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 Energy 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.

E.4.1: Fuel cell-based systems for transport applications

Scope:

To develop fuel cell-based systems for transport applications with improved performance at both single component and system level eventually combined with efficient and reliable units for fuel processing of liquid fuels to hydrogen (reforming of, for example, gasoline, diesel and kerosene) for on board application.

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

- Contribute to achieving competitive, sustainable and secure energy

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

- Enable more efficient power storage in order to guarantee power supply to mobile, portable and consumer products
- Larger supply availability of more reliable as well as small-sized / low-weight systems for power supply
- Increase power to weight ratio of storage systems in order to maximize yield at overall system level

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

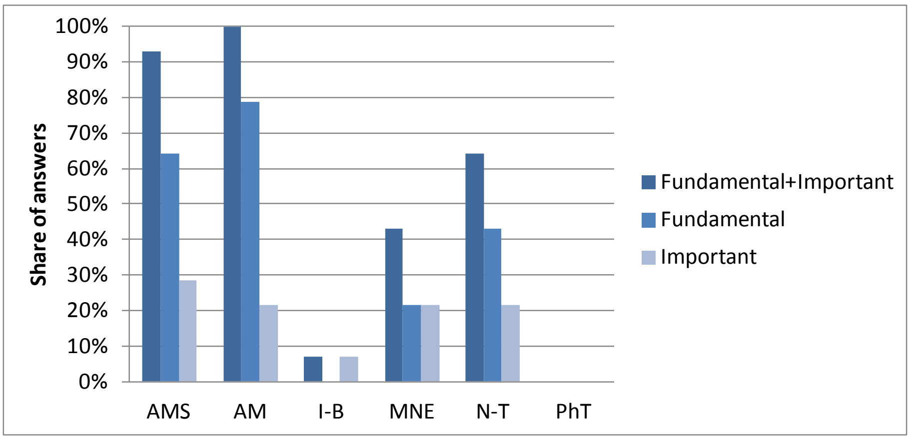
- Improvements in fuel cells toward increasing efficiency, reliability, cost-effectiveness
- Understanding of degradation mechanisms including through methods for lifetime prediction and testing for polymer electrolyte fuel cells (PEFCs) and solid oxide fuel cells (SOFCs)
- Improvement of performances of polymer electrolyte fuel cells (PEFC) stacks such as power density, durability, humidification, cathodic water management and contaminant tolerance
- Improvement of performances of solid oxide fuel cells (SOFC) stacks (with main use in Auxiliary Power Units (APUs) due to easy reforming) such as thermal cycling stability, robustness and reliability, tolerance to fuel impurities (e.g. sulphur)
- Development of high temperature polymer electrolyte fuel cells (HT PEFC), electro-catalysts and new materials for fuel cell (FC) components
- Development of fuel cell & battery hybrid systems
- Development of new reversible hydrogen storage materials
- Development of efficient and reliable units for fuel processing of liquid fuels to hydrogen (reforming), in particular for on board application (e.g. gasoline, diesel and kerosene)
- Increase system integration and system efficiency, including electronic equipment and components, in particular for polymer electrolyte fuel cells (PEFC) (sensors, control and power electronics, etc.)
- Development of cost-efficient manufacturing

Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of more performing fuel cells thanks to deploying solutions for solving degradation issues including through methods for lifetime prediction and the deployment of enhanced materials and structures. The integration of KETs could also contribute to the development of fuel cell and battery hybrid systems, of new reversible hydrogen storage materials and related equipment, of efficient and reliable units for fuel processing of liquid fuels to hydrogen (reforming), and of integrated systems, including electronic equipment and components (sensors, control and power electronics, etc.). The integration of KETs could finally contribute to render manufacturing of such systems and equipment more cost-efficient.

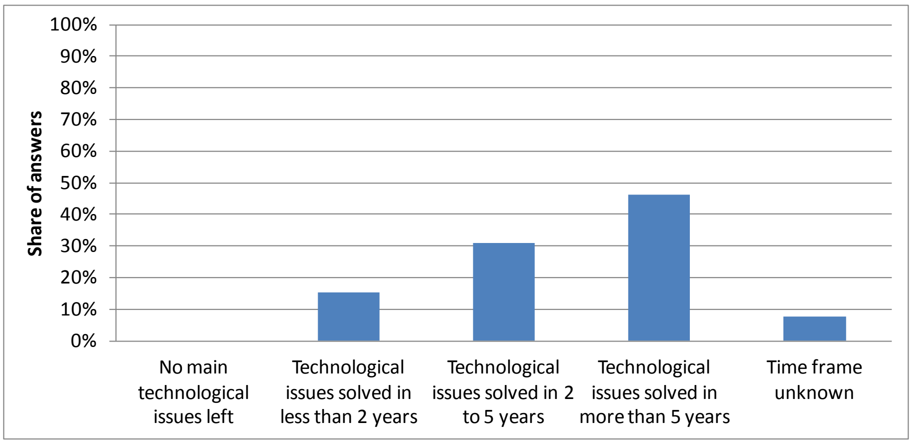
To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong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

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



Timing for implementation:

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



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

Additional information according to results of assessment:

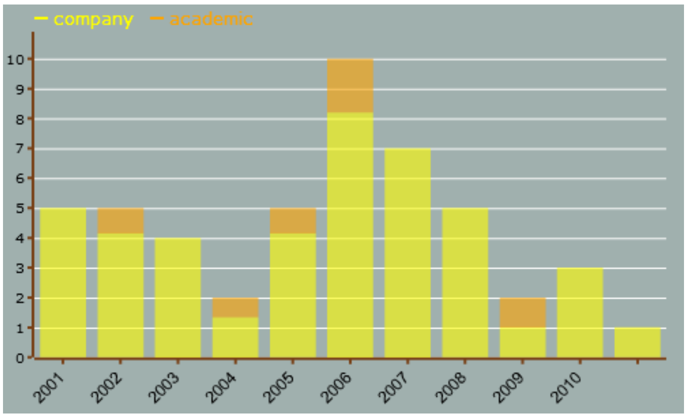
- ***Impact assessment:***
  - Fuel cells can improve energy efficiency in the transportation sector and contribute to mitigating climate change, especially when being fuelled by pure hydrogen produced by renewable primary energy sources. Transportation applications of fuel cell technology include motive power for passenger cars, buses and other fuel cell electric vehicles (FCEV), specialty vehicles, material handling equipment (e.g. forklifts), and auxiliary power units (APUs) for off-road vehicles. Today, fuel cell technology based vehicles are considered to be in the demonstration stage, requiring to become more cost-competitive with conventional and advanced vehicle technologies in order to gain the market share.
  - Nonetheless, according to the US Department of Energy (DOE), the trends for the fuel cell industry were encouraging in 2012. Total fuel cell shipments (i.e. including any application for fuel cell technology) increased in 2012 (34% over 2011 and 321% over 2008) while costs continued to decline, especially for light duty vehicle applications. In several European countries such as Germany, Sweden, Denmark, and Finland, besides in the US and Japan, efforts are being dedicated to deploying hydrogen fuelling infrastructures. There were moreover several collaboration announcements between car producers with regards to fuel cell electric vehicles, including Toyota and BMW's long-term strategic

collaboration to develop a fuel cell system jointly, and Daimler, Ford, and Nissan joining forces to jointly develop a common fuel cell system and launch commercial fuel cell electric vehicles (FCEVs) as early as 2017.

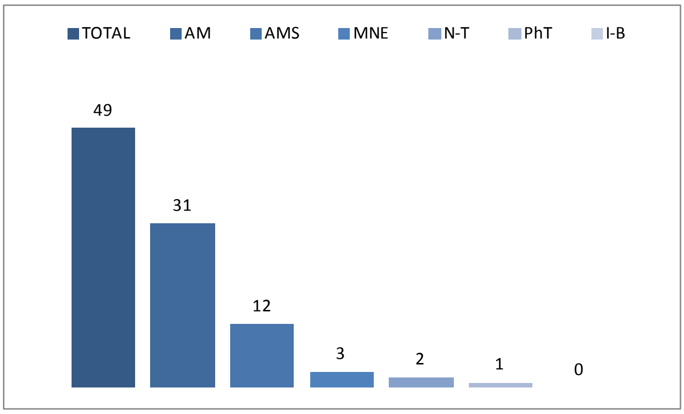
- Nearly 80% of total investment in the fuel cell industry was made in US companies in 2012, although UK was the next follower; 8 of the top 10 largest investors in fuel cell companies were from either the US or the UK, and collectively US and UK investors accounted for roughly 73% of all investment in the sector between 2000 and 2012. Despite this, however, the capacity to produce fuel cell systems at high manufacturing rates does not yet exist, and significant investments will still have to be made in manufacturing development and facilities in order to enable it. Once the investment decisions are made, it will take several years to develop and fabricate the necessary manufacturing facilities. Furthermore, the supply chain will need to develop which requires negotiation between suppliers and system developers, with details rarely made public.
- Nonetheless, in Europe, by 2030, the United Kingdom is projected to have 1.6 million FCEVs on the road, with annual sales of 300 000 fuel cell electric vehicles (FCEVs) in the UK alone, while the German Ministry of Transport announced its intention to build 35 new hydrogen fuelling stations, increasing the total number of stations to 50 by 2015.
- The Defence sector (in particular the US Department of Defense) is a world leader in the research, development, and demonstration of fuel cell technologies. Its support has contributed to significant improvements in fuel cell performance and reliability. This consolidated military knowledge is being implemented for civilian application, exploiting dual use technology.
- Sources: Breakthrough Technologies Institute Inc. for DOE, 2012 Fuel Cell Technologies Market Report, October 2013; Strategic Analysis Inc., Mass Production Cost Estimation of Direct H2 PEM Fuel Cell Systems for Transportation Applications: 2012 Update; October 2012

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

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



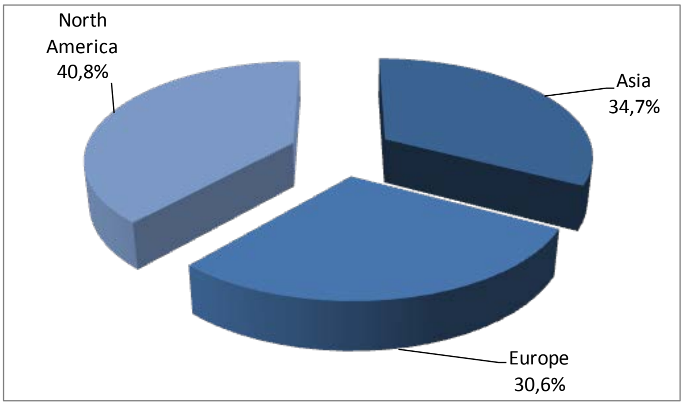
- Patents by KET(s):



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

KET(s)	*Number of patents*
AM	31
AM / IBT	1
AM / N-T	1
AMS	12
IBT	2
MNE	3
N-T	2
PhT	1

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection: