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

### Scope:

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

### Demand-side requirements (stemming from 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:

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

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

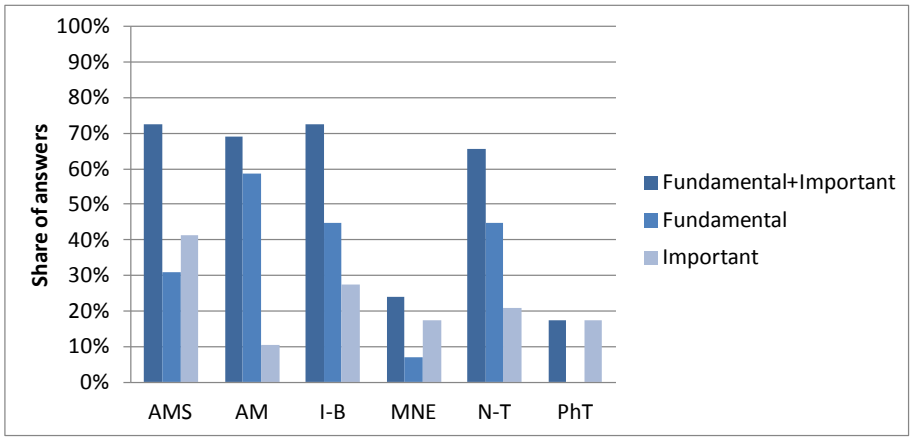
- Development of innovative material formulations
- Identification of alternatives for scarce chemical elements applied in catalyst technologies (such as Platinum, among others)
- Discovery, evolution and development of novel, robust and selective biocatalysts suitable for industrial use
- Catalyst engineering moving towards the design of the next generation of multifunctional catalysts by integrating knowledge on hetero-, homo-, single-site and biocatalysts, in order to achieve near 100% selectivity in multi-step and complex syntheses
- Development of regenerative / rejuvenable catalysts to optimize availability and reduce maintenance costs
- Development of high activity, high flexibility and high selectivity, even possibly regenerative / rejuvenable, catalysts to optimize various chemical reactions
- Combination of catalytic pathways with the selective and local application of alternative energy options (e.g. photons, electrons, microwaves, ultrasound) to yield highest energy efficiency

### Contribution by cross-cutting Key Enabling Technologies:

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

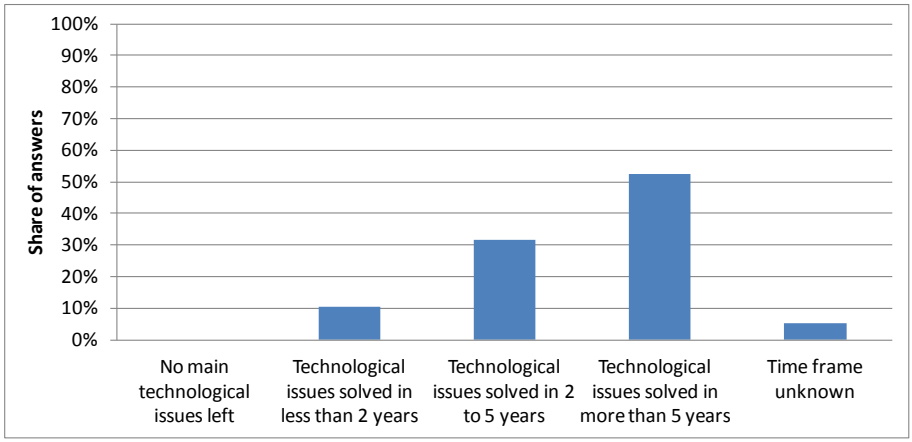
To this aim, the combination of KETs experts’ opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong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

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




### Timing for implementation:

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




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

### Additional information according to results of assessment:

- ***Impact assessment:***
  - According to the market research study by The Freedonia Group Inc, global demand for catalysts will rise annually of 5.8% to 14.4 billion Euro in 2016. Growth will reflect the continued expansion and modernization of the chemical, refining, and polymer industries especially of the world's developing nations, as well as a shift in product mix toward higher value, more efficient catalysts.
  - Both the polymerization and chemical catalysts markets are expected to grow the fastest through 2016, aided by healthy economies of developing countries that will drive increases in polymer and chemical production. New polymer and chemical capacity will continue to be sited in or near rapidly expanding consumer markets, as well as in countries with comparatively cheap supplies of natural gas (a primary polymer and chemical feedstock). As a result, rapid growth will occur in both Asia and the Middle East, while Brazil will lead strong growth in Central and South America.
  - Advances in both polymerization and chemical catalysts markets will reflect the adoption of higher value catalysts with increased activity and/or selectivity. For example, in polymerization catalysts, metallocene single-site catalysts will exhibit the fastest growth, while in chemical synthesis catalysts, biocatalysts will keep posting some of the fastest growth. The refining catalyst market will expand at a more moderate pace. Concerns about the impact of sulphur impurities in transportation fuels on

environmental air quality have led most of the world's high-income nations to enact strict regulations on fuel sulphur content over the past decade. This in turn helped drive strong growth in hydrotreating catalyst demand in otherwise mature refining catalyst markets. However, while efforts to reduce sulphur content in marine fuel oil will continue to support some demand growth in developed countries, most advances in refining catalyst demand will occur in developing countries, such as China and India, that will continue to expand their refined product production. Additionally, several of these developing countries are moving forward with their own low fuel sulphur regulations, which will further support catalyst demand growth.

- From a regional perspective, both the Asia/Pacific and Africa/Mideast regions will see high levels of growth in catalyst demand. In the Asia/Pacific region, modernizing industry, rising incomes, and increasing vehicle ownership will make the countries in that region attractive markets for producers. Companies will continue the trend of siting production facilities close to these markets, and expanding chemical, refined product, and polymer production will in turn necessitate higher levels of catalyst consumption. New capacity will be added in the Middle East as well, where the oil and gas resource-rich countries will continue to expand into downstream activities such as refining and polymer production. In North America, rising supplies of natural gas and oil have made these commodities available at prices lower than those seen in the developed economies of Western Europe and Japan. This situation is expected to persist and will have a significant impact on the refining, chemical, and polymer industries. Synthesis gas catalysts will post the strongest growth in the region as methanol capacity is once again expanded following a decade of rationalization, and as gas-to-liquid projects begin to come on stream near the end of the forecast period.
- Amongst the European catalyst market participants there are a number of important European headquartered companies as well as international companies also having production facilities in Europe. Important players are in this respect Akzo Nobel, Albemarle Catalysts Company, Arkema, Axens, BASF, Basell Polyolefins, Bayer, Borealis, Clariant International, CRE-Porocel, CRI/Criterion, (Royal Dutch Shell), Danisco (DuPont), DuPont, Evonik Industries, Eurecat, Eurosupport, Grace, Haldor Topsoe, Honeywell UOP, INEOS Polyolefins, Johnson Matthey, Novozymes, PQ Silicas UK (PQ Corporation), Polynt, Royal Dutch Shell, Süd-Chemie (Clariant International), Total.
- Sources: The Freedonia Group Inc., World Catalysts to 2016 - Demand and Sales Forecasts, Market Share, Market Size, Market Leaders, 2013; European Catalyst Manufacturers Association (ECMA), www.cefic.org; PR Newswire, www.prnewswire.com

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

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