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

Scope:

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

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

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

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

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

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

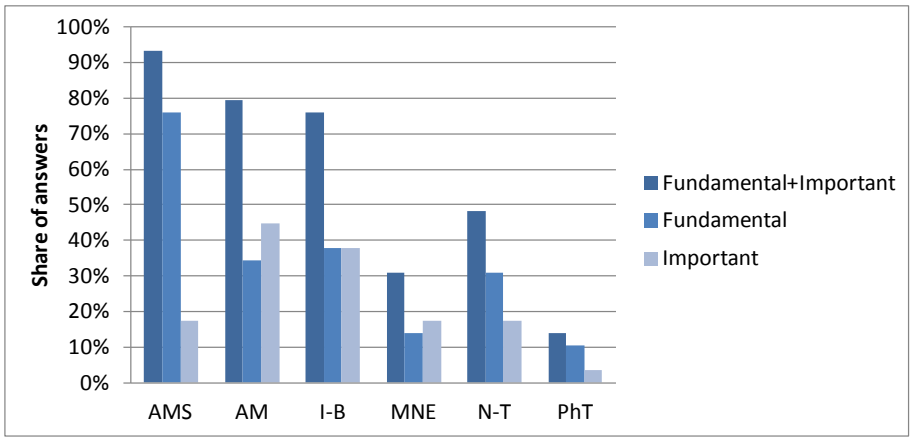
- Exploration of new reaction pathways and conditions, reduction of the number of reaction steps, introduction of intensified separation technologies and intensification in the energy input
- Development of hybrid / integrated reaction-separation systems combining (multi) reaction separation steps, or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

Contribution by cross-cutting Key Enabling Technologies:

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

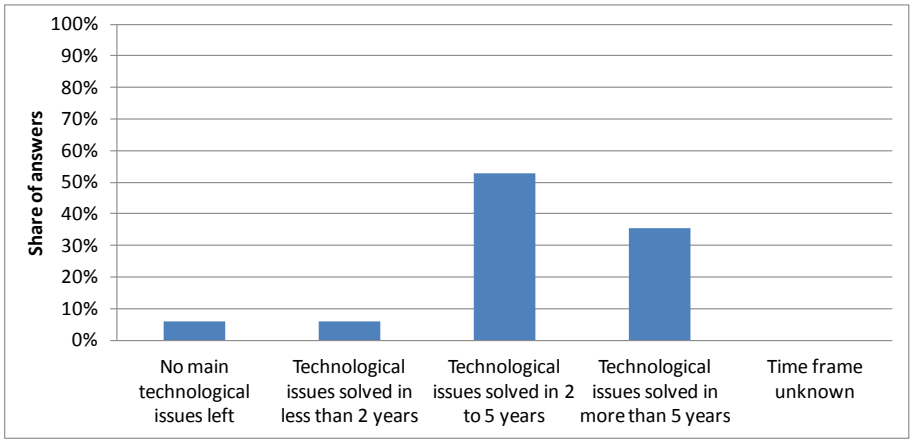
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong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

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



Timing for implementation:

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



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

Additional information according to results of assessment:

➢ ***Impact assessment:***

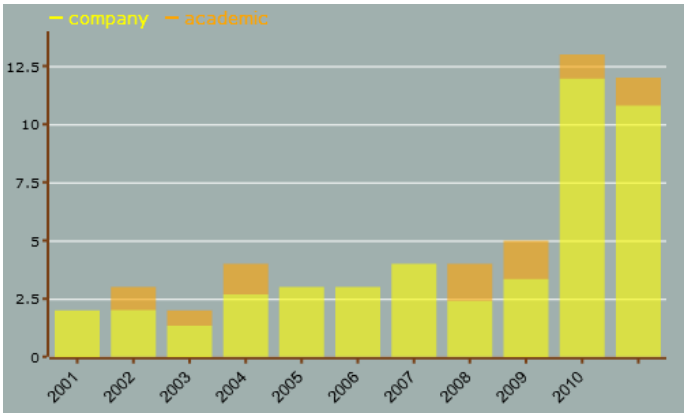
- The European chemical industry was worth 673 billion Euro in 2011 and the world's top exporter and importer of chemicals, with a record 49.1 billion Euro trade surplus in 2012. The sector produced 21.5% of the world's chemicals in 2011, employing 1.2 million workers and contributing 558 billion Euro to the

EU economy. Despite losing its top spot in world chemicals sales in favour of China, whose world chemicals sales market share reached 30.5% in 2012, the European chemical industry still holds a very important position (Source: The European Chemical Industry Council, www.cefic.org).

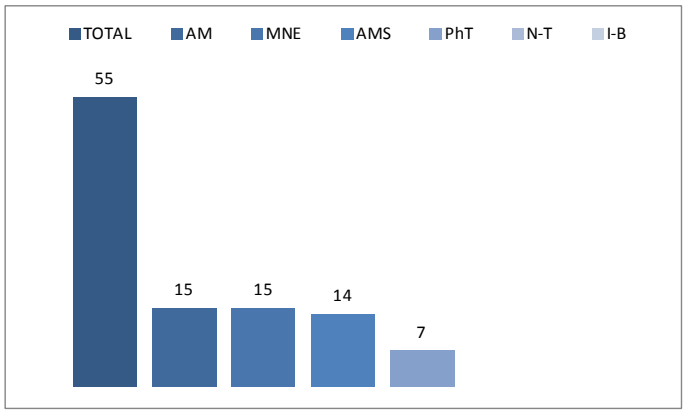
- Germany is the largest chemicals producer in Europe, followed by France, The Netherlands and Italy, which altogether generated 62.6% of EU chemicals sales in 2012, which was valued at 349 billion Euro. The share rises to nearly 87.7% when including UK, Spain, Belgium and Poland, while the other European countries generated together 12.3% of EU chemicals sales in 2012 (Source: The European Chemical Industry Council, www.cefic.org).
- The European chemical industry is furthermore a highly diversified sector. In terms of structure, a large number of SMEs dominate the scene besides fewer important large multinational players.
- The chemical industry underpins virtually all sectors of the economy, having a direct strategic impact on downstream chemicals users such as rubber and plastics, construction, pulp and paper, and the automotive industry, to name the biggest industrial users of chemicals. Other important users of chemicals are agriculture, textiles, metals, and the food and beverages industry (Source: The European Chemical Industry Council, www.cefic.org).
- Over the years, chemical processes have continually improved in terms of their greater utilisation of raw materials, improved safety and increased productivity whilst minimising waste and energy use. Yet, the European chemical industry is still facing the need to restructure and modernize by continuing to reduce energy as well as resources (i.e. both raw materials and water) consumption besides reducing waste as well as emissions generation at the same time. On the other hand, the European chemical industry faces the need to reduce time-to-market for new products, and a need to increase operational flexibility to enable swift responses to changing market trends in order to remain competitive in a global market. Within this framework technology leadership in the area of process intensification is of growing importance as commercial pressure on Europe from other lower cost production regions increases (Source: SusChem, www.suschem.org).
- Intensified reaction and process design covers many areas including smart design of the synthetic route itself, micro process technologies, catalytic reactions, fluid dynamics, separation technology, particle technology, advanced process control, integration and intensification of processes combined with new catalyst concepts and increasingly sophisticated computer modelling of chemical interactions and plant simulation (Source: SusChem, www.suschem.org).

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

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



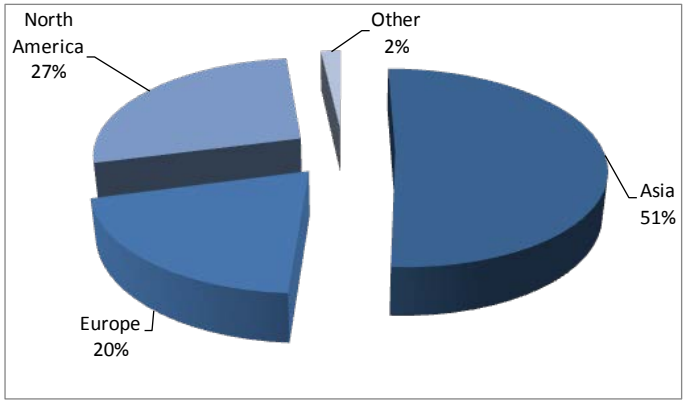
- Patents by KET(s):



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

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

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection: