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Study on methodology, work plan and roadmap for cross-cutting KETs activities in Horizon 2020

RO-cKETs

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Key Enabling Technologies and Digital Economy

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PREFACE

This document has been produced within the framework of Service Contract SI2.ACPROCE052968300 in response to Tender 214/PP/ENT/CIP/12/C/N01C012 and does only reflect the authors' view.

It constitutes the Final Report (Rev. 2) of the project "Methodology, work plan and roadmap for cross-cutting KETs activities in Horizon 2020" (RO-cKETs).

The Final Report is the responsibility of the coordinator of this project, D'Appolonia, and is a joint effort from the consortium partners CEA (Commissariat à L'Energie Atomique et aux Energies Alternatives); JIIP (the Joint Institute for Innovation Policy, joint undertaking founded by largest European RTOs, including TNO, TECNALIA and VTT); CNR-DSCTM (Italian National Research Council - Department of Chemical Science and Material Technology); IBEC Barcelona (Institute for Bioengineering of Catalonia), and the subcontractor Fraunhofer ISI (Institut fur System– und Innovationsforschung).

EXECUTIVE SUMMARY

Background

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 [...][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 Industrial Policy flagship initiative, as confirmed in the recent communication 'For a European Industrial Renaissance'[2].

As a first step towards an effective intervention, the Commission decided to focus part of its policy and supporting instruments (i.e. adoption of a thematic policy approach), and implement a cross-cutting KETs work programme as part of Horizon 2020. Rationale for this focus on cross-cutting KETs is that: 'While individual KETs are recognized as indispensable sources of innovation, the cross-fertilisation of different KETs is vital, in particular for the transition from R&D to pilot and industrial scale production'[1]. Whilst in fact 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.

This cross-cutting KETs work programme is a key element of the Commission's research and innovation framework programme. Rationale for such a dedicated programme is that: 'Innovation requires enhanced cross-technology research efforts. Therefore, multidisciplinary and multi-KET projects should be an integral part of the Industrial Leadership pillar […].'[3] The integration of different KETs represents therefore 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.

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

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[1] 'A European strategy for Key Enabling Technologies – A bridge to growth and jobs' (COM/2012/0341 final)
[2] COM(2014)14 final
[3] Regulation (EU) No 1291/2013 of the European Parliament and of the Council establishing Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020) and repealing Decision No 1982/2006/EC

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.

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 develop a roadmap for cross-cutting KETs activities.

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.

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 outlines how the combination of different Key Enabling Technologies could contribute to address the challenges facing European industry, economy and society.

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.

The roadmap for cross-cutting KETs activities

The main result of the study has been the preparation of a roadmap for cross-cutting KETs activities, which covers 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 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 locate.

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 tackle today's major societal challenges.

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, focusing on activities implying Technology Readiness Levels between 4 and 8.

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 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 those 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.

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 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.

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 carried out 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 (such as 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 to 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. Patents data were used as indicators of the technological as well as market relevance of EU-based actors in relation to individual innovation fields.

This approach allowed the definition of a **shortlist of 117 key innovation fields of industrial interest with the highest potential for answering markets, 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 distinguished 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 2013) for solving the main technological issues holding back to the achievement of cross-cutting KETs based products, prior to any time required in order to actually introduce those products in 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, actually 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, goods, and services as soon as new enabling technologies or technological solutions become available.

The roadmap was hence 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**.

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

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 the highest pervasiveness. The other equally important, more application-oriented domains collect innovation fields of industrial interest relevant for cross-cutting KETs developments, in whose respect high added value can be achieved in new product, process or service development thanks to the integration of cross-cutting KETs based components.

Within this framework, the specific roadmap outlining the potential areas of industrial interest relevant for cross-cutting KETs in the **Electronics and communication systems** domain is organized into four sub-domains, each grouping the key innovation fields of industrial interest relevant for cross-cutting KETs that have common demand-side requirements, as well as similar functionalities and shared markets. Accordingly, the four sub-domains in the Electronics and communication systems domain point out to:

- Improved Human-Machine interaction and interfaces,
- Breakthrough enabling components and circuits,
- Smart and user-centric consumer electronics,
- Communication as the backbone of the Information Society.

The roadmap outlining the potential areas of industrial interest relevant for cross-cutting KETs in the **Chemical processes, chemicals, chemical products and materials** domain is organized into three sub-domains, pointing out to:

- Competitive more sustainable alternatives to conventional materials,
- Advanced functional materials,
- Efficient processing of materials and chemicals.

The roadmap outlining the potential areas of industrial interest relevant for cross-cutting KETs in the **Manufacturing and automation** domain is organized into three sub-domains, pointing out to:

- Key processes, tools and equipment for competitive plants,
- Energy and resource efficient manufacturing,
- Smart and flexible manufacturing systems.

The roadmap outlining the potential areas of industrial interest relevant for cross-cutting KETs in the **Energy** domain is organized into four sub-domains, pointing out to:

- High potential renewable energy systems,
- Advanced non-renewable energy solutions,
- Solutions for the Smart Grid enforcement,
- Embedded energy systems.

The roadmap outlining the potential areas of industrial interest relevant for cross-cutting KETs in the **Transport and mobility** domain is organized into four sub-domains, pointing out to:

- More sustainable and green vehicles,
- Greener combustion-based vehicle propulsion,
- E-propulsion and wider e-mobility,
- Systems and infrastructure for vehicle operation into traffic.

The roadmap outlining the potential areas of industrial interest relevant for cross-cutting KETs in the **Construction** domain is organized into two sub-domains, pointing out to:

- Advanced and/or functional construction and building materials and components,
- Reliable and improved infrastructure management and operation.

The roadmap outlining the potential areas of industrial interest relevant for cross-cutting KETs in the **Civil security** domain is organized into one sub-domain pointing out to cross-cutting KETs based systems contributing to civil security, and considers furthermore a number of innovation fields pertaining to other domains that are relevant for dual use opportunities.

The roadmap outlining the potential areas of industrial interest relevant for cross-cutting KETs in the **Mining, quarrying and extraction** domain is organized into one sub-domain pointing out to cross-cutting KETs based systems contributing to enforcing efficient and environmentally friendly mining, quarrying and extraction.

The roadmap outlining the potential areas of industrial interest relevant for cross-cutting KETs in the **Environment** domain is organized into two sub-domains, pointing out to:

- Improved management of waste/wastewater or utilization of waste streams,
- Earth observation for environment monitoring.

The roadmap outlining the potential areas of industrial interest relevant for cross-cutting KETs in the **Health and healthcare** domain is organized into three sub-domains, pointing out to:

- Devices and systems for targeted diagnostics and personalized medicine,
- More efficient and less invasive drugs and therapies,
- Smart systems and robots for healthcare services.

The roadmap outlining the potential areas of industrial interest relevant for cross-cutting KETs in the **Training, education and edutainment** domain is organized into one sub-domain pointing out to advanced interfaces for training, education and edutainment.

The roadmap outlining the potential areas of industrial interest relevant for cross-cutting KETs in the **Textiles** domain is organized into two sub-domains, pointing out to:

- Novel functional and high performance fibres and fabrics,
- Improved, functional textile-based products.

The roadmap outlining the potential areas of industrial interest relevant for cross-cutting KETs in the **Agro-food** domain is organized into two sub-domains, pointing out to:

- Cost-efficient and safe food and food processing,
- Safe, sustainable and functional food packaging.

Within each of these sub-domains, each innovation field relevant for cross-cutting KETs is individually described in terms of the market needs it addresses, its underlying technical or industrial challenges mainly resulting from gaps in technological capacities, and the contribution that cross-cutting Key Enabling Technologies could have with respect to the innovation field. Highlights on potential markets and expected impacts associated to the specific innovation field are also provided inside fiches that individually describe each innovation field. In the fiches, results of a KETs-relevant patent scenario analysis undertaken in respect to each innovation field are also provided.

The roadmap constitutes a dedicated, self-standing document, which is composed of a core text and of dedicated fiches describing each individual innovation field comprised in the roadmap. The roadmap and the related fiches will be downloadable from the EC DG Enterprise and Industry's web pages:
(http://ec.europa.eu/enterprise/sectors/ict/key_technologies/ro-ckets/index_en.htm).

Main additional highlights emerged during the RO-cKETs study

Besides the roadmap, which constitutes the main result of the study, some additional highlights have been identified through dialogue with both policy makers as well as stakeholders throughout the study. The messages emerged from this dialogue have allowed to elaborate a set of clearly defined challenges and requirements and to propose a set of potential action lines that might be put in place by public authorities and stakeholders at the various levels in order to support and facilitate the development and subsequent deployment of cross-cutting KETs based products, processes, goods, or services, which are reported hereinafter.

- **Importance of keeping a bottom up approach in the generation of ideas for the development of cross-cutting KETs based products, processes, goods, or services**

As observed many times throughout the study, developments involving KETs, either individually or in a cross-fertilizing manner, can occur across Europe at large and are not necessarily concentrated in particular countries or regions. Certainly, regional or local clusters exist that may be (smartly) specialized in one or the other KETs in line with industrial development strategies pursued by the specific country or region. However, an important lesson learnt is that **any industrial undertaking, regardless of the location of its establishment, its size or the geographical dimension of its market(s), could generate interesting ideas for the development of cross-cutting KETs based products, processes, goods, or services effectively addressing demand-side requirements**.

This points out to the **need to keep a programme on cross-cutting KETs activities relatively open to a bottom up approach** capitalizing on companies' creativeness and inspiration. Having this in mind, despite some general indications about development lines, constituted in the roadmap for cross-cutting KETs activities by the most promising areas of converging industrial interest for cross-cutting KETs, more prescriptive indications are not opportune.

- **Need for value chain collaborations**

Another important consideration is that the cross-fertilization between KETs inevitably often implies technological complexity. KETs are multidisciplinary and cutting across many technology areas, and their cross-fertilization might require an even greater multidisciplinary effort due to the major number of technological elements involved that need to be integrated among themselves.

In this respect, both industrial stakeholders and policy makers engaged throughout the study remarked several times the **need to effectively address the development of cross-cutting KETs based innovative products, goods and services in collaborating networks engaging all value chain players**. This emerging way of collaboratively developing new products, processes, goods and services is the response to the fact that innovation is becoming increasingly open. While on the one side open innovation, as the way of working together in collaborative networks, enables major creativeness as well as major effectiveness in addressing demand-side requirements, especially if end users are actively involved along with the whole value chain, it increases at the same time complexity from a value chain management point of view, due to the fact that additional elements are added to a process that used to be more linear in the past.

To face such increasing complexity both from the technological as well as from the organizational point of view, today (differently from the past, when the tendency for large enterprises was mainly to internalize competencies and adapt their internal structure/organization to be able to master the whole eco-system and life cycle of an innovation), large enterprises tend to more and more often rely on external collaborations especially for specific technological input in case they believe they are not able to maintain the competencies in-house that are required for developing specific technological functionalities. In this regard, it has also to be highlighted that **many large enterprises' eco-systems can be importantly built-up by SMEs**, which can be providers of technological systems and components or of specialized services.

- **Need for cross-border collaborations**

An important consideration emerged throughout the study is that cross-cutting KETs developments would normally require value chain collaborations (see above point) and that these would rarely be found within a single region or even a single country. Much more probably, these value chain collaborations would need to be cross-regional or possibly even broader, highlighting the **need to extend value chains engaging with the cross-fertilization between KETs beyond regional or even beyond national borders**.

- **Role of SMEs in innovation-centred eco-systems**

SMEs can play a very important role in many innovation-centred eco-systems. **Either can SMEs be innovators themselves or they can be very important partners to large enterprises as providers of technological systems and components or as providers of specialized services**. Therefore, particular attention should be paid toward SMEs in regard to cross-cutting KETs activities.

- **Role of research- and technology-intensive SMEs as potential providers of cross-cutting KETs based technological systems and components**

Special attention should moreover be particularly paid to research- and technology-intensive SMEs, such as high-tech SMEs and spin-offs, as providers of cross-cutting KETs based technological systems and components. This particular group of SMEs may not always be prepared to master the whole innovation life cycle (which can in fact be a common challenge for all types of SMEs), especially due to the fact that they may lack the systemic view that cross-cutting KETs developments require. Moreover, this particular group of SMEs may be subject to higher risks, some of which are dependant from their distance from the end user market and, sometimes, from the lack of strong entrepreneurial and management skills that are essential elements for leading to successful market introduction of their technological innovations.

- **Role of anchor companies in the development of cross-cutting KETs based products, processes, goods, or services**

Collaborative value chains shall preferably be led by companies capable of taking the role of pivoting actor. Pivoting actors, or 'anchor companies', are industrial players capable of influencing the resting value chain actors by transferring them their vision and ambitions toward the development of highly competitive new products, processes, or services.

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ABBREVIATIONS AND ACRONYMS

Abbreviation / Acronym	Explanation
CEA	Commissariat à l'Énergie Atomique et aux Énergies Alternatives
CIP	Competiveness and Innovation Framework Programme
CNR	Consiglio Nazionale delle Ricerche
COSME	The EU programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises
EC	European Commission
ECLA	European patents Classification system
EIT	European Institute of Innovation and Technology
EPO	European Patent Office
ERDF	European Regional Development Fund
ESIF	European Structural and Investment Funds
ETP	European Technology Platform
EU	European Union
IC	Industrial Challenge
ICO	In-Computer-Only patents classification
ICT	Information and Communication Technologies
IPC	International Patent Classification
IPCEI	Important Project of Common European Interest
JIIP	Joint Institute for Innovation Policy
JTI	Joint Technology Initiative
JTU	Joint Technology Undertaking
KETs	Key Enabling Technologies
KIC	Knowledge and Innovation Community
LEIT	Leadership in Enabling and Industrial Technologies
MR	Market Requirement
MRL	Manufacturing Readiness Level
OLED	Organic Light-Emitting Diode
PMC	Product Market Combination
PPP	Public-Private Partnership
R&D	Research and Development
R&D&I	Research and Development and Innovation
RTO	Research and Technology Organization
SC	Societal Challenge
SIRA	Strategic Innovation and Research Agenda
SRA	Strategic Research Agenda
TNO	The Netherlands Organisation for Applied Scientific Research TNO
TRL	Technology Readiness Level
VTT	Technical Research Centre of Finland
WP	Work Package

INTRODUCTION

This document, constituting the Final Report (Rev. 2) of the project "Methodology, work plan and roadmap for cross-cutting KETs activities in Horizon 2020" (RO-cKETs), provides a comprehensive and detailed description of the methodology that has been developed within the framework of the RO-cKETs study and moreover reports about the roadmap for cross-cutting KETs activities, developed as a result of the methodology's implementation.

In the report, the project's context is briefly explained in Chapter 1 along with a description of the project's background, objectives and expected results.

Chapter 2 provides insight into the methodology that has been designed for the definition of the potential innovation fields of industrial interest relevant for cross-cutting KETs, highlighting the major practical steps of which it consisted along with approaches taken, options considered, findings, strengths, weaknesses and outcomes. Accordingly, the methodology is comprehensively described. Moreover, the proposed roadmap for cross-cutting KETs activities is reported. Actually, the roadmap is provided as a dedicated, self-standing document, which is composed of a core text and of dedicated fiches describing each individual innovation field comprised in the roadmap.

In Chapter 3, furthermore, a proposal for a cross-cutting KETs programme under Horizon 2020 is provided, comprising the proposed programme's structure along with the role of leading companies, SMEs, academic institutions, RTOs, and other stakeholders within it, the suggested mechanisms for update, and the proposed criteria for the selection as well as for the performance monitoring and assessment of cross-cutting KETs based projects. Expected impacts of such a programme as well as synergies with other EU programmes and policies are moreover reported. The chapter also provides the suggestion for a longer term agenda for actions by public authorities and stakeholders and an outlook on policy recommendations.

In Chapter 4, the correlation between the methodology and the original project work plan is provided. Chapter 5 finally provides a brief overall conclusion.

1. PROJECT BACKGROUND, PROJECT OBJECTIVES AND EXPECTED RESULTS

1.1. Project background

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)[4]. 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 […]'[4]. 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 Industrial Policy flagship initiative, as confirmed in the recent communication 'For a European Industrial Renaissance'[5]. 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.

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

As a first step towards an effective intervention, the Commission decided to focus part of its policy and supporting instruments (i.e. adoption of a thematic policy approach), and implement a cross-cutting KETs work programme as part of Horizon 2020. Rationale for this focus on cross-cutting KETs is that: 'While individual KETs are recognized as indispensable sources of innovation, the cross-fertilisation of different

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[4] 'A European strategy for Key Enabling Technologies – A bridge to growth and jobs' (COM/2012/0341 final)
[5] COM(2014)14 final

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This cross-cutting KETs work programme is a key element of the Commission's research and innovation framework programme. Rationale for such a dedicated programme is that: 'Innovation requires enhanced cross-technology research efforts. Therefore, multidisciplinary and multi-KET projects should be an integral part of the Industrial Leadership pillar […].'[6] The integration of different KETs represents therefore 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 develop a roadmap for cross-cutting KETs activities.

1.2. Project objectives and expected result

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 to 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 shall 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 main result of the study has been therefore the preparation of a roadmap for cross-cutting KETs activities, which 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 the societal and economic context in which they locate.

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 for cross-cutting KETs activities implying Technology Readiness Levels of between 4 and 8.

1.3. Purpose of this Final Report

This report aims at providing complete insight into the methodology that has been designed for the definition of the potential innovation fields of industrial interest relevant for cross-cutting KETs, highlighting the major practical steps of which it consisted. Accordingly, the methodology is comprehensively described and the result of its implementation, namely the roadmap for cross-cutting KETs activities, is provided. A proposal for a cross-cutting KETs programme is moreover discussed, comprising the proposed programme's structure, suggested mechanisms for update, proposed criteria for the selection as well as for the performance monitoring and

[6] Regulation (EU) No 1291/2013 of the European Parliament and of the Council establishing Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020) and repealing Decision No 1982/2006/EC

assessment of cross-cutting KETs based projects. Expected impacts of such a programme as well as synergies with other EU programmes and policies are moreover reported. The report finally provides the suggestion for a longer term agenda for actions by public authorities and stakeholders and an outlook on policy recommendations.

2. OUTLINE OF THE METHODOLOGY

2.1. Definitions

Within this framework, definitions are provided to be used as reference for the subsequent sections of the document.

2.1.1. Key Enabling Technologies

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.'

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.

Commission Communication (COM(2009) 512) "Preparing for our future: Developing a common strategy for Key Enabling Technologies in the EU"

2.1.2. KETs-based product

A KETs-based product is an enabling product for the development of goods and services enhancing their overall commercial and social value, induced by constituent parts that are based on nanotechnology, micro- and nano-electronics, industrial biotechnology, advanced materials and/or photonics, and, but not limited to, produced by advanced manufacturing technologies.

Commission Communication (COM(2012) 341) "A European strategy for Key Enabling Technologies – A bridge to growth and jobs"

2.1.3. Cross-cutting KETs

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. 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.

'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 contributions to new technological components or products.

2.2. Outline of the methodology

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 for 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, focusing on activities implying Technology Readiness Levels between 4 and 8. 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 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 those 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.

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 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.

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 carried out 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 (such as 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 to 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. Patents data were used as indicators of the technological as well as market relevance of EU-based actors in relation to individual innovation fields.

This approach allowed the definition of a **shortlist of 117 key innovation fields of industrial interest with the highest potential for answering markets, 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 distinguished 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 to the achievement of cross-cutting KETs based products, prior to any time required in order to actually introduce those products in 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, actually 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, goods, and services as soon as new enabling technologies or technological solutions become available.

The roadmap was hence 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**.

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, highlighting also cross-sectoral development opportunities and relevance for short term or medium term developments.

2.2.1. Starting point and assumptions and initial industrial sectors' clusterization

To execute the study activities, a market perspective had to be adopted, meaning that the demand side had to be particularly analysed and considered as the starting point for the work. Moreover, the request was that the study could be as broad as possible, thus taking possibly into account the whole industrial landscape. This reflected into the need for a broad action aimed at screening for market requirements and industrial challenges in the broadest possible range of industrial sectors representing the EU's industrial base.

Accordingly, the first step into the analysis of the demand side was the definition of an appropriate classification of industrial sectors, which had to be as comprehensive as possible. Within this framework, the classification of industrial sectors as defined by NACE Rev.2 codes was chosen as the starting point for the clusterization of industrial activities. The rationale behind this choice is that all economic activities are covered by NACE as the whole economy reports on these codes.

This classification was further elaborated by the team members as a next step in order to define a more relevant clusterization for the specific study aim. The result of this preliminary step was the list of industrial sectors potentially relevant for the study, which is reported in the table below.

Table 1: Initial industrial sectors' clusterization

#	Industrial sector
1	Renewable energy (Solar/Thermosolar, Wind, Biomass,…)
2	Robotics
3	Agriculture
4	Manufacture of textiles, apparel, leather and related products
5	Manufacture of chemicals and chemical products
6	Manufacture of pharmaceuticals, medicinal chemical and botanical products
7	Manufacture of computer, electronic and optical products, including consumer electronics
8	Manufacture of machinery and equipment n.e.c.
9	Construction
10	Road transport
11	Air / Aeronautics
12	Telecommunications
13	Medical devices
14	Mining and quarrying
15	Manufacture of food products, beverages and tobacco products

#	Industrial sector
16	Manufacture of electrical equipment
17	Manufacture of transport equipment
18	Logistics systems
19	Glass
20	Power Energy
21	Manufacture of coke, and refined petroleum products
22	Electricity, gas, steam and air-conditioning supply
23	Water supply, sewerage, waste management and remediation
24	Transportation and storage
25	Rail transport
26	Marine transport
27	Space and Defence
28	Education / Edutainment

Furthermore, the above industrial sectors were cross-checked against available acknowledged sources of information with European relevance, such as Strategic Research (and Innovation) Agendas issued by European Technology Platforms and other documents reporting about industrial challenges, which were already validated via public consultations, in order to make sure that industrial sectors of European relevance were duly taken into consideration.

Within this framework, it is particularly specified that:

- being ICT a technology oriented industrial sector, namely a sector which builds on the offer of technological solutions in a range of downstream industrial sectors (which constitute potential acceptor markets for ICT), ICT was transversally covered within relevant acceptor industries. It is furthermore specified that KETs may provide opportunity for technological solution to hardware technologies, but not to software technologies. As a result, ICT was mainly taken into account as far as hardware technologies are concerned.
- due to its peculiarity, the Space sector was individually covered apart from Air / Aeronautics (Sector # 27).
- the Defence sector was covered separately from the Space sector. It is hereby specified that the Defence sector has not been analysed as a target sector for cross-cutting KETs, but rather in the possibility for this sector to exploit cross-KETs based technological opportunities that have a dual use potential.
- Sector # 7 Manufacture of computer, electronic and optical products, including consumer electronics covers as well organic electronics and OLEDs.

2.2.2. Action I: Identification of innovation fields of industrial interest (and the related market requirements and industrial challenges relevant to societal challenges)

The demand side analysis started from the above clusterization of industrial activities according to NACE Rev. 2 codes.

As a starting point for this analysis it had been chosen to associate to each of the industrial sectors of the list relevant documents of European relevance reporting about market requirements and industrial challenges within a given sector, such as market studies, sector analyses, market as well as foresight studies, and Strategic Research (and Innovation) Agendas (SRAs/SIRAs).

Particularly, Strategic Research (and Innovation) Agendas (SRAs/SIRAs) issued by representative working groups with European relevance, such as European Technology Platforms (ETPs), Joint Technology Initiatives (JTIs) or Undertakings (JTUs) and Public-Private Partnerships, were taken as main reference and starting point for the analysis. The assumption here was that stakeholders' groups behind SRAs/SIRAs had already made a thorough screening of R&D&I challenges, which could contribute to identify relevant market requirements as well as industrial challenges within specific industrial sectors.

SRAs/SIRAs can be classified, according to our view, into two main categories, being:

- SRAs/SIRAs with 'horizontal' focus on industrial sectors, providing insight into specific industrial sectors rather than onto specific technologies (e.g. Textiles and clothing, Aeronautics, Construction, etc.).
- SRAs/SIRAs with 'vertical' focus on specific technologies, providing technology insights rather than insight onto specific industrial sectors (e.g. Photonics, etc.).

Documents of the first group were extensively analysed for their ability to provide indication of innovation fields and related market and industrial needs within specific industrial sectors, whereas documents of the second group were analysed for their ability to provide overview of the application potential of specific KETs.

The following Table provides an overview of this classification. Moreover, it provides an overview of those documents that have been excluded from the analysis due to having been considered irrelevant for the study.

Table 2: Classification of Strategic Research (and Innovation) Agendas

ETPs, JTIs/JTUs, PPPs		Horizon-tal	Vertical
ACARE	Aeronautics and Aviation	x	
ARTEMIS	Embedded Intelligence and Systems	x	
BRIDGE	Bio-based and Renewable Industries		x
Clean Sky	Clean Sky	x	
EBTP	Biofuels	x	
ECTP	Construction	x	
EeB	Energy Efficiency in Buildings	x	

ETPs, JTIs/JTUs, PPPs		Horizon-tal	Vertical
eMobility	Mobile and Wireless Communications	x	
ENIAC	Nano-electronics		x
EPoSS	Smart Systems Integration	x	
ERRAC	Rail Transport	x	
ERTRAC	Road Transport	x	
ESTEP	Steel Production	x	
ESTP	Space Technology	x	
ESTTP	Solar Thermal Technology	x	
ETP SMR	Sustainable Mineral Resources	x	
ETPIS	Industrial Safety	x	
EuMat	Advanced Engineering Materials and Technologies		x
EUROBAT	Battery Systems for Electric Energy Storage	x	
EUROP	Robotics	x	
EuroVR	Virtual and Augmented Reality	x	
FABRE	Farm Animal Breeding and Reproduction	x	
FoF	Factories of the Future	x	
Food	Organic Food and Farming	x	
FTC	Textiles and Clothing	x	
FTP	Forestry	x	
Future Internet	Future Internet	x	
GAH	Global Animal Health	x	
GC	Green Cars	x	
HFC	Hydrogen and Fuel Cells	x	
IMI	Innovative Medicines	x	
ISI	Satellite Communications	x	
MANUFUTURE	Manufacturing of the future		x

ETPs, JTIs/JTUs, PPPs		Horizon-tal	Vertical
Nanofutures	Nanotechnology		x
Nanomedicine	Nanomedicine	x	x
NEM	Networked and Electronic Media	x	
NESS	Networked European Software and Services		x
Net!Works	Communication Networks and Services	x	
Photonics21	Photonics		x
Photovoltaic	Photovoltaic Solar Energy Technology	X	
PLANTS	Plants for the Future	X	
RHC	Renewable Heating and Cooling	x	
RM	Rapid Manufacturing	x	
SmartGrids	Electricity networks	x	
SNETP	Nuclear Energy	Not relevant	
SPIRE	Process Industry	x	
SusChem	Sustainable Chemistry	x	
TPWind	Wind Energy Technology	x	
Waterborne	Waterborne Transport and Operations	x	
WSSTP	Water Supply and Sanitation	x	
ZEP	Zero Emission Fossil Fuel Power Plants	x	
SOBM	Service Oriented Business Models	Not relevant	

The analysis of the above documents has been furthermore complemented by an analysis of documents such as market studies, sector analyses, market as well as foresight studies of relevance for specific industrial sectors. A comprehensive list of references applied as the starting point for this part of the analysis was provided as Annex to the Interim Report.

The focus for such a broad analysis of horizontal reference documents of relevance for specific industrial sectors has been the identification of market requirements in a first instance as well as of industrial challenges in a second instance, which has occurred by industrial sector. Moreover, the relevance of market requirements towards the 7 major societal challenges identified in Europe 2020 and its flagship initiatives (Table 3) was established. Market requirements do in fact not necessarily originate from societal challenges; however, since some of the future relevant markets will for sure stem from societal challenges, this association was highlighted by attributing relevant societal challenges to specific market requirements, whenever this relationship existed.

Table 3: The 7 major Societal Challenges identified in Europe 2020 and its flagship initiatives

Societal Challenges
Health, demographic change and wellbeing
Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the Bioeconomy
Secure, clean and efficient energy
Smart, green and integrated transport
Climate action, environment, resource efficiency and raw materials
Europe in a changing world - inclusive, innovative and reflective societies
Secure societies - protecting freedom and security of Europe and its citizens

For each industrial sector, this information was collected and structured into a series of matrices.

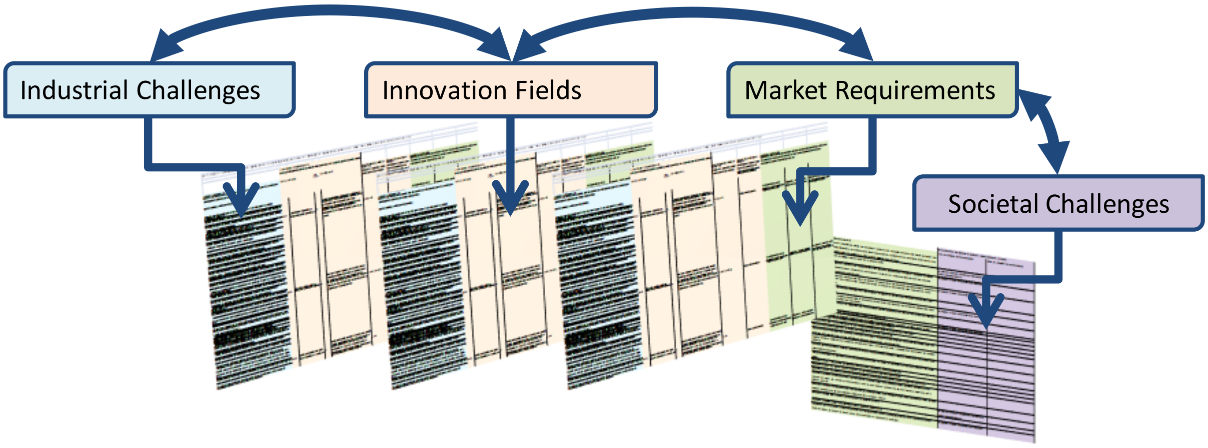


Figure 1: Overview of the matrices in which information about as well as relationships between Industrial Challenges, Innovation Fields (formerly termed Product/Market Combinations), Market Requirements and Societal Challenges were structured for each Industrial Sector

The following Figure depicts the first of these matrices, in which market requirements identified for a specific industrial sector were associated to societal challenges. Each market requirement was associated to up to two societal challenges, also establishing a relevance order. The picture provides an example extracted from the analysis of the 'Manufacture of textiles, apparel, leather and related products' sector.

	Relevance to H2020 Societal Challenges (if any)	
Market requirements	**1st in terms of relevance**	**2nd in terms of relevance**
Provide a safe and comfortable environment around us	Health, demographic change and wellbeing	Climate action, environment, resource efficiency and raw materials
Protect and take care of Europe's citizen health and wellbeing	Health, demographic change and wellbeing	Secure societies - protecting freedom and security of Europe and its citizens
Enhance mobility and better exploit energy solutions	Smart, green and integrated transport	Secure, clean and efficient energy
Use of natural resources in an efficient way and protection of the environment	Climate action, environment, resource efficiency and raw materials	Secure, clean and efficient energy
Ensure human safety and protection	Health, demographic change and wellbeing	Secure societies - protecting freedom and security of Europe and its citizens
Extend Europe's creative and innovative leadership	Europe in a changing world - inclusive, innovative and reflective societies	
Reduce the pressure of processing activities on water resources	Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the Bioeconomy	Climate action, environment, resource efficiency and raw materials
Decrease energy demand and address energy scarcity	Secure, clean and efficient energy	Climate action, environment, resource efficiency and raw materials
Increase the wellness of a fat and old society	Health, demographic change and wellbeing	
Protect and take care of workers health	Health, demographic change and wellbeing	
Address societal and individual customer needs and use scenarios	Europe in a changing world - inclusive, innovative and reflective societies	
Address mass-customization and industrial made-to-measure	Europe in a changing world - inclusive, innovative and reflective societies	

Figure 2: Market Requirements by Industrial Sector and their association to Societal Challenges (example)

In a second matrix, industrial challenges identified for a specific industrial sector were associated to the identified market requirements. The following picture provides an example of this association, also extracted from the analysis of the 'Manufacture of textiles, apparel, leather and related products' sector.

	Relevance to Market requirements	
Industrial challenges	**1st in terms of relevance**	**2nd in terms of relevance**
Develop 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	Ensure human (workers) safety and protection	Protect and take care of Europe's citizen health and wellbeing
Integrate smart textile materials and clothing (built in electronic related functionalities) that measure and react in a simple or advanced way	Ensure human (workers) safety and protection	Protect and take care of Europe's citizen health and wellbeing
Develop active textiles, which react autonomously or actively to the changing activities or conditions of the environment	Provide a safe and comfortable environment around us	
Develop fibres and textiles with enhanced functionalities and performances for better health, wellbeing and comfort characteristics	Protect and take care of Europe's citizen health and wellbeing	
Develop surface functionalization methods and processes for the production of fibres and textiles with enhanced performances	Extend Europe's creative and innovative leadership	
Develop textile products with enhanced care (cleaning, washing etc.) properties	Extend Europe's creative and innovative leadership	Address societal and individual customer needs and use scenarios

Figure 3: Industrial Challenges by Industrial Sector and their association to Market Requirements (example)

In a third matrix, innovation fields (originally termed Product/Market Combinations, PMCs) were identified. PMCs were defined as clusters of innovative and competitive products, goods and services, with similar functionalities and shared markets. They are clusters of different innovative products and/or services that use a similar solution concept (product functionalities) on a specific competitive application area (market), thereby fulfilling the same end-user function.

In the same matrix, the identified industrial challenges were furthermore associated to the identified PMCs (or innovation fields). The following picture provides an example of this association, also extracted from the analysis of the 'Manufacture of textiles, apparel, leather and related products' sector.

Industrial challenges	Product / Market Combinations
Develop 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	Textile products for improved human performance aimed at human safety and protection
Integrate smart textile materials and clothing (built in electronic related functionalities) that measure and react in a simple or advanced way	
Develop active textiles, which react autonomously or actively to the changing activities or conditions of the environment	Textile products for environmental protection and environmental risks mitigation
Develop fibres and textiles with enhanced functionalities and performances for better health, wellbeing and comfort characteristics	Textile products for better health, wellbeing and comfort
Develop 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	
Develop surface functionalization methods and processes for the production of fibres and textiles with enhanced performances	
Develop 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	
Integrate smart textile materials and clothing (built in electronic related functionalities) that measure and react in a simple or advanced way	
Develop textile products with enhanced care (cleaning, washing etc.) properties	Textile products with enhanced care (cleaning, washing, etc.) properties

Figure 4: Industrial Challenges by Industrial Sector and their association to Product/Market Combinations (example)

The tangible output of this analysis was a three-layered matrices structure, which identified Market Requirements, associating them to Societal Challenges; Industrial Challenges, associating them to the identified Market Requirements; and finally, Product/Market Combinations (or innovation fields), which constitute the central elements of these maps by industrial sector.

Notably, relations between the elements of these matrices are not one-to-one relations. They rather form a complex net of relations between Product/Market Combinations (PMCs) and their associated Industrial Challenges (ICs), Market Requirements (MRs), as well as Societal Challenges (SCs).

The identified Market Requirements, Industrial Challenges, Product/Market Combinations, and their association to Societal Challenges, as resulting from preliminary desk analyses carried out by the project team members, were furthermore validated with stakeholders as well as complemented by stakeholders' input through interviews and workshops. Views of more than 80 representatives of key industrial players in the industrial sectors in scope of the analysis were collected.

The result of Action I constituted the starting point for the next action, Action II, aimed at the identification of technological opportunities to be provided by KETs with a particular focus to cross-cutting KETs.

2.2.2.1. Highlights from interviews

Main findings of the interviews can be summarized in the following highlights. Interviewees were essentially of industrial extraction, with few exceptions. They were mainly managing directors, R&D managers, or in any case had managing roles within the company that allowed them having good awareness of the strategic directions of the company.

Having this in mind, as far as the responders' general awareness about KETs is concerned, results can be classified into two main groups. On the one side, interviewees reported about having sufficient awareness of KETs and of the discussion around KETs. This was particularly the case for companies having previously participated to the 6th or the 7th Framework Programme of the European Commission for Research and Technological Development and being actively participating to discussion/consultation groups at the European or also the national level, such as ETPs, JTIs or similar groupings dealing with R&D&I priorities definition. On the other side, interviewees representing companies having never participated to neither the 6th nor the 7th Framework Programme (or just occasionally), which are also normally not involved in any discussion/consultation groups at the European level (but possibly at the national, regional or local level), had limited to no awareness of the European discussion around KETs and of the action plan to boost KETs, despite finding the argument of high interest and recognizing the potential that KETs could have in future innovations.

Among both groups, however, according to almost all of the interviewees, companies were recognized to not have particular experience with KETs so far, resulting in KETs still not being much reflected into company's internal actions nor organization. Nonetheless, when having a look into the KETs taxonomies (see Annex), interviewees could in fact easily recognize keywords they were familiar with, thus pointing out, in some cases, to the fact that the company they work for is in fact already dealing with technologies that are at least close to KETs. About this point, some of them perceived that, in this case, there is actually a gap between the Commission's language, prone to categorizing technologies into broader families, and the practical application of KETs in industry.

Toward a successful practical application of KETs into products or processes, interviewees' opinions basically converged on the importance of EU programmes and on the need to have a model of support organized into three main layers:

1. a first layer focussing on the sharing of the knowledge generated from basic research and on applied research, promoting collaboration of industry with universities and RTOs;
2. a second layer focussing on industrial innovation and supporting actions aimed at the pre-competitive demonstration of products and processes including by pilot actions. This layer should operate on TRLs of 5 or higher with the objective to develop and introduce product and process innovation on the market on short term basis (3 years), promoting collaboration among industry, whereby the process should be led by industrial players capable of transferring their vision for innovation along the whole value chain, thus steering the change both downstream (suppliers) and upstream (customers);
3. and a third layer focussing on infrastructure development toward manufacturing and production, exploiting risk finance and loans and in which supplier-based relations would gain in importance along with the creation of representative monitoring data sets to create confidence around innovative technological solutions.

This envisioned model was mentioned by several interviewees and was deemed being effective toward achieving successful industrial deployment of innovative concepts. Besides this, interviewed industrial stakeholders envisioned that bureaucracy for the request of funding would be simplified and that authorization procedures for on field testing would be simplified as well. Particular comments concerned the need to provide support especially to high-tech SMEs both in terms of capital and management skills.

As regards the interviewees' vision on cross-cutting KETs, opinions were contrasting not only among interviewees representing companies belonging to different industrial sectors, but even among interviewees representing companies belonging to a same sector. As a general rule, the cross-fertilization between KETs was deemed being interesting, but not key and potentially capable of generating the risk of moving (by integrating different KETs) backwards in the TRL scale towards more basic research rather than towards the market. Instead, the opportunity to solve, by involving KETs (no matter whether individually or in combination among themselves), industrial challenges that cross-cut several industrial sectors by having a multi-disciplinary approach was deemed being most important. Also important was deemed the opportunity to improve, by involving KETs (again, no matter whether individually or in combination among themselves), existing technologies with an outlook to incremental rather than to breakthrough innovations. Another key aspect was identified in the necessity to synergistically collaborate at the whole value chain level in order to efficiently develop new products or processes, thus creating synergies between technological development, fabrication process development and early design, through R&D coordination to be achieved in the right timing.

When discussing about which KETs could be specifically combined among themselves in order to generate added value, a predominant role of Advanced Manufacturing Systems/Technologies was identified, very often mentioned in combination with any of the other KETs due to the need of leveraging on advanced manufacturing in order to exploit the potential of the other KETs. Other possible combinations were also mentioned, but were more specifically relating to specific product categories, hence pointing out to the fact that, upon opportunity, any combination would in fact be possible.

Regulation was mentioned by interviewees as representing a key driver for innovation for several of the industrial sectors in scope of the analysis, in cases not involving consumer markets (which follow different rules). Since the introduction of new regulation stimulates investment, markets are stimulated as a consequence. As soon as market needs would arise, moreover, industry would not have particular difficulties in deploying technological solutions if demanded by the market, as a general rule. For consumer markets, on the other side, trends would provide a similar stimulus to the creation of new markets. Dealing with mass markets, the ability by industry to decrease product cost by decreasing manufacturing costs is key along with the need to focus on high added value products.

Main potential barriers mentioned by interviewees can be summarized in missing norms and standards that in some cases may hinder exploitation of new technology by industry; hence the creation of new norms and standards is critical. Safety is also of particular importance when dealing with the introduction of new technologies, which actually add risk to consolidated practices.

Last but not least, the need to provide environments in which prototypes can be developed and tested was importantly mentioned. At the most, companies lack the equipment and facilities to test the output of their research and innovation projects on a real scale. Shared facilities where prototypes can be tested or demonstrated to customers in operating conditions can be of great benefit to industry according to interviews.

2.2.2.2. Ex-post reorganization of Product/Market Combinations (=innovation fields) into cross-sectoral domains

During the individual industrial sectors' analyses, areas of overlap between similar PMCs emerged. Therefore, a thorough consolidation activity took place ex post (i.e. after completion of Action I aimed at the broad analysis of the demand within all individual industrial sectors) in that the following aspects were taken into account.

First of all, similar PMCs within individual industrial sectors were aggregated in order to provide a single PMC entry embracing all the related individual PMCs' specifications.

Starting from the individual PMCs, clusters were furthermore created embracing individual industrial sectors whenever it emerged that a segmented classification into the individual industrial sectors would have led to duplication of PMCs, in order to avoid having redundancies of similar PMCs. Relevant examples in this respect are represented by the Energy related individual industrial sectors, namely 'Renewable energy', 'Power Energy', and 'Electricity, gas, steam and air-conditioning supply', which were all grouped within a broader 'Energy' cluster / domain, as well as by the Transport related individual industrial sectors, namely 'Road transport', 'Air/Aeronautics', 'Manufacture of transport equipment', 'Logistics systems', 'Transportation and storage', 'Rail transport', and 'Marine transport', which were all grouped within a broader 'Transport' cluster / domain. Within those broader domains, the same criterion of aggregating similar PMCs in order to provide a single PMC entry embracing all the related individual PMCs' specifications was applied, thereby reducing redundancies and leading to a more rationale organization of the PMCs.

In doing this aggregation of similar PMCs, the cross-sectoral aspects were looked at, looking particularly for challenges common to one and its nearby sectors. For 'Transport' particularly, many industrial challenges were identified in relation to individual PMCs, which were however similar in scope among themselves, that were in fact pointing to a same challenge, but were presented with different wordings depending on the individual sectors' own industrial culture. Integrating these challenges at transport macro-level meant looking for the common denominator, then necessarily wording the challenge in a less focussed way. Nevertheless, and this was checked with the interviewed stakeholders, the RO-cKETs team tried their best to make sure that any professionals from the individual sectors could recognize in the wording their own problematics.

Moreover, PMCs initially grouped under the framework of industrial sectors that are technology enablers for downstream applications were transferred to the downstream/application sector in case the PMC's application could be very clearly and singularly identified within a specific downstream application domain (e.g. PMCs originally grouped under the framework of the 'Robotics' industrial sector – which is in fact a technology enabler – with specific application within e.g. the Healthcare domain were transferred to a downstream cluster grouping all 'Healthcare' related PMCs, if instead they had specific application within e.g. the Civil Security domain, they were transferred to a downstream cluster grouping all 'Civil Security' related PMCs, and so on following this approach. The remaining PMCs from the 'Robotics' industrial sector not finding specific application within a specific downstream application domain were maintained within a cluster grouping Machinery, manufacturing equipment and automation systems, i.e. cluster M4).

At the end of this process the following clusters / domains were identified (stemming from the reorganization of the PMCs referring to the initially considered 28 individual industrial sectors) as presented in the below Table.

Table 4: New PMC clusters and main individual industrial sectors associated

M#	Cluster (Code M)	I#	Main individual industrial sectors associated (Code I)
M1	**Energy**	I1	Renewable energy
		I20	Power Energy
		I22	Electricity, gas, steam and air-conditioning supply
M2	**Transport**	I10	Road transport

M#	Cluster (Code M)	I#	Main individual industrial sectors associated (Code I)
		I11	Air / Aeronautics
		I17	Manufacture of transport equipment
		I18	Logistics systems
		I24	Transportation and storage
		I25	Rail transport
		I26	Marine transport
M3	**Healthcare**	I6	Manufacture of pharmaceuticals, medicinal chemical and botanical products
		I13	Diagnostics and medical devices
		I2	Robotics (aimed at healthcare systems and services)
		I12	Telecommunication (aimed at healthcare systems and services)
M4	**Manufacturing and Automation Systems**	I2	Robotics (aimed at industrial manufacturing and logistic services)
		I8	Manufacture of machinery and equipment n.e.c.
M5	**Electronic, Electric and Communication Systems**	I7	Manufacture of computer, electronic and optical products, including consumer electronics
		I12	Telecommunication systems
		I16	Manufacture of electrical equipment
M6	**Chemicals, Chemical Products and Materials**	I5	Manufacture of chemicals and chemical products
		I19	Glass
		I21	Manufacture of coke, and refined petroleum products
M7	**Agro-food**	I3	Agriculture (including animal breeding ad farming)
		I6	Manufacture of botanical products
		I15	Manufacture of food products, beverages and tobacco products
M8	**Environment**	I23	Water supply, sewerage, waste management and remediation
M9	**Civil security**	I2	Robotics (aimed at security and surveillance services and operations)

M#	Cluster (Code M)	I#	Main individual industrial sectors associated (Code I)
		I27	Space and Defence (dual use)
M10	**Construction**	I9	Construction
M11	**Textiles, apparel, leather and related products**	I4	Manufacture of textiles, apparel, leather and related products
M12	**Mining, quarrying and extraction**	I14	Mining and quarrying
M13	**Education / Edutainment**	I28	Education / Edutainment
n.a.	**Space and Defence**	I27	Space and Defence have been redistributed within other sectors according to dual use

2.2.3. Action II: Identification of technological opportunities (matching demand with technological offering provided by cross-cutting KETs)

As previously reported, the result of Action I constituted the starting point for the next actions. Starting from the map of PMCs, Action II focused on identifying technological opportunities to be provided by KETs and more specifically by the cross-fertilization between KETs to solving the identified Industrial Challenges thus technologically contributing to the identified Product/Market Combinations (or innovation fields, as they are more simply called in the roadmap document).

According to this method, Product/Market Combinations (or innovation fields) identified throughout Action I were screened by KETs experts in their potential to become receptors for KETs, and particularly for cross-cutting KETs. This association was made based on expertise and was aided by KETs taxonomies, which specify KETs into sub-groups of materials, products, and technologies contained within each broader KETs family.

For the purpose of matching the identified innovation fields with the technological offering to be provided by KETs and more specifically by the cross-fertilization between KETs high level experts in Key Enabling Technologies were extensively involved. Experts were mobilized via a dedicated Europe-wide online-based survey and 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 achievement of highly innovative products, processes, goods, or services. The analysis leveraged views of 272 experts in the six KETs.

Each of the consortium members moreover engaged technical experts belonging to their affiliation in this same exercise according to their specific expertise into one or the other KET.

Last but not least, this information was combined with the result of an extensive patent scenario analysis aimed at examining the KETs-related patenting activity in relation to each innovation field (see section 2.2.3.2.). A KETs-related patents database was exploited for the purpose, which had been obtained by having identified and extrapolated from patents databases only those patents dealing with KETs thanks to search strings delineating each of the six KETs.

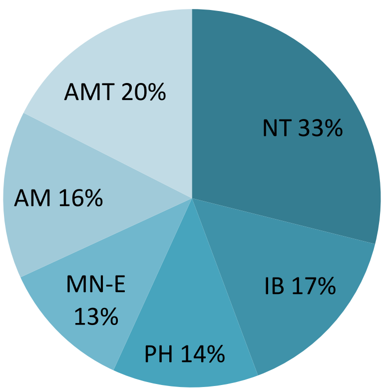
2.2.3.1. KETs experts survey

In order to collect expert opinions about the possible contribution that cross-cutting Key Enabling Technologies could have with respect to the identified innovation fields, a Europe-wide online-based survey was set up. Upon nominal invitation, high level experts in Key Enabling Technologies that had been previously identified by the consortium members were called to indicate 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, goods, or services.

The relevant target groups for this survey were technology experts with expertise over one or more specific KETs – mostly experts from academia and RTOs, knowledgeable of KETs (such as professors, researchers, group leaders, resort-leaders, etc.). The rationale behind the choice of this target group was that they are highly knowledgeable of technologies (as their employers are typically organized in technology fields) and also have a good overview of technologically possible applications, thus being highly qualified for answering questions on KETs involvement and especially on the potential cross-cutting KETs contribution towards the identified innovation fields.

As regards the survey's respondents characteristics and return rate, in total, 272 experts participated in the survey out of over 1557 experts that had been invited to participate from all over Europe (the sample of invited experts was initially 1237; this figure was extended to more than 1557 thanks to some voluntary initiatives to spread out the link of the survey). Experts were aimed to be roughly equally distributed over the six KETs as well as over broad geographic European regions (i.e. Western/Central Europe, Northern Europe/Scandinavia, incl. the Baltic area, Southern Europe/ Mediterranean area and Eastern Europe).

In order to allow decentralized yet controlled spreading of the survey, it was deliberately abstained from generating personalized log-ins for each invited participant. However the spread out to additional pools of invitees was monitored and the technology expert status was moreover requested and thus checked within the survey through initial questions used for the profiling and classification of the experts. Due to this reason a precise number of invitees cannot be given, however 1557 invitations were sent in the first place with the following distribution over the six KETs:



KETs expertise of the initially addressed field (no multiple answer, referring to the address source information)

NT: Nanotechnology; IB: Industrial biotechnology; PH: Photonics; MN-E: Micro- and Nano-electronics; AM: Advanced materials; AMT: advanced manufacturing technologies

Figure 5: KETs expertise according to the initial list of invited participants

The response rate with respect to the initial number of invitations was 18%, which is highly satisfying and exceeding the initial goal. Also as regards respondents, the KETs expertise was satisfyingly balanced with a slight underrepresentation of industrial biotechnology and photonics. Still, about 1/6 of the respondents had an expertise in biotechnology.

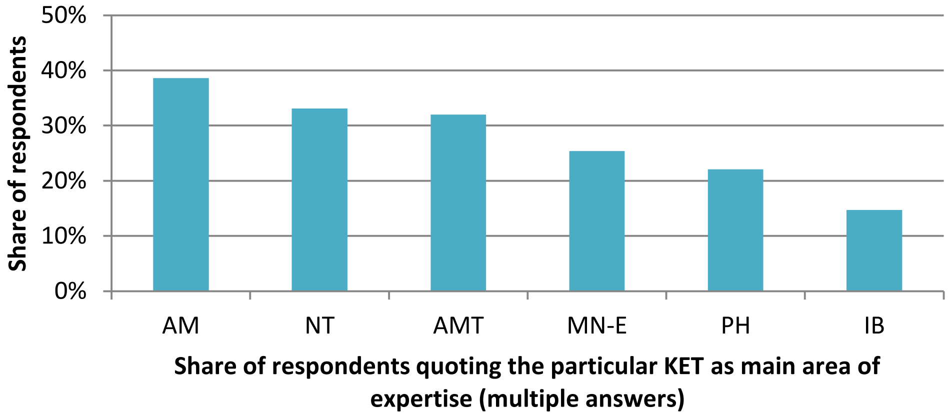


Figure 6: KETs expertise of respondents

Moreover, more than half of the respondents only quoted one KET as the main area of expertise, 1 out of 4 quoted two, and 1 out of 5 quoted three or more KETs as main areas of expertise. More than 90% of the respondents had an expertise of longer than five years.

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 submitted to the attention of respondents a list of the 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 from 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. In average, 49 innovation fields were shown to the experts for assessment of which in average 11 innovation fields were assessed by them. This result is highly satisfying; only about 25 of the 257 innovation fields were not assessed. 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 experts consultation process.

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.

KETs experts were additionally asked to provide opinion about how long it would take to solve the main technological issues holding back to the achievement of cross-cutting KETs based products within a specific innovation field. Answers had to be chosen among the 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 to group innovation fields into two main blocks, namely innovation fields with short-term priority relevance (if the answer 'from 2 years to 5 years' was provided) and innovation fields with medium-term priority relevance (if the answers 'from 5 to 10 years' or 'more than 10 years' were provided), despite actually 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, 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.

This second activity resulted in a list of innovation fields with cross-cutting KETs relevance, grouped within two main blocks according to their rather short-term or medium-term priority relevance, despite actually many of the innovation fields can be considered as being subject to continuous improvement throughout time.

Since it was a fundamental requirement to identify cross-cutting KETs opportunities, only innovation fields for which a rather strong interaction among KETs had been indicated as necessary were selected as relevant and further considered throughout the next assessment steps.

2.2.3.2. KETs-related patents analyses for assessment of technological scenario

Europe's KETs-related technological know-how and capacities as well as industry level of activity in relation to each innovation field could be understood including by making extensive use of patent scenarios analyses. The applied method is a mechanical one making extensive use of patents data to provide useful indications. Making use of patents analyses should not be overestimated but can be a useful complementary tool to stakeholder interviews, surveys, workshops and desk analyses.

The method's purpose was to specifically identify patents in relation to each innovation field at the intersection of a number of KETs, from which the technological scenario and trends as well as the industry level of activity with respect to the innovation field could be understood. Patenting activity in a given field can in fact not only be representative of technological strategies implemented, but also of industrial and marketing strategies with a certain level of approximation. More relevantly in certain fields than in others, filing for a patent is the usual way for a firm to protect itself in a market. Accordingly, in the qualitative assessment of innovation fields, besides information about technologies, much information regarding the marketing strategies of pools of applicants can be derived from patent scenarios analyses using patents-based indicators.

A KETs-related patents database was exploited for the purpose, which had been obtained by having identified and extrapolated from patents databases only those patents dealing with KETs thanks to search strings delineating each of the six KETs.

KETs can be in fact delineated in terms of search strings. Within search strings KETs are defined in terms of component technologies (aligned with international classifications such as the International Patent Classification (IPC) and the European Classification System (ECLA)). In the following Table, the original search strings defined by the KETs Observatory based on ICO classification (In-Computer-Only; additional codes used by EPO examiners) are reported.

Table 5: Search strings for Patents Analyses

Search strings for Patents analyses
Nanotechnology
B82Y or B82B
Micro- and Nano-electronics
(H01H00577) or (H01L) or (H05K0001) or (H05K0003) or (H03B000532) or (Y01N0012)
Photonics
(F21K) or (F21V) or (G02B0001) or (G02B0005) or (G02B0006) or (G02B001314) or (H01L002500) or (H01L0031) or (H01L005150) or (H01L0033) or (H01S0003) or (H01S0004) or (H01S0005) or (H02N0006) or (H05B0031) or (H05B0033)
Industrial biotechnology
(C02F000334) or (C07C002900) or (C07D047500) or (C07K000200) or (C08B000300) or (C08B000700) or (C08H000100) or (C08L008900) or (C09D001104) or (C09D018900) or (C09J018900) or (C12M) or (C12N) or (C12P) or (C12Q) or (C12S) or (G01N0027327)
not (A61 or A01)
Keywords: (BIOMAS* or CROP or CROPS or FEEDSTOCK* or (FEED M STOCK*) or (FEED?STOCK*) or BIOFUEL* or (BIO M FUEL*) or (BIO?FUEL*) or BIODIESEL* or (BIO M DIESEL*) or DIESEL or FUEL? or (BIO?DIESEL*) or BIOETHANOL* or (BIO M ETHANOL*) or (BIO?ETHANOL*) or DME or ENZYM* OR GA?lFICAT* or *REFIN* or HYDROL* or FERMENTAT*)
Advanced materials
(B32B009) or (B32B0015) or (B32B0017) or (B32B0018) or (B32B0019) or (B32B0025) or (B32B0027) or (C01B0031) or (C04B0035) or (C08F) or (C08J0005) or (C08L) or (C22C) or (D21H0017) or (H01B0003) or (H01F0001) or (H01F000112) or (H01F000134) or (H01F000144) or (Y01N0006)
Advanced manufacturing technologies
a) robotics/automation:
(B03C) or (B06B00016) or (B06B000300) or (B07C) or (B23H) or (B23K) or (B23P) or (B23Q) or (B25J) or (G01D) or (G01F) or (G01H) or (G01L) or (G01M) or (G01P) or (G01Q) or (G05B) or (G05D) or (G05F) or (G05G) or (G06M) or (G07C) or (G08C)
b) computer integrated manufacturing:
(G06) and ((A21C) or (A22B) or (A22C) or (A23N) or (A24C) or (A41H) or (A42C) or (A43D) or (B01F) or (B02B) or (B02C) or (B03B) or (B03D) or (B05C) or (B05D) or (B07B) or (B08B) or (B21B) or (B21D) or (B21F) or (B21H) or (B21J) or (B22C) or (B23B) or (B23C) or (B23D) or (B23G) or (B24B) or (B24C) or (B25D) or (B26D) or (B26F) or (B27B) or (B27C) or (B27F) or (B27J) or (B28D) or (B30B) or (B31B) or (B31C) or (B31D) or (B31F) or (B41B) or (B41C) or (B41D) or (B41E) or (B41G) or (B41L) or (B41N) or (B42B) or (B42C) or (B44B) or (B65B) or (B65C) or (B65H) or (B67B) or (B67C) or (B68F) or (C13C) or (C13D) or (C13G) or (C13H) or (C14B) or (C23C) or (D01B) or (D01D) or (D01G) or (D01H) or (D02G) or (D02H) or (D02J) or (D03C) or (D03D) or (D03J) or (D04B) or (D04C) or (D05B) or (D05C) or (D06B) or (D06G) or (D06H) or (D21B) or (D21D) or (D21F) or (D21G) or (E01C) or (E02D) or (E02F) or (E21B) or (E21C) or (E21D) or (E21F) or (F04F) or (F16N) or (F26B) or (G01K) or (H05H))

These search strings had been applied within patents databases in order to identify and extrapolate patents dealing with KETs. By this method a patents database had been created, which contains only patents dealing with KETs, thereby excluding all patents that do not have relations with KETs.

This KETs-related patents database was used on the one side in order to examine the KETs-relevant patenting activity in relation to each individual innovation field and on the other side to provide support to the assessment and prioritisation of innovation fields as foreseen within Action III. To this purpose, patents data were used as indicators of the technological as well as market performance of EU-based actors in relation to individual innovation fields.

The coverage of the patents data set built for this analysis goes from 2000 to 2010. In this respect, it is important to stress that patent procedures imply a time lag between the filing of a patent application and its publication. This implies that for the most recent years data tend to be incomplete only because applications have not yet been published.

As far as the dating of patents is concerned, the priority date, i.e. the first filing date of a patent application, was used. This date claims the right to file subsequent applications for the same invention at other offices, for a period of 12 months. The rationale for using this date, instead of the application or publication dates, is that this date is closer to the actual date of the invention. Moreover it allows identifying and regrouping patents belonging to a single family, identified by the same invention, avoiding redundancy of information.

In a complementary as well as gap analysis logic to other actions, patent scenarios analyses had a threefold objective. On the one side, they were used in order to identify and characterize the KETs-relevant patenting activity toward each individual innovation field, thus providing support to Action II in identifying KETs as well as cross-cutting KETs combinations contributing to an innovation field. On the other side, they were used in order to characterize Europe’s industry level of activity and market power in relation to the analysed innovation fields, thus supporting and complementing Action III. And third, they were used in order to qualitatively delineate the maturity level of technological solutions underlying innovation fields. To these aims, the KETs-related database was mined through pertinent IPC codes referring to as well as specific keywords describing individual innovation fields and specific patents-based indicators were exploited to derive information.

Patents by KET(s)

To the aim of complementing Action II, the information collected through the KETs experts survey was combined with the result of the KETs-related patent scenario analysis in that it was particularly cross-checked against the indication of the patents distribution by KETs and the related combinations of KETs identified in relation to each specific innovation field. 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 below Table. This allowed on the one side to identify relevant combinations of KETs and on the other side to understand the relevance of each KET as well as of each of the identified relevant combinations of KETs with respect to the innovation field.

Table 6: Patents by KET(s) and relevant combinations of KETs (EXAMPLE)

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

Maturity of technological developments

Furthermore, the shape of the patenting activity's trend curve, as combined with the relative share of industrial and academic applicants in relation to a specific innovation field, were used as indicators to provide useful qualitative information about the maturity of technological developments in a given framework, in the assumption that a growing trend curve would normally point out to an evolving technological scenario, in its infancy phase, especially in the case of a high share in the patenting activity by academic applicants, a stable trend curve would normally point out to technologies in the course of their validation in relevant environments or scales, and a descending trend curve would normally point out to technological maturity or even obsolescence in case of a sharply descending trend curve, according to the typical S-shaped curve describing technology life cycles.

According to the theories describing technological systems' evolution, all technologies, starting from the original, initial invention, evolve trough a multitude of additional developments and improvements, passing through an infancy phase, a maturity period and reaching at the end obsolescence (Figure 7). This development pattern is also normally reflected in patenting activity.

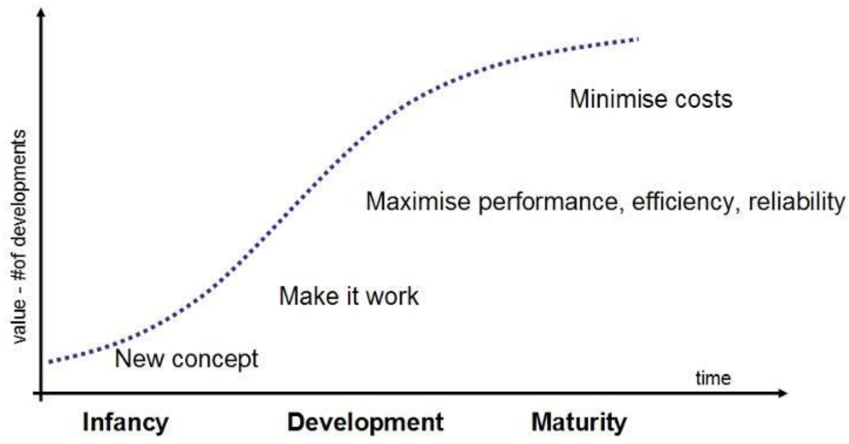


Figure 7: The "S"-shaped curve describing the evolution of technological systems

Furthermore, within this framework, a high share of academic applicants in the patenting activity points out to R&D activities going on in a given framework, highlighting lower technological maturity, whereas a high share of industrial applicants points out to innovation activities and a higher technological maturity. Types of applicants can be in fact distinguished into industrial ones and 'academic' ones, whereby the category labelled as 'academic' in fact comprises universities, research centres, RTOs, etc.

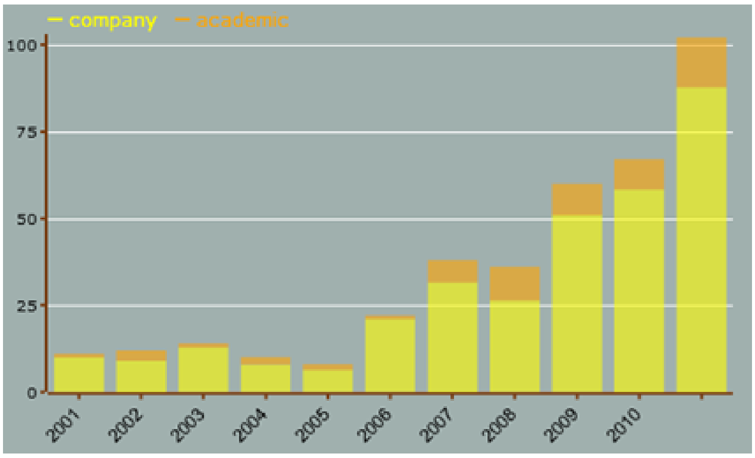


Figure 8: Patents evolution / trend, including by type of applicants (EXAMPLE)

From the above diagram, for example, a growing trend can be distinguished pointing out to an evolving technological scenario where industry has an important role already, which points out to high industrial interest/relevance, yet a developing technological maturity with validation in relevant environments most probably going on.

2.2.4. Action III: Assessment and prioritization (identification of the most promising areas of converging industrial interest for cross-cutting KETs)

To the aim of identifying the most promising areas of converging industrial interest for cross-cutting KETs, part of the 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 deskwork. A second Europe-wide online-based survey allowed gaining industrial experts' opinions with regard to market demand aspects. Moreover, also for this part of the analysis, patents-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. Extensive desk analysis activity allowed furthermore assessing potential markets and related drivers. All three sources of information were exploited as combined and complementing each other.

The applied prioritization method consisted in screening innovation fields and in qualitatively assessing them against prioritisation criteria. Given the broadness of the scope of this study, prioritisation was mainly qualitative rather than quantitative.

2.2.4.1. Definition of assessment and prioritisation criteria

The first step into the design of the assessment and prioritization mechanism was the identification of the assessment and prioritisation criteria to be applied. An initial list was thus drafted by the project team in order to be subsequently discussed, seeking for complementation and validation, with industrial stakeholders on the one hand and policy makers on the other hand. This occurred during the first set of two workshops that were held within the project, the first involving industrial stakeholders (in April 2013) and the second involving policy makers (in May 2013). Furthermore, the list of assessment and prioritisation criteria was discussed with the Steering Committee in June 2013. The following is the list of criteria that were taken in consideration in the design of the multi-criteria prioritization mechanism that was applied to the list of the identified innovation fields for the identification of the most promising areas of converging industrial interest for cross-cutting KETs.

Table 7: Criteria for the identification of the most promising areas of converging industrial interest for cross-cutting KETs

#	An innovation field represents a priority if:
1	it has a relevance towards Market Requirements and thereby has the capability to generate high economic impact in the EU
2	it provides the opportunity for job creation and generates positive impact on employment in the EU
3	it involves cross-fertilization between KETs, whereby the focus should be on TRLs 4-8 (as a fundamental assumption)
4	a complete value chain or at least the value adding activities are available in the EU
5	it capitalizes on know-how and skills that are available in the EU
6	it has social market economy relevance (which has always characterized the EU vs. the rest of the world)
7	a complete supply chain or at least the value adding activities are available in the EU
8	it has strategic relevance in the long term

2.2.4.2. Demand-side survey

An additional involvement of industry was sought for the further assessment of innovation fields aimed at the identification of the most promising areas of converging industrial interest for cross-cutting KETs. This was pursued in a second survey, designed as a gaining of assessments from industrial representatives in the sense of an "industry barometer of opinions" with respect to chances and potentials of the identified innovation fields in Europe in terms of market impact and opportunity toward industrial growth and job creation. By gathering assessments for each innovation fields, having the company's interest in mind and information about the innovation processes within the firm, the overall aim to assess innovation fields with respect to their potential of generating added value in Europe and to contribute to reindustrialization was addressed. Within this framework, it was important to assess whether there is a basis for the specific innovation fields in Europe today and whether the potential of those innovation fields is seen in the future.

Keeping this in mind, the targeted experts of this demand-side survey were experts from industry, knowledgeable of their companies' R&D activities and development directions and familiar with their sector as well as markets and with future relevant trends in the sector and for the company. Experts were therefore selected preferably from companies, but also among technology scouts or industrial associations/groupings, with the criterion that they should in any case cover the private sector's point of view.

The design of the survey took inspiration from the above assessment and prioritization criteria, considering that the assessment needed to be based on questions that could be realistically answered by industry experts (using a rather business "language" and contextualizing the assessment in relation to the company's business were key aspects in this respect) and needed furthermore to reflect rather real facts characterising industrial activity and plans in the framework of the assessed fields, keeping the survey as short, simple and precise as possible.

The target group involved representatives of manufacturing companies in the European Union. As representatives of SMEs mostly CEOs, CTOs/R&D managers were asked to contribute, whereas in large enterprises mostly people from strategic research planning, R&D managers, CTOs, technology managers, development directors, maybe innovation managers, in general people involved in technology portfolio development, were addressed. Thus, the target group comprised people who know their sector, markets and future topics relevant for the company as well as who are aware of the constraints of a technological change within a company. By limiting to representatives of firms located in the European Union, the European focus was maintained. The potential participants were identified by the project team members through publications, congress attendance, patents, contacts from interviews, associations, and contacts from each of the consortium members' own networks.

In order to have a balanced participation from all major European manufacturing industries, an equal distribution over the core manufacturing industries in the European Union was sought. Furthermore, representation from all four greater European regions was aimed at, namely:

- Western/Central Europe: France, Germany, The Netherlands, United Kingdom, Austria, Ireland, Belgium, Luxembourg;
- Northern Europe/Scandinavia, incl. Baltic area: Finland, Sweden, Denmark, Lithuania, Latvia, Estonia;
- Southern Europe/Mediterranean area: Spain, Italy, Portugal, Greece, Croatia, Slovenia, Malta, Cyprus;
- Eastern Europe: Poland, Czech Republic, Slovakia, Romania, Bulgaria, Hungary.

Finally, roughly half of the industry representatives should have come from SMEs to capture not only opinions from representatives of large companies but as well from small and medium sized firms, as they are the strong base of the European industry today.

To conclude, the sample did not aim to be representative in the first instance, but to cover major parts of European manufacturing as well as countries with a sufficient number of respondents, and ensuring at least a significant number of responses by SMEs.

The invitees address base contained 2175 addresses. Following the requirements of a business targeted survey, invitations provided personalized links for the respondents. Additionally, the access to the questionnaire was limited to invited persons only.

The analysis could leverage at the end 285 valid responses, which represented a satisfactory response rate of around 13%. All European regions were represented in the data. Three out of four regions were particularly well represented, whereas an underrepresentation of Eastern Europe counties was due to a lower share of firms from this region in the initial sample of addresses.

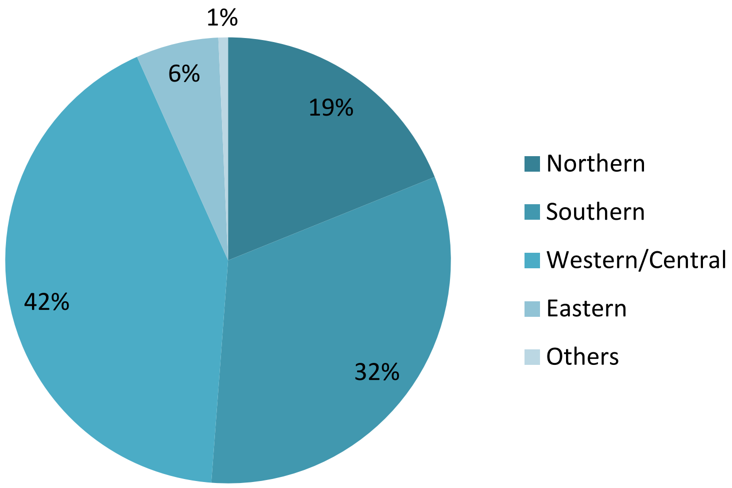


Figure 9: Geographical distribution of respondents

The share of SMEs and large enterprises was nearly equal in the data referring to respondents, which is highly satisfying.

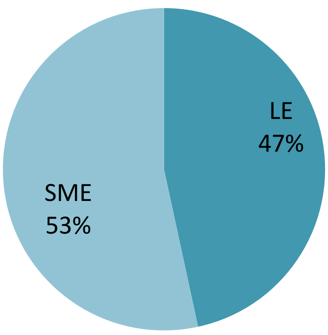


Figure 10: Company size distribution of respondents

Last but not least, positions/roles of respondents were in line with the qualitative requirement, with a majority of the industry stakeholders being involved in R&D activities of their firms and one fourth of the respondents acting as CTO or CEO, which renders the answers very valuable. All in all, characteristics of the respondents allowed to draw reliable conclusions.

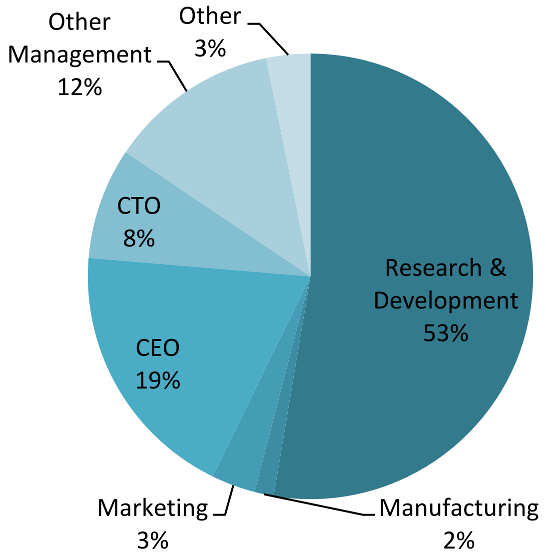


Figure 11: Position/role of respondents within their company

As regards the logic behind the survey, the aim was to get realistic and informed answers about innovation fields with respect to:

- exploiting companies and value added in Europe,
- strategic relevance to companies,
- economical potential,
- potential to create jobs,
- industrial manufacturing capacity in Europe,
- timing as regards market entry (short, mid, long term).

On the one hand, this was achieved by collecting hard facts about the companies' activities or R&D plans related to some of the innovation fields they identified themselves with because of these innovation fields having been indicated as being strategically relevant for them. On the other hand also softer facts such as the potential for job creation were asked for, rather with the intention to collect personal opinions though informed as well as referring to the company's perspective. In general, the respondents were encouraged to base their answers on facts rather than to provide mere uninformed believes because all of the questions were contextualized relative to the company's business.

As regards the questionnaire, it had been designed in such a way to allow industry experts to start the process by selecting first of all a product category in line with their business activities and the markets in which their products are sold or would be sold in the future (both current markets and future markets of interest were delineated). In case several markets were seen as relevant or potentially relevant to the company, the choice needed to be adjusted to the two main markets of interest (this was in order to narrow down the assessment onto a limited number of innovation fields linked to the markets of interest).

In a second step, according to the chosen markets of interest, industry experts were asked to delineate which specific innovation streams would be relevant for future markets (i.e. would meet market demands in the future). To do so, a list of relevant areas of innovation was displayed to the respondent. Such innovation areas reflected groups of innovation fields addressing similar applications and became later on, with some adjustment, the 'sub-domains' in the roadmaps.

As a third step, the system hence submitted to the attention of respondents a list of the innovation fields that were either directly classified within the framework of the chosen innovation area/sub-domain or cross-sectorally linked to such innovation area/sub-domain, within which to select the innovation fields of strategic relevance or interest for their company to assess in major details, by remaining strictly anonymous. Each of the innovation areas contained up to 14 innovation fields. These innovation fields were displayed to the respondent along with the request to assess the strategic relevance of each specific innovation field. Only for the highly and partially relevant innovation fields, the industry expert was asked whether the company already pursued R&D activities to develop new marketable solutions related to this particular innovation field.

Both questions allowed narrowing down the selection to innovation fields which were (highly) relevant and which were pursued within a company.

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 filtering logic is depicted in the following scheme.

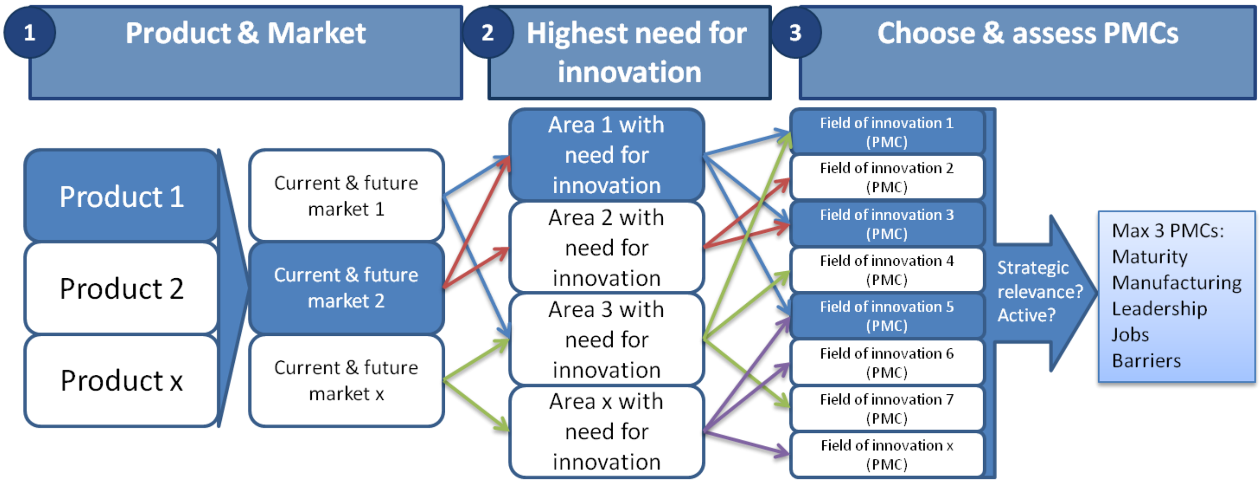


Figure 12: Filtering logic for industry experts survey

Thus, the respondent was asked to assess well known research activities of his/her company which are integrated in actual industrial innovation processes. The up to 3 most relevant innovation fields, where the company is active in, were then assessed in detail. Questions to each of the up to 3 innovation fields of major strategic relevance for the company addressed:

1. market strategy with product innovation activities in this field,
2. maturity: when to be successfully introduced into the market by the company,
3. current stage of development,
4. planning where the manufacturing of the products will be located,
5. company's role in advancement of this field (innovation leader or follower),
6. location of (other) innovation leader(s).

Two further, more general questions, encompassing all innovation fields previously assessed, addressed:

1. most relevant barriers that need to be overcome to achieve successful market implementation,

2. perspectives for creation of new jobs or for reduction of employment within the next five years.

If any gap was identified in relation to missing innovation fields of strategic relevance for future markets, the participant was invited to provide input in a free text box. With respect to this answer, again the respondent was asked for R&D activity, development stage and job creation.

If a company had innovation fields of relevance but no activity related to those, the respondent was asked for the reason not to pursue R&D with respect to the strategically relevant fields.

Finally, the respondents were asked to profile their company (multi-national, European or national, SME or large enterprise) and to indicate the approximate share of R&D expenditure as a share of the total turnover in 2013. The position of the respondent within the company and his/her location of the workplace were asked for afterwards.

The gathered input allowed capturing the strategic relevance for industry of each of the identified innovation fields, which was used in order to highlight the innovation fields of highest converging industrial interest.

This information was moreover complemented by extensive deskwork aimed at retrieving, whenever possible, information about potential market sizes and market trends for specific families of products, processes, goods, or services linked to the identified innovation fields, Europe's market shares, relevant European market players, value chains, employment, etc., and moreover combined with results of patent scenario analyses.

2.2.4.3. KETs-related patents analyses for assessment of impact aspects

The above pieces of information were once again combined with the result of KETs-related patent scenario analyses. The use of patents-based indicators has intrinsic limitations, but can anyway be a powerful aid in qualitative assessments. Hence, to the aim of complementing Action III, the information collected through the demand-side survey was combined with the result of the KETs-related patent scenario analysis in that it was particularly cross-checked against the indication of the patents distribution by applicant organization geographical zone and the patents distribution by geographical zone of priority protection, which 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.

By examining the patents-related information about the geographical establishment of applicant organizations, it is in fact possible to retrieve useful information about Europe's relative industrial strength with respect to other regions, in the assumption that European applicant organizations contribute to industrial strength in Europe. Moreover, by examining the patents-related information about the geographical zone of priority protections, it is possible to retrieve useful information about applicants' market strategies and hence, thanks to data aggregation, about Europe's market power with respect to other regions. This in the assumption, as anticipated above, that filing for a patent is used as a way for applicants to protect themselves in a market.

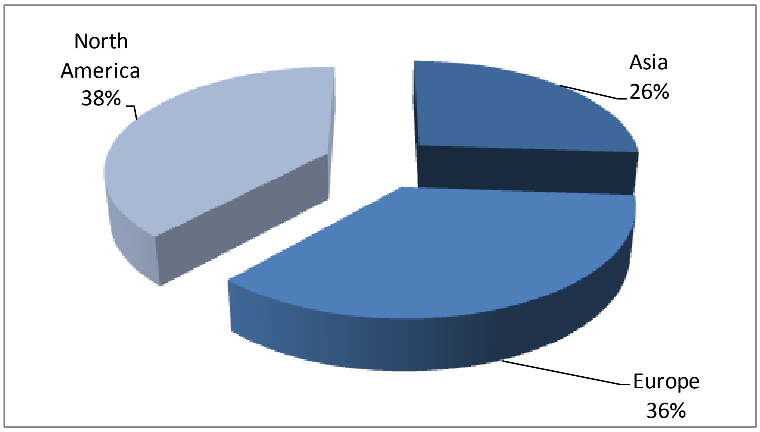


Figure 13: Patents distribution by applicant organization geographical zone (EXAMPLE)

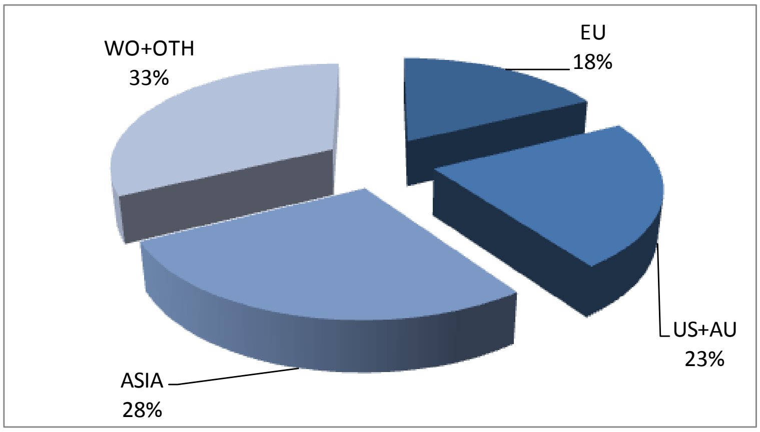


Figure 14: Patents distribution by geographical zone of priority protection (EXAMPLE)

This third activity resulted in a list of the 117 most promising innovation areas of converging industrial interest for cross-cutting KETs, selected based on their cross-cutting KETs relevance as well as on their highest potential for answering markets, industry and society demands.

2.2.5. Action IV: Description/characterization of the most promising areas of converging industrial interest for cross-cutting KETs

The described methodological approach allowed defining a list of key innovation fields of industrial interest with the highest potential for answering markets, industry and society demands from cross-cutting KETs developments, which constitute the nodes of the roadmap for cross-cutting KETs activities.

Starting from this list, as a final step in the development of the roadmap, innovation fields were first of all grouped within cross-sectoral domains and moreover classified within sub-domains. For each innovation field relevant for cross-cutting KETs activities, moreover, a dedicated fiche was developed, which describes the relevant information retrieved throughout the study for the specific innovation field.

2.2.5.1. The roadmap for cross-cutting KETs activities

The roadmapping activity has focused on exploring potential innovation areas in terms of products, processes, goods, 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 locate.

Cross-cutting KETs activities are accordingly expected to fulfill 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 significantly contribute to restoring growth in Europe and creating jobs in industry, contributing at the same time to tackle today's burning societal challenges.

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 between 4 and 8.

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.

The individual roadmaps for cross-cutting KETs activities as well as the fiches describing each individual innovation field comprised in the roadmap are provided as a dedicated, self-standing document.

2.2.6. Action V: Validation of the roadmap with stakeholders, policy makers, and the Commission

As a last action, the validation of the roadmap was sought. The validation process involved a number of stakeholders, policy makers, and the Commission. First of all, two workshops were organized in Brussels, before the public presentation of the roadmap at the final project's conference; one with stakeholders, pooling representatives of the vertical, technology-oriented ETPs (18 March 2014) and the other with policy makers, pooling particularly the regional/national agencies engaged in R&D&I policies definition (19 March 2014). The roadmap was furthermore presented at the RO-cKETs final conference (i.e. the RO-cKETs dedicated session of Conference "Key Enabling Technologies for a European Industrial Renaissance", which was held in Brussels on 2-3 April 2014).

The documentary basis for allowing these stakeholder groups to provide comments was a brochure-like document giving an overview of the methodological steps undertaken and of the identified important fields for future cross-cutting KETs developments, which was handed out at the conference and moreover distributed by both the project team and the Commission to several stakeholder groups after the conference. The Commission particularly took care of providing the document to and collecting the feedback from the Member States Group on KETs, the Sherpa Group, and several experts inside the Commission. The RO-cKETs team moreover took care of providing the document to and collecting the feedback from the technology-oriented ETPs, the Steering Committee members, and any other stakeholder, who expressed the interest to comment and remark.

An overall time window of more than 3 months was given to the aforementioned stakeholder groups in order to analyze the draft outcomes of the study and provide suggestions. With the support of the Steering Committee and the European Commission a procedure was agreed for dealing with the specific comments collected throughout this process, in order to fully benefit from all valuable inputs received.

2.2.7. Additional actions and assessments

2.2.7.1. Applicability of TRL and MRL based assessments in the project

Technology Readiness Levels (TRLs) are a systematic metric/measurement system that supports assessments of the maturity of a particular technology and the consistent comparison of maturity between different types of technology, thus providing a useful means to assess the risk associated with technology development.

The TRL measure was originally developed by NASA in the 1980's. Its original definition and scale only included seven levels, which were later expanded to nine. The metrics is nowadays used by both governmental agencies and many of the world's major technology-based companies to assess the maturity of evolving technologies (such as materials, components, devices, etc.) prior to incorporating them into a system or sub-system, especially in the case this passage would necessitate of relatively large investments and therefore careful strategic as well as investment decisions would need to be taken (companies in the aeronautics industry represent a clear example of actors making extensive use of the TRL metric/measurement system).

Similarly, Manufacturing Readiness Levels (MRLs) are a systematic metric/measurement system that supports assessments of the manufacturing maturity and risks underlying manufacturing processes related to a particular technological system or product. The metric is useful to take informed decisions related to investments in manufacturing processes.

Within this framework it has to be considered that both TRL and MRL are measures referring to individual technologies, whose characteristics are specifically known, and are therefore hardly transferable to broader groups or families of technologies, unless they are used as a range to indicatively provide information about the maturity of the particular technologies underlying the group or family of technologies of interest.

Hence, for a particular technology, the TRL can be specifically determined, whereas for a family of technologies, only a range of TRLs can be indicated based on the TRLs of the particular technologies underlying the family of technologies of interest. The same occurs for the MRL. For a particular technological system or product, the MRL can be specifically determined. For a family of systems or products, only a range of MRLs can be indicated based on the MRLs of the systems or products underlying the family of systems or products of interest.

According to the above statements, for a cluster of products addressing a same or a similar functionality by applying a variety of technological solutions, as are defined the Product/Market Combinations, or the innovation fields, determining the TRL or the MRL are not obvious tasks. Neither the TRL nor the MRL can be specifically determined because of the variety of technological solutions underlying the cluster of products of interest. In such a condition, it would only be possible to indicate a range of TRLs or MRLs based on the TRLs or MRLs of the technological solutions underlying the cluster of products of interest, if such technological solutions would be known. If in addition the products would be innovative ones and the applied technological solutions would not be known besides the fact that many technological solutions would be applicable to address a similar functionality, determining TRL or MRL is deemed to not be feasible at all. In such a situation, indication, with approximation, of the technological or manufacturing maturity could be qualitatively given based on the available information.

2.2.7.2. Assessment of the usefulness of the Innovation Readiness Level approach

An innovation lifecycle includes two macro phases, being technological development and market evolution. The Innovation Readiness Level (IRL) looks therefore not only at technological development but as well at market evolution, providing a framework for managers to position themselves and take into account key elements relating to innovation over its lifecycle.

In the process of managing innovation, both TRL and MRL provide useful checklists of key characteristics of technological development phases so that the risk associated with technology development as well as related manufacturing processes development could be appropriately assessed, and thus managed. Yet, innovation is not only associated to successful technological development (which would be more appropriately termed 'invention'). Innovation is rather a process that involves a multitude of aspects mutually depending one on each other, in which not only technology, market and organization but also other key aspects need to be taken into account such as partnership and risk.

The conceptual framework of IRL developed by Tao et al. (2010) comprises six phases (i.e. readiness levels) and considers five key aspects that determine the effective implementation of innovation, being:

1. Technology,
2. Market,
3. Organization,
4. Partnership,
5. Risk.

Accordingly, the lifecycle of innovation is divided into six phases, and for each phase, associated assessment aspects and criteria are identified, namely:

1. Concept: Basic scientific principles of the innovation are observed and reported, and the technology feasibility is confirmed, meaning that critical functions and/or characteristics are confirmed through experiments (equivalent to TRL 1-3), furthermore demand side aspects (such as customers needs and market demand) are observed, and first approaches are taken toward working with leading customers to confirm demand side aspects and strategic directions,
2. Components: Individual components are developed and validated through testing, and prototypes are developed to demonstrate the technology (equivalent to TRL 4-6), furthermore the IP is protected, end-customers are identified, the business potential is carefully analyzed and a business plan is issued comprising a detailed market launch plan; from an organizational point of view, not only the technological risk but as well the organizational risk are considered, an investment plan is initiated and the investment has started,
3. Completion: Technological development is completed and the complete system functionality is proven in the field (equivalent to TRL 7-9), the IP is definitely protected, the technology/product is documented and its launch can occur once specific needs and requirements of customers are known, market segments, sizes and shares have been predicted, pricing and launching options have been set according to careful market positioning, business modeling as well as planning, which encompasses a careful analysis of the market and competitive framework, the creation of partnerships, marketing, the development of sales

channels and customer relationships, the formalization of the corporate organization,
4. Chasm: The technology/product is first introduced in the market, expertise is formed, and market positioning, partnerships, sales channels, customer relationships, marketing strategies are consolidated,
5. Competition: The market reaches a mature phase, market positioning is maintained and enhanced including through product innovation, differentiation (as regards both products and services), the creation of new partnerships, etc.
6. Changeover/Closedown: The market reaches a declining stage, and learning from experiences occurs based on which strategic decisions are taken on whether to re-innovate technology, inaugurate new markets, transform the business model, and provide for corporate re-invention, in order to seek and develop competitive advantage (changeover), or whether to alternatively exit the market (closedown).

Basically, IRL is a comprehensive framework depicting the development of an innovation over its lifecycle and can therefore provide a useful checklist of criteria for managing an innovation life cycle. Encompassing TRL and MRL, IRL does however not only look into technological development, which is only one key aspect of innovation, but as well into other key aspects, such as market, organization, partnership, and risk, which determine the effective implementation of innovation. By providing better monitoring and control, IRL is intended to help implement innovation over the lifecycle more effectively and is thus expected to apply as a management tool as well. Within this framework, **IRL is applicable** at company as well as **at project level**.

Especially for the purpose of project monitoring and assessment, IRL is therefore considered to be a more comprehensive systematic metric/measurement system than either TRL or MRL individually (or even combined among themselves), though the latter two being equally important for assessing specific aspects of technology development.

Yet, IRL alone does not provide for the required information that is necessary, for managers in order to take informed strategic decisions, nor for project controllers for monitoring and assessing a project's performance, if not combined with other appropriate tools. As said, it is rather a checklist of criteria that have to be fulfilled prior to take next steps in an innovation lifecycle, and in this sense it can be extremely useful, but **it needs to rely on several other more practical tools that shall be applied in order to provide for the specific information that is fundamentally required for the actual detailed assessment of risks**. Provided that technological risk is appropriately assessed, thanks to undertaking the various steps foreseen by the TRL and MRL frameworks, **business planning is also considered to be a crucial practical instrument to provide for an effective assessment of the risks inherent in the launch of a new business or a new product on the market** once there would be the conditions to do so.

Since cross-cutting KETs activities will in general include activities closer to market and applications, they particularly refer to phase 2 as well as to a part of phase 3 – up to TRL 8 – of the IRL framework. The assessment aspects and criteria associated to these phases are therefore considered to be highly relevant for cross-cutting KETs activities. While some assessment aspects are covered by the TRL and MRL frameworks, other crucial aspects that have to be fulfilled prior to take next steps in an innovation lifecycle, such as, particularly, the protection of the IP and the careful analysis of the business potential of an innovation (based on the identification of market segments and end-customers, the analysis of the competitive framework, the consequent prediction of market sizes and shares, the creation of partnerships, etc.), are not. Since all these aspects form part of the specific contents of a business plan, and since the related steps should have been already undertaken for an innovation developed until TRL 8, business planning is deemed to be a crucial practical instrument to provide for an effective assessment of the risks inherent in the launch of a new business or a new product on the market once there would be the conditions to do so, to be applied both as a self-assessment tool and for documenting the results of the analysis into each of the above assessment aspects.

3. PROPOSAL FOR A CROSS-CUTTING KETS PROGRAMME UNDER HORIZON 2020

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)[7]. 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 [...][7].'

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.

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.

As a first step towards an effective intervention, the Commission decided to focus part of its policy and supporting instruments (i.e. adoption of a thematic policy approach), and implement a cross-cutting KETs work programme as part of Horizon 2020. 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.

Within this framework, the main scope of the RO-cKETs study has been to develop a methodology by which to identify opportunities for cross-cutting KETs developments and consequently to develop a roadmap for cross-cutting KETs activities, identifying the potential innovation fields of industrial interest relevant for cross-cutting KETs. Such a roadmap shall provide input to the Commission for the preparation of the cross-cutting KETs part of Horizon 2020. Taking the demand side as a starting point, the roadmap identifies in fact the most promising areas of innovation for cross-cutting KETs that address clear industrial and market needs, providing indication of opportunities for the cross-fertilization between KETs for developing innovative and competitive products, processes and services in a broad number of industrial sectors.

In order to provide comprehensive input to the preparation of the cross-cutting KETs work programme of Horizon 2020, the study shall furthermore formulate a proposal for a cross-cutting KETs programme that shall include, among other items, selection criteria for cross-cutting KETs projects besides criteria and performance indicators for projects monitoring and assessment.

3.1. Proposed structure for a cross-cutting KETs programme under Horizon 2020

According to opinions of industrial stakeholders collected throughout the interviews as well as at the workshops organized within the framework of the study, a successful practical implementation of cross-cutting KETs projects should be supported by a programme organized into two kinds of activities:

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

1. a first kind of activities focussing on the development of first ("ugly") small scale prototypes built in a laboratory environment, promoting collaboration of industry with academic institutions, RTOs and other technology transfer organizations, operating around TRL 4, which should be fed from new knowledge and technological concepts generated throughout basic research, technology formulation and applied research up to the proof of concept (i.e. from activities conducted outside the cross-cutting KETs programme, aimed at generating new knowledge and technological concepts in each of the specific KETs, operating for this on TRLs in the range 1-3);
2. a second kind of activities focussing on industrial innovation and supporting actions aimed at the pre-competitive demonstration of products and processes including by pilot actions. This kind of activities should operate on TRLs of 5 or higher (up to TRL 8) with the objective to develop and introduce product and process innovation on the market on short term basis (3 years), promoting collaboration among industry, whereby the process should be led by industrial players capable of transferring their vision for innovation along the whole value chain, thus steering the change both downstream (suppliers) and upstream (customers).

These two sets of activities specifically falling within the framework of a cross-cutting KETs programme should be complemented by a third set of activities, not being part of the cross-cutting KETs programme itself, but being aligned with it, focussing on infrastructures/facilities development toward manufacturing and production, exploiting risk finance and loans or guarantees as well as national/regional funding such as funding provided under the Structural Funds, in which customer-supplier based relations would gain in importance along with the creation of representative monitoring data sets to create confidence around innovative technological solutions.

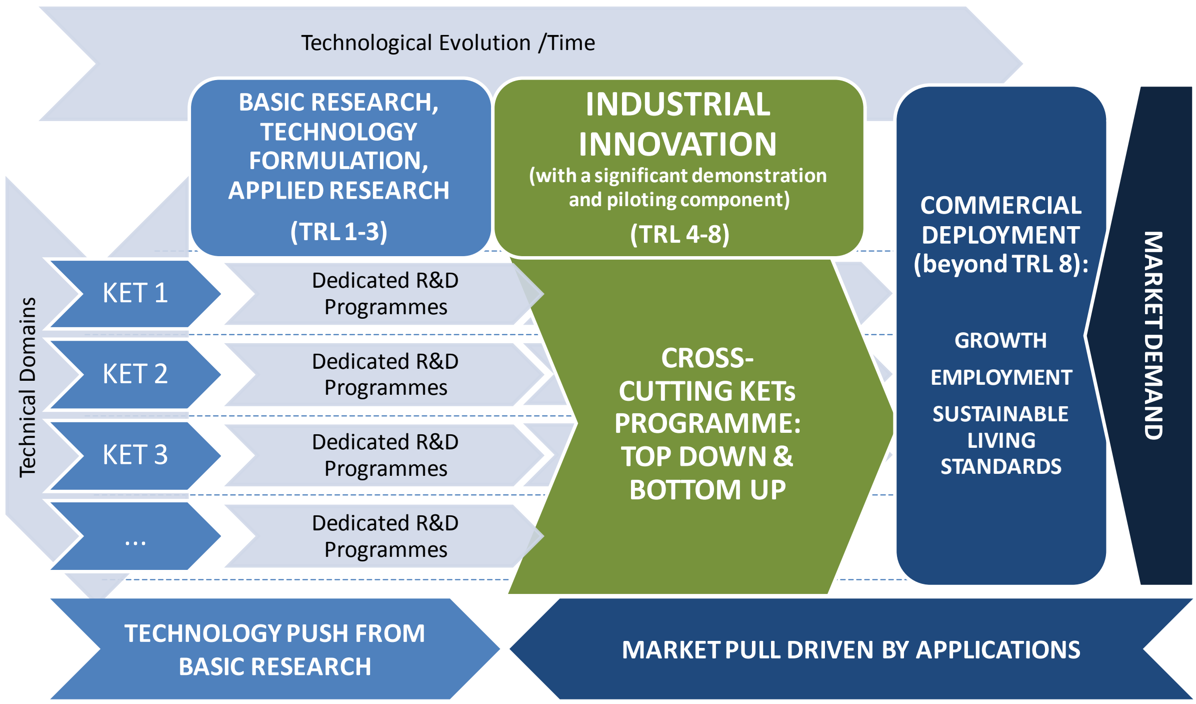

Figure 15: Proposed structure for a cross-cutting KETs programme under Horizon 2020

According to this model, basic research, technology formulation and applied research related to individual KETs conducted in the framework of dedicated R&D programmes would feed important technological developments corresponding to TRLs 1-3 to the cross-cutting KETs programme. The latter would hence leverage new technologies whose concepts would have been already proven and engage industry in preparatory projects carried out in strict collaboration between industry and the research community (including academic institutions, RTOs and other technology transfer organizations) so to create the initial backbone for the development of innovative and competitive products, processes and services. Within this framework, preparatory projects should be aimed at developing and testing, at this stage in laboratory or relevant reduced scale environments (corresponding to TRLs 4-5), prototype components in relation to which the cross-fertilization between KETs could provide a clear added value and competitive advantage. Such cross-cutting KETs based components should later on enable the development of innovative products, processes, or services by industry, and therefore industry should be involved in projects under this kind of activities since the early stages of their development in order to steer developments and confirm that they can actually deliver industrially viable solutions capable of adequately satisfying demand related aspects.

Flowing into the second kind of activities, these cross-cutting KETs based components should be upgraded to or integrated into pre-competitive prototypes of innovative products, processes, or services. Projects in this respect should be aimed at demonstrating the so developed component as well as system prototypes in industrially relevant environments first and in operational environments as a next step. Besides the components/systems, manufacturability should be assessed at this stage in that manufacturing and production methods or processes should be conceptually developed and relevant manufacturing/processing steps should be validated at the reduced scale. Pilot scale demonstrators of complete systems should then be developed and in this respect manufacturability should be assessed on industrially relevant scales in that applicability of industrially relevant manufacturing methods/processes (as adapted to the new components/systems) should be proven (not only from the technical but also from the economic point of view). First steps toward system completion and qualification should also be undertaken. Associated to projects under this kind of activities, industry should clearly have a dominant role and collaboration with the research community (i.e. academic institutions, RTOs and other technology transfer organizations) should be instrumental to achieve industrial objectives. Moreover, the whole value chain (inclusive of relevant suppliers as well as customers) that is necessary to achieve the development of innovative products, processes, or services and their future deployment onto relevant markets should be covered as well as each industrial player in this value chain should have a sound exploitation plan in that respect. Preferably, an anchor company capable of transferring its vision along the whole industrial value chain should steer each project under this kind of activities. Projects under this kind of activities and especially those that have reached the higher TRLs (i.e. TRLs 7-8) should clearly document the business potential of the proposed cross-cutting KETs based innovative products, processes, or services by a sound business plan.

Such business plans should be the documentary basis to attract additional financing sources for the development of first-of-a-kind, commercial-scale industrial demonstration projects in the form of either risk-sharing or risk financing. This third kind of activities should focus on infrastructures/facilities development toward manufacturing and production and, from an organizational point of view, on building strong customer-supplier based relations along the whole value chain. Besides exploiting risk finance and loans or guarantees, this kind of activities could use as well as national/regional funding such as funding provided under the Structural Funds.

Hence, in line with this model, a cross-cutting KETs programme should encompass different types of projects that should span across the whole chain of technological development starting from TRL 4, thus covering, with particular characteristics, each phase, from the stage of technology validation in laboratory environments to large scale pilot prototyping and demonstration, namely:

- **Preparatory projects**: small to medium sized collaborative R&D&I projects focused on developing and validating cross-cutting KETs based components thanks to experimental testing in laboratory and relevant environments (i.e.

having their focus on TRLs 4-5). These projects should set the basis for the development of early pre-competitive prototypes of innovative products, processes, or services and for value chain building and demand aspects exploration;

- **Innovative product, process or service development projects**: medium to large sized collaborative R&D&I projects focused on the upgrading or the integration of the cross-cutting KETs based components explored up to TRLs 4-5 into early pre-competitive prototypes of innovative products, processes, or services and on the early demonstration of the so developed component as well as system prototypes in industrially relevant environments and in operational environments (i.e. having their focus on TRLs 5-7). These projects should also tackle the development of manufacturing and production methods and processes as well as explore market potentials and demand related aspects in detail.
- **Projects aimed at the pilot scale demonstration of complete systems**: large or very large sized collaborative projects with a large pre-competitive demonstration component aiming at demonstrating complete systems thanks to pilot prototyping and demonstration in real operational environments or settings (i.e. having their focus on TRL 7-8). These projects should also assess manufacturability on industrially relevant scales. They shall be particularly aimed at confirming techno-economic feasibility of cross-cutting KETs developments from the various aspects points of view and as such be aimed at generating hard evidence as well as at collecting all technical/economic key parameters needed for investment decisions for industrial deployment.

3.2. Mechanisms for updating the roadmap and work plan

Each of the strategic objectives, represented in the roadmap by the key innovation fields of industrial interest with highest potential for answering markets, industry and society demands from cross-cutting KETs developments, can be met through a combination of activities at different TRLs, each contributing in the short or medium term. Streams of R&D&I actions (typically associated to either ‘preparatory projects’ or to ‘innovative product, process or service development projects’ as highlighted in Section 3.1) and demonstration actions (typically associated to ‘projects aimed at the pilot scale demonstration of complete systems’ as also highlighted in Section 3.1) can be organized along waves starting from the current readiness levels of technologies and moving along time towards increasing the readiness level of those technologies; the beginning of a new wave (starting with preparatory projects at low TRL focused on developing and validating cross-cutting KETs based components thanks to experimental testing in laboratory and relevant environments) is foreseen whenever a new disruptive technology stream becomes available through fundamental research discoveries or when innovation activities at higher TRL would highlight knowledge gaps that need to be filled by R&D activities.

R&D activities would hence respond to filling gaps in technological capacities thereby providing enabling solutions (i.e. cross-cutting KETs based components) for subsequent integration within early prototypes of innovative products, processes, or services and their larger scale implementation at demonstration level; as such, R&D actions are precursors to demonstration actions, but on the other hand they are also triggered by challenges encountered within demonstration activities, if any. In this latter case, challenges encountered within large demonstration activities would generate new “R&D waves” if new enabling solutions could be proposed.

The birth of a new wave along a specific development line does not necessarily mean that the previous wave should be abandoned: demonstration actions along that line could still enable “first wave” pilot scale demonstration of complete systems, that may occur in parallel to “second wave” R&D&I actions devoted to resolve specific bottlenecks associated to activities referring to the “first wave”.

Within the RO-cKETs study, the framework and strategic objectives (i.e. the expected cross-cutting KETs developments related to key innovation fields), along with an indicative timing for providing dedicated support, have been defined and suggested as input to the Commission (proposed timing is individually reported in each fiche in line with the priority relevance – short-term or medium-term – identified for each innovation field). From this initial suggestion, the timing for providing dedicated support should be derived by the Commission, also taking into account that many of the proposed innovation fields can actually be considered as being subject to continuous, incremental improvement. In fact, they are associated with well-established market needs driving the continuous development of new products, processes, goods, and services as soon as new enabling technologies or technological solutions become available.

In the wake of launching the biannual work programmes as foreseen by Horizon 2020, the Commission might perform additional surveys among the stakeholders' community at large in order to update priorities and needs of each industrial sector related to cross-cutting KETs according to the strategic objectives outlined in the roadmap and to assess the current and foreseen readiness level of the related enabling solutions. On the basis of such a dedicated consultation, it will be possible to define the time when specific supporting contribution for each of the strategic objectives defined by the key innovation fields of industrial interest with the highest potential for answering markets, industry and society demands from cross-cutting KETs developments could be provided. This consultation will make it possible to define the expected timeline of activities needed to accomplish the programme's goals: this timeline will provide the overall framework to be mirrored in the structure of forthcoming calls for proposals.

In line with this suggested procedure as well as with the procedures applied for the preparation of the other Work Programmes in Horizon 2020, it is hence suggested that the activation of specific R&D&I or demonstration actions for single development lines is defined biannually through a dedicated scoping document. The scoping document would then form the backbone of the part of the biannual work programme that would be dedicated to cross-cutting KETs, sketching the calls and topics to be addressed within each year's activities in order to achieve the strategic objectives represented in the roadmap by the key innovation fields of industrial interest with highest potential for answering markets, industry and society demands from cross-cutting KETs developments. On the basis of a biannual stakeholders consultation performed for the scoping document, it will be possible to revise the roadmap and the present work plan (e.g. adding new innovation fields, eliminating innovation fields that no longer constitute a strategic objective, updating if a strategic objective should be better addressed by a preparatory project, an innovative product, process or service development project or a project aimed at the pilot scale demonstration of complete systems according to progress in the state of the art, etc.), for instance taking into account new technological developments or discoveries.

3.3. Proposed criteria for the selection of cross-cutting KETs based projects under Horizon 2020

Proposed criteria for the selection of cross-cutting KETs based projects under a cross-cutting KETs programme are a logic consequence of the above structure for a cross-cutting KETs programme and related characteristics. Criteria should be distinguished into fundamental high level criteria and specific criteria, a list of which is provided hereinafter.

3.3.1. Fundamental high level criteria

Cross-cutting KETs activities are expected to combine 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 significantly contribute to restoring growth in Europe and creating jobs in industry, contributing at the same time to tackle today's societal challenges. In addition, several other important high level criteria should be fulfilled. Within this framework, the following fundamental selection criteria can be formulated and suggested:

- **Projects shall bring together and integrate different KETs and reflect the interdisciplinary nature of technological development**. In this respect the cross-fertilization of different KETs shall create value beyond the sum of the individual technologies. The cross-fertilization between KETs shall moreover provide a clear added value and competitive advantage. Each of those aspects shall be explicitly justified within project proposals in that the contributing KETs shall be clearly defined and the way they would be integrated concretely described as well as the value created by this integration beyond the sum of the individual technologies argued. Furthermore, the added value and competitive advantage provided by the cross-fertilization between KETs shall be defined and described in a concrete and identifiable manner.
- **projects shall be of a major innovative nature or constitute an important added value in terms of R&D&I** in the light of the state of the art in the sector concerned (or the sectors concerned in case projects would be of cross-sectoral relevance).
- **Projects shall contribute to address societal challenges as well as have the potential to concretely contribute to restoring growth in Europe**. In this respect, projects shall have **concrete potential for commercial deployment** of the developed innovative products, processes, or services and as such represent **opportunities for the creation of concrete business cases** capable of generating value added in Europe. Such potential shall be clearly justified within project proposals starting from a **detailed analysis of the demand**. It shall moreover be evidenced by the existence of concrete perspectives of economic benefits provided to the industrial proposers, which shall be explicitly defined as well as quantified within project proposals.
- **Projects shall thereby involve a significant number of industrial undertakings as well as involve co-financing by the involved beneficiaries**.
- **Projects shall contribute to creating jobs and/or increasing KETs-related skills in industry**. In this respect, besides having the potential to provide economic benefits to the concerned industrial proposers, projects shall moreover contribute to create new jobs at the premises of the industrial proposers or at least help to maintain current employment levels but increasing the level of, especially, KETs-related skills among employees. Specific impacts on employment shall therefore also be defined and described in a concrete and measurable manner in project proposals.
- **The benefits of projects shall not be limited to the concerned industrial proposers but shall have wider relevance and application to the European economy or society through positive spill-over effects** (such as having systemic effects on multiple levels of the value chain, or up- or downstream markets, or having alternative uses in other sectors). The latter shall be clearly defined and described in a concrete and identifiable manner in project proposals.

3.3.2. Specific criteria

In addition to the above fundamental high level criteria, several other more project specific selection criteria should be fulfilled, namely:

- **Projects shall involve important collaborative interactions among the beneficiaries.** The latter shall be reflected not only in terms of the number of participants but as well in terms of **value chain coverage**. Cross-cutting KETs activities may imply a re-organization of complete value chains within a number of industrial sectors. The need for this re-organization stems from the need to integrate, in the product development process, technologies that may be completely new for a specific sector, and thus, all the related capabilities required to face appropriately the product development phase. This has to occur on two levels; on the level of disciplines (to ensure that all disciplines concurring to the cross-cutting KETs development are covered) and on the level of the supply chain (to ensure the establishment of a supply chain that integrates all the required cross-cutting KETs based components towards the commercial phase). The need for this re-organization is most evident for traditional value chains, which need to be extended beyond their conventional players in order to integrate new players with the specific capabilities in KETs and cross-cutting KETs based components. A good example of this situation may be represented by the textiles and clothing sector. Driven by the need to restructure, the textiles and clothing industry is already experiencing a period of change in the supply chain as well as value chain. Among others, this industry is particularly experiencing a change from providing commodities to providing specialty products, in whose regard the cross-fertilization between KETs can find a relevant role. The integration of cross-cutting KETs based components into wearable textiles and clothing capable of measuring and communicating human living functions (including through integrating sensors, flexible screens, embedded energy storage or harvesting devices, etc.) - which is one of the innovation fields of industrial interest relevant for cross-cutting KETs considered in the roadmap, for example - requires integration between value chains operating in the textiles and clothing sector and others operating in the electronic and telecommunications systems and components sector. Another example may be represented by the electric vehicles value chain that needs to integrate with the electric batteries value chain as well as the value chain ensuring electrification of the European infrastructure. In order to ensure an adequate value chain coverage, projects should thus involve industrial players of all relevant value chains and prove that there would be no important gaps in the capability of the extended value chain to face a joint product development. Collaborations with academic institutions, RTOs and other technology transfer organizations shall moreover be promoted where instrumental to achieve the project's industrially relevant objectives. Especially for lower TRLs (in the range 4-5) the latter shall be involved to ensure that all necessary disciplines are adequately covered in order to knowledgeably face the multidisciplinary cross-cutting KETs developments, but importantly they shall also be involved for higher TRLs in the case they could provide relevant testing facilities and equipment for the testing and validation of prototypes in relevant environments. The number of the involved beneficiaries shall in any case adequately fulfil the specific functional requirements of the project in terms of roles' coverage. High-tech industrial organizations shall importantly be involved as suppliers of relevant KET-related components and have determinant roles in the specific cross-cutting KETs developments. Relevant customers shall moreover be involved and allow to validate demand related aspects. An anchor company capable of transferring its vision along the whole industrial value chain should preferably steer the project.

- **Each industrial proposer in the value chain should have a sound exploitation plan reflecting concrete plans for a future commercialization** of the developed cross-cutting KETs based innovative products, processes, or services, evidence of which shall be clearly provided in project proposals.
- For cross-cutting KETs developments especially in sectors in which SMEs play an important role, **projects shall significantly involve SMEs to cover roles that are instrumental for the achievement of the project's objectives**. Participation of SMEs shall not (only) be demonstrated by the number of SME undertakings participating in the projects, but (also) by the budget reserved to them.

- **Projects shall address the development of either cross-cutting KETs based products or services or of cross-cutting KETs based manufacturing or production processes** with a high innovation content.
- **Projects shall thereby have a clear market potential and associated economic impact** that justifies the specific investment by the participating organizations (especially the industrial ones in this respect) as well as the financial support to be provided by the European Commission. Such market potential shall be realistically described and calculated and the associated economic impact shall be duly quantified within project proposals. Individual economic benefits to the industrial proposers shall be quantified as well. Expected Return on Investment shall be specified along with a clear description of how it is calculated. A rationale of how the contribution by the European Commission would help to lower the financial risk associated with the project shall also be provided. To this aim, proposers should submit, within their proposals, exploitation and business plans associated with their project, which should describe how the consortium intends to use the results of the activities carried out during the project. Considering that cross-cutting KETs activities will, in general, include activities closer to market and applications, the primary use of the results of the activities should be the development, creation and marketing of a cross-cutting KETs based product or process, or the provision of a service involving cross-cutting KETs. Outlined plans should of course be appropriate to the scale and development status / TRL of the specific project, yet be convincing in providing information on how the planned exploitable results would contribute to the business and growth strategy of the different partners (with focus on the industrial partners).

3.4. Proposed means and criteria for the performance monitoring and assessment of a cross-cutting KETs programme under Horizon 2020

With a view to ensure the achievement of a dedicated programme's mission and objectives, the Commission will have to assess the programme's performance by means of a balanced performance measurement system, which shall be aligned with the performance measurement system that is applied to other parts of Horizon 2020, but keep a specific view on cross-cutting KETs. The fundamentals of this system are to monitor and assess over time the specific programme's progress as well as impacts and to support the full deployment of a result oriented culture.

Such a performance measurement system shall be designed to encompass three levels of monitoring and shall be based on performance indicators, a selection of which is proposed hereinafter.

Firstly, the aggregated impact at Union level of the implementation of the programme shall be assessed. A common set of impact indicators to assess the impact at the European Union level of the implementation of the cross-cutting KETs programme shall be applied. This first level shall contain indicators to measure the programme's contribution to the general objectives of Horizon 2020, the Innovation Union and the policies on Key Enabling Technologies. Although the cross-cutting KETs programme will be a crucial trigger for the achievement of these objectives, achievement of these objectives will not be the direct result nor the sole responsibility of the programme on cross-cutting KETs.

Table 8: Common impact indicators to assess the aggregated impact, at the European Union level, of the implementation of a cross-cutting KETs programme

Indicator	Unit
Economic growth	
Net additional gross value added	Purchasing Power Standard (PPS)
Jobs	
Employment creation (overall)	Full-time equivalents
Employment creation in manufacturing	Full-time equivalents
Employment creation in R&D&I positions	Full-time equivalents

Secondly, these common impact indicators should be complemented by programme-specific output as well as result indicators. These shall reflect the programme's specific mission and objectives and aim at monitoring the progress within the cross-cutting KETs programme and measuring how the specific research and innovation targets defined within the roadmap for cross-cutting KETs activities are met (output and result).

Table 9: Programme-specific output indicators to assess the progress of the implementation of a cross-cutting KETs programme

Indicator	Unit
Number of enterprises receiving support	Number of enterprises
Number of enterprises receiving grants	Number of enterprises
Number of enterprises receiving financial support other than grants	Number of enterprises
Number of new enterprises receiving support	Number of enterprises
Number of small- and medium-sized enterprises receiving support	Number of enterprises
Number of enterprises cooperating with research institutions	Number of enterprises
Number of enterprises receiving support per industry sector	Number of enterprises
Number of enterprises receiving support per theme	Number of enterprises
Financial support provided to enterprises (grants)	EUR

Indicator	Unit
Financial support provided to enterprises (non-grants)	EUR
Private investment matching public support to enterprises (grants)	EUR
Private investment matching public support to enterprises (non-grants)	EUR
Number of projects suitable for receiving joint financial support under Horizon 2020 and ESIF	Number of projects
Number of projects with close to market activities (i.e. with high TRL)	Number of projects

Table 10: Programme-specific result indicators to assess the result of the implementation of a cross-cutting KETs programme

Indicator	Unit
Number of KETs as well as cross-cutting KETs related patents filed	Number of patents
Ratio between number of enterprises receiving financial support other than grants and number of enterprises receiving grants[8]	Ratio
Number of enterprises supported to introduce to the market new cross-cutting KETs based products, processes, goods, or services developed in supported R&D&I projects	Number of enterprises
Number of enterprises supported to introduce to the market new cross-cutting KETs based products, processes, goods, or services developed in supported R&D&I projects and committed to manufacturing in Europe	Number of enterprises
Employment increase in supported enterprises directly associated to the introduction to the market of new cross-cutting KETs based products, processes, goods, or services developed in supported R&D&I projects	Full-time equivalents
Employment increase in supported enterprises (overall)	Full-time equivalents
Employment increase in manufacturing in supported enterprises	Full-time equivalents
Employment increase in R&D&I positions in supported enterprises	Full-time equivalents

[8] If this ratio would be too close to zero, it would be an indicator of research and innovation projects' results supported by grants poorly flowing into market application and commercialization

Indicator	Unit
Take-up of developed technological solutions by manufacturing industries as well as relevant service industries	Number of technological solutions

Thirdly, project-specific output as well as result indicators shall complement the former two sets of indicators. These indicators shall constitute the third level monitoring tool and shall be directly set by projects in regard to their specific goals, objectives and claims regarding the specific impact that the project would have on both economic growth and employment. These indicators shall allow monitoring the progress and assessing the success of each cross-cutting KETs based project supported under the cross-cutting KETs programme.

3.5. Proposed means and criteria for the monitoring and assessment of cross-cutting KETs based projects under Horizon 2020

While the means for the assessment of the accomplishment of the overall strategic objectives of a cross-cutting KETs programme are described in the previous section, this part is aimed at providing suggestions as regards tools as well as criteria to be applied in order to accomplish the assessment of cross-cutting KETs based projects under such a cross-cutting KETs programme.

To assess projects' performance as well as the impact of projects' results, the use of various tools and the assessment of the projects against a series of specific criteria shall be foreseen in line with the rules of Horizon 2020 as well as the specific characteristics that cross-cutting KETs developments should have (as reported in previous sections). While the proper implementation of projects should be checked according to the rules foreseen by Horizon 2020, cross-cutting KETs based projects should be additionally assessed against a number of programme-specific criteria. Such criteria shall be defined in line with the projects' selection criteria and the above described second level indicators and provide the means for the assessment and verification of the selected projects' performance.

In line with the criteria defined for the selection of cross-cutting KETs based projects, the following monitoring and assessment criteria are suggested for the performance evaluation of individual projects both throughout their implementation and after their completion.

Table 11: Monitoring and assessment criteria for the performance evaluation of individual projects

Projects' selection criteria	Monitoring and assessment criteria for the performance evaluation of individual projects
Projects shall have concrete potential for commercial deployment of the developed innovative products, processes, or services.	To allow the assessment of the continued relevance of the projects against this specific programme's objective, this aspect shall be explicitly justified within the plan for the exploitation and dissemination of the results. The latter shall not only be provided as a final version at the end of the projects but as well as preliminary versions along with the projects' periodic technical reports. This shall allow the Commission or external reviewers to assess the progress made with respect to commercial plans that shall be carried on in parallel to technical development plans within projects. Moreover, at the end of projects, along with projects' final reports and final versions of the plan for the exploitation and

Projects' selection criteria	Monitoring and assessment criteria for the performance evaluation of individual projects
	dissemination of the results, projects should clearly document the business potential of the proposed cross-cutting KETs based innovative products, processes, or services by a sound and concrete business plan. Besides other relevant aspects typical of a business plan, such a document shall clearly describe the applicable business model along with already concretely identified business partnerships and their respective roles in the proposed business as well as value chain. Whenever, in order to guarantee an adequate value chain coverage, a minor part of such business partnerships would still have to be identified, the business plan shall report concrete actions toward identifying such missing value chain partners.
Projects shall have a clear market potential and associated economic impact. **Individual economic benefits to the industrial proposers shall be quantified.** **Expected Return on Investment shall be specified.**	The business plan to be delivered along with the final reporting shall provide, among other relevant aspects typical of a business plan, a detailed market analysis. This shall encompass a careful analysis of the market and competitive framework and a clear definition of the market segments to be addressed based on a careful analysis of end users/customers expectations, besides the definition of realistic market shares to be gained by the proposed solution. Starting from this comprehensive market analysis and identified potential market figure, the associated economic benefits to the industrial proposers (and for any additional business partner in line with the described value chain) shall be quantified and explicitly provided as a figure.
Projects shall contribute to creating jobs and/or increasing KETs-related skills in industry.	To allow the assessment of the continued relevance of the projects against this specific programme's objective, this aspect shall be explicitly justified as well within the preliminary plans for the exploitation and dissemination of the results. Expected impacts on employment shall therefore also be defined and described in a concrete and measurable manner in projects' preliminary as well as final plans for the exploitation and dissemination of the results.

3.6. Impact and benefits to the EU resulting from a cross-cutting KETs programme

KETs have the inherent ability to enable advances in all industries and sectors as well as in all regions and countries and the same can be said for the cross-fertilization between KETs, as observed throughout the roadmapping exercise conducted within the RO-cKETs study, which has focused on exploring potential innovation areas in terms of products, processes, or services with respect to which the integration of KETs can provide an added value, taking into account the main market drivers for each of those innovation areas.

According to the study results, developments involving cross-cutting KETs can occur across Europe at large and as such they are not dependant from an industrial undertaking's location of establishment, nor are they dependant from a company's size or geographical dimension of its market(s). Within this framework, whilst determining the exact market potentials of cross-cutting KETs is difficult, the direct economic impacts that the development of cross-cutting KETs based products, processes, goods, or services can generate is expected to be considerable.

As evidenced by the developed roadmap and the many innovation fields identified as being relevant for cross-cutting KETs developments, cross-cutting KETs can feed into many different industrial value chains and sectors in heterogeneous ways. Thereby, they can create value along the whole chain – from technologies, sub-systems and components, through whole systems, equipment and devices, to products, processes, goods and services. Cross-cutting KETs developments moreover transversally cross-cut across industrial sectors and as such they can have the same systemic relevance to European industries as KETs individually.

Each of the domains, sub-domains and innovation fields, in respect to which cross-cutting KETs developments have been identified as being relevant, points out to relevant markets capable of sustaining significant value added as well as employment in the EU, as evidenced in the roadmap document in regard to the domains and individually in the fiches annexed to the main document, which singularly refer to the innovation fields, whenever relevant figures could be identified at the level of the innovation field.

3.7. Synergies with other EU programmes and policies

Key Enabling Technologies are of systemic relevance. They have the inherent ability to enable advances in all industries and sectors as well as in all regions and countries. The European Commission is therefore seeking to adapt EU instruments and policies in support of KETs deployment and has already achieved in several of its intents.

Developments involving KETs, either individually or in a cross-fertilizing manner, can occur across Europe at large and are not necessarily concentrated in particular countries or regions. Yet, regional or local clusters exist that may be (smartly) specialized in one or the other KETs in line with industrial development strategies pursued by the specific country or region. This is why the European Commission is seeking for synergies between the European Structural and Investment Funds (ESIF) and Horizon 2020 for Key Enabling Technologies, which also applies to cross-cutting KETs developments. This is being achieved by the Commission thanks to raising awareness on KETs as drivers for industrial competitiveness in regions and encouraging regions to take up KETs that are relevant for their smart specialisation. The Commission is also dedicating effort in stimulating interaction between national/regional actors and stakeholders engaged in R&D&I activities within Horizon 2020 in order to enhance synergies. Complementarities as well as interregional cooperation are moreover being promoted between the regions. In particular the alignment and complementary use of R&D&I funding and structural funds is being promoted. Within this framework, Key Enabling Technologies have been singled out as a priority investment area for the European Regional Development Fund (ERDF). Moreover, the opportunity to exploit combinations of grants and repayable financial instruments has been enabled along with the possibility, under the Structural Funds, of receiving financing up till first production (TRL 9), which strongly supports KETs integration in regional smart specialization strategies as well as a seamless support toward commercialization.

The opportunity to exploit combinations of grants, with particular reference to the Structural Funds, is particularly relevant for closer to market cross-cutting KETs activities and, in this respect, especially for those projects aimed at the pilot scale demonstration of complete systems (see section 3.1), for which large investments would be required. Such large or very large sized projects aiming at demonstrating complete systems thanks to pilot prototyping and demonstration in real operational environments or settings, shall be particularly aimed at confirming techno-economic feasibility of cross-cutting KETs developments from the various points of view and as such be aimed at generating hard evidence as well as at collecting all technical/economic key parameters needed for investment decisions for a subsequent industrial deployment. Accordingly, these kinds of projects would be precursors of first market replication projects, which could also exploit the Structural Funds or repayable financial instruments including those provided by the European Investment Bank.

A Memorandum of Understanding has in fact been signed between the European Commission and the European Investment Bank that will pave the way for improved access to finance for investments in Key Enabling Technologies. The Memorandum of Understanding defines KETs as a mutual priority area for the Commission and the European Investment Bank, providing details on the eligible support for KETs-related projects, including all stages of R&D&I up to first production. Thereby the Commission will ensure, together with the European Investment Bank, that vital lending is provided to eligible private sector investments in product demonstration and first production projects promoting KETs as well as cross-cutting KETs activities across all European regions. Through this Memorandum of Understanding the Commission intends to continue with the European Investment Bank its vital R&D&I support to KETs projects, notably through the financial instruments proposed under Horizon 2020 and COSME, the EU programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises, which foresees, among other measures, improved access to finance for SMEs through two different financial instruments, namely the Loan Guarantee Facility and the Equity Facility for Growth. Despite not specific for cross-cutting KETs activities, both the financial instruments funded by the COSME budget can help SMEs to obtain financial support in the form of lending for private sector investments aimed at the first market application and commercialization of cross-cutting KETs based products obtained as a result of cross-cutting KETs activities conducted under Horizon 2020. Besides providing access to financing for growth oriented companies that do not fall under the focus of Horizon 2020, COSME will also aim at developing better framework conditions for SME growth in the context of industrial change in particular through clusters and in sector of strategic interest, and supporting the internationalisation of business activities of SMEs[9].

Actually, also Horizon 2020 has two new instruments dedicated to SMEs, which could be exploited for funding cross-cutting KETs activities, despite not specifically, namely the SME Instrument and the Fast Track to Innovation pilot instrument. The SME Instrument is aimed at offering business innovation support to SMEs, allowing SMEs (including single companies) to obtain funding and support for high-potential innovation projects that will help them grow and expand their activities internationally. It foresees several thematic, yet quite open calls under both the section Societal Challenges and the specific part Leadership in Enabling and Industrial Technologies (LEITs) and is thus deemed to be an important opportunity for SMEs engaging with the development of cross-cutting KETs based products, processes, goods, or services as well, despite not specifically thought for cross-cutting KETs activities, because it can stimulate the generation of bottom-up ideas for cross-cutting KETs developments. Also in a logic of allowing SMEs to come up with bottom-up ideas related to cross-cutting KETs developments, the Fast Track to Innovation (pilot) instrument can be an opportunity. Consisting at present of a pilot instrument, it aims to reduce the time from idea to market and to increase the participation in Horizon 2020 of industry, SMEs and first-time industry applicants. Thereby, it should stimulate private sector investment, promote R&D and innovation with a focus on value creation, and accelerate the development of innovative products, processes and services, aiming particularly at nurturing trans-disciplinary and cross-sector approaches and business-driven innovation clearly demonstrating a realistic potential for quick deployment and

[9] Horizon 2020 Work Programme 2014 – 2015, Innovation in small and medium-sized enterprises, Revised, European Commission Decision C (2014)4995 of 22 July 2014

market take-up[10], thus being well aligned with the objectives of the cross-cutting KETs programme.

Key Enabling Technologies have been also defined as a priority area for the Important Projects of Common European Interest (IPCEIs). IPCEIs can actually be relevant for all policies and actions that fulfil common European objectives, in particular as regards the Europe 2020 objectives, the Union's flagship initiatives and key areas for economic growth such as the Key Enabling Technologies. As part of the Commission's State Aid Modernisation (SAM) initiative, the European Commission has adopted a new Communication, entered into force on 1 July 2014, setting out criteria under which Member States can grant public support for the implementation of IPCEIs in line with EU state aid rules. The Communication sets an ambitious modernisation programme of state aid control to foster sustainable, smart and inclusive growth. It is aimed at facilitating the implementation of major projects that can make a significant contribution to economic growth, jobs and the competitiveness of the European industry and economy, having the capability to trigger strong spill-over effects on the entire Single Market and the European society, but that are often difficult to finance because of the significant technological or financial risks and the necessary transnational cooperation such projects entail. The Communication will enable Member States to fill the funding gap and thereby realise projects that otherwise would not have taken off, including projects involving KETs and cross-cutting KETs.

According to its Strategic Innovation Agenda, the European Institute of Innovation and Technology (EIT) will also partly engage with Key Enabling Technologies, and in particular with their cross-fertilization, providing a framework (i.e. a forum) for interaction and promotion of cross-disciplinary skills and competences, particularly for the combination of multiple Key Enabling Technologies. In 2016, the EIT will particularly launch a call for a new Knowledge and Innovation Community (KIC) in the theme of 'added-value manufacturing', which will help meeting Horizon 2020 priorities in terms of advanced manufacturing and processing, and its specific objective of "transforming today's industrial forms of production towards more knowledge intensive, sustainable, low-emission, trans-sectoral manufacturing and processing technologies, to realize innovative products, processes and services". Actually, since 'advanced manufacturing' is comprised among the KETs and 'manufacturing and automation' represent also a relevant target field for cross-cutting KETs activities according to the defined roadmap for cross-cutting KETs activities, synergies with the EIT in this domain might be sought. Since capacity-building will be a central element of a KIC in added-value manufacturing, and this will concern both the supply of high qualified work force and the possibility of establishing the KIC as a forum for interaction and promotion of cross-disciplinary skills and competences, particularly for the combination of multiple key enabling technologies as proposed by the High-Level Group on Key Enabling Technologies, the ground for the creation of synergies in this domain is deemed to be fertile.

3.8. Longer term agenda for actions by public authorities and stakeholders

Innovation and the industrial production of KETs-based products are two important components of the European Union's strategy aimed at keeping pace with the EU's main international competitors, restoring growth in Europe and creating jobs in industry, at the same time addressing today's burning societal challenges. KETs are at the core of the EU Industrial Policy flagship initiative, as confirmed in the communication 'For a European Industrial Renaissance' (COM (2014)14 final), and the development of cross-cutting KETs based products, processes, or services is also an important part of this strategy. Within this framework, there is a need to address

[10] Horizon 2020 Work Programme 2014 – 2015, Fast Track to Innovation Pilot, European Commission Decision C (2014)4995 of 22 July 2014

KETs-related issues in order to respond to the fast-changing requirements of industry in this respect.

Some challenges have been identified through dialogue with both policy makers and stakeholders throughout the RO-cKETs study. These challenges can only be effectively addressed by the mobilisation of Member States and industry, whereby the European Union can provide a platform for exchange of best practices and well-focused solutions.

The messages emerged from the study have allowed to elaborate a set of clearly defined challenges and requirements and to propose a set of potential action lines that might be put in place by public authorities and stakeholders at the various levels in order to support and facilitate the development and subsequent deployment of cross-cutting KETs based products, processes, goods, or services.

3.8.1. Main observations or identified challenges

Importance of keeping a bottom up approach in the generation of ideas for the development of cross-cutting KETs based products, processes, goods, or services

As observed many times throughout the study, developments involving KETs, either individually or in a cross-fertilizing manner, can occur across Europe at large and are not necessarily concentrated in particular countries or regions. Certainly, regional or local clusters exist that may be (smartly) specialized in one or the other KETs in line with industrial development strategies pursued by the specific country or region. However, an important lesson learnt is that **any industrial undertaking, regardless of the location of its establishment, its size or the geographical dimension of its market(s), could generate interesting ideas for the development of cross-cutting KETs based products, processes, goods, or services effectively addressing demand-side requirements**.

This points out to the **need to keep a programme on cross-cutting KETs activities relatively open to a bottom up approach** capitalizing on companies' creativeness and inspiration. Having this in mind, despite some general indications about development lines, constituted in the roadmap for cross-cutting KETs activities by the most promising areas of converging industrial interest for cross-cutting KETs, more prescriptive indications should not be given.

Need for value chain collaborations

Another important consideration is that the cross-fertilization between KETs inevitably implies major technological complexity. KETs are multidisciplinary and cutting across many technology areas, and their cross-fertilization might require an even greater multidisciplinary effort due to the major number of technological elements involved that need to be integrated among themselves.

In this respect, both industrial stakeholders and policy makers engaged throughout the study remarked several times the **need to effectively address the development of cross-cutting KETs based innovative products, goods and services in collaborating networks engaging all value chain players**. This emerging way of collaboratively developing new products, processes, goods and services is the response to the fact that innovation is becoming increasingly open. While on the one side open innovation, as the way of working together in collaborative networks, enables major creativeness as well as major effectiveness in addressing demand-side requirements especially if end users are actively involved along with the whole value chain, it increases at the same time complexity from a value chain management point of view, due to the fact that additional elements are added to a process that used to be more linear in the past.

To face such increasing complexity both from the technological as well as from the organizational point of view, today, fewer large enterprises, than in the past, tend to internalize competencies and adapt their internal structure and organization in order to be able to master the whole eco-system and life cycle of an innovation (i.e. starting from the development of an idea up to its market introduction and further company growth, spanning through technology scouting and identification, early design, detailed design, components testing, prototyping, validation through pilot production and testing, production set up, commercialization, etc.). More and more often, instead, large enterprises tend to rely on external collaborations especially for specific technological input in case they believe they are not able to maintain the competencies in-house that are required for developing specific technological functionalities. In this regard, it has also to be highlighted that m**any large enterprises' eco-systems can be importantly built-up by SMEs**. The latter can be providers of technological systems and components or of specialized services.

Need for cross-border collaborations

An important consideration emerged throughout the study is that cross-cutting KETs developments would normally require value chain collaborations (see above point) and that these would rarely be found within a single region or even a single country. Much more probably, these value chain collaborations would need to be cross-regional or possibly even broader, highlighting the **need to extend value chains engaging with the cross-fertilization between KETs beyond regional or even beyond national borders**.

Role of SMEs in innovation-centred eco-systems

It has to be highlighted once again that SMEs can play a very important role in many innovation-centred eco-systems. **Either can SMEs be innovators themselves or they can be very important partners to large enterprises in quality of providers of technological systems and components or of specialized services**. Therefore, **particular attention should be paid toward SMEs** in regard to cross-cutting KETs activities.

Role of research- and technology-intensive SMEs as potential providers of cross-cutting KETs based technological systems and components

Special attention should moreover be particularly provided to **research- and technology-intensive SMEs, such as high-tech SMEs and spin-offs, in quality of providers of cross-cutting KETs based technological systems and components**. According to the above considerations on the major complexity of cross-cutting KETs developments, this particular group of SMEs may not be prepared to master the whole innovation life cycle (which is in fact a common challenge for all types of SMEs) and is moreover subject to higher risks, some of which are dependant from their distance from the end user market and, sometimes, from the lack of strong entrepreneurial and management skills that are essential elements for leading to successful market introduction of their technological innovations.

Role of anchor companies in the development of cross-cutting KETs based products, processes, goods, or services

Collaborative value chains shall preferably be led by companies capable of taking the role of pivoting actor. Pivoting actors, or 'anchor companies', are industrial players capable of influencing the resting value chain actors by transferring them their vision and ambitions toward the development of highly competitive new products, processes, or services.

Need to raise awareness about KETs among the industrial community

As a last observation, it is worth to be highlighted that some industrial stakeholders as well as policy makers perceived that there is actually a gap between the Commission's language, prone to categorizing - in this case technologies into broader families - and the practical application of KETs in industry. As emerged during the workshops with both industrial stakeholders and policy makers, and especially according to interviews with industrial representatives, several industrial stakeholders declared not to have particular experience with KETs so far. Nonetheless, when having a closer look into the KETs taxonomies, interviewees could easily recognize keywords they were familiar with, thus pointing out, in several cases, to the fact that the company they work for is in fact already dealing with technologies that are at least close to KETs. As a general rule, it was observed that many organizations are already involved in cross-cutting KETs developments without being really aware of the specific terms and definitions applied at the European policy level for such developments. This suggests that, while KETs are already part of the common language for public authorities at both the European, national and regional levels, there is instead limited perception among industry of what KETs actually refer to, the same also applying to cross-cutting KETs. There is therefore a need to raise awareness about KETs among the industrial community, with the objective to make industry more familiar with the opportunities offered by the Commission and by Member States and regions in their field.

3.8.2. Suggested actions

The above considerations altogether suggest some actions that might be put in place by public authorities and stakeholders at the various levels in order to support and facilitate the development and subsequent deployment of cross-cutting KETs based products, processes, goods, or services.

Many of these actions are the responsibility of the Member States and Regions. Some of them have already launched dedicated initiatives, as observed by dialogue with policy makers. The Commission should continue encouraging them to further develop their policies in line with a long-term agenda and encouraging others to do the same, in particular by facilitating the exchange of good practices.

To complement activities of Member States and Regions, the Commission should concentrate its own efforts on actions bringing added value at EU level, in line with the subsidiarity principle, as it is recognised that some actions advocated by stakeholders have a clear EU dimension. These should be promoted by the Commission in close cooperation with Member States, Regions and stakeholders.

3.8.2.1. Action lines at the European level

Raising awareness about KETs among the industrial community

While KETs have become part of the common language for public authorities at both the European, national and regional levels, the RO-cKETs consortium could experience that there is limited perception among industry of what KETs actually refer to. The need to raise awareness about KETs among the industrial community, with the objective to make industry more familiar with the opportunities offered by the Commission, Member States and regions in their field, has been identified as a consequence.

Especially among the industrial community, KETs should better be promoted and disseminated by the Commission (as well as by Member States and regional authorities in a second instance), not only as the six broad KET families, but also referring to what these broader families actually include. To this aim, it is suggested to refer to KETs taxonomies, which further specify KETs into sub-groups of materials, products, and technologies contained within each broader KET family. According to the practical experience made with KETs taxonomies within the study, these simple tools can effectively exemplify what the broader KET families could actually include, thus being an effective practical aid for increasing perception among industry and enhance industry stakeholders' understanding about KETs.

Creation of an online-based tool aiding in KETs related technology scouting and identification

In order to facilitate the scouting and identification of suitable technologies and related capabilities for their cross-cutting KETs developments by industrial undertakings, an option could be provided by the creation of an online-based mapping tool that shall aid organizations interested in KETs-related developments in the identification and localization of KETs related technological capabilities or excellences across Europe. This tool could be integrated with other instruments developed by the EC.

Differently from the KETs observatory, which provides EU, national policy makers and business stakeholders with information (quantitative and qualitative) on the performance of Member States and competing economies regarding the deployment of KETs[11], as well as differently from the Smart Specialization Platform, which assists EU countries and regions to develop, implement and review their Research and Innovation Strategies for Smart Specialisation (RIS3), also including information about KETs[12], such a mapping tool could be practically addressed to business stakeholders and be dedicated to contain information about where in Europe KETs related capabilities could be found among academic institutions, RTOs, excellence centres including specialized pilot testing facilities, or providers of cross-cutting KETs based technological systems and components (including high-tech SMEs and spin-offs). Such a tool should be regarded as a kind of one-stop-shop of KETs related capabilities to be practically exploited by industrial stakeholders in retrieving value chain partners for the development of KETs based products, processes, goods, or services.

3.8.2.2. Action lines at the various levels (European, national, regional)

Alignment of the cross-cutting KETs programme and national and/or regional R&D&I strategies

As evidenced by the two workshops with the policy makers, alignment of the cross-cutting KETs programme and national and/or regional R&D&I strategies would be envisaged, with the Commission, the Member States and regional authorities already working in this direction. In particular the alignment and complementary use of R&D&I funding and structural funds is being encouraged.

For the purpose of this alignment, the methodology developed within the RO-cKETs study might provide inspiration and could be replicated/adapted in order to allow the identification of key innovation fields of industrial interest with highest potential for answering markets, industry and society demands from cross-cutting KETs developments at the national or regional scales.

Supporting research- and technology-intensive SMEs as potential providers of cross-cutting KETs based technological systems and components

Allowing research- and technology-intensive SMEs to be active providers of cross-cutting KETs based technological systems and components requires that they are supported both in the technological scouting and identification phase as well as in the downstream application of their products into innovative and competitive products, processes, goods and services thanks to collaboration with technology providers on

[11] https://webgate.ec.europa.eu/ketsobservatory
[12] http://s3platform.jrc.ec.europa.eu

the one side as well as industrial players at the downstream end of the supply chain on the other side.

Technology identification is normally not the most difficult step for research- and technology-intensive SMEs, which are prone to technological development. More problematic for them is instead finding suitable environments in which prototypes can be actually developed and tested, since, at the most, those companies lack the equipment and facilities to test the output of their research and innovation projects on a real scale. In this respect shared facilities where prototypes can be tested or demonstrated to customers in operating conditions can be of great benefit to this type of SMEs.

Another difficult task for this particular type of SMEs is engaging with the commercial exploitation of their technological systems and components, especially if they would be young SMEs or start-ups. To the aim of successfully introducing new products, processes, goods or services in the market and be subsequently competitive with the new business, entrepreneurial and management skills are vital. Horizon 2020 will interact with the COSME programme targeting SMEs, allowing not only SMEs to obtain funding under Horizon 2020, but also offering them the opportunity to benefit from coaching and mentoring services aimed at improving their entrepreneurial and innovation management skills such that the SMEs would be better able to overcome the barriers to growth post-Horizon 2020 participation. In the case of the dedicated SME instrument this will be achieved through a coaching and mentoring service delivered during the company’s participation in the instrument through collaboration with the Enterprise Europe Network (established under the Competiveness and Innovation Framework Programme (CIP) for the period 2008-2014, which will be re-established under the Competiveness and SME programme (COSME) for the period 2015-2021). In this respect, it would be recommended that also Member States and regions would adopt policies of systematically providing highly professional coaching facilities or expert mentoring to help those companies to develop stronger entrepreneurial and innovation management skills.

Networking or brokerage events for facilitating the creation of innovation chains

As already introduced, value chain collaboration is crucial in order to master the complexity of cross-cutting KETs based innovative product, process or service development projects. Moreover, at the early stages of an innovation life cycle addressed to develop a new cross-cutting KETs based product, process or service, the value chain might need to be also extended to actors such as academic institutions, RTOs, or excellence centres including specialized pilot testing facilities, which might not be partners in a future value chain addressed to commercialization of the innovation, but might instead be essential during the innovative product, process or service development stages.

In order to facilitate the creation of such innovation chains, a useful option could be provided by the organization of networking or brokerage events. Such events can be useful at all levels (i.e. regional, national, European), since partnerships among industrial undertakings having brilliant ideas toward cross-cutting KETs based products, processes, or services might normally be generated from a few individuals coming together e.g. because of local proximity, and might then require to extend collaboration to value chain partners to be found either in the same country or region or internationally, since cross-cutting KETs based development will quite probably occur across borders of a same region or even country. As a result of these considerations, it would be suggested that the Commission, the Member States and the Regions would dedicate efforts and resources to address the systematic organization of such events.

3.9. Conclusions and outlook on policy recommendations

The study highlighted that any industrial undertaking, regardless of the location of its establishment, its size or the geographical dimension of its market(s), could generate interesting ideas for the development of cross-cutting KETs based products, processes, goods, or services effectively addressing demand-side requirements. Yet, the cross-fertilization between KETs implies often technological complexity, thus requiring greater multidisciplinary efforts and, as a result of the need to face this requirement by value chain collaboration, good skills in effective innovation chain management. Large enterprises are normally capable of mastering the whole innovation life cycle, even in a scenario of increased complexity (both technological and operational/organizational), which is however not as easy for SMEs.

Despite this difficulty, SMEs can play a crucial role in many innovation-centred eco-systems. Either can SMEs be innovators themselves or they can be very important partners to large enterprises as providers of cross-cutting KETs based technological systems and components or as providers of related specialized services. Discussion with stakeholders indicates that research- and technology-intensive SMEs, especially if they would be young companies or start-ups, may not be prepared to master the whole innovation life cycle and particularly lack of the strong entrepreneurial and management skills that are vital for leading to successful market introduction of their technological innovations.

Policies should particularly address this target group. In this respect, existing instruments should be improved or specific new support measures should be designed in order to focus on those companies, and, among them, on those with a real growth potential. Supporting R&D&I will continue to be a central policy subject for all types of SMEs. However, consolidating especially the entrepreneurial and management skills of, particularly, research- and technology-intensive SMEs is crucial for successful future commercialization of their technological innovations. R&D&I activities are to be considered as strategic investments, and allowing research- and technology-intensive SMEs to be active providers of cross-cutting KETs based technological systems and components requires that they are supported both in the technological identification phase as well as in the successful downstream application of their technologies into innovative and competitive products, processes, goods and services. As in many cases, technological identification may not be an obstacle for this type of companies. Policies should however be more consistently addressed to management issues. To the aim of successfully introducing new products, processes, goods, or services in the market and be subsequently competitive with the new business, entrepreneurial and management skills of those companies should be strengthened. To this aim, Horizon 2020 will interact with the COSME programme targeting SMEs, allowing not only SMEs to obtain funding under Horizon 2020, but also offering them the opportunity to benefit from coaching and mentoring services aimed at improving their entrepreneurial and innovation management skills such that the SMEs would be better able to overcome the barriers to growth post-Horizon 2020 participation. In the case of the dedicated SME instrument this will be achieved through a coaching and mentoring service delivered during the company’s participation in the instrument through collaboration with the Enterprise Europe Network. In this respect, it would be recommended that also Member States and regions would adopt policies of systematically providing highly professional coaching facilities or expert mentoring to help those companies to develop stronger entrepreneurial and innovation management skills beyond R&D&I project funding.

It is often the combined engagement in an innovative product development project of small and large players that allows for the effective translation of R&D&I results into concrete applications that can result in growth and job creation for all the engaged players. In this regard it would be envisaged that policy makers would provide measures to help SMEs to engage with larger players, improving their way to collaborate with such players, including across borders.

Cross-cutting KETs developments carried out collaboratively in networks engaging whole value chains will rarely be found within single regions or countries even. These developments will much more probably take place at a much larger scale, requiring to extend value or innovation chains beyond regional or even beyond national borders in order to adequately fill in gaps in the value or the innovation chain. Policy measures by Member States should therefore strongly support the creation of European international partnerships.

4. CORRELATION BETWEEN METHODOLOGY AND ORIGINAL PROJECT WORK PLAN

4.1. How the methodology relates to WP1

The objective of Work Package 1 was to provide an innovative and reliable methodological approach through which to identify the most promising areas of converging industrial interest for cross-cutting KETs, defining their scope and strategic impact, and moreover to develop a roadmap delineating such promising areas of converging industrial interest for cross-cutting KETs. A further objective was to present criteria for the selection and subsequent performance evaluation of cross-cutting KETs projects.

In the following table, the WP1 tasks and sub-tasks with their main outcome in brief and their relation with the methodological actions extensively described in previous paragraphs, are presented.

Table 12: WP1 tasks and sub-tasks

Task	Main outcomes in brief	Relation with methodology
T1.1 Identification of industrial and market needs, key nodes and value chain		
T1.1.1 Identification of relevant value chains/industrial sectors	Comprehensive list of relevant industrial sectors to be analysed	Action I: Identification and clustering of industrial sectors to be analysed
T1.1.2: Preliminary identification of industrial and market needs (by desk study)	Preliminary list of market requirements and industrial challenges clustered per industrial sector	Action I: Identification of market requirements and industrial challenges per industrial sector
T1.1.3: Validation of industrial and market needs (by extensive involvement of stakeholders)	Validated list of market requirements and industrial challenges clustered per industrial sector	Action I: Validation by means of interviews to relevant stakeholders within each industrial sector
T1.1.4: Identification of technology and industrial requirements to address societal challenges	Map of market requirements and industrial challenges; association of market requirements to societal challenges	Action I: Identification of market requirements and industrial challenges per industrial sector, creation of a map highlighting relations between industrial challenges, market requirements and societal challenges

Task	Main outcomes in brief	Relation with methodology
T 1.1.5: Identification of key nodes	List of innovation fields and their description, including through their underlying industrial challenges and through specification of their related market needs	Action I: Definition of innovation fields
T1.2: Technological know-how and production capacities in the EU		
T1.2.1: Definition of KETs and establishment of KETs and multi-KET relations to key nodes	List of innovation fields with cross-cutting KETs relevance	Action II: Definition of the innovation fields with cross-cutting KETs relevance (through KETs-related patent scenario analyses as well as KETs experts survey)
T1.2.2: Mapping of EU's technological know-how and related actors	Characterization of the KETs-relevant patenting activity toward each innovation field	Action II: Examination of KETs-relevant patenting activity toward each innovation field
T1.2.3: Characterization of TRL	Classification of innovation fields into innovation fields with short- and medium- term priority	Action II: Examination of KETs-relevant patenting activity toward each innovation field and use of patents-based indicators as well as KETs experts survey to distinguish between innovation fields with short- and medium-term priority based on qualitative information about the maturity of technological solutions
T1.2.4: Characterization of MRL	Classification of innovation fields into innovation fields with short- and medium- term priority	Action II: Examination of KETs-relevant patenting activity and deskwork and use of patents-based indicators as well as KETs experts survey to distinguish between innovation fields with short- and medium-term priority based on qualitative information about the maturity of technological solutions (including, whenever possible, the maturity of related manufacturing processes)
T1.2.5: Assessment of the usefulness of the Innovation Readiness Level approach	Results of the assessment	Dedicated assessment

Task	Main outcomes in brief	Relation with methodology
T1.2.6: Assessment and prioritization of KET cross-fertilisation opportunities	List of the most promising areas of converging industrial interest for cross-cutting KETs, validated with stakeholders	Action III: Definition of the most promising areas of converging industrial interest for cross-cutting KETs (through KETs-related patent scenario analyses as well as demand-side survey)
T1.3: Selection criteria for cross-cutting KETs based projects		
T1.3.1: Definition of relevant criteria	List of selection criteria	Dedicated list of criteria and means for verification
T1.3.2: Quantification of relevant criteria	List of selection criteria and associated means for verification	Dedicated list of criteria and means for verification
T1.4: Assessing the impact of project results		
T1.4.1: Implementation of monitoring tools at project level	Monitoring and assessment criteria for the performance evaluation of individual projects and associated means for verification	Dedicated list of criteria and means for verification
T1.4.2: Definition of Key Performance Indicators	List of KPIs for programme assessment	Definition of Key Performance Indicators for programme assessment
T1.5: Inter-linkages with other EU programmes		
T1.5: Inter-linkages with other EU programmes	List and description of synergies with other EU programmes and policies	Dedicated list and description

4.2. How the methodology relates to WP2

Work Package 2 was devoted to the implementation of all the developed and already validated methodological steps (from WP1) in order to collect the necessary information that concurred to the definition of the cross-cutting KETs work plan and roadmap.

In the following table, the WP2 tasks and sub-tasks with their main outcome in brief and their relation with the methodological actions described above are presented.

Table 13: WP2 tasks and sub-tasks

Task	Main outcomes in brief	Relation with methodology
T2.1: Definition of the background		
T2.1: Definition of the background	Overall background situation with regard to KETs and cross-KETs in the EU	Action II: Patent scenarios analyses broadly referring to industrial sectors/value chains Description of overall background situation with regard to KETs and cross-KETs in the EU
T2.2: Definition of vision and strategic objectives		
T2.2: Definition of vision and strategic objectives	Vision and strategic objectives associated to cross-cutting KETs	Action III: Key nodes identification through assessment and prioritization
T2.3: Specification of product demonstration and industrial needs in cross-cutting KETs		
T2.3: Specification of product demonstration and industrial needs in cross-cutting KETs	Identified innovation fields relevant for cross-cutting KETs developments and related roadmap/ fiches	Action III: Key nodes identification through assessment and prioritization Indication of types of potential projects to be launched detailing their scope and characteristics
T2.4: Definition of the implementation plan		
T2.4.1: Time schedule definition T2.4.2: Budget allocation	List of short- and medium-term actions	Grouping of innovation fields into short-term and medium-term opportunities Indication of possible projects' size
T 2.5: Definition of the expected impact		
T 2.5: Definition of the expected impact	Highlights on major impacts associated with the different key innovation fields in the relevant fiches	Assessment of major impacts associated to each innovation field within the relevant fiches

Task	Main outcomes in brief	Relation with methodology
T 2.6: Definition of mechanisms for update		
T 2.6: Definition of mechanisms for update	Mechanisms for updating the roadmap and work plan	Dedicated description

5. CONCLUSIONS

The present deliverable is the "Final Report" for the study "Methodology, Work plan and roadmap for cross-cutting KETs activities in Horizon 2020". The report provides a comprehensive and detailed description of the methodology that has been developed within the framework of the RO-cKETs study and moreover reports about the roadmap for cross-cutting KETs activities, developed as a result of the methodology's implementation.

Accordingly, it provides insight into the methodology that has been designed for the definition of the potential innovation fields of industrial interest relevant for cross-cutting KETs, highlighting the major practical steps of which it consisted along with the approaches taken, options considered, findings, strengths, weaknesses and outcomes. Moreover, it describes the proposed roadmap for cross-cutting KETs activities (actually, the roadmap is provided as a dedicated, self-standing document, which is annexed to this report). The report also includes a proposal for a cross-cutting KETs programme under Horizon 2020 and suggestions for a longer term agenda for actions by public authorities and stakeholders and an outlook on policy recommendations.

ANNEX 1
ROADMAP FOR CROSS-CUTTING KETS ACTIVITIES IN HORIZON 2020
(INCLUDING THE FICHES INDIVIDUALLY DESCRIBING THE POTENTIAL AREAS OF INDUSTRIAL INTEREST RELEVANT FOR CROSS-CUTTING KETS)

ANNEX 2
KETs Taxonomies

ADVANCED MANUFACTURING SYSTEMS

Advanced (bio)chemical processes

- Self assembly of (nano) materials
- In-Situ generation of nanostructured materials
- Enhanced bio- and enzymatic catalytics

Micro-electronics and photonics manufacturing technologies

- Clean Rooms
- R2R manufacturing and flexible electronics / photonics
- Wafer production technologies
- Chips and MEMS packaging technologies
- Wafer stepper technologies
- Non-crystalline solar PV sheets manufacturing technologies

High Performance Manufacturing

- Net shape manufacturing
- Rapid prototyping technologies
- Adaptable and reconfigurable production equipment
- High speed manufacturing systems
- Automation and robotized manufacturing
- Micro-factory and micro-manufacturing systems.
- Integration of front-end and back-end manufacturing
- New technologies for casting, material removing and forming processes.
- 3D printing
- The new human-centered production site.
- Advanced joining technologies
- Laser based cutting and welding

Innovations in the organisation of manufacturing

- User centered manufacturing

- Enhanced knowledge management systems
- Virtual Factories
- Advanced security systems

Maintenance and repair

- On-line/remote monitoring, control and maintenance
- Manufacturing strategies for renovation and repair
- Methodologies and tools for sustainable maintenance of production equipment.
- Advanced sensory systems for quality control and process characteristic

Modelling, design and simulation

- Decision support systems for design
- Virtual labs
- Computational tools
- Modelling and simulation of advanced plant-wide control
- Modelling and simulation, based on
- Advanced complex system theories

Advanced metrology and testing

- Adaptive and fault tolerant process automation, control and optimization technologies and tools
- Smart testing facilities tools for analysis nanostructures
- Advanced decision-making tools for zero defect manufacturing
- Large-scale testing and validation of robotics-based and other automated manufacturing

ADVANCED MATERIALS

Lightweight/ultrastrong materials and structures

- Light weight metals
- Ultra strong materials
- Cut-resistant materials

Materials to withstand more aggressive environments

- Erosion resistant materials and coatings
- Pressure resistant materials

- Materials resistant to aggressive chemical environments
- Heat resistant materials
- Materials for extreme weather conditions
- Anti scratching materials and coatings
- Fire resistant coatings

Surface engineering and coatings

- Noise protective coatings
- Anti-reflection coatings
- Easy-to-clean, anti-fouling, anti-icing coatings
- Anti-bacterial coatings
- Anti-corrosion coatings
- Low friction coatings
- Gas sealing materials

Biomaterials

- Natural fibers
- Bioactive materials
- Natural and bio-based materials
- Biocompatible materials
- Biomedical materials
- Bio-degradable materials

Electronic and optical functional materials

- Photo-chromic materials
- Photolithographic printing materials
- LED lighting materials
- Electrical materials for IC and devices
- Magnetic materials
- Flexible lighting panels
- Flexible displays and electronics
- (O) LED materials
- Plastic electronic materials

- Rare earth materials
- Battery materials
- Fuel cell materials
- Photovoltaic materials

Smart and multifunctional materials, devices and structures

- Environment sensitive materials
- Self-healing materials
- Advanced packaging materials
- Memory materials
- Information integrated materials
- Bio-sensor materials
- Chemical sensor materials
- Technical textiles
- Smart textiles
- Micro encapsulating textiles
- Advanced insulation materials and coatings

Industrial and other materials

- Catalytic materials and coatings
- Membranes for chemical processing
- Advanced adhesives
- Materials designed for reuse/recycle/remanufacture
- Nanoparticles
- Materials with reduced environmental impact through life
- Filtering materials
- Self-manufacturing materials
- Printing materials for structures (3D)
- Nano-materials

INDUSTRIAL BIOTECHNOLOGY

Modification and Optimization

- Synthetic biology
- Metabolomics
- Engineering and synthesis of proteins and peptides (including large molecule hormones)
- Proteomics, protein isolation and purification, signalling, identification of cell receptors
- Metabolic engineering
- Directed evolution

Biorefineries

- Sugar platform
- Platform chemicals
- Cereal, oilseed, lignocellulosic and feedstock biorefinery
- Syngas biorefinery
- Utilization of CO_2 as feedstock

Bioprocessing

- Fermentation
- Bioleaching
- Biopulping
- Biobleaching
- Biodesulphurisation
- Bioremediation
- Biofiltration
- Phytoremediation
- Downstream processing

Biocatalysts

- Enzymes
- Cells and cell preparations

Host organisms

- Fungi

- Bacteria
- Yeasts
- Algae
- Insects
- Plants

Bioinformatics

- Construction of databases on genomes, protein sequences
- Modelling complex biological processes, including systems biology

MICRO- AND NANO-ELECTRONICS

Micro Processing Units

- Quantum computing
- Propagated Instruction Processor
- Optical computing
- Molecular / DNA computing

Computer memory

- DRAM
- Flash
- Quantum dot memory
- Optical memory
- Magnetic memory devices

Micro transducers (sensory devices, actuators)

- Mechanical sensory devices
- Electro chemical sensory devices
- Bio-sensory devices
- Imaging sensors
- Bio-nano generators
- Electro acoustic sensors
- Nanobots
- Micro energy tranducers

- Photo-electric devices
- Micro actuators

Power electronics

- High energy lasers
- Power grid technologies
- High energy electromagnetic emitters
- High power converters
- Power generation electronics
- Micro energy generation (e.g. harvesting)

Screens and displays

- LED panels
- OLED panels
- Lighting electronics
- LCD display
- (O) LED displays
- Flexible displays

Hardware architectures

- Systemon a chip
- Application specific integrated circuits
- Reconfigurable hardware
- Defect and fault tolerant architectures
- Quantum information processing
- Photo-electric systems
- Systems in package
- Seamless connectivity and interoperability (hardware)
- Reference architectures, standards (hardware)
- 3D stacking

MNE manufacturing technologies

- Clean rooms technologies
- Wafer and other substrate production technologies

- Packaging technologies
- Advanced tooling, sawing, drilling, molding technologies
- Photolitographic technologies
- Theoretical modelling on micro&nano-electronic systems
- Positioning, mounts, tables, vibration isolation technologies
- Inspection, testing and metrology technologies

NANOTECHNOLOGY

Nanostructured coatings

- Tribological
- Functional
- Adhesives/Sealants

Nanostructured materials

- Nanocomposites
- Carbon based materials
- Metal and ceramic based materials
- Polymer based materials
- Other (micelles, dendrimers, hollow nanocapsules)

Fluids

- Nanofluids
- Dispersions

Nanosensors

- Electrical
- Optical

Nanomachines

- Top down (e.g. NEM, piezomotors)
- Bottom up (e.g. molecular machines)

PHOTONICS

Displays and Illumination

- Displays
- LED, OLED, non-laser light sources

Photonic Energy

- Solar and Alternative Energy

Optoelectronics and electronics

- Electronics, components
- Optoelectronics components or devices (non-telecom)
- Optomechanical components, equipment, systems
- Optical communication devices and equipment

Laser, optics, fiber optics

- Fiber Optics and accessories
- Laser components and accessories
- Lasers and systems
- Misc consumables and equipment
- Emerging Photonics Technologies
- Optical Fabrication Equipment
- Optical Components – Lenses
- Silicon photonics, photonics circuits and interconnects
- Optical Components – filters, mirrors, other optics

Manufacturing equipment

- Lithographic equipment
- Materials processing equipment

Mounts and positioning

- Positioning Equipment and accessories
- Mounts, Tables, Vibration Isolation

Sensors, Detectors, cameras

- Cameras and Imaging system
- Detectors and Sensors

Signal Analysis, Data Processing, Computing

- Computing / Data Processing
- Electronic / Digital Imaging
- Electrical / Signal Analysis Equipment

Test and Measurement; Instrumentation

- Astronomical Instruments & Telescope Microscopy
- Spectroscopy devices, tools and equipment
- Test and Measurement, Metrology

Materials

- Optical Coatings, Thin Films
- Photonic Materials
- Nanotechnology, Nanophotonics

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