2025 (COM(2014) 397 final).

➢ ***Results of patents scenario analysis:***

- 7 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- No significant patent-related figures can be reported in this field

AF.2.2: Cost-efficient consumer food packaging with increased environmental sustainability

Scope:

Consumer food packaging as well as other single use containers for food generates vast amounts of waste whose reduction, recycling and/or reuse are called for. Solutions include more sustainable packaging designs aimed at packaging waste minimization, as well as packaging items aimed at material recycling or item reuse. Product examples include, e.g. recyclable (including biodegradable/compostable) as well as reusable packaging items along with the enhancement of the infrastructure and/or logistics supporting the recycling and/or reuse practices.

Specific technical/industrial challenges (mainly resulting from gaps in technological capacities):

- Improvement of packaging design by eco-design approaches aimed at minimizing the use of packaging materials and/or enhancing materials separation
- Demonstration of simple, environmental friendly, biodegradable/compostable, recyclable and/or reusable packaging items aiming at the reduction of waste from packaging
- Improvement of sorting as well as separation techniques aimed at sorting/separating

packaging materials toward material recycling

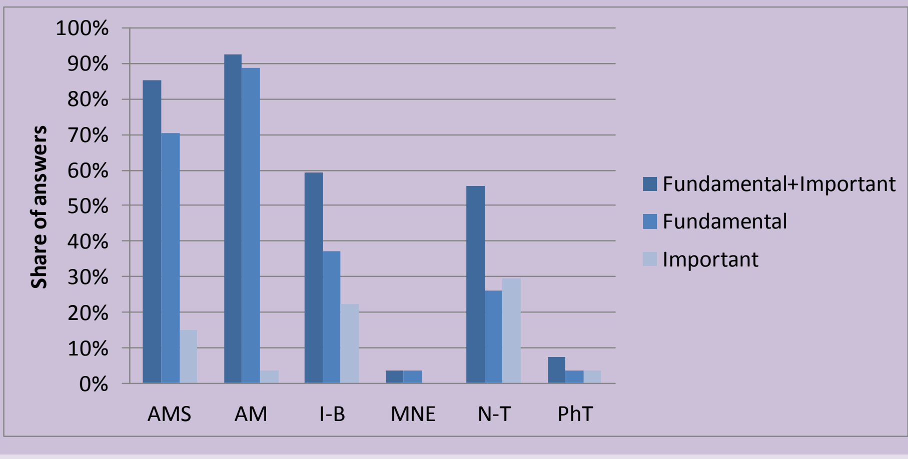
- Enhancement of the infrastructures and logistics enabling for the composting of compostable packaging items
- Enhancement of the infrastructures and logistics enabling for the separation as well as separate collection of recyclable packaging items
- Enhancement of the infrastructures and logistics enabling for the reuse of food packaging items

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development as well as the demonstration of solutions such as more advanced environmentally friendly, biodegradable/compostable, recyclable and/or reusable packaging items aiming at the reduction of waste from packaging, including thanks to the enhancement of the infrastructure and logistics enabling the management of packaging waste.

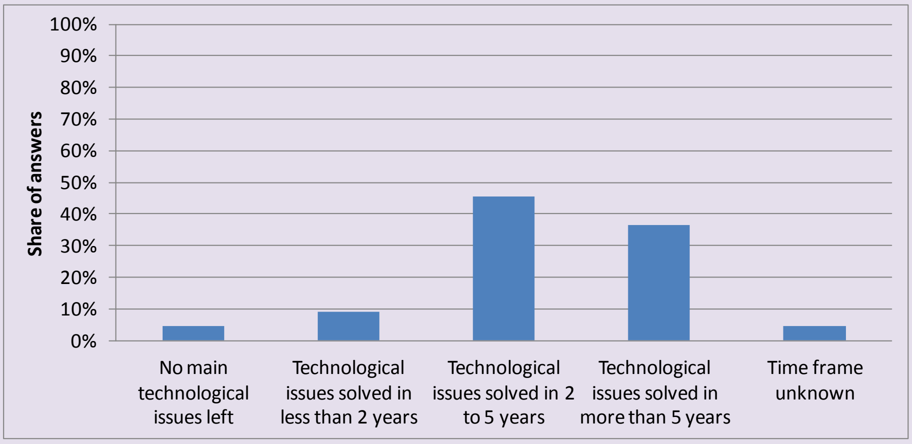
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

- Advanced Manufacturing Systems (AMS)
- Advanced Materials (AM)
- Industrial Biotechnology (I-B)
- Nanotechnologies (N-T)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of 2 to 5 years, yet significant consensus by experts indicates also longer periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the

achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

- ***Impact assessment:***
  - According to the Market Intelligence study "The Future of Sustainable Packaging to 2018", consumer demand, government legislation and technology advances will propel sustainable packaging to a 180 billion Euro market by 2018. According to the study, the most common sustainable packaging trends are downsizing/lightweighting of packaging; increased recycling and waste recovery; increased use of recycled content; increased use of renewably sourced materials; improvements in packaging and logistical efficiency. The report concludes that the issue of sustainable packaging will continue to grow in importance over the next decade thus driving innovation in this field.
  - Innovation in packaging has a wide reach, particularly in the food and beverage industry. Several companies are implementing sustainable packaging not only to benefit the environment, but as well as a branding mechanism that can help in differentiating a company by appealing to environmentally conscious consumers. As a reported example, European beer maker Carlsberg recently teamed up with a group of global suppliers to develop the next generation of packaging products that are optimized for recycling and reuse. Moreover, several are the reported examples of paper packaging that incorporates cellulose-rich waste from various sources.
  - Within this framework, it is also reported that the recycled material packaging market segment is currently dominated by paper packaging, followed by metal, glass and plastic. While the demand for recycled plastics remains strong, the material faces several challenges, including lack of infrastructure for collection and sorting, international market competition for existing recovered materials and compliance with requirements related to food and drug content, which all constitute opportunities for improvements in this field.
  - Source: Smithers Pira, The Future of Sustainable Packaging to 2018, 2013
- ***Results of patents scenario analysis:***
  - 1 KETs-related patent identified in the period 2001-2011 for the specific Innovation Field in relation to KETs
  - No significant patent-related figures can be reported in this field

HOW TO OBTAIN EU PUBLICATIONS

Free publications:

- one copy:
  via EU Bookshop (http://bookshop.europa.eu);

- more than one copy or posters/maps:
  from the European Union's representations (http://ec.europa.eu/represent_en.htm);
  from the delegations in non-EU countries
  (http://eeas.europa.eu/delegations/index_en.htm);
  by contacting the Europe Direct service (http://europa.eu/europedirect/index_en.htm)
  or calling 00 800 6 7 8 9 10 11 (freephone number from anywhere in the EU) (*).

  (*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

Priced publications:

- via EU Bookshop (http://bookshop.europa.eu).

Priced subscriptions:

- via one of the sales agents of the Publications Office of the European Union
  (http://publications.europa.eu/others/agents/index_en.htm).

NB-04-14-199-EN-N

Publications Office

doi: 10.2769/92111