European Commission

This fiche is part of the wider roadmap for cross-cutting KETs activities

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

The complete roadmap for cross-cutting KETs activities can be downloaded from:

http://ec.europa.eu/growth/industry/key-enabling-technologies/eu-actions/ro-ckets

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

This innovation field is part of the wider roadmap for cross-cutting KETs activities developed within the framework of the RO-cKETs study. The roadmap for cross-cutting KETs activities identifies the potential innovation fields of industrial interest relevant for cross-cutting KETs in a broad range of industrial sectors relevant for the European economy.

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 can 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.

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

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

Scope:

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

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

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

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

- Production of high performing materials with improved functionalities

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

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

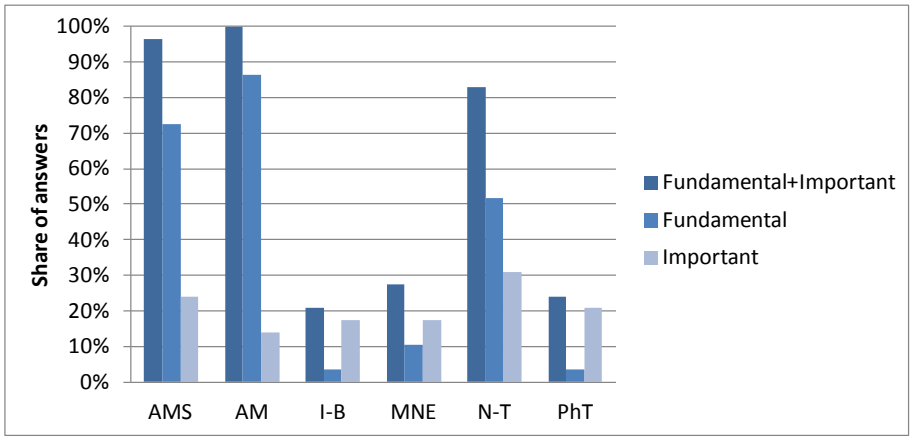
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of ceramics, intermetallics, alloys, superalloys and metal/ceramic-based composite materials for high-performance applications, thanks to the development of novel materials addressing the important issues of durability, efficiency and cost of final applications, , along with more efficient and economic production technologies, also including secondary production based on scrap recycling or the implementation of high precision near shape

casting and other processing and finishing capabilities to produce optimal products and semi-products that reduce manufacturing operations, costs and material waste in later manufacturing operations.

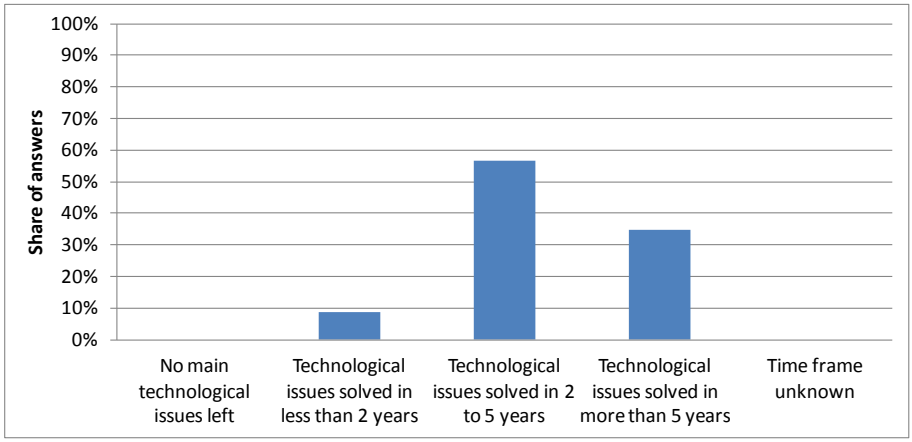
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong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

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



Timing for implementation:

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



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

Additional information according to results of assessment:

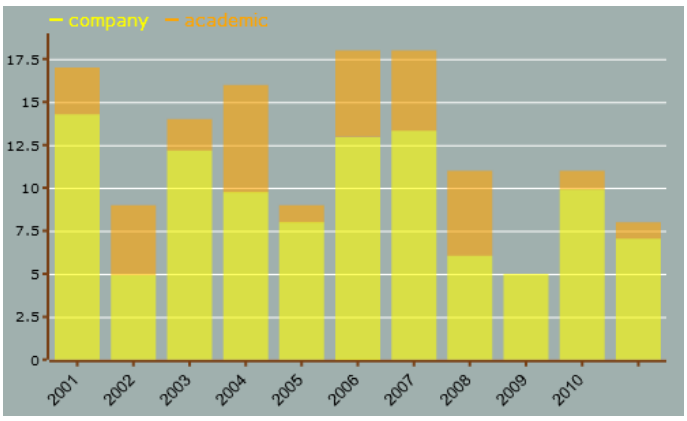
➢ ***Impact assessment:***

- Ceramics, intermetallics, alloys, superalloys, and metal/ceramic-based composite materials are mainly developed and applied for high-performance engineering applications mainly in the fields of energy and transport.

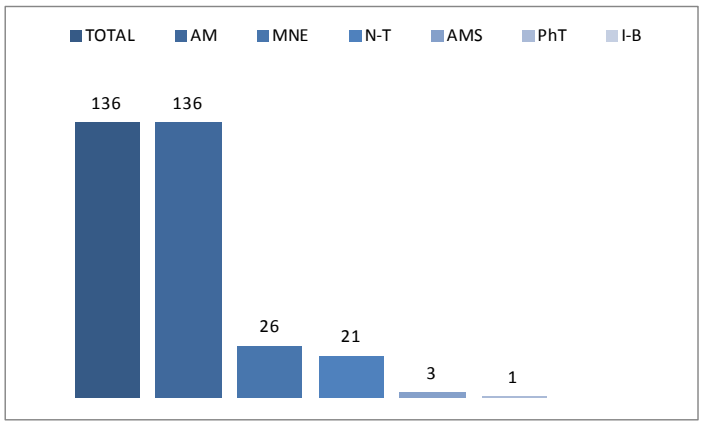
- Materials developed at the first instance for gas turbine and other engine-related high temperature components (e.g. valves, nozzles, etc.) had high temperature tensile strength as the prime requirement. This requirement however quickly changed as operating temperatures rose. Stress rupture life and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

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

- 136 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Unstable trend curve (number of patents per year) with descending trend in most recent years
- Highest share of industrial applicants with intermittent relevant patenting activity by academic applicants, most probably standing for new technologies having been patented in the corresponding periods, yet low patenting activity of the latter type of applicants in most recent years:



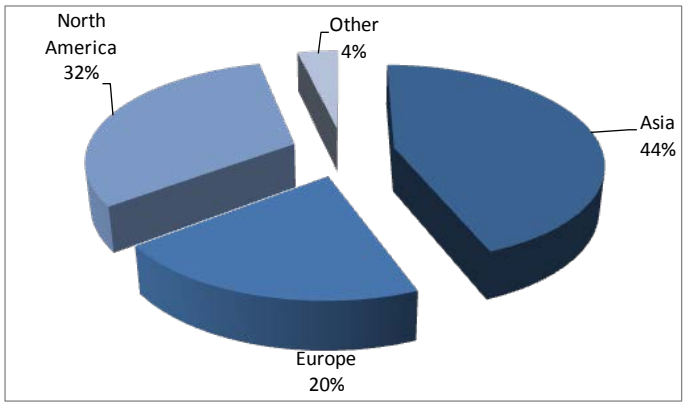
- Patents by KET(s):



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

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

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection: