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# Ex post evaluation and impact assessment of funding in the NMP thematic area

Annex Report

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Research and Innovation

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Directorate-General for Research and Innovation
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EUROPEAN COMMISSION

# Ex post evaluation and impact assessment of funding in the NMP thematic area

## *Annex Report*

Edited by Dr. Chr. Enzing

Directorate-General for Research and Innovation
Key Enabling Technologies

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## GUIDE FOR THE READER

This is the Annex Report to the Main Report with the main results of the evaluation and impact assessment of the FP7 NMP Theme. This annex report presents in more detail the methodologies for data collection and data analysis, and the full results of the evaluation.

This Annex Report holds six chapters, with the results of the six methodological parts of the evaluation study. Each chapter can be read as seperate document, with an introduction, explanation of the methods used and the results. The names of the authors of each part are included in the chapter text.

The table below explains to which chapters of the Main Report the results presented in the separate chapters of this Annex Report have contributed.

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# 1. STRATEGIC CONTEXT ANALYSIS

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## 1.1 Introduction

This chapter presents the results of the strategic context analysis that was performed as part of the evaluation of the FP7 NMP Theme.

The main objective of this analysis was to provide a view on the on-going relevance of the NMP Theme, setting its objectives against two contextual environments:

- The related socio-economic contexts and the identified needs for policy intervention;
- The policy contexts, both at EU and Member States level.

We have characterised the socio-economic contexts and their needs for public intervention as identified in EC and other policy documents and we investigated how and why those needs evolved over time – including drivers and barriers. On the basis of this we have assessed to what extent the FP7 NMP theme at the various levels (overall, NMP Programme/PPPs, topic areas and funding schemes) intended to respond to those (evolving) needs over time.

In the policy contexts we have provided an overview of NMP Theme related policies and programmes in five selected European member states and assessed to what extent the NMP Theme was aligned, anticipated, guided or complemented NMP-related policies and programmes funded at the national level.

Both analyses have been built upon extended desk research and interviews. Information sources include EC policy and national policy documents and studies related to the NMP theme, ex-ante impact assessments and evaluation studies, sector roadmaps and the scientific literature. High-level interviews with experts in the thematic area have been used to validate and provide further support to our findings concerning the socio-context analysis (Section 1. 2). The list of experts (see Appendix A at the end of this report) includes experts with responsibility in relevant and thematically related decision groups as well as participants of the programme who, on a personal level, appeared in our participant database multiple times in various thematic areas. This latter group also informed our analysis of NMP related policies at the country level (Section 1.3).

## 1.2 Socio-economic context analysis

### *1.2.1 Introduction*

In this section we present our findings related to the relevance of the NMP Theme activities within the socio-economic context of the different sectors and thematic areas that relate to the activity of the NMP Theme, composed by the N, M and P areas of the NMP Theme and the three PPPs (Factory of the Future, Green Car, Energy efficient Buildings). With regard to barriers, drivers and challenges affecting the different sectors and thematic areas, the high-level interviews with experts was conducted to confirm the validity of the findings based on desk research.

We give a brief overview of the significance and trends of the key sectors relevant to the three areas of the NMP Theme and the three related PPPs, chiefly, to outline the key barriers to successful and widespread innovation that exist within them. For each area and PPP, the final section draws conclusions on the alignment between the activities supported and their context in terms of economic and societal issues and identified challenges, and whether the NMP Theme was able to engage the major players in each of the areas.

Unlike the other areas of FP7 NMP, the Integration area does not target particular economic sectors or markets and, as a result, an analysis of the barriers that the area was supposed to address was not possible. On the other hand, there is a strong sense of relevance and need of the technology integration concept. The relevance of the Integration area comes from the necessity to structure multidisciplinary projects integrating the other three areas of NMP and to bring together different technologies and materials to tackle specific challenges or application domains. As a result, the Integration area can be considered as a pre-cursor of the “multi-KETs” or “cross-cutting KETs” initiatives[1].

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[1] The Integration area comprises 19% of the programme funding and around 20% of the projects. The area differentiates from other areas by containing a higher share of unique participants (30%). Integration also

### *1.2.2 Nanosciences and nanotechnologies*

Key characteristics

Nanotechnology is a field of technology that aims at developing "the understanding and control of matter at dimensions between approximately 1 and 100 nanometres, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modelling, and manipulating matter at this length scale"[2]. Nanotechnology is a key enabling technology that can bring benefits to many different manufacturing processes and products. The upstream segment of the nanotechnology value chain includes raw-materials producers and well as raw materials intermediary product producers involved in scaling down material using techniques such cutting and etching. The downstream segment of the value chain comprises companies that develop and produce nano-enabled end products[3]. Industries that have nanotechnology applications include, amongst others, electronics and engineering, chemicals, health care and pharmaceuticals, textiles and construction, defence, and energy.

The OECD (2010)[4] also argues that nanotechnology can best be described as a field that is both science-based and demand-driven. R&D in the sector largely stems from larger companies that focus their production on market demand and are able to generate a critical mass of R&D. Cooperation with academia is of key importance, especially to smaller companies, and helps sourcing new knowledge. Relative to the overall trend in patent application data, universities are frequently owners of patent but companies still own the majority of them[5]. According to the EC (2013)[6], nanoscience is driven by fundamental research, with substantial government involvement.

Advancement in the nanotechnology industry is seen as potentially helping to address "some of the most pressing global challenges such as those related to energy constraints, climate change, affordable health care and global access to clean water"[7]. This recognition has driven substantial public investment towards the industry since the early 2000's, and particularly in the EU since the start of FP6 in 2002. A substantial part of the funding was directed through universities, directly or in collaborative university-industry projects[8].

Estimates for the size of the global market for nanotechnologies range widely. So far, many of the forecasts have proved to be optimistic. However, it is expected that the demand for nanotechnology products will increase more rapidly than world production"[9]. The EC (2012)[10] expects a global market size of around $27b by 2012-2015. For several reasons, it is challenging to acquire a precise estimate of the size of the global market and the effect of nanotechnology on the industry and wider economy. As already referred to above, nanotechnology plays a part in various industries. Although there is a vast market for nanotech developments, it includes sectors that are struggling to reach pre-crisis levels. Across-industry, substantial growth is expected.

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has a large share of Coordination and Support Actions (35% of the projects), and the projects include more different types of stakeholders. This is mainly because all ERA-NET activities are in this area. Also the area is characterised by a high proportion of projects targeting specific societal challenges or application fields.

2 Christopher Palmberg, Helen Dernis and Claire Miguet. OECD (2009), Nanotechnology: and overview based on indicators and statistics. STI Working paper 2009/7.

3 Ibid.

4 OECD (2010) The impact of nanotechnology on companies. OECD. Paris.

5 EC (2013). Comparative Scoreboard and Performance Indicators in NMP. Research Activities Between the EU and Third Countries.

6 Ibid.

7 Christopher Palmberg, Helen Dernis and Claire Miguet. OECD (2009), Nanotechnology: and overview based on indicators and statistics. STI Working paper 2009/7. pp 12.

8 EC (2011) Cross-sectoral Analysis of the Impact of International Industrial Policy on Key Enabling Technologies.Within the Framework Contract Sectoral Competitiveness ENTR/06/054.

9 ZEW and TNO (2010) European Competitiveness in Key Enabling Technologies. Centre for European Economic Research (ZEW) and TNO. pp. 97.

10 EC (2012) A European strategy for Key Enabling Technologies (KETs) – A bridge to growth and jobs. European Commission, June 2012.

Major barriers

There are several prominent barriers that inhibit the advancement of nanotechnology across EU countries, with a mix of 'hard' market failures and 'soft' system failures[11]:

- 'Hard' market failures:
  - Access to funding;
  - Access to skills;
  - Fierce non-EU competition in some sectors (i.e. electronics and semiconductors);
  - Fragmentation of market and lack of collaboration along the supply chains.
- 'Soft' system failures:
  - 'Overwhelming' amount of academic relations and less partnering with corporations;
  - Difficulty in communicating value proposition;
  - Uncertainty over consumer demands and regulatory constraints.

The barriers that are featured prominently include access to funding, access to skills, and collaboration along the supply chains (which implies research-industry and industry-industry collaboration).

From the interviews with high-level experts, regulatory and legislative barriers in the nanotechnology field are also considered as potentially hindering innovation.

In addition, the experts also highlighted issues with agreeing to the current definitions of nano-substances used by FP7. Some of them expressed concerns because, depending on the definition taken, substances with already known properties such as dye, lacquer and other natural substances are eligible for nanoscience and nanotechnologies support, potentially displacing projects on newer and more innovative nano-substances and materials. The lack of consistency in nano-registers across the EU adds to this situation, with several member states setting their regulations using different definitions. This issue of inconsistent definitions across Europe can lead companies as well as research actors to avoid the term nano to avoid conflicts established by the term.

Other regulatory issues are located in the toxicological domain and the related actions funded under FP7. In the view of some of the experts, there were too many small projects focusing on sometimes superficial topics. They would have preferred fewer and larger actions aimed at fundamental issues. Furthermore, the coordination of the actions aiming at toxicological issues was not optimal.

Globalisation or fierce non-EU competition was not perceived by high-level experts as a barrier, but was more perceived as a challenge to which European industry needs to adapt. There is a perceived slowness in Europe when translating research into commercial results, compared with competitors in Asia that are not subject to the same rules and regulations. This difference in regulatory frameworks can mask the impact that the FP7 activities of the nano field have in improving the competitiveness of European industries, compared to companies in the US and Asia. On the other hand, experts agree that Europe has a strong potential in setting European high-level standards that are then accepted and adopted globally. For nanotechnology, this potential is currently somewhat untapped. Europe has the possibility to set up standards that not only enhance the competitiveness of European actors but also influence companies elsewhere.

The experts see access to skills not as a huge issue. Nanotechnology is a field in which various disciplines come together. As a result there is always less people with the required competences, reaching from chemistry to engineering. Skill shortages are a complex topic, which involves at times unrealistic expectations from industry and lack of adequate compensation to professionals, rather than an actual shortage of people willing to work or get educated in the fields.

Networking and coordination issues across FP7 NMP activities were flagged. In the view of experts the separation of activities between the nanotechnology and materials topics was not always clear

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[11] The Case for Public Support of Innovation. At the sector, technology and challenge area levels. Produced by Technopolis Ltd for the UK Department of Business Innovation and Skills (July 2014).

in FP7. However, there is a general perception that this has been addressed for the most part under H2020.

Relevance of funded activities

The 'Nanosciences and nanotechnologies' area makes up about 25% of all projects funded under NMP and accounts for about 23% of EC contribution, making it by a small margin the largest of NMP areas. The potential applicability to a vast range of different industrial sectors makes this emphasis appropriate; its characterisation as a 'disruptive' technology highlights simultaneously the difficulty in estimating its added value precisely, as well as underscoring the importance for Europe to be a leader in this field.

Four action lines exist within this area with a minimum of 14 separate call topics in each of them and between 39 and 64 projects funded in each action line. The range of action lines, call topics and projects within this thematic area line up especially well with the results of the portfolio and composition analysis. The experts interviewed confirm that the amount of funding under FP7 NMP was adequate in relation to the calls. Since the 2009 EC Nanotechnologies Action plan, the EC focus on Nanotechnologies has included issues related to the environment, health, safety and society. The consulted experts applaud these efforts and feel that a dialogue has been created through the FP7 NMP and that calls under this programme are very comprehensive and cover all relevant areas under Nanotechnologies.

Looking at the funding data, issues around lack of funding and uncertainty about demand are responded to through the large share of projects dedicated to connecting the potential of nanotechnology with substantive user needs and demands from several key sectors. However, the experts consulted point out that, in their view, the approach in the nano area of FP7 NMP focused too much on the basic aspect of nanoscience research, especially in the first part of FP7. There is a general concern that calls on nanotechnology were mostly targeted on nanoscience research without sufficient focus on the use of nanotechnology to address societal and environmental challenges. Lack of application targets and support to production was seen as a general drawback that limited the potential impact of the activities in this support area on the economic growth of the sector in Europe. This problem was partly addressed with the introduction of the PPPs and a shift towards application-oriented funding in the rest of the Nanoscience and Nanotechnology projects. Experts also stress that, from the general information supplied by the EC and from the phrasing of the first H2020 calls, they can see that this issue has been mostly resolved in Horizon2020.

The electronics sector was identified as the key site of growth for nanotechnology, whilst there is no particular emphasis on this sector within the call topics and projects awarded. However, it should be noted that not all topics that are relevant for NMP areas are actually covered by the FP7 NMP Theme. In the case of nano-electronics, much of the work is done in FP7 ICT. With respect to this, the experts stressed that collaboration and coordination with other FP7 Themes - Health, ICT and Environment - still has room for improvement. Although overlaps are not seen as an issue (mainly because they are not really overlaps, but activities that tackle similar problems from different angles) there is a demand for less complexity and clearer information on what are the boundaries of NMP and what is supported by which FP7 Theme. Some of the consulted experts also argue that this issue has been resolved with the transition towards H2020.

Furthermore, there are large sections of the action lines and call topics devoted to (1) safety, and (2) improving networks, coordination and supply-chains, both of which were highlighted as key problems. Safety is identified as a key problem in the pharmaceutical/ chemical industry, which, after electronics is the other major growth area for nanoscience, making this an especially important and pertinent area for this thematic area to cover. Additionally, there are some thematic calls (especially one call in the 'cross-cutting and enabling R&D' action line) aimed at improving the skills base, which responds well to the problem of skills shortages.

Aside from a slight under-representation of activities relating specifically to the electronics sector (and that are dealt with elsewhere in FP7), the Nanoscience and Nanotechnology area is exceptionally well tailored to the barriers and problems encountered in nanoscience and nanotechnology, with no immediately noteworthy omissions or unexpected inclusions.

Going forward, the consulted experts suggest new foci of interest will need to be incorporated into this area to ensure it stays relevant with the needs of the community. Nanotechnology is a fast growing sector and at times the market participants are not able to digest all the developments. As a result, safety and training activities related to nano, raw materials considerations, nanotechnology standardisation and awareness raising activities are visualised by companies as a demand to be satisfied by researchers, research organisations and research projects.

### *1.2.3 New Materials*

Key characteristics

Historically, improving the properties of materials has been one of the most recurrent industrial innovation activities. Most of the work of the materials sector involves improving the properties of materials in terms of functionality, performance, reliability, user friendliness as well as health and environmental compatibility. Advanced materials use the knowledge of nanotechnology and biotechnology for new product and process development[12]. Other developments of interest include the development of more sustainable materials, such as bio-based materials, composite materials, materials with self-heating or self-repairing properties, nanotechnology enabled materials, materials with a reduced energy consumption, improved energy storage and energy transmission properties. According to EC (2009)[13] a substantial amount of advanced material solutions are based on a multi-material approach.

The industries that are particularly involved in materials innovations are the chemical industry, the automotive and the metals industry. Technological developments in materials can have a positive impact on a range of application areas, across the manufacturing chain. According to EuMaT[14], "materials technology has been considered as one of the mega-technologies together with biotechnology and information technology, which shall have the greatest influence on the industrial development, society and well-being of the citizens. In applications like semiconductors, high temperature super alloys for aircraft engines, industrial gas turbines and aerospace materials, technology has received recognition as a mission critical key technology". The application of advanced materials can reduce product life cycle costs substantially; relevant examples are developments in coatings for equipment and the development of lighter structures for transport[15].

There are several priority areas for the EU in the materials sector:

- Materials for ICT (e.g. optical nanostructures, organic and molecular electronics, biomaterials) and energy (generation, production, transportation).
- Materials for health and an enhanced quality of life: construction and buildings, materials for the environment, materials for security and safety, textile and design.

In terms of major players there is considerable experience in material sciences R&D across the EU. Overall, the Netherlands, Germany and the UK are the most commercial players but these member states have strengths across different sub-sectors, such as functional materials (DE, PL), materials for energy and sustainability (UK), pharmaceutical industry (DE), the sub-sector biomaterials (UK), materials for ICT (with ST microelectronics) and adhesive bonding technology and surfaces (DE).

Major barriers

There are a few notable barriers to research and deployment of advanced materials[16]:

- There is a fragmented supply-chain. This means that there is insufficient information flow across the different actors in a given industry/sector, generating coordination and collaboration problems. Collaboration between research and industry is key to ensure innovative ideas and advancement should be implemented at the broadest industrial base possible. Developments in the field benefit from total product life cycle considerations (e.g. to minimise waste).
- Competition from low-cost manufacturing countries creates additional pressure on the advanced materials industry.
- The industry is constrained by limited access to natural resources and raw materials, and their respective cost over time. Although the industry is dependent on natural resources

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[12] EC (2012) Economic foresight study on industrial trends and the research needed to support the competitiveness of European industry around 2025 Final Report. Fraunhofer.

[13] EC (2009) Proposition paper on future RTD activities of NMP for the period 2010-2015. NMP Expert Advisory Group (EAG).

[14] EuMaT (2012) The European Technology Platform for Advanced Engineering Materials and Technologies Strategic Research Agenda.

[15] Ibid.

[16] The Case for Public Support of Innovation. At the sector, technology and challenge area levels. Produced by Technopolis Ltd for the UK Department of Business Innovation and Skills (July 2014). pp 112-119.

and raw materials, advanced materials that implement nanotechnologies have a substantial scope to reduce the material input. This was further confirmed by talks with experts, who stressed that raw materials issues are becoming more relevant. Experts pointed out that FP7 NMP contained some activities devoted to this topic and the consideration of raw materials efficiency was implicit in many of the projects.

- The commercialisation of advanced material technology requires an assessment of potential health risks[17]. This may have several regulatory consequences.

Standardisation of methods for new materials and properties is a related necessity. Experts consulted insisted on standardisation as a key concept in both the materials and nanotechnology domains in order to enhance Europe's competitiveness and global positioning in the NMP Theme.

It is important to note that for the industries that apply advanced materials there are industry specific industry–related barriers. For example, in the chemical industry there are regulatory barriers specifically related to nano-materials[18].

Additionally, there are some barriers that will play a role across industry and technologic fields. For example, the NMP industry overall, is constrained by the access to a specialised labour force (researchers and generalists)[19].

<u>Relevance of funded activities</u>

The area 'New Materials' makes up about 23% of all projects funded under NMP and accounts for about 21% of EC funding. Given the potential applicability of advanced materials to the full range of industrial sectors covered by FP7 as a whole, this relatively large share of NMP activities does not appear unwarranted.

There are six action lines within this thematic area; within each of these there were several calls, resulting in between 14 and 64 funded projects per action line. The action lines, and the call topics within them likewise, respond especially well to the key barriers and problems identified in the preceding analysis. A fragmented supply-chain was highlighted as a key barrier; two action lines specifically are aimed at networking, integration and coordination, with several call topics and projects in both of them tackling this problem explicitly. Competition from low-cost manufacturing countries was likewise noted, and there are several call topics relating to cost-effectiveness in various contexts. Dependence on natural resources was found to be a key problem, which is addressed via specific call topics and projects geared at developing new materials to substitute scarce resources, and also more generally via research and development into new materials.

However, the experts consulted stressed that the raw materials challenge was tackled from a very 'basic research' oriented perspective (i.e. the chemistry of the different elements) rather than taking a more applied or industrial view, with actions that could be readily implemented. This comment aligns well with the fact that, looking at the project data from a TRL perspective, the materials area is the one most oriented to fundamental research (see Annex 2 with the results of the portfolio and composition analysis). In this occasion the experts didn't comment on whether they see this issue as having been resolved by the new H2020, possibly because those consulted still have not participated in any project of the societal challenge on 'resource efficiency and raw materials'.

One key barrier is the issue of safety and health risks of new materials. This was highlighted as a key problem that needs to be tackled in order to formulate suitable regulation and legislation on the use of new materials, and it is also necessary in order to instil consumer and demand-side manufacturer's confidence in new materials. As a result, a targeted effort to look into safety and health risks of new materials needs to be considered. Looking closer into individual projects, it is clear that some of them contain a safety-related dimension in specific work packages. This is especially true in projects targeting health related applications and societal challenges. On the other hand, given the seriousness of this problem, a more explicit emphasis - e.g. in the form of call topics or action lines devoted to this issue – would have been expected.

In conclusion, action lines and projects are well-tailored to the barriers.

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[17] EC (2009) Proposition paper on future RTD activities of NMP for the period 2010-2015. NMP Expert Advisory Group (EAG).

[18] EC (2012) Economic foresight study on industrial trends and the research needed to support the competitiveness of European industry around 2025 Final Report. Fraunhofer.

[19] Ibid.

### *1.2.4 New Production Technologies and Factories of the Future*

Key characteristics

The advanced manufacturing is a substantial component of the manufacturing industry in Europe and is a key driver for innovation, productivity, growth and job creation[20]. Specifically for advance manufacturing the following sectors can be considered important: photonics, automotive and vehicles and machinery. Within the NMP Theme, the European manufacturing sector is directly targeted both in the New Production Technologies area as well as through the Factories of the Future (FoF) PPP. The two try to address a different set of problems within the manufacturing sector and have different rules on how they provide support. However, the context for the manufacturing sector in Europe is the same for both of them. For this reason, to assess whether the activities that they supported were relevant to the context, they are analysed together.

The manufacturing industry grew from a turnover of €600bn in 2009 to €650bn in 2010 and is expected to continue to grow well into the future. The market size for advanced manufacturing technologies is expected to increase from $150bn to $200bn in 2015[21]. Moreover, Europe's leading role in the manufacturing industry (with 34 million employees) also attracts foreign investors. Industrial production accounts for 16% of Europe's GDP and 80% of Europe's exports are classified as manufactured products. Germany is by far the best performing European country in high-tech manufacturing (for the indicators: turnover, number of enterprises, number of employees and gross investments in tangible good), followed by France, UK and Switzerland[22].

Megatrends will have a considerable impact on nearly all types of manufacturing sectors and as a result drive structural changes in the sector. The following are the main drivers that are shaping the manufacturing sector today:

- Pressure to maintain a competitive advantage;
- Demand for high performance and precision with rapidly changing requirements (mass customisation);
- Cost reduction, pushes efficiency:
    - Enhanced networking and organisational learning;
    - ICT enabled intelligent manufacturing;
    - Sustainable manufacturing;
- Standardisation regarded as key: enabler of innovation, barrier to undesirable outcomes (i.e. poor product quality);

Larsen et al. (2011)[23] identify Europe as the leading region in advanced manufacturing technologies:

- The volume of patents in Europe in advanced manufacturing technologies is higher than in other parts of the world;
- About half of these patent applications are from Germany;
- A substantial volume of applications comes from France and the UK;
- A substantial amount of the patent applications are made by industrial giants such as Siemens, Bosch, and Continental.

Additionally, clusters around advanced manufacturing play an important role as catalysts for R&D, innovation and development (e.g. the UK Advanced Manufacturing Park (AMP) attracts companies such as Rolls Royce, Castings Technology International (CTI), and TWI's Yorkshire Technology Centre.

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[20] European Commission, Factories of the Future: http://ec.europa.eu/research/industrial_technologies/factories-of-the-future_en.html. Following the EC document, in 2009 it was estimated that 31 million people across the European Union were employed in the manufacturing sector with each job creating an additional job at least in services.

[21] Larsen et al. (2011) Cross-sectoral Analysis of the Impact of International industrial Policy on Key Enabling Technologies. Published by European Commission, DG Enterprise and Industry.

[22] Eurostat (2013) Annual Enterprise Statistics, NACE R2.

[23] Larsen et al. (2011) Ibid.

Major barriers

A report produced by Intelligent Manufacturing Systems (IMS)[24] in 2012 identifies a number of barriers faced by the manufacturing industry. In addition to this, an earlier report by Pablo (2009)[25] identified a number of barriers to innovation faced by the manufacturing sector. Additional barriers are identified by the EC (2012)[26] and Larsen et al. (2011)[27]. It is important to note that there are many different parts of the supply chain which fall under the umbrella 'manufacturing'.

Main barriers are to development are:

- Outsourcing to emerging economies;
- Availability of cost and finance;
- Lack of qualified personnel: lack of investment in training and difficulty for employers to predict relevant skillset;
- Internationalisation:
  - Firms not fully aware of potential benefits of exporting. Lack of necessary knowledge and capability to exploit overseas opportunities;
  - International differences in culture, language and regulatory frameworks (including IP);
  - Access to export markets are dominated by larger, more established firms;
- Fragmented manufacturing value chain and lack of know-how on how to commercialise RD&I developments;
- Lack of information on benefits of technology and uncertainty around new market opportunities.

These challenges and barriers were further validated through high-level interviews with experts. Experts agreed that market structure and pressure from non-EU competition was a challenge for industry, but also contributed as an incentive to innovate. Increasing R&D investments in Asian countries have shifted production outcomes and the higher value-added parts of the value-chain to these countries, thereby shifting also the revenues. However, the experts did not see that as paralysing of European manufacturing industry, but more as a 'call to action'.

Regulatory and legislative barriers were seen as particularly slowing down innovation only in some specific areas of manufacturing, such as those close to the food and chemical industry. Experts regarded standardisation of manufacturing as a necessary but complex issue that needs to be looked at more thoroughly.

Skill shortage issues were seen as important from two different perspectives. On one side, companies asking for very specific knowledge that is not always easy to find on the market, especially for SMEs. On the other, there is still work needed around defining which sets of competences human beings in the automated factories of the future need, and what types of employment roles are going to be generated.

With regard to access to finance, the consulted experts pointed at a generalised European issue of access to credit for production-oriented companies and at a generalised short termism from manufacturing industries to invest in longer-term research projects. Solving financial barriers and credit limitations is not within the remit of FP7 NMP. However, it was pointed out that the PPPs had been particularly relevant here, as it had fostered the development of new business models as well as the development of a financial track at the end of projects. This is regarded as a positive outcome of the PPP.

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[24] IMS is an industry led international business innovation and R&D programme established to develop the next generation of manufacturing and process technologies through multi-lateral collaboration. IMS provide global services to institutions from their supporting regions including the EU, Mexico and the USA.

[25] Pablo et al. (2009) Revealed versus Deterring Barriers to Innovation: Evidence from the 4th Community Innovation Survey.

[26] EC (2012) Economic foresight study on industrial trends and the research needed to support the competitiveness of European industry around 2025 Final Report. Fraunhofer.

[27] Larsen et al. (2011) Ibid.

Regarding the raw materials challenge, the views of consulted experts highlighted the differences of approach between the Materials area and the New Production Technology area and FoF PPP. In the Materials area, one of the experts pointed out the relevance of the work carried out in the search for materials that can substitute rare earth metals, among others. On the other hand, for the New Production Technologies area and FoF PPP, the most relevant way to tackle the same challenge has been through rethinking manufacturing and minimising waste and defective products.

Relevance of funded activities

Approximately 13% of the projects and EC contributions of the NMP Theme are devoted to **New Production Technologies**, this is significantly smaller than the Nano, Materials and Integration areas but similar to the profile of FoF.

The New Production Technologies area nine action lines comprise a total of 28 calls; out of these actions lines, two – 'adaptive production systems' and 'rapid transfer and integration of new technologies into the design and operation of manufacturing processes' – have an especially large amount of projects funded (27 and 20 respectively).

The New Production Technologies calls cover a relatively broad set of topics in advanced manufacturing. This includes call topics from chemical synthesis to the exploitation of technologies to safety management. The majority of the projects is focused on four call topics with 'adaptive production systems' accounting for 29.3% of projects. New Production Technologies tend to attract more research-based projects with a focus on more generic production efficiency increases and new ways of production. New Production Technologies also addresses problems associated with inadequate networks and poorly coordinated supply chains and are directly addressed in several calls, lines and individual projects.

The **Factory of the Future** PPP clearly lies within the NMP domain but also has strong support from the ICT Theme (contribution to EC funding: NMP €400m and ICT €200m; industry matches the other €600m). Approximately 13% of the projects and of EC contribution in NMP are devoted to the FoF PPP.

Together New Production Technologies and FoF form a relatively large proportion of the total NMP efforts, reflecting the important role of the advanced manufacturing in Europe in job and wealth creation.

There are 27 call topics for FoF covering a variety of topics from resources to processes to production systems to sustainability, all of which correspond well to the context of advanced manufacturing and the barriers that the industrial manufacturing sector faces (see Section 2.4). Each call resulted in between one and six funded projects, the only outlier being 'Manufacturing processes for products made of composites or engineered metallic materials', which resulted in 13 projects. This call like many of the other call topics for FoF had high levels of industry participation with projects having a more applied focus on specific industries. This industry specific focus has helped to directly address problems such as the 'dependency on volatile supplies of raw materials' and 'the lack of competitiveness in comparison to emerging economies that have lower marginal labour costs' as well as issues around flexibility and the adaptability of factories, with some projects also implicitly or explicitly aimed at standardisation. Indirectly, these problems have also been tackled through projects working towards greater efficiency and the use of new materials in manufacturing with some overlap with New Production Technologies.

The relevance of the different topics and barriers tackled was stressed in the interviews with experts; they highlighted the importance of research in new flexible production systems based on extensive use of ICT technologies. Overall, the call topics correspond well to the context of advanced manufacturing, the need for new production technologies and the barriers and problems associated with this area. Some of these problems are addressed more implicitly, without specific call topics and action lines, the two key examples being 'dependency on volatile supplies of raw materials', and 'the lack of competitiveness in comparison to emerging economies that have lower marginal labour costs'. Though these problems are not directly addressed in any of the call topics or action lines, they are addressed indirectly via projects working towards greater efficiency or the use of new materials in manufacturing. Problems associated with inadequate network and poorly coordinated supply chains are directly addressed in several calls, lines and individual projects. Also directly addressed are issues around flexibility and the adaptability of factories, with some projects also implicitly or explicitly aimed at standardisation.

The wider problem of a lack of funding for innovation is implicitly addressed by the very existence – and comparatively significant size – of both the New Production Technologies area and the FoF PPP within the NMP Theme. Other issues such as skills shortages, lack of information on new technologies and their benefits are not specifically addressed by the programme. As a result, the action lines and projects do not alleviate all barriers associated with this sector some also fall outside the programme's realm.

Nevertheless, overall, the scope of the advanced production technologies and FoF PPP allows for a range of activity that is closely aligned with the particularities and the problems and barriers associated with the sector. One of the consulted experts also made specific remarks on the experience of several SICA projects in the production domain, which included partners from Russia. Although these projects presented challenges with regard to matching timelines and incentives amongst partners, they were regarded as relevant from the point of view of generating positive synergies with new participants.

One important issue raised by the experts was the synergies generated by the presence of production and manufacturing topics in the FoF PPP. Experts commented positively on the synergies generated by the presence of production and manufacturing topics in both a thematic area of the NMP Programme and in a dedicated PPP. One of the major outcomes of the work done in FP7 has been the development of hybrid manufacturing systems with increased flexibility and increased usage of IT systems. In terms of thematic overlap, one of the experts pointed out that while there were some punctual cases (e.g. some transport projects with manufacturing components overlapping with New Production Technologies or FoF projects, or between projects funded by DG RTD and DG Connect) this was for mostly a positive redundancy, which at the end helped combining different approaches to solve joint challenges in the field. Another expert pointed out that, in his view, the main overlap was seen in national programmes, where funding was more likely to be allocated to actors and topics of lesser significance, something could have been better solved by those actors involved in the NMP. Overall, there was agreement that the PPP had been a great addition. However, the PPP as a meta-structure on top of FP rules should avoid generating unnecessary overhead for industrial actors.

Going forward into H2020, the consulted experts see the evolution of the NMP New Production Technologies area and the FoF PPP as fitting the wider context of a Framework Programme more focused on applications and activities of validation and scale-up of technologies, stressing that also sustainability aspects will be key for projects and employment in the manufacturing sector in the near future (something that the current NMP Theme and PPP have already addressed through several related call topics).

### *1.2.5 Energy efficient Buildings PPP*

Key characteristics

The construction sector experienced steady growth up to the financial crisis. However, the sectors' relative contribution to EU Gross Value Added did not decrease in the crisis years. This public-private partnership relates to an especially important sector, both in terms of economic activity, as well as in terms of resource consumption:

- The construction sector accounts for 30% of industrial employment in the European Union;
- It contributes about 10.4% of EU Gross Domestic Product;
- The sector consists of about 3 million enterprises, 95% of which are SMEs;
- Overall 48.9 million workers in the EU depend directly or indirectly on the construction sector;
- EU-27 figures from 2007 showed that within the construction market, the buildings industrial sector (residential and non-residential) was the largest economic sector, as its construction and refurbishment accounted for 80% (€1,200bn) of the total construction sector output (€1,519bn)[28].

Aside from the economic significance, it is worth noting that the construction sector is the highest energy consumer in the EU (about 40%) and it is the main contributor to Greenhouse Gas (GHG) emissions (about 36% of the EU's total $CO_2$ emissions and about half of the $CO_2$ emissions that are not covered by the Emission Trading System)[29].

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[28] Compiled from several different sources in: EC (2010) Energy-efficient buildings PPP – Multi-annual Roadmap and longer term strategy. Prepared by the Ad-hoc Industrial Advisory Group, EC/ERA/Eeb PPP.

[29] Ibid.

There is a need to ensure the EU construction sector continues to grow and prosper and the issue of emissions and energy usage also highlights the need for research and innovation from an environmental point of view (reflecting EU targets on energy efficiency and greenhouse gas emissions).

Major barriers

The following key market failures and barriers to innovation have been identified in the market for energy efficient buildings:

- Skill shortages: both in contractor and professional services;
- Construction materials, techniques and processes have long periods of testing, development and industry take-up;
- Lack of funds and/or inability to secure finance for energy efficiency measures;
- Lack of a holistic approach to the overall building operation;
- Information asymmetries, such as:
    - Need for greater understanding of user needs;
    - Lack of awareness of cost-effective energy saving opportunities;
    - Wrong user perception on the return of certain key technologies.

Some of these barriers and failures were f confirmed in the interviews we had with key experts. With regard to competition, the Energy efficient Buildings (EeB) PPP helped reduce the barriers to competition that SMEs in the sector often find by establishing newer ways of collaboration among actors in the industry working towards new energy efficiency concepts for buildings. In view of the experts, regulatory and legislative issues were not a major concern of the PPP under FP7. However, they agree that standardisation in construction is one of the main issues that needs more consideration going forward. Potential synergies with standardisation of materials and production processes are here evident.

In view of the consulted experts, skills had not been a major problem in their perception in the building industry. However, the attitudes of employers and employees are still too traditional, which usually slows down the uptake of new technical solutions considerably.

Credit constraints for new or retrofitted energy-efficient construction projects were noted as an especially significant barrier. One of the consulted experts pointed out that the Finnish government has launched an envelope-financing scheme to give members of the PPP access to finance by the government.

Relevance of funded activities

The EeB PPP accounts for about 7% of the total number of NMP projects funded and for 8% of total EC NMP funding. In this PPP, 18 call topics were issued, with between one and six projects funded in each. On average individual projects in this PPP are slightly larger than those in other PPPs and NMP areas, most likely owing to the fact that scale and integration/coordination in built environment projects are especially high, and demonstrations simply take up more space, time and resources than they do in other sectors. Moreover, the share given to this PPP reflects broadly the significance of the construction sector, whilst still keeping it below for instance the relatively more significant manufacturing sector. The NMP Theme contributes most to this PPP (€250m) the other are Energy (€125m), ICT (€100m) and Environment (€25m); the other half is matched by industry.

The range of different call topics reflects several different barriers to innovation identified. This includes aspects such as developing new means of producing energy-saving technologies and products more cheaply and efficiently, through use of - for instance - new materials. The barriers targeted include network fragmentation, lack of testing and quality control of techniques and processes, and organisational problems encountered in re-developing, retrofitting and renovating old buildings. The programme did not focus on the explicit development of new technology. Aside from the problem of skills shortages in the sector, which this kind of funding programme is not equipped to deal with, all key barriers highlighted are targeted by the calls, either implicitly or explicitly. Overall, both the range of calls, and the range of projects have a strong focus on problems stemming, not necessarily from science and technology itself, but on the intersection between technological developments and user needs: faster and efficient retrofitting, coordination of building projects and technology installation, cost-effectiveness. These are features that relate to the key barriers, and also have at least some relevance in the majority of funded projects in the EeB PPP.

The consulted experts stressed that one of the major outcomes from the PPP is that it is fostering a change of attitude of the involved industry actors. Not only the perception towards innovative solutions has changed, but also the energy efficiency perspective has evolved from one entirely focused on the building towards a more comprehensive value-chain approach, including aspects such as maintenance and impact on tenants and landlords. Although the change in perspective was strongly initiated by economic aspects, the orientation of the PPP towards societal challenges also contributed to sustaining it. The experts also pointed out that, going along with this change in perspective, the PPP has also contributed to find new business models and new approaches in industry players. The EeB PPP is seen as an optimal setting to get industry, researchers and other intermediaries of the buildings sector together to jointly act for change.

Overall, contrasting the contours and barriers of the sector with an overview of the EeB PPP does not highlight any areas of concern, and in fact points to a part of the NMP platform that is of suitable size and scope, funds projects that respond well to most key barriers in the sector and broadly involves suitable key players from an appropriate range and selection of countries.

The experts further stressed that in EeB PPP there were no major topics missing. However, it was also pointed out that going forward a stronger emphasis will be needed on the interaction among building components and systems, contributing to a more holistic picture of the challenges in the sector. One of the consulted experts considers the H2020 "lighthouse" calls a step in the right direction[30]. However, the shift from single projects with a clear focus on various research actions to lighthouse initiatives may prove to be too challenging for several actors involved in the projects because of the high internal communication and project management skills that such large projects require. A stronger focus on the interaction between building and energy system in the work programme, for example by fostering participation also of users such as the town councils, might be sufficient to ensure the continued relevance of the support.

### ***1.2.6 Green Car PPP***

Key characteristics

Transport is an especially broad economic sector, a 'system of systems', that comprises both the development and manufacturing of vehicles themselves, as well as the infrastructures, physical and digital, in which they operate. Additionally, and across these various sub-sections and subdivisions, there are private and public components, as well as a wide variety of different links connecting and coordinating the various components of the wider transport sector.

The transport sector as a whole accounted for 5.1% of GVA in the EU-27 in 2009, with 10.6 million people (or 5.0% of the total EU-27 workforce) employed in this sector, and EU-27 private households spending 13.0% (€904b) of their total consumption on transport-related items (vehicles, fuel, bus, train, etc.)[31]. The drivers for the development of the green car are clear. Innovation to ensure Europe's position at the forefront of this global sector would be of considerable direct economic benefit. Additionally, the risks and economic cost of currently existing congestion and pollution provides additional rationale for focus on innovation this field.

Experts confirmed the validity for the original rationale to establish a PPP to support the European automotive industry in the 2008 crisis. A green-car funding scheme was needed to help kick-start the automotive industry transition towards a more sustainable mobility model. The idea at the outset was to improve existing technologies (combustion engine) as well as to develop a track towards electric mobility. The consulted experts stress that the introduction of the Green Car (GC) PPP especially increased the commitment from industry to electric mobility. The establishment of shared roadmaps was a major contributor to this shift. Moreover, when the PPPs were established the instrument was completely new and hardly any tools were available on how to structure it. This ended up giving more freedom and flexibility to the interested parties and the different stakeholders were able to tailor the PPP to suit their own needs and to accelerate learning within the industry.

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[30] See "Smart cities and communities" H2020 call by DG CONNECT (H2020-SCC-2014).

[31] EU Transport in Figures – statistical pocketbook 2012. EC.

Major barriers

Wiesenthal et al. (2011)[32] provided an analysis, which places different modes of transport on a scale ranging from 'state monopoly' to 'most intense competition', and where better conditions for innovation are argued as being in the middle of this scale[33]. Intelligent Transport Systems (ITS) comprise various forms of digital systems, services and infrastructures that enhance the safety, ease and efficiency of use of the transport system. Overall, the barriers to innovation in transport systems differ from those noted on vehicle and fuel innovations in the sense that barriers are not so much centred on the supply chain and materials, and more on data availability, networking issues, operationalisation, as well as understanding of the products, their functions and implications.

Within this broad framework, a general list of obstacles to innovation that affect the transport sector can be drawn, with especial emphasis on those that affect the development of the 'green car':

- Path dependency in the wider national transport infrastructure;
- Cost of production of electric vehicle batteries;
- Uncertainty about consumer demand and concern as to long-term reliability of current solutions (i.e. batteries);
- Skills and network related barriers;
- Availability of a reliable and diversified supply of metals (i.e. for electrical motors and batteries);
- Negative spill-overs (first-mover disadvantage): companies cannot appropriate the full benefits of their innovation.

In the expert interviews, the barriers affecting the green car industry were further analysed. The issue of regulation and legislation was not seen as a big issue. However, standardisation requests to the industry have been an important topic during the 2007-2013 period. In this PPP, regulatory or legal aspects were not targeted, but the PPP contributed to standardisation activities that took place in parallel to it.

In terms of globalisation and market power, monitoring the competitiveness of European automotive industry has always been a major subject of the Green Car PPP. This was done with regard to technological trends as well as funding scheme developments (e.g. comparing the support received by automotive companies from Europe, the US and Asia when they wanted to establish new production plants or research centres). Also the PPP has allowed interacting in workshops with the automotive industry overseas, which has permitted the European industry to have a clearer picture of global developments, in turn benchmarking their own activities.

In opinion of the consulted experts, skills barriers only play a major role in the area of electro-chemical competencies needed in battery research and production. In this area it was stressed that Europe still lacks far behind Asia. Besides this particular area of skills shortages, the main concern in the discussions and actions of the PPP was focussed on boosting the currently smaller numbers of competent employees. The need for vocational education of employed engineers was stressed as a subject matter of the PPP, in particular in the areas of e-engine and energy management as well as light construction by new materials.

The issue of access to raw materials was a particularly touchy subject related to green car developments. When the PPP was established, some traditional industry representatives had strong objections against the green car idea based on sustainable energy. The argument was that electric cars just shifted the issues around the sustainability of transportation elsewhere, as electric cars used too many scarce resources and rare earth metals (such as lithium and neodymium, mined mostly in Latin America and China). Accordingly, a lot of points were raised to veto that direction. Studies carried out in the context of setting up the PPP provided more balanced input to industry

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32 Wiesenthal, T. G. Leduc, P. Cazzola, W. Schade, J. Koehler (2011) Mapping Innovation in the European transport Sector - An assessment of R&D efforts and priorities, institutional capacities, drivers and barriers to innovation. JRC European Commission, available at: http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26129/1/lfna24771enn.pdf.

33 ITF (2010) Transport and Innovation: Unleashing the Potential. International Transport Forum, available at: http://people.hofstra.edu/jeanpaul_rodrigue/downloads/Transport%20and%20Innovation_Leipzig_Summary_JPR.pdf.

representatives, dispelling many of these concerns and prejudices. Consulted experts regard this paradigm shift as one of the most relevant outcomes of the GC PPP.

Relevance of funded activities

The role of the NMP Theme in the GC PPP underpins the horizontal nature of nanotechnology, materials and production research and innovation. However, the support from the NMP Theme in the GC PPP is relatively small. In total five FP7 Themes fund this PPP initiative and the contribution of NMP Theme is relatively small: €60m of the €500m (the other €500m is matched by industry). The other FP7 Themes financing this PPP are Energy (€220m), Transport (€120m), ICT (€50m) and Environment (€50m). The GC PPP comprises just 2% of the total number of NMP projects and 2.5% of EC funding in the NMP Theme.

There are only seven separate call topics for this PPP, each providing funding for one to four projects. The GC PPP continues under H2020 and coordination of activities will become even more important going forward.

The consulted experts point out that the new PPP has shifted its focus more towards the transfer and integration of components for green vehicles and that the rationale for support is still relevant, with significant challenges for industry in the coming years. The collaboration between various DGs in the context of the GC PPP has worked very well under FP7 and should be preserved in H2020.

Some of the call topics explicitly focused on the issue of batteries, while others have a more generic scope on the use of new materials. However, the list of projects awarded across these call topics has an almost exclusive focus on batteries, either on optimisation and development of Li-ion batteries, using new materials or nanotechnology to improve safety, efficacy or other elements related to the existing technology, or using new materials other than Li-ion to develop batteries suitable for electric vehicles.

The foci of the awarded projects correspond well with the barriers that we identified: cost of production of batteries, quality of batteries, and supply of necessary metals for batteries were all key problems pointed out across the literature. At the same time, the virtually exclusive focus on batteries is surprising, given the broad range of technologies and sub-sectors that this thematic area sought to address. Advanced internal combustion engines, alternative fuels, and most notably the field of intelligent transport and logistics systems are completely absent from the list of awarded projects, something that is not completely unexpected, given that most of this work is bound to be carried out through FP7 Transport and FP7 Energy.

The interviews with experts reveal, however, some concerns regarding the strengths of the links between the GC PPP and research in complimentary topics carried out elsewhere. According to our consulted experts, smart grid and infrastructure topics were initially covered by the road maps but they were never established as a funding scheme in the PPP. There were only parts of the general topics placed in calls, e.g. projects that dealt with battery charging issues. However an overall energy system level for electric mobility was lacking. This link was stronger in projects of the mainstream NMP Theme, where synergies between materials and nanotechnology call topics were common and well established. For example, it was found that the GC PPP had insufficient links with contemporaneous activities in the topics of fuel cells and hydrogen. As intelligent mobility becomes more and more important, additional topics will need to be included in the agenda, both for the areas currently tackled by other FP7 Themes (e.g. car to car and car to infrastructure communications) as well as in those topics within the remit of the NMP Theme. The ERA NET Mobility (co-funded by the Commission as part of the FP7 ERA-NET Plus scheme, but not part of the FP7-NMP activities) was also highly complimentary to the GC PPP and aimed at member state cooperation in the automotive industry. However, the speed in the ERA-NETs was found to be slower, compared to the progress established in the PPPs.

At a more general level, there are some issues to be pointed out. Firstly, it is noted that the presence of free-rider effects are a problem in the automotive sector, often discouraging businesses to spend money on research and development, as they will not be able to appropriate the full benefits. The very existence of a platform targeted at part-funding research and development in this sector is therefore a suitable response. Secondly, the analysis highlighted some network, coordination and cooperation failures. The existence of some integration/ coordination actions related to the transport sector, but outside the GC initiative itself, indicates some degree of response to these, though it is highly unclear whether they are targeted specifically at the kind of coordination and network problems described here.

Other barriers that were pointed out in our analysis above are not addressed by this PPP, e.g. consumer awareness, path-dependencies and skills shortages. As a result, these barriers may hamper sectorial outcomes, even if the NMP platform were to be optimally utilised.

### *1.2.7 Main findings on relevance in the socio-economic context*

Socio-economic context and barriers to innovation

Our analysis in the previous sections shows there is a broad range of barriers inhibiting innovation in the sectors targeted by the NMP Theme. After outlining the key barriers to innovation that exist within these areas, however, there are issues that are both inside and outside the remit of the NMP Theme. Most of the barriers and challenges identified in the literature and relevant policy documents were confirmed by the experts that were interviewed to confirm the validity of our findings. The interviews also provided more depth to the analysis of the context, pointing out why some of the barriers occur and to which degree they are seen as showstoppers of innovation in the different fields.

For example, in the Nanotechnology area, main issues that hamper innovation are related to access to skills, and collaboration along the supply chains. This signposts the importance of an assessment whether research-industry and industry-industry collaborations were effectively tackled during the NMP Theme. The experts also stressed the importance of consistency in regulatory issues across countries for new products and innovations to spread. In terms of sector size and potential, all accounts forecast substantial growth of the nanotechnology sector, although figures vary widely depending on the source and of the method of calculation. We have turned at past and current trends of key European industrial sectors, but they can seldom be linked to a single one of the NMP thematic areas, as they are all linked to all of them.

For the New Materials area, the results show that barriers to research and deployment of advanced materials are mainly related to fragmented supply-chains, difficult collaboration between research and industry and the need to arrive at standardisation of methods and properties for new materials, something that was further stressed by experts. In addition, raw materials issues are becoming more of a concern.

In the case of the New Production Technologies area and the FoF PPP, the barriers revolve around market power and access and use of advanced skills. In terms of market power export markets are dominated by larger and more established firms, which coincidentally are the ones suffering less from the lack of availability and cost of capital. Other companies not in this position will suffer from high levels of risk associated with long-term investments in innovative new production technologies. While this is prevalent in the literature, the experts also point out that this challenge is nothing more than an incentive and a 'call to action' for European manufacturing industry to take innovation seriously. In terms of skills, the lack of qualified personnel in production industries adds to the fact that firms may not be fully aware of the potential benefits and potential competitive advantages resulting from investment in the development of new production technologies. The consulted experts added other issues - such as lack of access to finance and a general short termism from manufacturing industries - to this list of challenges.

In the Energy efficient Building field the issues revolve around the need for greater understanding of user needs and lack of awareness of cost-effective energy saving opportunities. In addition, the building sector also suffers from a lack of funds and/or inability to secure finance for innovative construction projects, something that was particularly stressed as a potential showstopper by experts. Other identified challenges relate to the lack of trained professionals and a general reluctance of the industry to take up new construction methods and energy efficient technologies. These professionals are the ones who will bear the reputational risks associated with a poor quality implementation and maintenance and the views of end-users towards innovative, energy-saving solutions will entirely depend on real-world (rather than on theoretical) performance.

The Green Car and intelligent transport fields have difficulties in bringing innovations to the market due to very high start-up and implementation costs. This, coupled with a lack of knowledge on the part of potential customers, can slowdown investment and innovation in the transport sector after the first push provided by the European recovery package. Skills barriers have been noted by experts, but only in very specific areas of battery technology, where Europe still lags behind Asian economies. Also related to the manufacturing of batteries and electric engines are the issues dealing with access to raw materials.

Although the available forecasts for areas covered by the FP7 NMP project significant growth going forward, the areas themselves are mostly based on existing industrial sectors with low to average growth trends. The importance of these sectors for the European economy, coupled with the hit they took during the worst period of the financial crisis, underpin the rationale for their support in search of growth. This promise of growth in these markets rests mainly on innovation and on the degree to which inefficiencies and barriers can be effectively minimised. These barriers, challenging most of the areas can be summarised as regulatory barriers, challenges related to globalization, internationalisation and trade, skill shortages, network and coordination challenges (in specifically across the value chain and between industry and research institutions), and access to natural resources and raw materials that feed into the production function.

Relevance of the funded activities in FP7 NMP

Together with the review of the technical, scientific and socio-economic context we have been able to assess the relevance of the activities funded in the NMP areas and PPPs. First, we assessed the thematic side of the different areas and PPPs by taking into account the relevance of the funded action lines and calls, as compared to the context. Secondly, we validated these findings through a set of high-level interviews.

For example, the Nanoscience and Nanotechnology area is very well tailored to the barriers and problems encountered in the strategic context of nanoscience and nanotechnology, with no immediately noteworthy omissions or unexpected inclusions. The Nano area in FP7 has evolved towards a more application-based area, taking also into account health and safety issues. Experts noted that, because nanotechnology is a fast growing sector, at times the market participants are not able to digest all the developments, so they tend to expect more support from the programme than what would be expected when talking about a more traditional area. We found that the Nanosciences and Nanotechnology area has also delivered on these expectations, as there are some call topics (especially one call in the 'cross-cutting and enabling R&D' action line) aimed at tackling skill shortages and other related sector barriers.

Not all the topics relevant to the NMP markets are delivered through the NMP Theme; for instance the electronics sector - identified as the key site of growth for nanotechnology - is covered by FP7 ICT. This highlights the importance of coordination and cooperation between the different FP7 Themes to ensure all relevant fields are supported. This effect also needs to be taken into account when we look at PPPs only in terms of the funding that was provided by the NMP Theme, as for example in the GC PPP a substantial amount of work is delivered through FP7 Transport.

In the New Materials area we noted the dependency on natural resources, which is on the one hand addressed more generally by research and development into new materials, but there are also specific call topics and projects geared at the substitution of scarce or difficult to source materials. This example underlines the importance of looking into specific types of support schemes such as international cooperation activities to see if they were adequately funded and were used as response to this key barrier and issue. The New Materials area is the one with a lower average TRL of projects, indicating a focus on basic research. As a result, the relevance of the New Materials area is harder to assess in terms of whether the area directly tackled the main contextual issues and challenges. Experts agree that, while the main challenges have been tackled effectively, the relevance of the work carried out in this area increased, as FP7 NMP was reoriented towards a more application-based programme. However, in the New Materials area this also caused the migration of materials projects to the newly funded PPPs, something that also affected in general the New Production Technologies area (e.g. graphene projects in the FoF PPP). As a result, the projects and call topics that remained in the New Materials area during the second half of FP7 were those where the 'considerations of use' for the resulting research were not that central to the project. For the other areas we found that most pressing topics are adequately represented in the action lines and call topics of the areas or PPPs.

On a general note, the issues that fall into the remit and overall objectives of the NMP Theme are tackled within the funded activities and underline the general relevance of the NMP Theme as regards the context and identified barriers. Our conclusion is that the FP7 NMP Theme has been successful in addressing a number of important barriers to innovation in the industrial sectors. The rationale for having an NMP Theme in FP7 was and still is valid, as many of the problems identified still apply. New technologies created in NMP are essential for building supply and value chains to deliver consumer goods and services.

The PPPs have grown to represent a considerable part of the budget of NMP. Consequently, their effect from a strategy-planning point of view for the NMP Theme has become significant. The core RTI programme has become the tool for funding research on new enabling technologies for all industry sectors and (as an initiator of technologies) to address the EU grand challenges, while the more applied topics have migrated to the PPPs. By introducing the PPPs, technology development is directly linked to innovation needs in specific sectors.

We conclude that the introduction of the PPPs in the FP7 NMP Theme has contributed to a better balance in FP7 NMP in terms of supporting different phases in the research, technology and innovation part of the value chain. FP7 NMP in its first phase was focused too much on basic research. Even though the NMP Theme aimed at improving industrial competitiveness from the beginning, the PPPs brought this goal closer by concentrating on specific sectors and their future challenges. The introduction of the PPPs implied a better matching of the programme with the needs of the specific sectors and also dealing with the specific barriers to innovation in these sectors. The relevance of the programme was strongly improved with the launch of the PPPs and with the reorientation towards call topics focused on applications and societal challenges. As stressed by the consulted experts, the PPPs have not only been relevant from the point of view of supporting critical industrial sectors during a crisis period, but have served as an instrument of collective learning and contributed to approaching positions between actors in the research and industrial worlds, taking crisis conditions and turning them into an opportunity to unlock innovation in established and emerging sectors.

In order for the programme to remain relevant in the future, maintaining the focus on application-oriented call topics, an emphasis on standardisation and a value chain approach of the consortia in the projects are aspects that repeatedly appear as potential success factors going forward.

## 1.3 Policy context analysis

### *1.3.1 Introduction*

This chapter aims to contrast the FP7 NMP programme with relevant NMP related programmes at the national level, in order to assess synergies and complementarities and to assess the outcomes of the analysis of the FP7 NMP programme strategy level also in a national context.

The initial set of countries to analyse were those that had a track record of technology oriented R&D funding focused on Key Enabling Technologies (KETs). We have studied a number of documents dealing with studies that, as part of their activities, have made an inventory of national policies and policy instruments in the field of KETs[34].

The selection of the set of five countries has been made on the basis of the following criteria, and with consultation with the project steering group:

- Presence of substantial NMP-related industries and national programmes;
- Availability of information (e.g. in existing studies);
- When several countries are relevant, increasing the geographic balance.

The final selection of five member states, validated by the Commission, comprised: France, Germany, Ireland, Italy and the Netherlands.

Cross-checking with the results of our composition analysis (see the Annex 2 report), these five countries fit well with some of the most involved in the programme, which means they have a large critical mass in NMP, and are a good sample of both small and large member states.

Each of the member states and related national policies is described according to the national context, its NMP related strategy and funding instruments and its complementarities and synergies with the FP7 NMP Theme.

### *1.3.2 France*

<u>The national context</u>

A large proportion of research in France in the field of NMP is concentrated in a number of public bodies. Main actors in the field of NMP in France include the Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA), the French Centre for Scientific Research (CNRS), and the Agence Nationale de la Recherche (ANR). Other players in the research landscape are the various grandes écoles, universities and laboratory, and research foundations. Additionally, bpifrance provides financing and co-investment solutions for firms of different sizes (guarantees, loans, SME finance) with the main objective of supporting, SME growth, entrepreneurship and competitiveness.

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[34] 1) Cross-sectoral Analysis of the Impact of International Industrial Policy on Key Enabling Technologies Final report - 28th March 2011, Ecorys et al. In Annex 3 National Innovation Policy Profiles of a number of countries including: France, Germany, Italy, UK (only EU MS included). 2) Emerging Global Trends in Advanced Manufacturing, Shipp, et al. March 2012, Includes Annex on National Policies and Investments. Germany and United Kingdom are the only two EU MS included. 3) The KETS Observatory website with information on most EC MS's KETs relevant programmes, that also address the N, M and P technologies. Available at: https://webgate.ec.europa.eu/ketsobservatory/policy. 4) The mKET Pilot Lines country reports on KETs policies plus the Benchmark Study Summary report.

The CEA research areas comprise of (1) defence, (2) energy, (3) fundamental research, and (4) technology. Under the domain of technology, the CEA is working in the following research field in NMP areas: micro and nanotechnologies (nanoscience, nanotechnology for health and energy, and nanotechnology for risk preventions) and nanomedicine[35]. The CNRS is a large public research institute under supervision of the Ministry of Education. It has ten institutes, out of which the institute of chemistry (INC) and the institute of physics (INP) conduct research in the domain of nanotechnology.

Strategy and funding instruments

Although there are multiple programmes in the field of NMP/KETS in France, the funding focus of such programmes is usually broad and not specifically tailored to specific NMP thematic areas. Laurent (2010) in 'Les politiques de nanotechnogies'[36] describes that France has initiated more dispersed policy in the field of nanotechnology.

In the 1990's and early 2000's, public interest in NMP areas was rather low key. But, in 2003, the OPECST, the French 'Parliamentary office for the Evaluation and scientific and technological choices' indicated some interest in semi-conductors and nanotechnology and at a later stage in the application of nanotechnology in medicine.

This application of nanotechnology became enforced with the establishment of the Agence Nationale de la Recherche (ANR) in 2005, with the objective of financing projects in higher levels of education and research. One major initiative of ANR was the 'Investment in the Future' programme (Investissements d'avenir) that was launched in 2009. The KETS Observatory describes this initiative as public equity investment in regional clusters of excellence, specifically in laboratory of excellence and institutes of technological research. With a public budget of €35b large scale projects are supported with an emphasis on technology related issues such as "acceleration of technology transfer", "innovation platforms", "development of digital economy", and an "ecotechnology funds". This includes the funding of projects in the field of nanoelectronics, nanobiotechnology and environmental research[37].

In 2013, the administrative council of ANR adopted a new plan of action for 2014, in line with the French strategy for 2020. This agenda only sketches broad guidelines and does not make reference to specific NMP areas. The French Horizon 2020 support system sets out rather broad guidelines for the strategic plan, for a three-year project[38]. The programme, under the heading of stimulating industrial revival, makes reference to the EC identified KET and to strategic technological sectors: nanoelectronics, nanomaterials, micro- and nano-fuidics, software, and miniaturised intelligent systems. An interesting statement in the document 'France Europe 2020' (2014) is that the national re-industrialization effort will be able to draw upon innovation to boost productivity and growth. Advanced manufacturing is identified as a means by which France can realise a reversal of de-industrialization. The term 'advanced manufacturing' is referred to as an Anglo-Saxon term.

Large-scale 'pôles de compétitivité' initiatives also play a substantial role in shaping the research and innovation landscape in France. At the heart of the competitiveness pole are cooperation actions between research, industry and the public sector. As described by Laurent (2010)[39], nanotechnologies are seen as tools to support these competence poles and in the coordination initiatives between research centres, laboratory, and national research programmes. For example, the industrial 'pôle de compétitivité' in Grenoble that has a focus on nanotechnology has a specialisation in micro nanoelectronics.

Moreover, the CNRS the CEA and the French government have launched six centres of competence in the field of nanotechnology, referred to as C'nano[40]. The C'nano are active is several regions in France. Their objectives are to generate scientific collaboration between laboratory, research

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35 http://www.cea.fr/technologies.

36 http://docs.eclm.fr/pdf_livre/345LesPolitiquesDesNanotechnologies.pdf.

37 http://investissement-avenir.gouvernement.fr/content/action-et-projets and http://www.agence-nationale-recherche.fr/financer-votre-projet/plan-action-2014/ and http://www.agence-nationale-recherche.fr/fileadmin/documents/2013/ANR-Clefs-PlanAction2014.pdf.

38 http://era.gv.at/object/event/15/attach/Roger_Genet.pdf and http://www.france-science.org/IMG/pdf/France-europe-2020_-_a_strategic_agenda_for_research_technology_transfer_and_innovation.pdf.

39 http://www.minalogic.org.

40 http://www.cnano.fr/spip.php?article1&lang=fr.

centres, and researchers, provide a structure to the regional research programme and serve as a regional point of reference.

One of the KET-related policies, identified by the KETS Observatory, is the French 'Bourse de Technologies' that is coordinated by bpifrance[41]. The Bourse de Technologies is a database of patented technologies (including patens in the field of NMP), for patents issued in France and it is free of access. Target groups are: innovative SMEs, large firms, individual project holders, etc.

Complementarities/ synergies with the FP7 NMP Theme

Because of the large-scale collaborative nature of, in particular, the competitiveness poles, NMP policy in France targets both development of basic research, applied research and prototyping, as well as the deployment of new technology systems. Experts consulted pointed out that ANR calls can have large overlaps with the calls from FP7 NMP (also in terms of timelines).

Because the competitiveness poles initiatives are large-scale projects, they are comprehensive and integrate across research organisations and industrial giants, and to some extent, SMEs. French partnerships to involve industry in research initiatives are still seen by experts as anecdotic rather than system-wide, as compared to some other European member states. The competitiveness poles receive substantial support from the public sector, generating opportunity for development across the different TRLs.

The EU FPs can have an important contribution to the French programme as they open the French research system to a large multidisciplinary research base and provide access to an international perspective. Experts stress that French scientists benefit especially from the creation of European networks, which can generate a change in the French research culture (with many non English-speaking French scientists). Programmes that can successfully generate international collaborations and possibly the mobility of researchers may, under specific conditions, speed up advancement along the TRL. (Non-French) researchers, interested in the various NMP in which France has a specific competitive advantage, may find opportunity to exchange best practices via the EU FPs.

### *1.3.3 Germany*

National context

Germany is a somewhat special case among the member states, as it has a very broad and a well-developed research base and the largest European manufacturing base in all key areas of interest. There is therefore little need for specialisation, such as other – especially smaller - member states may require. Instead, Germany has several initiatives to support all three key areas, largely aimed at application to industry, rather than for instance development of basic research or fostering emerging industry. Overall, Germany already has one of the highest Business R&D expenditures in the world. As a share of sales, Germany lags behind several leading industrial nations in R&D intensity.

The focus at the national level with a strong priority on the inclusion of businesses (including SMEs) appears warranted. Overall, scientific production and quality indicators as well as patent indicators indicate that both a sophisticated research base and a major world-leading industry exist. The connection between the two, though also strong, is the least developed aspect, at least in cross-national comparisons between leading world players.

The actions undertaken in Germany are largely initiated and coordinated by the Ministry for Education and Research (BMBF), and to a lesser extent by the Ministry for Economy and Technology (BMWi) and various other bodies.

One of the key points stated in the German Government's action plan is to ensure safety of nanotech products, to ensure consumer acceptance. This is repeatedly made explicit. In terms of the specific NMP thematic areas, they frequently appear classified alongside other KETs, most notably photonics, biotech and especially microelectronics (often presented in tandem with nanotechnology).

41 http://www.bpifrance.fr. Previously, la Bourse de Technologies was implemented by Oséo, which in 2013 became an integral part of bpifrance.

Strategy and funding instruments

There are approximately 22 policy initiatives at the national level in Germany that are relevant to the NMP subject area. There are a number of generic instruments that are particular relevant for NMP and a number of programmes that address N, M and/or P.

The most relevant programmes – which specifically address one or more of the NMP areas - are:

- The Framework Programme Microsystems;
- The Nano Initiative Action Plan programme;
- The Framework Programme Materials Innovations for Industry and society;
- The Framework Concept for the Production of Tomorrow;
- The Programme Promotion of Joint Industrial research;
- Central Innovation Programme SME.

The Framework Programme Microsystems was part of the High-Tech Strategy for Germany and microsystems engineering and nanotechnology ate considered as two complementing disciplines of miniaturisation in science and technology. The programme ran from 2004-2009 with a budget of €180.5m. Nanotechnology provides access to so far unused, completely novel effects, whilst microsystems engineering allows for the development of complete systems solutions. Demand-oriented technological priorities are defined and existing priorities revised over the whole term of duration of the Programme. The definition of the priorities thereby closely follows the concept of lead innovations, which are innovations based on novel technologies targeted at value added chains with significant macroeconomic potential. The most important feature of a lead innovation is its high leverage effect in terms of growth and employment. The focus of the programme is on collaborative projects between industry (especially SMEs) and research.

The Nano Initiative Action Plan programme (active since 2002) is also part of the High-Tech Strategy for Germany and is a joint initiative of eight ministries: BMBF, BMWi, the Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), the Ministry of Health (BMG), the Ministry of Defence (BMVg), the Ministry of Labour and Social Affairs (BMAS) and the Ministry of Food, Agriculture and Consumer Protection (BMELV). Based on the identification of the growing importance of nanotechnology, this is a multi-purpose strategy with several dimensions aimed at further consolidating Germany’s position as leader in the field. Key foci of the strategy are the creation of new jobs and markets, leading-edge innovations, networking of research institutions and actors, using chances of European and international co-operation, strengthening of SMEs and new spin-offs, supporting young scientists and initiating societal discourses concerning nanotechnology's chances and risks. The main elements of the strategy are to open up potential markets and boost employment prospects in the field of nanotechnology. But as well as a key component of research and development funding on specific technologies within the wider nanotech field, the programme also includes funding measures for targeted support of R&D intensive SMEs, offering existing companies assistance in the early stage of consolidation, as well as a competition for early stage researchers in nanosciences, and public awareness campaigns, to educate the public about safety and foster debate on tackling the risks and recognising the opportunities of nanotechnology.

The Framework programme Materials Innovations for Industry and Society has three key goals: strengthening the enterprises’ innovative power, considering social demand and using research and technology for sustainable developments The approach is to generate materials-based product innovations in a holistic approach while simultaneously taking account of the social demand for new material developments as well as of sustainability aspects. In its lead goals BMBF wants the programme to orient to internationally agreed cornerstones of sustainability. In concrete terms, these requirements are reflected in the specific funding activities, which focus on relevant topics such as health, mobility, information/communications and sustainability.

At the project level, the framework programme pursues the following goals, which act as research policy guidelines:

- Exploiting the innovation potential of materials and their technologies with a view to developing new products and processes with social benefit;
- Accelerating the innovation process in industry by creating efficient cooperation structures between industry and science with increasing incorporation of SMEs (e.g. by building up suitable infrastructures, collaborative projects);

- Contributing towards solving socially relevant problems especially caused by demographic developments in our society;
- Dovetailing R&D with education/training initiatives, contributing towards creating a European research area and intensifying internationalization, above all by greater participation of German R&D actors in the EU framework programmes, but also expanding bilateral cooperation with countries like China, Korea, Brazil and Israel.

The main rationale of the Framework Concept for the Production of Tomorrow is to foster the German manufacturing industries in an ever more dynamic and competitive environment by developing new production technologies and systems. The research programme (since 1999, with budget of €403m) is therefore problem-driven and comprises four thematic fields of action: Market orientation and strategic product planning, Production processes and production equipment, Cooperation of producing enterprises and People in flexible enterprises. Within and across these thematic areas, BMBF supports research on new production technologies with the objective of developing model solutions for future-oriented production in Germany and providing research results for broad use in particular in SMEs. It was designed as a "learning programme" in which expert forums identify research needs to be addressed consequently in collaborative research projects. Applications will be assessed along the criteria of economic relevance, orientation towards the future (cutting-edge technology, high risk innovation), systemic approach (inter-disciplinarity, cooperation between business and science, concepts for project controlling) and breadth of potential impact (sector-wise), education and further training aspects.

Innovation Alliances was an instrument (2007-2012) that funded strategic cooperation between industry and public research in key technology areas, especially those that demand a large amount of resources and a long time horizon. Through a public-private partnership, the federal government provided funding for R&D and other innovation-related activities for specific, long-term co-operative R&D projects, which can range from fundamental research to prototype development (€500m provided by federal government, €3bn by industry). The federal government's contribution is typically 20%, with the remaining 80% of funding coming from business. Each innovation alliance is set up as a long-term co-operative research project through an industry initiative and involves several industry partners as well as public research organisations. Consortia of public and private actors can submit projects at any time. They typically emerge out of previous activities, often funded under thematic R&D programmes. Projects are selected based on a quality assessment of the new technology to be developed; it has to be a break-through technology of global impact that will strengthen the competitiveness of the German economy and with high-level of commitment of the industrial partners. Innovation alliances received funding when industry was ready to cover at least 80% of total project costs.

The IGF Promotion of Joint Industrial Research programme is active since 1994 and gives grants for R&D projects solely to the 106 sectorial research institutions that are members of the Association of Industrial Research Organisations (AiF). Budget in 2010 was €130m. Projects are carried out by those institutions or on their behalf by consortia of companies and/or research organisations. These institutions have been founded by SMEs from certain sectors in order to carry out R&D that is in the joint interest of the membership firms. Objective of the programme is the mitigation of structural disadvantages of SMEs in R&D activities. Joint R&D is intended to support co-operation with institutes of higher education and industry-related research institutes and thus diversify the risk associated with R&D activities, putting SMEs in a better position to participate in the R&D activities and benefit from their results.

The Central Innovation Programme SME (since 2008, with an annual budget of €500m)) is an application-oriented funding programme that aims to reduce the risks of R&D-projects by funding a share of the costs for SMEs. It provides grants to SMEs to help them finance research and innovation projects. Applications can be submitted in all technologies, sectors and topics (with the KETs, including Nanotech, Materials and advanced manufacturing among the explicitly stated possibilities). The programme places a particular priority on supporting collaboration between businesses and research organisations in order to accelerate the transfer of cutting-edge technologies into marketable products. Criteria for approval of funding are chiefly the innovative content and good market opportunities of the funded projects.

<u>Complementarities/ synergies with the FP7 NMP Theme</u>

Given the breath of the German public policy in NMP-related areas, there is not a gap that EU programmes specific German policy and programmes could cover.

There is a large basis to generate complementarity between the EU programme and the German programmes. Nanotechnology, materials and advanced manufacturing are all served with several initiatives, integrating research organisations, large industrial players and SMEs, and encompassing long-term developments and near-market projects alike. Moreover, the high level of frontier research and innovation make German partners ideal partners for collaboration in EU programmes

However, the German strategy does not exist in complete isolation from European level framework programme action. Thus, the programme Materials Innovations for Industry and Society has as its explicit aim to also foster greater participation of German players in EC FP projects. More broadly, BMBF's Action plan for Nanotechnology notes a commitment to integrating activities in Germany with international R&D activities, citing specifically EC FP, as well as OECD collaborations. The purpose of this is however defined broadly, citing the importance of connecting German R&D activities to the wider network and knowledge base that exists internationally, exporting and important talent and research results. These are of course generic points, leaving the FP7 NMP theme effectively as an additional source of funding for research and development in these fields which, aside from a certain level of internationalisation and additional networking, adds mainly in terms of overall quantity rather than complementarity to the funding available in Germany.

### *1.3.4 Ireland*

The national context

Ireland is a relatively small member state with a limited science base as compared to Europe's major players. Additionally, it only recently transitioned from a manufacturing to an innovation and knowledge driven economy, evidenced by the fact that until 1998 there was no history of coordinated investment in research. As such, the conditions in Ireland hardly allow for investment in all areas of new science and technology, and have therefore instead focused on identifying key emerging strengths and ensuring specialisation. Thus, in the late 1990s, niche areas within ICT and biotechnology were highlighted as key areas for development. Following this, the Science Foundation Ireland (SFI) was established in 2000 with a budget of €646m, to provide grants for researchers, for investigators, conferences and symposia, and for collaboration with industry. The majority of SFI efforts was channelled into areas in line with the recommendations for priority areas.

More recently, though ICT and biotechnology are still key strengths in Ireland, nanotechnology has been identified as a key priority for Ireland, with significant emerging strength. Though in terms of trade, industrial biotechnology is a key strength in Ireland, at the level of patents, research and development, nanotechnology has gained in significance. Patent (citation) data show that Ireland is belonging to the group of countries that is performing at the highest level: that of country on 'the production frontier of patent and trade performance' (see also Xin et al. (2007)[42]).

The 2006-2013 Strategy for Science, Technology and Innovation presents a comprehensive and integrated government innovation policy for Ireland, in which biotechnology and nanotechnology are explicitly promoted as the two KETs of particular interest and focus, with photonics, photovoltaics, fuel cells and geothermal technologies cited as other KETs worth fostering, but little explicitly mentioned desire to emphasise either Advanced Materials or Manufacturing technologies.

As such, in 2010 Forfas launched Irelands Nanotechnology Commercialisation Framework 2012-2014, for which there is no equivalent for the other KETs of interest to this study, further evidencing the extent of specialisation observable in Ireland. Although there is no explicit specialisation on advanced materials similar to nanotechnology, advanced materials are understood as a key application field of nanotech. This needs to be kept in mind, as it is certainly an explanatory factor for why advanced materials do feature in the scope of funding instruments in Ireland, despite the multiple pronouncements on the prioritisation of nanotechnology.

Except for SFI, also Enterprise Ireland (EI) and the Higher Education Authority (HEA) are funding source for the concerted specialisation on nanotechnology in Ireland.

Strategy and funding instruments

There are two major funding sources at member state level in Ireland - Technology Centres and the Centres for Science, Engineering and Technology programme – and a number of other initiatives that are relevant to NMP.

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42 Xin Li, Yiling Lin, Hsinchun Chen, Mihail C. Roco (2007) Worldwide nanotechnology development: a comparative study of USPTO, EPO, and JPO patents (1976–2004). Journal of nanoparticle research 9(6) pp. 977-1002.

Technology Centres are collaborative entities established and led by industry, and are resourced by researchers associated with research institutions qualified to undertake market focused strategic R&D for the benefit of industry. This scheme was launched in 2007 and is still running, with would operate with centres operating with State funding around €1m per year over a five year period. It is a joint initiative of Enterprise Ireland and IDA Ireland allowing Irish companies and multinationals to work together in these centres. Generally, the centres are based in a university, with support from partner colleges to deliver on the research needs of the companies. There are currently 15 centres in the Technology Centres Programme, five of them in the manufacturing and materials field:

- Irish Centre for Manufacturing Research – ICMR;
- Pharmaceutical Manufacturing Technology Centre – PMTC;
- Irish Centre for Composites Research – IComp;
- Microelectronic Circuits Centre Ireland – MCCI;
- Collaborative Centre for Applied Nanotechnology – CCAN.

The aim of the Centres for Science, Engineering and Technology (CSET) programme of Science Technology Ireland is to strengthen the links between academia and industry. The programme that started in 2002 has a number of goals: address key research questions, foster the development of new and existing Ireland based technology companies, attract industry that could make a significant contribution to Ireland's economy, and to expand educational and career opportunities in science and engineering. It is a key requirement of the programme that CSET-funded centres must exhibit outstanding research quality, intellectual breadth, active collaboration, flexibility in responding to new research opportunities, and integration of research and education. By 2012, ten such centres were in existence. The allocated grants are from €1m to €5m. The overall funding for CSET centres in the period 2003-2012 was €316m, with €42.8 specifically devoted to the nanotech field.

Though these are the only two initiatives explicitly aimed at NMP, other initiatives that have awarded significant numbers of grants in these areas, are:

- ETS Walton Visitor Award enables international academic and industrial researchers to visit and collaborate with Irish research groups. The awards are offered on a worldwide competitive basis.
- US and Ireland R&D Partnership, launched in 2006, involves funding agencies across three jurisdictions: the USA, the Republic of Ireland and Northern Ireland. Prioritised thematic areas are Nanoscale Science and Engineering, Sensors and Sensor Networks, Telecommunications, Energy and Sustainability, and Health.
- Principal Investigator Programme (PI) is one of a number of programmes aimed at developing Ireland's basic research capabilities.
- Research Frontiers Programme (RFP), aimed at supporting innovative, significant and internationally competitive research in a broad range of disciplines in Science, Mathematics and Engineering, and to provide a base of support to underpin Irelands strategic priority areas of science and technology, as well as to provide a mechanism to identify changes to strategic priorities in the future.

Complementarities/ synergies with the FP7 NMP Theme

In Ireland, there is some funding available for advanced materials and manufacturing through a number of national funding instruments. National policy also covers advanced materials within the nanotechnology theme, but synergies and complementarities between Irish national policy and the FP7 NMP Theme need to be understood chiefly in the context of the strong specialisation on nanotechnology.

FP6 and FP7 contributed some degree of funding for Irish nanotech research, though this was a relatively small amount compared with SFI's investment (€167m through SFI and €34m through FP6 and 7 combined). This national funding contributes to the focus of Ireland on this key strategic priority. The extent to which EU funding allows Ireland specialise further in the field of nanotechnology is unclear. A typical advantage of EU-level funding would be that it entails internationalisation of research. However, as outlined above, Ireland does have funding programmes geared specifically at international collaboration. So in this respect, FP7 contributions to Irelands nanotechnology landscape by adding more channels for internationalisation and international cooperation

The absence of strategic priority in advanced materials and manufacturing means that the NMP theme could provide opportunity to expand into new areas. However, these opportunities exist in areas where Ireland does not have significant strengths

A study on EU policy initiatives on KETs conducted a case study on Ireland's nanoscience/ nanotechnology platform[43]. The report notes some key deficiencies in EU programmes, which cast doubt on the extent to which synergy and complementarity is in fact taking shape on the ground[44]. Given that the lack of 'critical mass' and absence of major industrial partners within Ireland have been identified as a hindrances to greater proliferation of Irelands strengths in nanotechnology, these criticisms of FP7 support in this area is especially concerning, and puts into question whether those complementarities that could exist have actually been taking shape.

### *1.3.5 Italy*

<u>The national context</u>

Although low with respect to other EU member states, 1.27% R&D expenditure as a proportion of GDP represents a substantial increase from the beginning of the 21st century, when this percentage was close to 1% of GDP. This increase can be largely attributed to the private sector.

As described by the KETS Observatory, the Italian national research programme, (Programma Nazionale di Ricerca-PNR (€6.08b for 2011-2013), outlines the strategic lines and priorities for the Italian research system. The new national research programme for 2014-2020 was also released in February of this year[45].

The KETS Observatory notes that the programme does not explicitly identify KETS areas. However, the programme does outline several strategic priorities relevant to NMP it makes specific references to strategic priorities for Italian research, in, amongst others, nanostructures and new materials. Reference is made to the strategic importance of mechanical properties, electromagnetic properties and chemical properties that are in line with the demand of space technologies and transport infrastructure needs. An additional objective is that of strengthening governance structure and collaboration.

The EC (2013)[46] identified the Inter-Ministry Committee for Economic Planning (CIPE) as the highest level of S&T policy coordination in Italy. The CIPE approves the national research programme. The Ministry of Education University and Research (MiUR) coordinates the S&T activities and the national research programme and distributes funding to universities and research institutions. The Ministry for Economic Development (MED) is directly involved in supporting and managing industrial innovation[47].

Additionally, the following organisations are working in NMP related areas:

- The Italian Space Agency (ASI), funded by MiUR and by the Ministry of Defence;
- The National Agency for New Technologies, Energy and Environment (ENEA);
- The National Research Council (CNR).

The CNT is the largest public research institution in Italy and is funded by the MiUR. The majority of Italy's finding programmes are coordinated by the CNR. Some of the research institutes that are connected to the CNR are the Istituto dei Materiali per l' Elettronica ed il Magnetismo (IMEM) and the Instituto Nano.

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43 DG Enterprise and Industry (2012) Exchange of good policy practices promoting the industrial uptake and deployment of Key Enabling Technologies. IDEA, ZEW & WIFO

44 There are too many programmes and differences in approach in FP7 and accompanying programmes – The terminology and rules need to be streamlined and simplified – CIP, JTIs, Article 169, KICs, ERC, ERA, STREPs, CSAs, NOEs, KETs, ERA NETs, ERANET+, PPPs etc. This is too much, particularly for companies to understand and to get to grips with the landscape. […] It should be easier to access European research facilities and there should be European Fab-labs in order to create European critical mass. This will also help smaller countries to access state-of-the art facilities.

45 See http://hubMiUR.pubblica.istruzione.it/web/ricerca/pnr and http://www.MiUR.it/Documenti/ ricerca/pnr_2011_2013/ PNR_2011-2013_23_MAR_2011_web.pdf

46 EC (2013), Annex 4 Country level NMP research actions and strategies.

47 Ibid.

Strategy and funding instruments

There are roughly 16 general programmes in Italy that tackle topics related to NMP. The KET Observatory outlines the five major policy initiatives that are implemented in Italy; we present them in more detail.

The Italian Technological Districts[48] programme of MiUR aims at supporting R&D activities in specific sectors and districts. It has provided support for 25 or above districts across the different regions of Italy. Some of the districts focus on specific NMP areas; these are industrial biotechnology, nanotechnology, advanced materials, advanced manufacturing, micro- and nanoelectronics. One example of an Italian Technological District is the Italian cluster for nanotechnology in Veneto, launched in 2002. The Veneto Nanotech district received €60m funding. Except from support of MiUR, the cluster benefited from support from the regional government, which included also support from universities and other organisations in the Veneto region. Other examples of districts are the advanced material district in Lombardi and the advanced mechanics district in Emilia Romagna.

The Italian flagship 'Progetti Bandiera' programme (14 projects in total) ran in the period 2010-2013. It includes three flagship projects in the NMP area: Future Factory on advanced manufacturing technology (€12m), NanoMax on nanotechnology (€23m) and ELECTRA-FERMI-EUROFEL on nanotechnology and advanced materials (€45m). For example, the flagship project Future Factory is a research programme, which is coordinated by CNR and was launched in 2012. This project complements FP7 NMP initiatives, funding research under the following macro objectives[49]: Factory for Customised Products; Evolutionary and Reconfigurable Factory; High-performance Factory; Sustainable Factory and Factory for the People.

In terms of output, the research should either contribute to the development of innovative products, new solutions or new frameworks for factory design and management. The projects also seek to strengthen cooperation between universities and industry, and institutes – one component is to promote training initiatives.

The Industria 2015 programme of MED started in 2007 (budget of €1.02b for 2008-2010). It is part of Italy's wider industrial policy framework, set up under the government of Prodi II and intended to support Italy's private sector during the crisis. The initiative is aimed at high-tech technology and upgrading SMES; it also includes some support to NMP areas, specifically manufacturing industry and new technologies. The three instruments are projects for industrial innovation, network of enterprise and innovative finance.

The projects for industrial innovation, are a more novel component in industrial policy in Italy, and are in line with the macro objectives set out in the national reform programme of Italy (efficient energy, sustainable mobility, new technologies for life/life sciences, new technologies for 'made in Italy', and innovative technologies for cultural heritage).

RIDITT, the Italian network for innovation and technology transfer to SMEs provided funding for and monitored the programmes on innovation at the national, regional, and local level. It was funded by a number of Ministries of Economic Development of specific region. The budget was €12.5m for high-tech innovation and €5m for 'la domotica'. One of the technological areas of RIDITT was advanced materials, micro and nanotechnology. Since 2009 no new projects have been launched[50]. One example of a project funded was: 'Hi-tech' aims at supporting the creation of new firms in high-tech under invested areas'. Target groups of the network were consortia of universities, industry, including SMEs, and foreign partners.

FAR, the Industrial Research Support fund of MiUR supported research projects submitted by companies, science parks, research centres and consortia. Various research projects in field of energy efficiency, sustainable mobility, new technologies, life science technologies and innovative technologies for cultural activities have been funded including some NMP-related projects. The overall budget was €2,029m for 2011-2013 (not specific for NMP).

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48 http://www.distretti-tecnologici.it/home.htm

49 http://www.fabbricadelfuturo-fdf.it/news
http://www.fabbricadelfuturo-fdf.it/wp-content/uploads/Bandiera_STchallenges_F_EN.pdf .

50 http://www.sviluppoeconomico.gov.it/; http://riditt.mise.gov.it/temi/programmi-incentivi/ricerca-policy

Complementarities/ synergies with the FP7 NMP Theme

Contrary to some other EU member states, in Italy there have not been programmes specifically directed at NMP areas. Because several of the policy initiatives are organised under the MiUR, there is a strong emphasis on research. In response to the overall technology gap, eligibility for several policies/instruments is dependent on the formation of consortia of research institutes, industry, and public bodies. Moreover, some efforts are made to tailor the focus to areas of strategic importance to the Italian industrial sector. Also, the national research programmes (2011-2013 and 2014-2020) identify internationalisation of the Italian research system as one way to increase knowledge transfer[51]. The national research programme is based on input from major (Italian) stakeholders and thus reflects the research and innovation needs of Italian research landscape and industry.

The Italian national research programme, shifted from a three-year to a seven-year programme (2014-2020) with the main objective of aligning with the European Framework Programme Horizon 2020. As explained in the programme, the Italian policies are aligned with the EU programme with the scope of avoiding inter-temporal conflict but also to avoid procedural incompatibilities. Finally, the new programme aims to increase transparency in the governance across the different programme lines. As stated, the new Italian research programme aims at re-gaining competitiveness and leadership in the EU. It has set ambitious targets to augment the research capacity of Italy. The new research programme is still being revised but it is expected that the later version will be updated to include a section on initiatives under KET.

Overall, from a political perspective, Italy has recently invested substantially in aligning its overarching policy programme with that of the EU. In doing so, it aims to maximise the possibility to generate synergies, amongst others in the field of NMP, relevant for the Italian industrial base and the Italian research landscape.

### *1.3.6 The Netherlands*

The national context

The major actors in the field of science, technology and innovation policy in Netherlands are:

- The Ministry of Education, Culture and Science (OCW);
- The Ministry of Economic Affairs (EZ);
- The Advisory Council for Science and Technology Innovation Policy (AWTI), an independent advisory body to the Dutch government;
- The Royal Netherlands Academy of Arts and Sciences (KNAW), whose tasks are (among others) to advise the Dutch Government on matters related to scientific pursuit;
- Netherlands Organisation for Scientific Research (NWO) and its Technical Sciences division (STW). NWO is the national research council and funding agency. NWO themes related to NMP are Healthy living, Water and climate, Sustainable energy, Connecting sustainable cities and Materials: solutions for scarcity. STW funds technical research and developments projects and promotes the application of research results.

Except for the - technical - universities and their specialised research centres in micro and nanotech such as MESA (UTwente), Kavli Institute for Nanosciences (TUDelft) and the Holst institute (TUEindhoven) a number of research organisations are active in the field of NMP. This includes the Netherlands Organisation for Applied Technological Research (TNO); this is the largest national research organisation. TNO is partially funded by the government. It works on a number of themes in which NMP plays an important role (industrial innovation, health living, energy, mobility, built environment, information society, defence, safety and security). Another research institute in the field of NMP is the Institute for Fundamental Research on Matter (FOM). A number of research fields of FOM are related to the NMP theme (subatomic physics, nanophysics/-technology and condensed matter and optical physics).

Strategy and funding instruments

In the Netherlands there are several active funding programmes in or related to the NMP areas. The Dutch programmes are mostly project based and several focus on generating cooperation between academia, research institutes and the private sector and the Top Sector Programmes are an important governmental instrument for funding public private partnerships (PPPs).

[51] See action plan https://www.researchitaly.it/uploads/30/3b_Azioni_PNR.pdf

One of the ten top sectors is High-Tech Systems and Materials (HTSM). In 2014, more than half of the budget for the top-sectors is allocated to HTSM (€4.8m of €8m)[52]. The HTSM programme builds on the success of several previous funding programmes including the Innovation Programme High-tech Automotive Systems[53]. The top sector HTSM has three main subjects: advanced materials, devices and components (nano-electronics), systems and equipment (nano-patterning and nano-inspection). Several of the other top-sectors also have some relation to NMP; e.g. Agro Food, Energy, Life Sciences, Chemistry, and Water[54]. The High Tech Automotive Systems (2007-2011) programme emphasis on electronics and photonics, focused on the development of efficient powertrains, lightweight constructions, vehicle dynamics control, human machine interaction and Electric Vehicle Technology (EVT), has partly been continued under HTSM.

Several funding programmes for NMP research are coordinated by the NWO/STW and the FOM. FOM research grants include:

- Industrial partnership programmes (since 2010) with 21 projects including on nanomedicine, nanomaterials and engineering;
- High Tech Materials call, an initiative that is part of the HTSM, with a total budget of €1m (50% co-financing). This initiative was coordinated with M2i, a network organisation for universities and industry in the field of functional and structural materials[55]. Application areas relevant to the call are: hybrid materials and composites; advanced metals, multifunctional textiles, surface and interface engineering, nanoscale and nanostructured materials and soft materials.

NanoNextNL is the national micro and nanotechnology research programme (2011-2015) in which more than 100 companies, universities, research centres and institutes and university medical centres participate. Government funding for NanoNextNL is €125m, the other 50% of the total NanoNextNL budget is co-funded by the research organisations and industry. The programme includes risk analysis and technology assessment, energy, nanomedicine, clean water, food, Beyond Moore (advanced nanoelectronics devices, functional nanophotonics, nano-bio interfaces and devices), nanomaterials (supramolecular and bio-inspired materials and multilayered and artificial materials), bio-nano, nanofabrication and sensors and actuators. NanoNextNL is the successor of NanoNed (2004-2011) a €50m programme (with similar co-funding); also this programme is of the Ministry of EZ.

NanoLabNL is an open access laboratory facility for research in nanotechnology that is open since 2004 to academics and business. There are NanoLabNL facilities in four locations in the Netherlands: Delft, Eindhoven, Twente and Groningen. Total investment €74m excluding host investment, and additional €2.5m and €10m in kind by companies.

Additional financing options for SMEs, working in the area 'advanced materials and advanced manufacturing technology', is provided via the Dutch Small Business Innovation Research programme (SBIR).

Complementarities/ synergies with the FP7 NMP Scheme

Giving the relative small size of the economy, the Netherlands is one of the top most innovative countries. The country invests a large proportion of capital in R&D, has a substantial track record in the volume of publications and patent applications, and several big industries players working in the NMP field. At the same time, the Netherlands remains a small country and must specialise in order to remain at the frontier. Specialization in NMP is organised via a bottom-up fashion, via the launch of (collaborative) projects with industry.

Also in line with challenges and barriers effecting nanotechnology uptake, the Netherlands has also launched initiatives such as Nanopodium, in order raise awareness and stimulate public dialogue about the opportunities and threats posed by nanotechnology and its resulting applications. As a result, experts pointed out that these activities complement those of the EC, regarding the work on social and ethical issues involved in the use and impact of nanotechnologies.

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52 http://www.rvo.nl/sites/default/files/2014/05/MIT-2014%20verdeling%20budget%20over%20topsectoren%20en%20instrumenten%20en%20regio.pdf

53 http://www.rvo.nl/subsidies-regelingen/innovatieprogramma-hightech-automotive-systems-htas

54 Further detailed outlines in: Roadmap Route Nano Technology and Dutch opportunities. http://www.nanonextnl.nl/images/stories/downloads/Nanotechnology%20in%20the%20topsectors.pdf.

55 http://www.m2i.nl/about-m2i

Despite the relative small size of the country there are several clusters, or pockets of excellence, for example, with Philips and the Eindhoven University of technology, both located in Eindhoven, this city forms an interesting hub for applied research in the field NMP. The Dutch top sectors programme naturally has the aim to foster the Dutch strategic competencies and competiveness.

The FP7 NMP generates partners for the Dutch existing programmes and NMP collaborative networks. Some of the programmes are somewhat organised under similar conditions, via projects and collaborations. The FPs can be used to scale-up existing endeavours in the field of NMP, supply additional foreign expertise, exchange of ideas, and can help connect research and industry along different phases of the TRL.

### *1.3.7 Conclusions*

Overall we can conclude that in the five countries analysed there is coverage of the N, M and P areas by national funded research programmes, but not in an integrated programme as the FP7 NMP programme. As such NMP as an integrated programme is not the focus of research technology and innovation policies in the five countries (or in other countries[56]).

In some countries, FP7 NMP might have had a direct and positive impact on coordination of national policies as these national policies (and programmes) address also the technologies and application areas of FP7 NMP. We found that the priorities, timing and procedures of national programmes in Italy were adapted to better match FP7 NMP (and other parts of FP7). This approach should stimulate Italian actors to participate in FP7. In Ireland, one of the FP7 NMP effects mentioned was diversification of the technology base (not just nanotech), international collaboration partners (less emphasis on non-EU partners) and the industrial structure (adding manufacturing activities to service activities). In the Netherlands, FP7 NMP is perceived as an opportunity to share Dutch experiences with public-private collaboration and ethical aspects of new technologies. In addition, FP7 NMP allows for scaling up technology development and pilots. For large countries that are among the leaders in the field of NMP, such as Germany and France, the impact of FP7 NMP on national policy is small. Both Germany and France already addressed, and will continue to address, a broad range of NMP topics at various TRLs. In Germany, FP7 NMP is perceived as an opportunity to further increase collaboration between research organisations and industry, and to share knowledge with other countries. In France, FP7 NMP is considered as a mechanism to increase international collaboration.

[56] Braun et al. (2013) mKETs-PL working document. Benchmarking Study Summary.

# 2. PORTFOLIO AND COMPOSITION ANALYSES

*Authors: Bea Mahieu, Xavi Poteau and Christien Enzing, Technopolis Group.*

## 2.1 Introduction

This report presents the results of the portfolio analysis (Section 2.1) and the composition analysis (Section 2.3), based on the analysis of FP7 NMP data provided by eCorda database and interviews with high-level experts (see Appendix 1). These analyses provide an overview of the 'inputs' (i.e. the funding) of the FP7 NMP Theme for the attainment of its objectives. Also it presents the size and weight of the different groups of projects in the overall theme and grouped along the specific objectives of the funding schemes and the topic areas and PPPs. The analyses also look into the constituency of the participants in the NMP Theme activities. Both - funds and participants - set the premises for the analysis of results and impacts of the FP7 NMP Theme at the thematic and stakeholder levels. They provide basic information relevant to an assessment of goal attainment via a comparison of actual composition of the constituency with the composition implicit in the programme goals, focusing on the different actors involved in the activities and their geographical location. Finally, we draw our conclusions on the main findings (Section 2.4).

## 2.2. Results of the portfolio analysis

Baseline

The FP7 NMP Theme comprises 799 projects, amounting to a total cost of €4,658.44m of which the EC has contributed a total of €3,229.37m (an average funding intensity of 69.5%). These projects are divided into nine different support sub-schemes that can be grouped into six categories: collaborative projects, large-scale integrating projects, small or medium-scale focused research projects, coordinating actions, supporting actions and ERANETplus projects. On average, each project has received an EC contribution of around €4m.

Overall, the programme has supported new projects starting from 2008 to 2014 and ending from 2009 to 2018. During the period 2010-2011 there were less projects launched than expected, which we attribute mainly due to the reorientation of the programme and the launch of the PPPs. As a result, in percentage terms almost half of the projects have started in the period 2012-2014.

Only 42% of the projects concluded their activities by the start of this evaluation. This underlines the importance of looking into enabling factors (e.g. relevance of funded activities, adequacy of participant profiles, etc.) with a view on determining whether the programme has put in place the adequate pathways for impact.

At the time of the evaluation most PPP projects were still on-going, only 12% were concluded by the start of the evaluation. Data are different in the PPPs though, with a percentage that drops to 5.5% in the Energy efficient Buildings PPP. For the Green Car PPP, 50% of the projects are already in their second half, although this area contains few projects, so it is not representative of all the PPPs.

For the NMP thematic areas, around half of the projects were concluded at the time of the evaluation. For the New Production Technologies area this percentage goes up to almost 70%. This correlates well with the fact that the work programmes of the FP7 NMP Theme already indicated that after the introduction of the PPPs there would be a gradual migration of projects from the 'New Production Technologies' area to the PPPs.

Funding statistics

Each project in the NMP Theme belongs to a specific area of the programme - Nanosciences and Nanotechnologies, Materials, New Production and Integration – or to one of the three PPPs: Factories of the Future (FoF), Energy Efficient Buildings EeB) and Green Car (GC).

The PPPs account for ~25% of EC funding in the FP7 NMP Theme (Figure 1). Nanosciences and Nanotechnologies is the largest area in terms of number of projects, participations and funding (with 24% of the projects and 22% of the EC contribution)[57]. A total of 279 call topics launched the projects, in the case of some areas (N, M and P) organised around different action lines.

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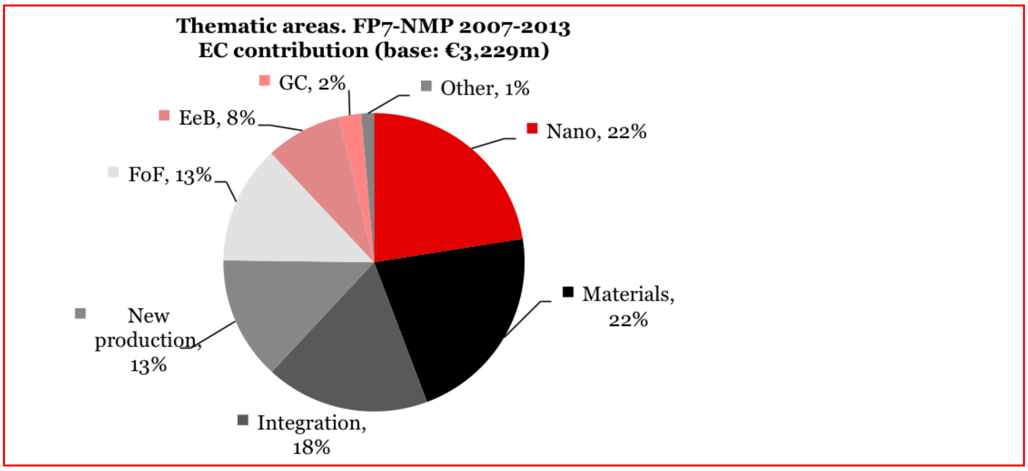
57 There are a small number of projects (9) that have been categorised as 'Other'. These usually refer to special cases where projects were supported jointly with the FP7 Environment, KBBE or Energy Themes.

**Figure 1** EC contribution per area of FP7-NMP 2007-2013




Source: eCorda data (2014)

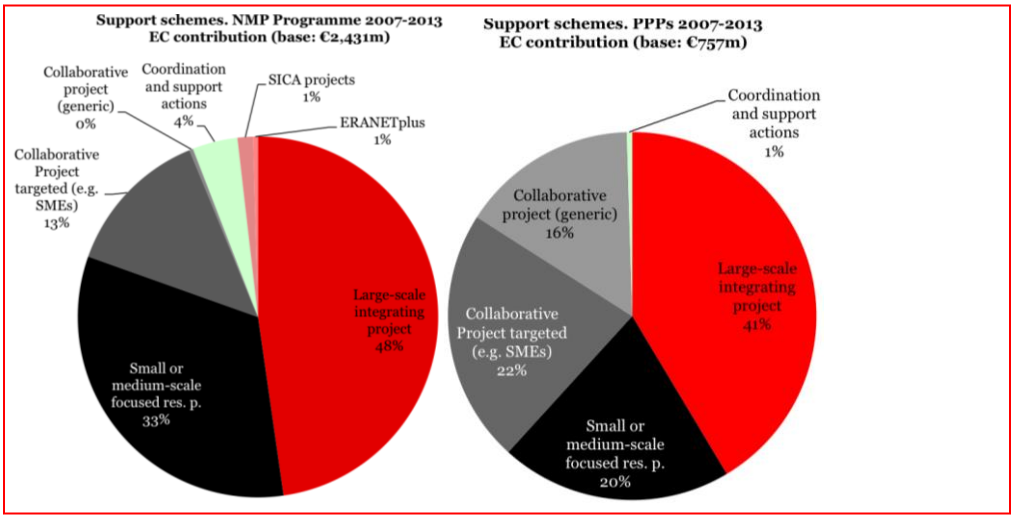
Support schemes

Figure 2 shows the distribution across the different support schemes and sub-schemes for the NMP Theme and the PPPs. Large-scale integrating projects are at the core of the NMP Theme, with more than 45% of the overall EC funding.

Small and medium scale research projects are the most numerous and collaborative projects represent about a fifth of the programme, both in terms of EC contribution and number of projects. Although coordination and support actions represent around 13% of the programme in terms of projects, in terms of EC contribution their share drops to less than 4%.

Additionally, in terms of participations and unique participants, there are more unique participants in both large-scale integration and small/medium scale focused projects than in Collaborative projects and Coordinating actions.

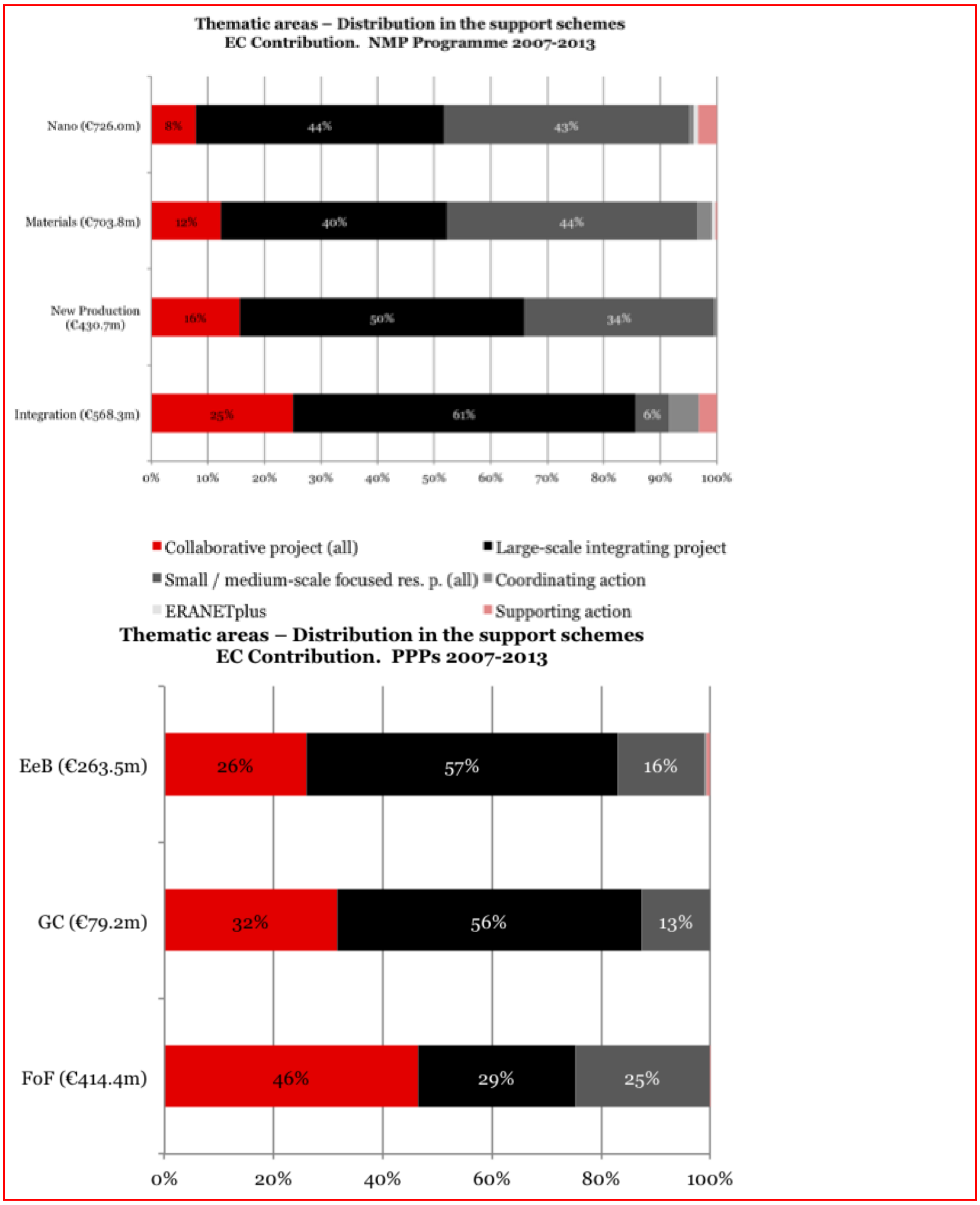
**Figure 2** EC Contribution across the support schemes (2007-2013)




Source: eCorda data (2014)

We observe a different use of the support schemes in the different areas (Figure 3). Nanosciences and Nanotechnologies and Materials hold a higher share of Small/medium scale focused research projects, while the Integration area contains large shares of Large-scale Integrating Projects as well as more Coordination and Support Actions than the others.

**Figure 3** EC contribution across support schemes, by area (2007-2013)




Source: eCorda data (2014)

Technology readiness level

The projects of the FP7 NMP Theme have been categorised along their Technology Readiness Levels (TRL). For this we used the nine-point TRL scale as suggested by the High-Level Group on KETs (see Figure 4, below). We positioned projects based on their specific funding schemes, action lines and call topics for projects where they belong to[58].

For the overall NMP Theme, more than 70% of the overall funding focuses on TRLs between 3 and 6, in almost equal measure in the TRL3-4 and TRL5-6 categories. Still, the NMP Theme covers both extremes in the TRL scale too, with around 10% of the funding for projects at TRL 1-2 and 15% at TRL 7+.

[58] CSA projects have been labelled as 'Not applicable'.

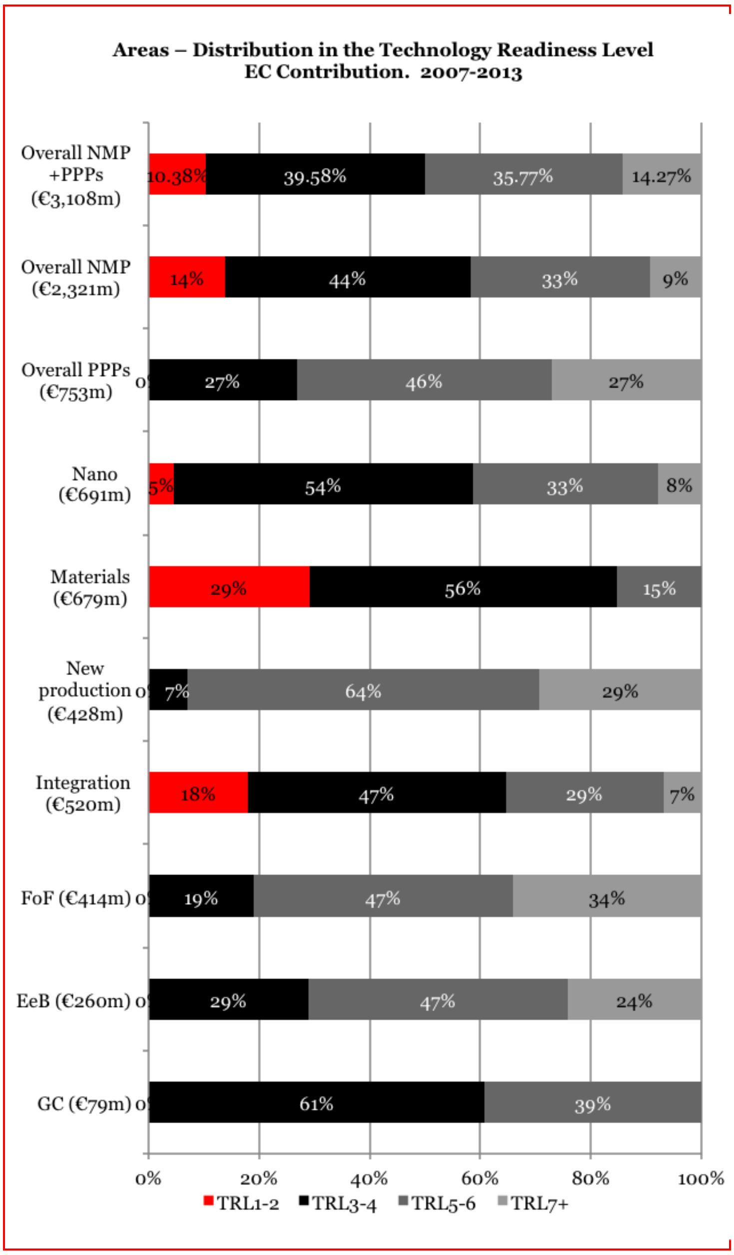
**Figure 4** Technology Readiness Levels scale

| Level | Description | Scale Used |
|---|---|---|
| 1 | Basic principles observed and reported | TRL1-2 (principles and concepts) |
| 2 | Technology concept and/or application formulated | |
| 3 | Analytical and experimental critical function/ characteristic proof-of-concept | TRL3-4 (lab validation/testing) |
| 4 | Technology validation in a laboratory environment | |
| 5 | Technology validation in a relevant environment | TRL5-6 (in situ validation/demonstration) |
| 6 | Technology demonstration in a relevant environment | |
| 7 | Technology prototype demonstration in an operational environment | TRL7+ (pilot deployments, scale-up, prototyping, etc.) |
| 8 | Actual technology system completed and qualified through test and demonstration | |
| 9 | Actual technology system qualified through successful mission operations | |

Source: High-Level Group on KETs and Technopolis (2014)

The FP7-NMP Theme underwent several changes during the period 2007-2013. To analyse this, we classified the call topics for projects as to their orientation.

**Figure 5** EC contribution across TRLs, per area and PPP (2007-2013)




Source: eCorda data (2014)

We distinguished between call topics:

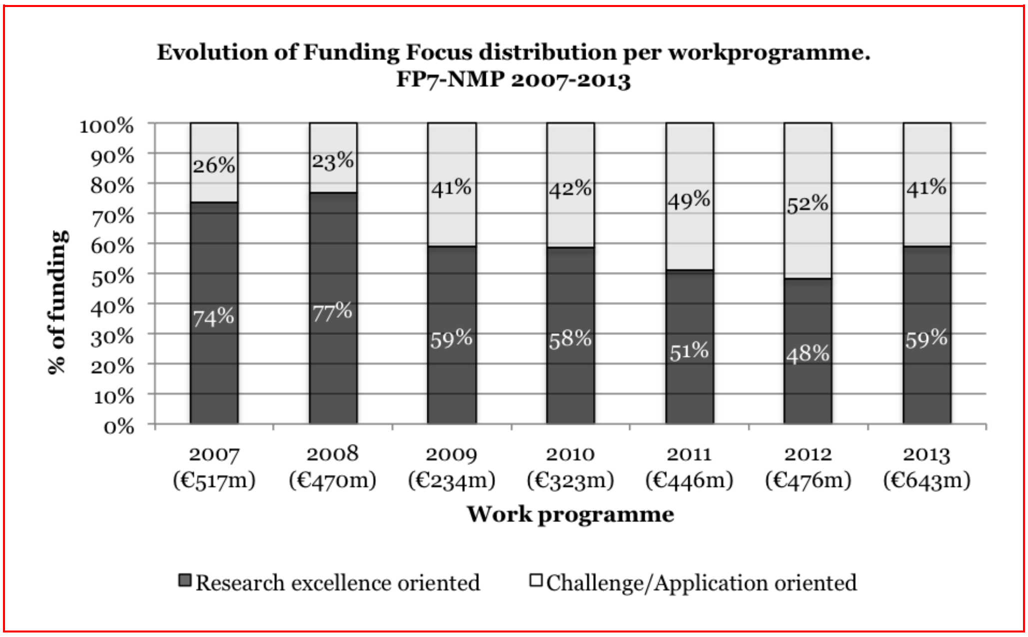
- Supporting an orientation or focus towards societal challenges/applications.
- Supporting more fundamental research, not limited to particular applications/challenges.

According to this categorisation, around a third of the NMP Theme projects responded to call topics that specify applications or challenges.

Figure 5 (see previous page) shows the overall distribution of the NMP Theme across TRLs, for the areas and PPPs. We observe that the Green Car PPP is the most fundamental research oriented thematic area within the PPPs and that New Production Technologies has a TRL distribution that is close to that of the PPPs. Materials is the area with a higher share of the funding going to projects at lower TRLs. As expected, in the mainstream NMP Theme almost half of the projects and funding fall into TRL3-4 while in the PPPs the main share is in TRL5-6.

Figure 6 shows the amount of funding launched in each of the FP7 NMP work programmes in each year for these two major focus areas. We observe that there has been a clear trend since the second half of 2009 towards funding research related to specific challenges and applications, arriving at an overall 40:60 distribution. This trend did not have major implications on the focus of the projects in terms of TRL.

**Figure 6** Evolution in the distribution of funding, according to funding focus

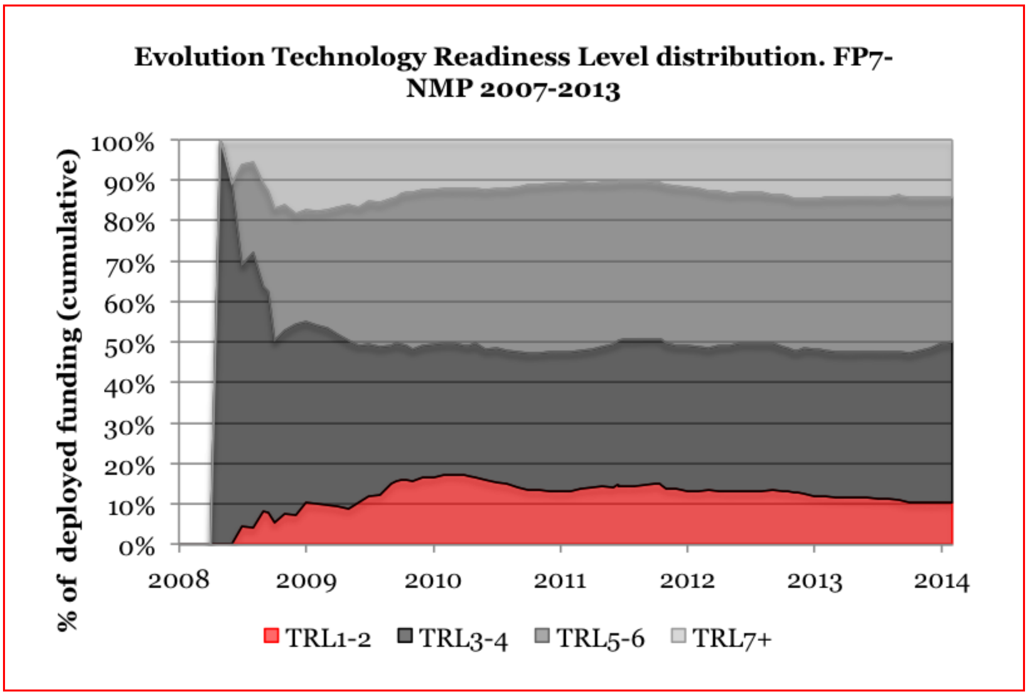



Source: eCorda data (2014)

Figure 7 shows for FP7 NMP, the funding allocations per TRL cluster over the period 2007-2013. The figure distinguishes between projects that are closer or further from the market (represented by lower or higher TRL). The EC funding distribution between the proportion of funding at TRL lower than 4 and TRL higher than 5 remained essentially stable (50%). However, there is a small change after 2011, with a slight increase of funding at TRL7+ and a slight decrease in TRL1-2, which allowed arriving at the final distribution of ~15% TRL7+, ~35% TRL5-6, ~40% TRL3-4 and ~10% TRL1-2.

Additionally, if we break down this distribution between the 'pre-PPP' (projects started 2008-2009) and the 'post-PPP' (2010-2014) era, we can confirm that, while the overall TRL distribution has remained stable, the projects with a higher TRL have been mostly migrated to the PPPs (see Figure 8 below).

**Figure 7** Evolution in the distribution of funding, per TRL cluster (2007-2013)




Source: eCorda data (2014)

**Figure 8** EC funding of CP projects (excluding CSA) across TRL distribution in the pre and post PPP phase

| Pre-PPP (2008-09) | TRL1-2 | TRL3-4 | TRL5-6 | TRL7+ | EC Funding (€m) |
|---|---|---|---|---|---|
| NMP | 16.6% | 33.0% | 37.7% | 12.6% | 925.3 |
| Post-PPP (2010-14) | | | | | |
| NMP | 12.1% | 51.7% | 29.1% | 7.1% | 1396.5 |
| PPP | 0% | 26.8% | 46.1% | 27.1% | 753.5 |

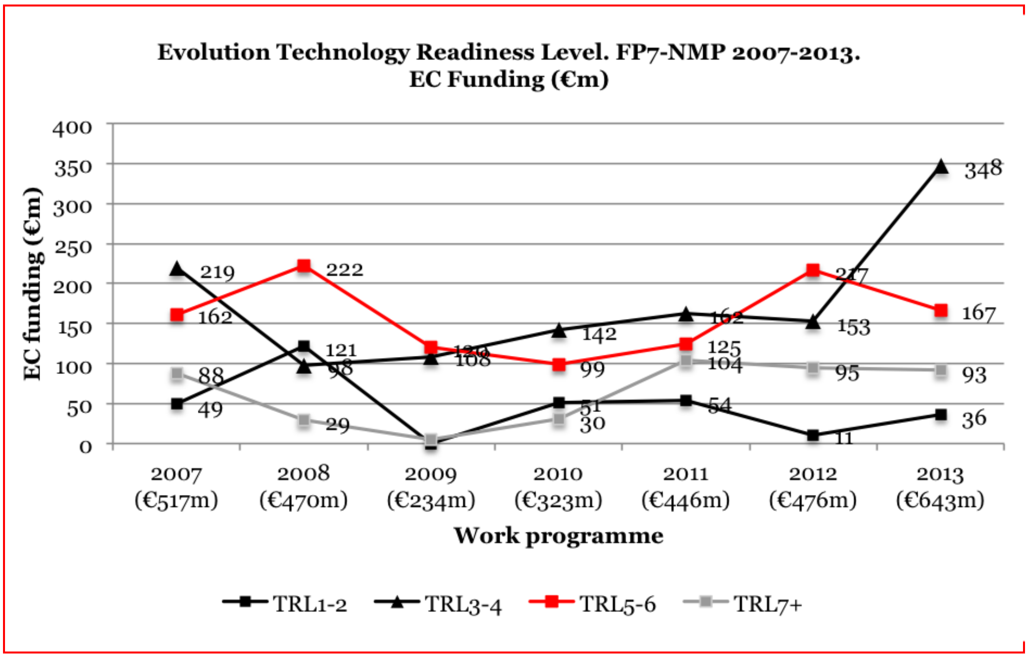
Source: eCorda data (2014)

This a priori classification of the project portfolio in TRLs has been validated in other data collection exercises, such as case studies and the participant survey. The participant survey asked project participants to rate the TRL of their projects at the beginning and the end of the project. The responses of the survey confirm that the classification that has been conducted here is closer to what participants expect the TRLs to be at the end of the projects. More insight to the TRL question as well as some additional methodological issues are raised in the main report, where all the findings are triangulated.

Figure 9 takes a closer look at the amount of the annual funding across the TRL. It shows the amount of annual funding that was deployed for the period 2007-2013 and the rebalancing between the different TRLs.

What is remarkable is that the 2013 NMP work programme has funded relatively large amount of projects at TRL3-4. In the beginning of the 2013 NMP work programme document it is stated that the emphasis of the 2013 work programme will be in demonstration and innovation activities, including pilots and scale-up to the industrial environment. While this would have meant a majority of the effort in TRL5-6, the description of the actual calls for projects shows that the technologies that are covered are more in the lab phase than in the industrial phase, which means TRL3-4.

**Figure 9** Size of annual work programme funding, by TRL




Source: eCorda data (2014)

Some recommendations were repeatedly flagged by the experts in terms of the expected composition of the consortia of FP7 NMP projects, especially at higher TRLs. For projects that are supposedly closer to the market, experts stressed the need to ensure the calls specify skills such as management and marketing as a prerequisite to join such consortia. The consortia need to be formed by people and organisations that know how to 'sell the projects to the companies involved' in order to ensure that commercialisation efforts go ahead. Experts also flagged the importance of involving the complete supply or value chains in the projects, something that, while it is not always possible, should be strongly encouraged. Case studies already confirm that this is the case for a good share of the projects overall. Involvement of the supply/value chain correlates well with projects where the individual project results remain relevant to the different industrial stakeholders.

## 2.3. Results of the composition analysis

Participations and participants

The community of participants comprising the project teams of the FP7 NMP Theme is vast. The NMP Theme had a total of 10,089 participations, an average of 12.62 participations per project. These 10,089 participations correspond to 4,584 unique participants. This means that, on average, each participation has received €320k of EC contribution, which implies an average EC support of €704.5k per unique participant. Overall, two thirds of the projects comprised between 6 and 15 participations.

Geographical distribution of participants

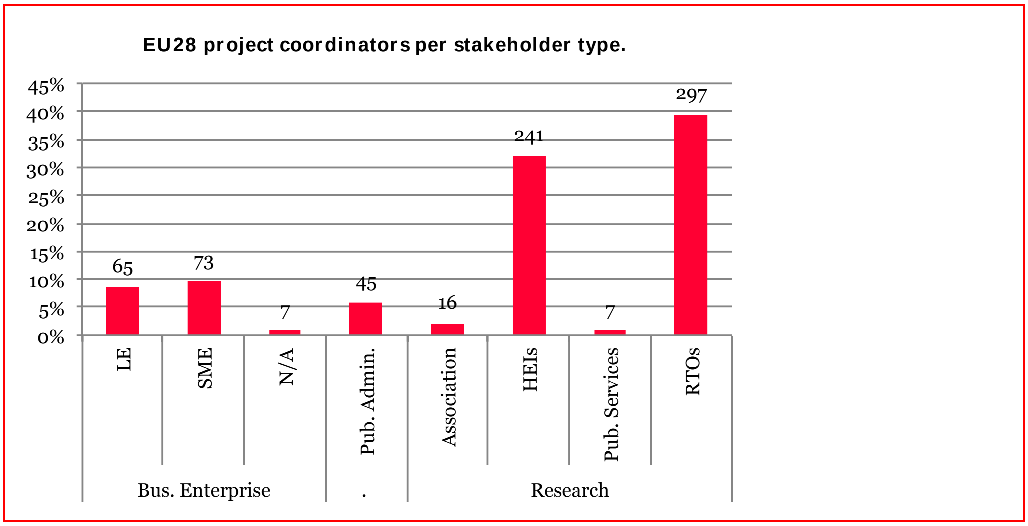
The community of participants of the FP7 NMP Theme is geographically concentrated. We found that participants from 71 different countries took part in the NMP Theme. However, the EU15 represented more than 80% of the programme participations and funding and 78% of all unique participants. Around half of EU15 funding went to Germany; the country's participants received almost the double of the funding received by any other of the main participating EU15 countries such as the United Kingdom, Spain and Italy.

The newer EU member states (EU13) represent only around 9% of the unique participants and around 4% of the funding. Poland and Czech Republic are the most involved in the NMP Theme, followed by Hungary and Romania. The group of Associated Countries (including Norway, Iceland, Switserland) represent 6.7% of all participations and around 4% of the funding. The rest group left holds 3.2% of all participations and includes all other EU countries, BRICSAM countries (Brazil, Russia, India, China, South Africa and Mexico) and the rest of the world; the main beneficiaries in this rest group are Turkey, Russia, Canada and Greenland.

Coordinators

Figure 10 shows that most project coordinators are from research organisations: from research and technology organisations (RTOs) (40%) and HEIs (32%).

**Figure 10** FP7 NMP Project coordinators by stakeholder type (2007-2013)




Source: eCorda data (2014)

RTOs often play a pivotal role in pre-competitive technology development and are a linking pin between research partners and companies. Only 19% of the project coordinators are from companies (LE and SME).

Germany accounted for the highest share in project coordinators (18%), followed by Spain (15%), UK and Italy (just over 12%), France (almost 8%) and the Netherlands (just over 6%).

Comparison with FP6 NMP is not obvious as the stakeholder categories that are used in the report with the results of the evaluation of FP6 NMP are different from the ones we have used. In FP6 NMP 8% of the coordinators were from SMEs and 32% from commercial partners. In case the latter are large enterprises and other types of companies, than the number of coordinators from industry has decreased considerably.

Core group of participants

There is a core group of 275 organisations that participated in more than six NMP projects during FP7. Out of these 275 organisations in the core group, 41 of them are companies (15%), with participation of both small and medium sized enterprises (SMEs) and large enterprises (LE): see the table below.

**Figure 11** Companies in the core participants group (number of projects)

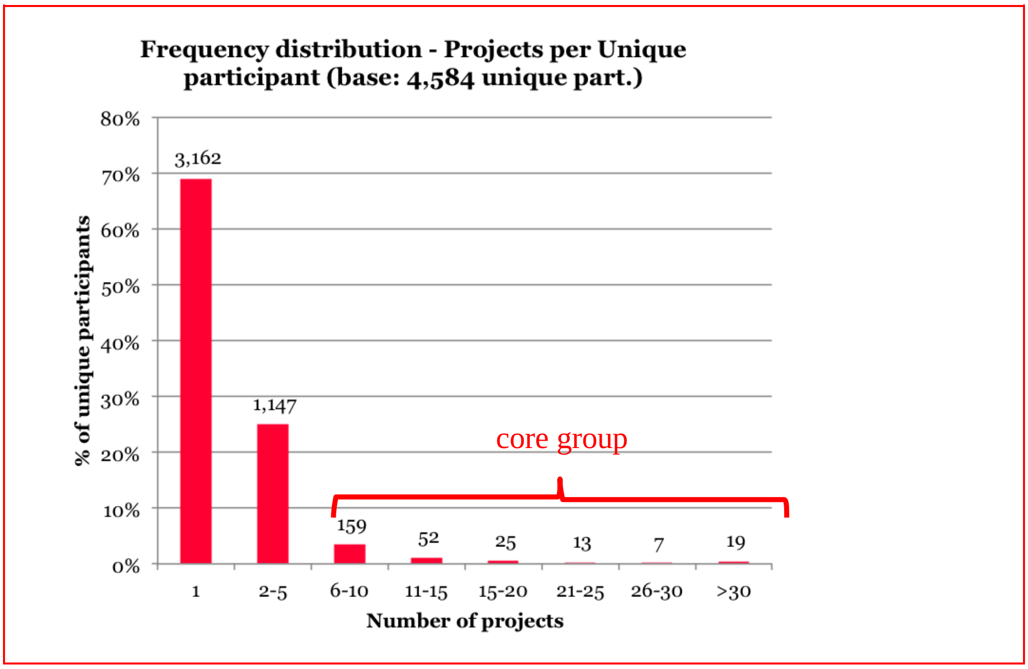
| **Company name** | **Size** | **Country** | **# Proj** | **NMP** | | | | **Oth** | **PPP** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **N** | **M** | **P** | **I** | | **EeB** | **FoF** | **GC** |
| Centro Recherche FIAT | LE | IT | 50 | 9 | 10 | 8 | 9 | 1 | | 9 | 4 |
| Acciona | LE | ES | 49 | 5 | 6 | 3 | 7 | | 23 | 5 | |
| D'Appolonia | LE | IT | 39 | 1 | | 4 | 15 | | 18 | 1 | |
| BASF | LE | DE | 21 | 7 | 7 | 3 | 3 | | 1 | | |
| Siemens | LE | DE | 18 | 4 | 2 | 4 | 3 | | | 5 | |
| EADS | LE | DE | 17 | 4 | 6 | 1 | 4 | | | 2 | |
| Johnson Matthey | LE | UK | 17 | 4 | 7 | 1 | 3 | | | | 2 |
| NPL | LE | UK | 15 | 11 | 1 | | 2 | | | 1 | |
| BAYER | LE | DE | 13 | 3 | 1 | 5 | 3 | | | | 1 |
| NetComposites | SME | UK | 13 | 2 | 3 | | 3 | | 2 | 3 | |
| FIDIA | LE | IT | 13 | | | 6 | 1 | | | 6 | |
| MBN Nanomateriales | SME | IT | 12 | 3 | 2 | 2 | 2 | | 2 | 1 | |
| PHILIPS | LE | NL | 12 | 4 | 5 | 1 | 2 | | | | |
| R-Tech | SME | DE | 11 | | 5 | 1 | 5 | | | | |
| C-Tech Innovation | SME | UK | 11 | 1 | 1 | 1 | 6 | 1 | | 1 | |
| TEKS SARL | SME | FR | 10 | | | 4 | 2 | | | 4 | |
| MOSTOSTAL | LE | PL | 10 | 1 | | 1 | 1 | | 7 | | |
| PROFACTOR | SME | AT | 10 | 1 | 1 | | 1 | | 1 | 6 | |
| ARKEMA | LE | FR | 10 | 3 | 4 | 1 | 2 | | | | |

| Company name | Size | Country | # Proj | NMP | | | | Oth | PPP | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | N | M | P | I | | EeB | FoF | GC |
| EVONIK | LE | DE | 10 | 2 | 2 | 6 | | | | | |
| ALMA | LE | FR | 10 | 3 | 1 | 1 | 3 | 1 | | 1 | |
| Nanocyl S.A. | SME | BE | 9 | 6 | 2 | | 1 | | | | |
| CESI | SME | IT | 8 | | | 5 | 1 | | | 2 | |
| FESTO | LE | DE | 8 | | | 3 | 1 | | | 4 | |
| CEGASA Internacional | LE | ES | 8 | | 1 | | | 1 | | | 6 |
| THALES | LE | FR | 8 | 3 | 3 | | 1 | | | 1 | |
| Electrolux | LE | IT | 8 | | 2 | 2 | 1 | | | 3 | |
| ESI GROUP | N/A | FR | 8 | | 1 | 1 | 3 | | | 3 | |
| PLASMACHEM | SME | DE | 8 | 8 | | | | | | | |
| TTS | SME | IT | 8 | | | 3 | | | | 5 | |
| VOLVO | LE | SE | 8 | 1 | 1 | 1 | | | | 2 | 3 |
| VW | LE | DE | 7 | | 2 | 1 | | | | 1 | 3 |
| Colorobbia Italia SP | LE | IT | 7 | 4 | | | 3 | | | | |
| BOSCH | LE | DE | 7 | 1 | 1 | 2 | | | | 3 | |
| Avanzare | SME | ES | 7 | 4 | 1 | | 1 | | | 1 | |
| CEDRAT | SME | FR | 7 | 2 | | 2 | | | | 3 | |
| Materialise | LE | BE | 7 | | | 1 | 2 | | | 4 | |
| OSM | SME | IL | 7 | 2 | 1 | 1 | 2 | | | 1 | |
| DIAD SRL | SME | IT | 7 | | 1 | 6 | | | | | |
| SOLINTEL | SME | ES | 7 | | | 1 | | | 6 | | |
| GZE | SME | IT | 7 | 1 | | 2 | 4 | | | | |
| DAIMLER | LE | DE | 7 | | 1 | 1 | 2 | | | 2 | 1 |

Source: eCorda data (2014) LE=Large enterprise, SME= Small and medium sized enterprise

Almost 70% of the unique participants took part in only one project (Figure 12); the remaining participants (around 31%) took part in more than one project.

**Figure 12** Frequency distribution: number of projects per unique participant



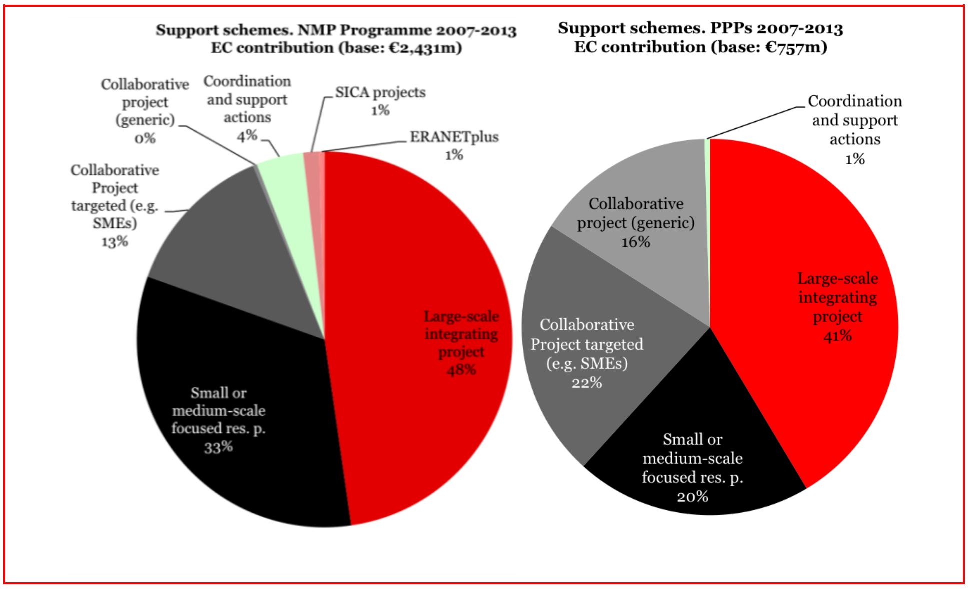

Source: eCorda data (2014)

<u>Stakeholder categories</u>

Research organisations accounted for 59% of the EC funding. Participation of the research community is evenly distributed between Higher Education Institutions (HEI) (universities mainly) and research institutes (research and technology organisations). Other parts of the research community such as Associations/networks and Public Services are only involved marginally. When we look at the number of participations, the research community accounts for half of the participations in the programme.

The NMP Theme is a clearly industry-oriented theme. The business community has a very significant participation in the programme receiving almost 40% of EC funding. We found that 68% of the unique participants in the programme are companies (in FP6 NMP this was 55%), so business enterprises most often participate in one project only while research organisations often participate in more than one project. The share of LEs involved is significant, with 20% of unique participants. SMEs represent the highest proportion of unique participants[59]. In FP6 NMP about one fifth of company participation were SMEs (total industrial organisations participation was 54.7%)[60].

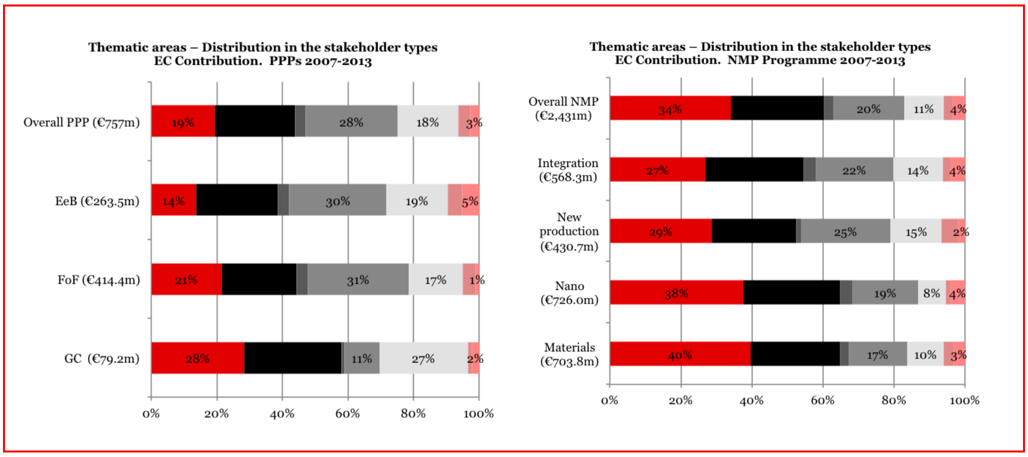
**Figure 13** EC contribution across stakeholder types (2007-2013)




Source: Technopolis, based on eCorda data (2014).

Figure 14 shows the distribution of EC contribution across stakeholder type, per area and PPP. The areas with the most business enterprise participation are the ones related to production technologies: New Production Technologies and FoF PPP. Industry participation is also high in more fundamental research areas such as Nanotechnology and Materials.

**Figure 14** EC contribution across stakeholder type, per area and PPP (2007-2013)




Source: Technopolis, based on eCorda data (2014). Same legend as Figure 13

SMEs are more numerous than LEs in almost all areas and PPPs except for the GC PPP, where on average 2.2 LEs for each SME participated in the programme. Industrial participation in FP7 NMP reflects the structure of the different research and industry sectors. Industry participation increased after the PPPs were introduced: from 46% of the participations in collaborative research projects in 2009 to 53% in 2013 (Figure 15).

With regard to the research community, HEIs are more numerous and represent a higher share of the funding than research institutions in all areas except for the FoF and EeB PPPs. Overall; the Public Administration stakeholders only represent 4.4% in terms of number of participations and 3.5% in terms of funding. They are most present in the Integration area and the EeB PPP. Participant of research organisations dropped from 52% of the participations in collaborative research projects in 2009 to 44% in 2013.

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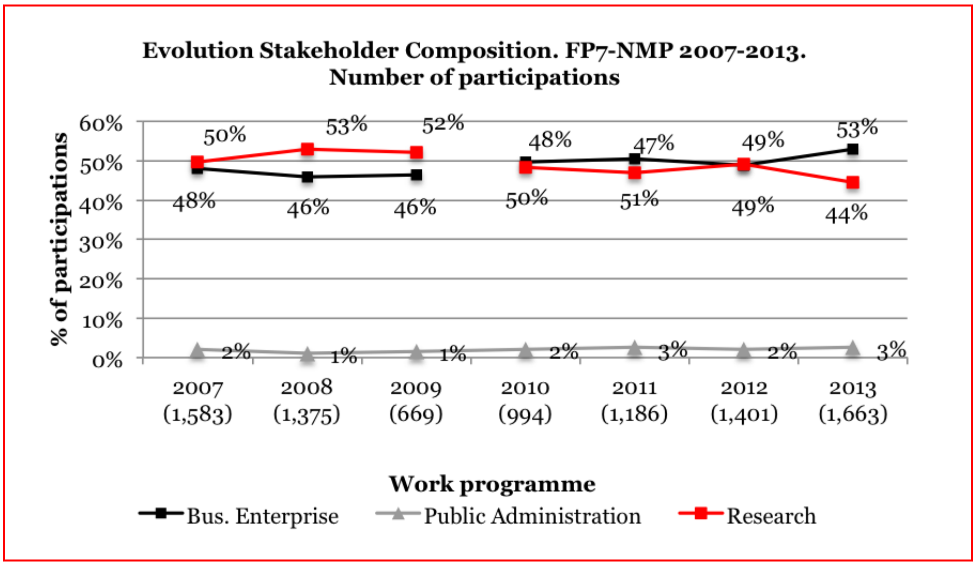
59 For a small share of companies, their size (SMEs or LE) could not be determined using available data.

60 Inno AG and Atlantis Research S.A. (2011) Ex Post Evaluation of FP6 (NMP). Project level. EC Report EUR 24935 EN.

**Figure 15** Stakeholder participation in collaborative research projects (2007-2013)




Source: eCorda (2014)

In terms of support schemes and sub-schemes across stakeholder types, we observed that business participations are most numerous for Collaborative projects (CP), especially those targeted to a special group (CP-TP), where more than 40% of the funding of this support sub-scheme goes specifically to SMEs. Large-scale integrating projects (CP-IP) also have a very balanced distribution of both business enterprise and research actors. Coordination and support actions (CSA-CA and CSA-SA) are the support sub-schemes that have a more evenly distributed participation of all stakeholder types (but with a significant share of research institutes). For ERA+ activities, the main participants are public administration stakeholders, which also take the majority of the funding for these projects.

The distribution of project coordinators in the different stakeholder types is shown in Figure 16 for EU28 countries. We can see that there are marked country differences in terms of who are the stakeholders that use to take the lead for projects.

**Figure 16** Number of project coordinators, per EU28 country and stakeholder type

| | Companies | | | Public Adm. | Research | | | | Base |
|---|---|---|---|---|---|---|---|---|---|
| | LE | SME | N/A | | Assoc. | HEIs | Pub. Serv. | RTOs | |
| EU13 (new) | | | | | | | | | |
| CZ | 0% | 25% | 0% | 0% | 0% | 50% | 0% | 25% | 4 |
| HU | 0% | 20% | 0% | 20% | 0% | 0% | 0% | 60% | 5 |
| LT | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 2 |
| PL | 25% | 0% | 0% | 0% | 0% | 38% | 0% | 38% | 8 |
| SI | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 2 |
| SK | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 1 |
| EU15 | | | | | | | | | |
| AT | 5% | 24% | 0% | 10% | 0% | 52% | 0% | 10% | 21 |
| BE | 12% | 12% | 0% | 0% | 6% | 41% | 6% | 24% | 34 |
| DE | 4% | 7% | 2% | 0% | 0% | 28% | 0% | 58% | 134 |
| DK | 17% | 6% | 0% | 0% | 0% | 50% | 0% | 28% | 18 |
| ES | 10% | 6% | 0% | 9% | 10% | 10% | 0% | 56% | 114 |
| FI | 0% | 3% | 0% | 10% | 0% | 28% | 0% | 59% | 29 |
| FR | 7% | 5% | 0% | 5% | 4% | 7% | 7% | 65% | 57 |
| GR | 12% | 12% | 0% | 12% | 0% | 38% | 0% | 27% | 26 |
| IE | 5% | 0% | 0% | 5% | 0% | 90% | 0% | 0% | 21 |
| IT | 25% | 10% | 1% | 1% | 1% | 26% | 0% | 37% | 93 |
| LU | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 1 |
| NL | 6% | 4% | 4% | 42% | 0% | 33% | 0% | 10% | 48 |
| PT | 0% | 14% | 0% | 0% | 0% | 29% | 0% | 57% | 7 |
| SE | 3% | 3% | 0% | 0% | 0% | 57% | 0% | 37% | 30 |
| UK | 4% | 22% | 1% | 1% | 0% | 55% | 1% | 16% | 96 |
| EU28 | 9% | 10% | 1% | 6% | 2% | 32% | 1% | 40% | 751 |

Countries with no project coordinators are not shown. Source: eCorda data (2014)

Participation by area and PPP

In the Nanoscience and Nanotechnology area the Germany, France and Netherlands are the key players. Out of the Top 10 major participants in this thematic area, German participants are represented most frequently (Fraunhofer), followed by France in the second and third place (CNRS and CEA) and the Netherlands (TNO). UK organisations are less frequently participants.

More generally, projects within this area were led by organisations from a broad range of countries and a suitable inclusion of relevant players is observable. Conversations with experts further stressed the perception that nanotechnology is specifically strong in France, Germany and the UK and that Spain is catching up quickly to the major players in Europe and may become a strong player in the near future.

The range of participants across countries is suitable and reflects key players at both national and institutional levels. With regards to the involvement and role of the private sector, experts mentioned that in the nanotechnology field the synergies with the European Technology Platforms (e.g. electronics, health) should be preserved and strengthened as they provide an opportunity for industrial players to develop roadmaps and thereby influence EC programming.

Germany, the Netherlands and Switzerland are the countries with most commercial players in the New Materials area; well-known major firms include Siemens, Roche, Philips, Thyssen-Krupp. However, the firms themselves are not represented in the top-ten participants for this thematic area at all, and Germany and Switzerland only have one Top 10 participant each in this area. With materials being such a horizontal topic, it is no surprise that the companies mentioned above develop most of their participation in FP7 NMP in other areas, reaching out to the materials topic for specific activities of interest, but having a more evenly spread participation across the thematic areas and PPPs. Also, some relevant companies in the field may not even appear in the materials area, developing all their activities in other parts of FP7 NMP because the project is targeted to a specific application or production process (e.g. graphene manufacturers in the Production thematic area or FoF PPP). It can be concluded that for this area, due to its horizontal nature, looking at participations from a thematic area perspective will give inconclusive results on whether the participant organisations do in fact reflect the important stakeholders in the field.

The major companies in Europe that are active in the New Production Technologies area and the FoF PPP – such as Siemens and Bosch - do not feature as prominently as expected within the Top 10 participants of these areas. Besides this mismatch at the level of individual participants, there are also some striking features in terms of countries of the participants' origin. Whilst the UK and France were highlighted as key players in this area, the two countries are absent from the Top 10 lists of participants in both the production technology area and the FoF PPP. Meanwhile, Germany, as undisputed European leader in this field, would be expected to have a large share of participants. In the case of the production technologies thematic area this is indeed the case, with six of the Top 10 participants being German. However, with just one of the Top 10 for the FoF PPP (Fraunhofer), Germany is effectively underrepresented, given its significance in the field.

In terms of participants, the EeB PPP is suitably inclusive. Unlike for instance the automotive sector, the construction sector does not have quite the same 'core group' of large producers (i.e. equivalent to e.g. BMW, Renault, etc.), and likewise there is not the same small group of core countries hosting all major players. The Top 10 participants in the EeB PPP are thus from a range of larger and smaller European countries, and feature some of the largest players in industry (e.g. Acciona) and research (e.g. Fraunhofer, Tecnalia).

The countries that are best represented in the GC PPP are Germany and France and Italy and Spain; altogether the main players in the European automotive industry are represented. This is the case in terms of countries, and to a large extent also in terms of organisations, with a large car manufacturer (Renault) and at least one major research institutions associated with the supply chain (Fraunhofer) featuring among the most involved parties. Centro Richerche Fiat, while not being amongst the Top 10 participants in the Green Car PPP, is one of the companies with the most funding in the overall NMP Theme and the first company to feature in the 'core group' of repeating participants. This highlights the fact that companies targeting a specific sector (in this case automotive) do not approach the NMP Theme on a thematic basis, but participate in projects across the range of thematic areas to the extent the call topics fit within their internal R&D needs.

## 2.4 Main findings of the portfolio and composition analyses

The results of the portfolio and composition analyses show that the bulk of the EC funding (more than 45%) was delivered through large-scale integrating projects, with small and medium scale research projects being the most numerous. Collaborative projects represent about a fifth of the programme, both in terms of EC contribution and number of projects. The NMP Programme represents around 75% of the NMP Theme in terms of number of projects, participations and funding (with 80% of unique participants), with the remaining participants and funding belonging to the three public-private partnerships.

Nanosciences and Nanotechnologies is the largest area in terms of number of projects, participations and funding (with 24% of the projects ant 22% of the EC contribution). New Materials is the second largest area, followed by Integration. The Integration area contains fewer projects but a higher share of unique participants (30%). The projects in it were more inclusive of different types of stakeholders.

The New Production Technologies area is not as large as the Nano, New Materials or Integration areas. It has a very similar profile to the FoF PPP. A priori, the main expected difference between the two would have been their stakeholder compositions and their TRL profiles. However, the data for the funded projects shows that the two areas are also similar in terms of number of participating business enterprise, as well as in their TRL distribution. That would initially suggest that there has been an overlap between the two areas. However, by analysing the project pipeline we saw that New Production Technologies projects are almost finished, while FoF PPP projects are mostly in their first half. This suggests a migration of projects from the New Production Technologies area to the FoF PPP, something that was already indicated in the NMP Theme work programmes.

The analysis of EC funding focus and TRL distribution across time reveals how the NMP Theme has evolved during FP7. The focus or orientation of funding has increased towards call topics that support research tackling specific application domains and societal challenges, effectively bridging smoothly with Horizon 2020. However, in terms of the TRL distribution we observe that the programme already incorporated projects across all the TRL range since the beginning, and that although different work programmes emphasised different TRLs, no significant change occurred over time on a cumulative basis. The programme funding maintained a stable balance of 50:50% between projects with TRL larger than 5 and those with TRL lower than 4.

Two thirds of the projects in the NMP Theme have between 6 and 15 participants and almost 70% of unique participants took part in just one of them. However, there is a core set of 275 organisations that participated in the NMP Theme in more than six projects during FP7. In terms of geographical distribution, more than 98% of the programme activity lies within the EU28 and EFTA countries, with other areas only showing a very sporadic involvement.

The NMP Theme is a clearly industry-oriented theme and this focus was even more pronounced in FP7. FP7 NMP has been rather successful in attracting companies. Overall industry participation in framework programmes has been decreasing: it fell from 39% in FP4 to 31% in FP6 and in 2010 it accounted for only 25% in FP7 (FP7 Interim Evaluation report, 2010). Meanwhile in FP7 NMP, business community participation accounted for almost 40% of EC funding and compared to FP6, its participation rose from 55% to 68% of the unique participants. SMEs – an important target group of EC policies – even accounted for two-third of industry participants. The EC has been very successful in attracting more SMEs to the programme as in FP6 NMP one-fifth of the participating industrial organisations (55% of all organisations) were SMEs. Almost one half of them are active in the application area 'Materials, Chemistry, Chemical Processes'. NMP is not the only theme that is successful in attracting industry; the other themes are Transport, Security and Energy (FP7 Interim Evaluation report).

Nevertheless, companies took a less initiating role in the FP7 projects: only 19% of the projects were coordinated by the industry sector. This is surprising, especially seeing the introduction of the industry-oriented PPPs in the second half of FP7.

Research organisations represented a lower share of participations than in FP6: about 30% of the participations compared to 34% in FP6 NMP.

When analysing the TRL profile per different stakeholder types, we observed that in the business community, LEs worked more at lower TRLs than SMEs. The differences in TRL distribution between the participating SMEs and LEs can be interpreted as being both expected and unexpected. For example, experience from previous framework programme evaluations supports the explanation of SMEs being more applied and risk averse, with lower tolerance for long and uncertain projects, while large enterprises use these projects to network and stay at the forefront of current developments. On the other hand, for some of the NMP areas one could also expect a significant share of small spin-offs and start-ups generally working at lower TRLs, with a higher share of SMEs in call topics focused towards more fundamental research providing support for this interpretation.

Although we found that major players do feature to some extent in the different parts of the programme, often these may not be represented in the Top 10 most funded participants for the specific area. This highlights the fact that companies targeting a specific sector (e.g. automotive) do not approach the NMP Theme on a thematic basis, but participate in projects across the range of thematic areas to the extent the call topics fit within their internal R&D needs. As a result, companies that may not appear as the top participants in a specific thematic areas may have a very substantial involvement in the NMP Theme overall.

# 3. CASE STUDY REPORT

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## 3.1 Introduction

This report presents the results of the case studies. Case studies allowed for an in-depth analysis of the behaviour of actors and the mechanisms via which FP7 NMP leads to output and impact for various types of participants and for society at large. Case studies also allowed for exploring portfolio effects (actors often combine FP7 projects with other R&D&I projects) and governance topics such as project initiation, consortium creation, project management, administrative procedures, European added value and follow-up projects.

By means of introduction, Section 3.1 describes the case study methodology and presents the structure of the report.

The two main criteria/strata for sampling the case studies are:

- The areas - Nanoscience and Nanotechnology, New Materials, New Production Technologies, Integration - and Public Private Partnerships (PPPs): Factories of the Future (FoF), Energy efficient Buildings (EeB) and Green Car (GC).
- The funding sub schemes (CP-Integrated Projects, Coordination and Support Actions-Coordination or networking Actions, etc.).

Projects were sampled from categories (area/PPP x funding sub scheme) with a relatively large number of FP7 NMP projects (Figure 17). If a category contains 10 or more projects, two projects from this category were sampled. If a category contains 4-10 projects, one project was sampled. As such, the sample is representative and covers the variety of FP7 NMP projects. This purposeful sampling strategy resulted in a sample of 51 projects.

**Figure 17** Summary of result of sampling strategy (number of projects)

| | N | M | P | I | EeB | FoF | GC |
|---|---|---|---|---|---|---|---|
| CP | | | | | 1 | 2 | 1 |
| CP-FP | 2 | 2 | 2 | 2 | 2 | 2 | 1 |
| CP-FP-SICA | | | | | | | |
| CP-IP | 2 | 2 | 2 | 2 | 2 | 2 | 1 |
| CP-SICA | | 1 | | | | | |
| CP-TP | 2 | 2 | 2 | 2 | 1 | 2 | |
| CSA-CA | 1 | 2 | | 2 | | | |
| CSA-ERA-Plus | | | | | | | |
| CSA-SA | 2 | | | 2 | | | |

In each category ('box') of the area/PPP x funding sub scheme with 4-10 projects, we sampled one project with the TRL that is most prominent in this specific category. In each category of the area/PPP x funding sub scheme with more than 10 projects, we sampled two projects that are different in terms of TRL (the two TRLs that are most prominent in this category).

Note that the funding sub scheme influences consortium size (e.g. the difference between CP-Integrated Projects, CP-Targeted projects and CP-Small or medium-scale focused research projects) and the area/PPP influences TRL (e.g. the majority of Nanotech projects being at a lower TRL than the majority of PPPs). The specific approach of PPPs influences the number of public and private actors in a consortium and, to some extent, the size of the consortium.

The sample includes projects that are finalised (which brings clear advantages in discussing output and impact) and projects that are in their second half (which brings clear advantages in terms of covering the evolution of FP7 NMP). Projects in their first half were not sampled because information about output and impact would be modest.

The draft sample was checked for covering a variety of countries (in terms of the country in which the organisation of the Project Coordinator is based) and for covering projects with low, medium and high EU contributions (below 2 million Euro, between 2 and 6 million Euro, above 6 million Euro). The draft sample was discussed with our Project Officer. A small number of changes were made. For example, in one category of area/PPP x funding sub scheme, we replaced a project with a Project Coordinator from a country that was over-represented by a project with a Project Coordinator from a country that was under-represented (based on the Composition Analysis). Appendix A contains the list of projects in the sample.

A case study protocol was developed to guide the team of case study researchers. The protocol includes the questions to be answered (derived from the evaluation questions of the study) and the sources to be used for the desk research (including project websites and project documentation such as the project plan, the Grant Agreement, key project deliverables, Review Reports by the project technical assistant and Assessment Reports by the EC's project officer). For each case study, we did two or three interviews, including the project coordinator and at least one project participant from industry. As much as possible, case studies have been allocated to case study researchers with expertise in the specific research area of individual projects.

Between early May and mid July 2014, the case study team prepared 51 case studies and in July andAugust 2014, the case study team prepared a consolidated, cross-case analysis (version 1). This analysis was based on a close reading of the 51 individual case studies and a case study team workshop, 17 July 2014, Brussels. The analysis resulted in 19 main insights and conclusions, plus an overview of detailed statements and recommendations made by interviewees. In September 2014, the case study researchers validated whether the 19 main insights and conclusions are supported by their individual cases (0 = not, 1 = partly, 2 = fully supported). To this end, we circulated an Excel matrix, 23 August 2014. This approach allowed us to make explicit which case study results are based on nearly all cases (>45), the majority of cases (26-45), a substantial number of cases' (10-25) or several cases (3-9). Moreover, the Excel matrix allowed us to explore whether certain results hold for specific areas (such as Nanotech), specific sub funding schemes (such as Collaborative Projects-Targeted projects), specific TRLs (e.g. 3-4) and specific consortia (such as PPPs and/or consortia with more than 20 members). The cross-case analysis was adapted accordingly.

The structure of the remainder of this report is as follows. Section 3.2 presents the basic characteristics of the projects and consortia in the sample of 51 FP7 NMP projects (e.g. heterogeneity of project partners). Based on the case study details, a typology of six types of projects emerged. Section 3.3 discusses the project objectives and relevance as well as the motives of individual participants. Section 3.4 presents the overall picture and the main examples of output. Section 3.5 discusses the results regarding scientific and technological impact; Section 3.6 does the same for economic impact. Section 3.7 presents the results and expectations regarding social and environmental impact. Section 3.8 discusses the contribution of FP7 NMP to the creation and extension of social networks in the European Research Area. Section 3.9 presents how the projects achieve European Added Value, using the terminology of the overall FP7 evaluation (effectiveness, efficiency and synergy). Section 3.10 contains the reflection by interviewees on the administrative procedures of FP7 NMP. Section 3.11 presents the recommendations made by interviewees.

## 3.2 Basic characteristics of projects and consortia in the case study sample

The basic characteristics of projects and consortia have been analysed in the composition and portfolio analyses (see Annex 2 Report). Additional details have been explored in the set of 51 case studies. To some extent, the case study results with respect to the basic characteristics of projects and consortia follow from the case study sampling strategy.

The case studies confirm that there are very different consortia in terms of the number of partners ('from 2 to 50'), the composition of the consortium (universities, schools for applied science, research organisations such as Research and Technology Organisations (RTOs), large enterprises (LEs), SMEs, industry associations, public agencies, NGOs) and business sectors (not just high tech manufacturing sectors but also textiles, energy, health, construction, housing and IT services).

The large majority of projects are multi-disciplinary with actors from various backgrounds such as technical sciences, environmental sciences and social sciences. This applies especially to TRL 3-4 and TRL 5-6 projects. It applies to projects supported by different funding schemes (including CSAs) and in different areas and PPPs (PPPs but also Nanotech and Materials, for example).

Several case studies of PPPs (especially Green Car), Collaborative Projects (e.g. Integrated Projects) and CSAs (especially Strategic Actions) describe the difficulties in managing large consortia and the negative impact on project output and impact. Although the definition of large or too large differs between types of projects, it was mentioned that research consortia with more than 15 to 20 participants are hard to manage. The same holds for CSAs with more than 25/30 participants.

Interviewees referred to the influence of the formal or informal requirements about consortium size by the EC (in the call text and between the lines) but also to situations in which two consortia (potential competitors) were merged and situations in which consortia adopted an 'additional partners will not harm-mentality.'

We found examples of EC requirements, EC signals and consortium mergers that resulted in consortia with many participants with a small role. It also led to very loose links between work packages (with few synergies from being in one project) or to work packages that are interdependent while actors did not fully acknowledge these interdependencies (which results in hold-up problems and delay).

It was also mentioned that several large consortia and large projects, including a number of PPPs, resemble a research and innovation programme rather than a project. One of the implications is that the EC partly delegates priority setting and decision-making to well-established stakeholders instead of maintaining strong influence by EC officials and independent reviewers (e.g. influence on funding research on emerging technologies, radical innovation and solutions that are proposed by outsiders). Interviewees observed this without a value judgement. This observation is relevant in the context of the possible role of EC executive agencies in the future when the role of Project Officer (PO) is being handed over from DGs to agencies. This may support the trend towards funding large PPPs.

The case studies confirm the variety of projects in terms of TRL at the start of the project. However, the case studies also reveal a number of drawbacks in using TRLs to describe and position projects. First, interviewees explained that different technologies that are developed and combined in one project could be at different TRLs. Second, and related, interviewees mentioned iterations or feedback loops in the innovation process and so called concurrent research. This implies that development and pilot activities may give reason to do additional research, before a second pilot is planned. Moreover, these activities may take place in parallel, e.g. developing and piloting components of a system, while other components are still in the early development stage. Third, interviewees were aware of the concept of TRL but there were several examples of different interpretations of the (main) TRL in the same project. For example, it is not always easy to distinguish between the different types of lab pilots and real-life pilots between TRL 4 and 7. Fourth, and related, interviewees did not always have a thorough overview of the project, which is needed to comment on project progress in terms of moving to a higher TRL.

With only few exceptions, the case study interviews validate the TRL of projects, as derived from the works programmes and call text (presented in the portfolio analysis of the Annex Report 2). For example, the study team assessed that a project can be positioned as TRL 3-4 (based on the area/PPP and call text) and one interviewees for this project mentioned 1-2 and 3-4, another interviewee mentioned 3-4 and 5-6, and one interviewee mentioned 5-6. More in general, TRL 3-4 appeared to be most difficult in terms of demarcation from other TRL. Moreover, TRL identification appeared to be challenge for projects in the New Materials area, as materials were developed, enhanced and used.

Despite the variety of projects and consortia and despite the drawbacks of the TRL concept (e.g. consortia that combine TRL 3-4 and 5-6), six archetypical projects and consortia emerged from the cross-case analysis (Figure 18, next page). The number of projects is taken from the eCorda FP7 NMP database, to illustrate the relevance of specific types of projects and consortia.

The case studies illustrate that the 'cut' between small/medium-sized consortia and large consortia is around 15 consortium members. Unsurprisingly, consortia that are relatively large tend to include partners from several different scientific disciplines and business sectors. Cases illustrate how large consortia include actors from business sectors along the value chain from materials, to production of components, to manufacturing of integrated systems, installation and maintenance providers and potential users of these systems.

More in general, the case studies reveal that nearly all large consortia are well balanced in terms of including universities, research organisations (such as RTOs) and firms in several sectors across the value chain. Examples were also found in the set of small and medium-sized consortia. It appears that consortia succeed in involving this variety of actors, while at the same time avoiding competition within the consortium. This is a well-know trade-off that is referred to by several interviewees. Note that large integrated consortia can be initiated by industry, universities, research organisations or a combination of these actor types.

However, there are several examples of consortia that were too dependent on one or two firms downstream in the value chain. Interviewees mentioned that innovation and commercialisation would have benefited from involving additional firms, e.g. firms that are active in different geographic markets and/or downstream sectors and involving specialised downstream SMEs as well as large firms.

**Figure 18** Six archetypical projects and consortia in FP7 NMP

| | | **Consortium size, disciplines and sectors** | |
|---|---|---|---|
| | | **Small and medium-sized consortia** (2-14 members), mostly involving actors from one or two scientific disciplines and business sectors (different parts of the value chain) | **Large consortia** (>14 members), mostly multi/trans-disciplinary and involving actors from three or more business sectors (full value chain approach) |
| **Technology Readiness Level at start of project** | Low TRLs (1-4) | 'Research projects'<br>'In search of breakthroughs'<br><br>*274 projects* | 'Early stage development projects'<br>'Building bridges between disciplines and between sectors'<br><br>*84 projects* |
| | High TRLs (5-8) | 'Late stage development projects'<br>'Technical and small-scale pilots'<br><br>*211 projects* | 'Building coalitions for commercialisation'<br>'Large-scale pilots and demonstrators'<br><br>*126 projects* |
| | TRL not applicable | 'Events, best practices and standardisation'<br>Most of the Coordination and Support Actions - Supporting Actions (CSA-SA)<br><br>*69 projects* | 'Global platforms, ERA-NETs and European Technology Platforms'<br>Most of the Coordination and Support Actions - Coordination or networking Actions (CSA-CA)<br><br>*35 projects* |

Source: eCorda database (2014). The total number of FP7 NMP projects is 799.

Note the link between consortium size and the funding sub schemes. For example, CP-Integrated Projects (CP-IP) and Coordination and Support Actions-Coordination or networking Actions (CSA-CA) require large consortia. As such, the EC influences the balance between small and large consortia. The set of case studies indicates no clear relation between TRL and the type of actor that is initiating or driving a consortium and project. For example, low TRL projects are driven by universities and RTOs but also by large firms. Note the link between TRL and the areas/PPPs and call text. For example, the Nanosciences and Nanotechnologies and New Materials areas have an emphasis on low TRL calls and projects. The same holds for part of the GC PPP (e.g. calls on battery technologies). As such, the EC influences the balance between consortia/projects with a focus on low or high TRLs.

## 3.3 Objectives and relevance

<u>The objectives of the projects</u>

The case studies illustrate the range of objectives of the FP7 NMP programme and its specific areas, calls and projects. The paragraphs below will elaborate on the challenges that are addressed by the projects and on the output. First, we make three observations about the objectives.

The first observation is that the official objectives of nearly all projects, as described in the project documents and mentioned during the interviews, emphasise economic objectives and progress towards high TRLs. Challenges and objectives related to science and technology are mostly presented as a means to an end: the ultimate objective is to develop and commercialise new products, services and processes. Along the same lines, social and environmental objectives are mentioned (safety, inclusion, energy efficiency, etc.) but phrasing often is abstract. Still, a number of large project and consortia elaborate on social and environmental objectives.

It is mentioned that meeting social and environmental objectives depends on meeting economic objectives; and social and environmental success is considered as a side-effect of economic success (rather than the other way around). In other words: projects take steps towards the development and implementation of new technologies and solutions; subsequent steps such as actual use, fine-tuning and scaling up could lead to social and environmental impact. There are exceptions such as projects that focus on social and environmental objectives and deal with safety of nanomedicines and of nanotech in general, and with standardisation of energy efficient solutions. Note that there is more attention for environmental objectives than for social objectives.

A second and related observation is that the evolution of EU-funded NMP research towards higher TRLs (between FP6 and FP7 and within FP7 through the introduction of PPP) creates a number of risks for defining and selecting projects. Risks were identified in several Green Car projects and in projects in the Integration and Nanotech areas. In proposals, consortia have to explain how they will move up several TRLs (e.g. from 3-4 to 5-6) or how they focus on higher TRLs, even in situations where lower TRLs still need substantial work by the consortium and their peers. In order to secure funding, consortia are tempted to overpromise in terms of moving up TRLs in one project of three/four years. In short: overstretching a project. This can be difficult to identify by proposal reviewers. Moreover, consortia that seek EU funding are tempted to position their project at a higher TRL with clear and immediate opportunities for commercialisation. In short: selling the same project at a higher TRL. One example of overstretching is to emphasise the pilot or demonstrator element of a project, whereas most of the project concerns research and early stage development.

Third, it was stressed that the maximum duration of projects (four years) puts a constraint on moving up several TRLs in one project. Requirements and expectations should be realistic. More in general, it was mentioned that a four years maximum period is understandable from a governance and accountability perspective, although a six year period betters fit the domain of NMP.

<u>The scientific, industrial/economic, societal and environmental challenges</u>

The set of case studies describes a range of scientific and technological challenges related to the properties of materials (such as graphene, lithium-ion, ceramics, nanoparticles and coatings) and potential use in products (such as microprocessors, batteries, prosthetics, glass and turbine engines, respectively). Moreover, the case studies illustrate how FP7 NMP projects combine different technologies. One of many examples is an energy production, energy storage and energy management system that maximises the benefits of solar energy, wind energy and traditional energy production. As mentioned above, FP7 NMP includes projects with TRL 1-4. Scientific and technological challenges are most prominent in these projects but they are also prominent (or even leading) in projects with an emphasis on TRL 5-8.

In nearly all cases, industrial and economic challenges are phrased in terms of increasing competitiveness of European high-tech sectors by launching new products and services, by developing new production processes (that are energy efficient, reliable, flexible and that allow for high-precision manufacturing) and by using these products, services and processes to increase the productivity and quality in downstream sectors such as automotive, consumer electronics, aerospace, construction and health. The case studies are very different in terms of specific examples of industrial and economic challenges (try to be the first, the best, the cheapest, etc.) and in terms of the relative position of European actors vis-à-vis US, Asian and other actors (maintain leadership, catch-up, collaborate, etc.).

The main social challenges to emerge from the case studies are healthy and active ageing (e.g. implants and prosthetics), safety (e.g. in the context of products that are based on nanotechnologies or in the context of batteries in cars) and inclusion (e.g. production of textiles and other products for people with disabilities). As mentioned above, nearly all projects emphasise industrial and economic objectives, only a few address social or environmental objectives.

> The LifeLongJoints project, a CP-IP with 14 partners, develops silicon nitride coatings for implants such as artificial hips. The project includes material/coating development and testing of coatings, pilot production of implants, and modelling and simulation for testing of implants. The consortium includes universities (covering materials, health and manufacturing disciplines), SMEs that provide simulation software and SMEs and large firms that manufacture orthopaedic devices.

The main environmental challenges to emerge from the case studies are energy efficiency and resource efficiency in general, e.g. increase the production of alternative energy sources, use less water and energy in manufacturing processes, use less materials and create less waste.

> The ENEPLAN project, a CP-IP with 17 partners, develops an ERP-like planning tool for manufacturing systems that are energy efficient, highly flexible, and, at the same time, closely adapted to individual components and products that are produced. The project's planning tool covers the whole plant operation, including supply of materials and other resources, overall planning of the plant operation (such as the routes that products follow within the plant and the scheduling of the production), down to programming of individual steps and processes, and a green energy consumption/planning tool that confronts the required production volumes with weather forecasts (e.g. sun and wind). The potential for increased resource efficiency is estimated at 20/30% depending on advances in data gathering (e.g. sensors), algorithms and data presentation, and on the characteristics of the application areas such as the automotive and aerospace sectors that are present in the consortium.

Motivation for participation

Interviewees were open about their motivation for participating in specific projects and in FP7 NMP in general. We list the six motives that were mentioned most frequently during the case study interviews.

- Access to funding for research and innovation activities.
- Access to state-of-the-art knowledge.
- Access to actors that work in different business sectors and application areas.
- Collaborate with leading European firms, universities and research organisations.
- Expand and integrate our knowledge with the knowledge of other actors, e.g. by crossing the boundaries of scientific disciplines and business sectors.
- Access to partners and potential clients in other countries.

The motives were not very different for universities, LEs, SMEs and other types of actors.

Having clear motives for participation contributed to actually achieving the goals of individual participants and meeting the objectives of projects. This will be elaborated on in Sections 3.4 (output), 3.5 – 3.8 (impact) and 3.9 (European Added Value).

## 3.4 Output

Overview of outputs

Output is according to plan, for nearly all projects. This applies most clearly to the following types of output:

- Publications such as conference papers, scientific articles in low/medium impact journals, articles in business press (e.g. industry magazines), flyers, brochures and videos.
- Patent applications, in some projects only (The Barcode, ROMEO, TRANS-INT, DIPLAT, GREENLION, LABOHR, LISSEN).
- Events such as workshops and conferences.
- Measurement instruments, visualisation, software and other tools (e.g. characterisation instruments for nanostructured materials, nano-indentation instruments, risk assessment tools).
- Designs of products, integrated systems and production lines.
- Proofs of Concept.
- Prototypes.
- Contributions to trade fairs and other business events.
- New materials, products, services and processes including enhanced materials, components, devices and integrated systems (e.g. rare-earth-free magnets, nanotubes).
- Small-scale pilots.

It can be mentioned that FP7 NMP consortia have learned to use a broad range of publication types and dissemination platforms. For example, project workshops are combined with conferences that are co-organised with other projects, with industry associations, European Technology Platforms and European Commission DGs.

Documents and interviews indicate that a challenge for executing an FP7 project lies in preparing and running pilots and demonstrators. This holds especially for large-scale pilots with users and pilot production lines that require different types of knowledge (coming from inside and outside the consortium), collaboration or agreement from outside the consortium (e.g. regulators and public agencies) and substantial financial resources (the matching funds that are anticipated in the project plan and additional resources).

To some extent, the nuanced picture of large-scale pilots and demonstrators reflects that a number of projects studied (including PPPs) were not finalised when the case study interviews took place. A similar timing effect was observed when discussing specific types of publications. It often takes between one and two year before project deliverables and conference papers are developed into an article for a high impact journal and are published in such a journal. Along the same lines, contributions to standardisation processes were said to take place at the very end of a project or when the project has ended.

Different types of actors emphasise different types of output. This reflects the various motives for joining consortia and the various organisational goals. The examples provided are straightforward, e.g. universities focusing on publications, research organisations focusing on patents and prototypes, large firms focusing on products and systems that can be launched on the market and SMEs that work on specific, specialised tools.

The RESSEEPE project - REtrofitting Solutions and Services for the enhancement of Energy Efficiency in Public Edification - is a PPP project funded by the Collaborative Project funding scheme. An experienced project coordinator led the consortium with 25 partners. The consortium is dominated by SMEs and was pursuing several commercialisation strategies. RESSEEPE, moving from TRL 5-6 to TRL 7, is a pragmatic example on how to improve the value proposition of introducing energy efficiency measures in the renovation and retrofitting of public buildings. The main benefit of this project comes not only from combining different disciplines and further developing the variety of technical solutions for energy efficiency in buildings, but also from studying and providing tools to achieve a cost-effective integration of all of them. As such, the project takes a more systemic view of the issues that affect energy efficiency in buildings and aims to develop the 'missing pieces' such as diagnostic and decision making tools for the right combination of energy efficiency measures. Pilots are carried out in three large-scale demonstrators (public buildings), with 52% of the project's budget allocated them.

The balance between specific types of output differs between the NMP areas and PPPs. For example, case studies about Nanotech and Materials projects indicate that publications (especially scientific articles and conference papers) are the main type of output. In addition, there are patent applications and patents granted. To some extent, this is because most projects in these areas are at low TRLs. However, case studies about the PPPs EeB and FoF describe a rich mix of outputs, including pilots and demonstrators. As such, high TRL projects 'add up' the different types of output, from academic publications to demonstrators. In between the 'extremes' of fundamental Nanosciences and Nanotechnology projects and PPPs with demonstrators are projects in the New Production Technologies and Integration areas, and the GC PPPs. This is reflected in the output, including Proofs of Concept, designs, lab testing and small-scale pilots.

The specificities of CSAs are reflected in the types of output. The emphasis is on a range of publications and events, including the examples mentioned above but also roadmaps, awareness campaigns (e.g. regarding the safety of nanotech) and contributions to policy making and regulation.

The NANOCHARM project, a CSA-SA with a small consortium of eight partners from seven countries, developed a road map on industrial needs in ellipsometry and polarimetry characterization specifications (procedures, techniques and instruments for analysing nanomaterials), including references to specifications that are used in the US and Japan, proposals for a shared terminology, recommendations for the next generation of characterisation instruments, and implications for training of researchers, engineers and operators across Europe.

More in general, observations about the characteristics and output of CSAs are:

- The objectives of CSAs are not very tangible or specified ('vague goals').
- The diversity of CSAs is huge:
    - from medium-sized to large consortia;
    - from established consortia (e.g. a follow up of an FP6 project) to new consortia for emerging technologies, new application areas or Eastern European countries;
    - from preparing research priorities and roadmaps (with a role for ETPs) and monitoring innovation trends (e.g. observatories) to addressing regulation/standardisation issues and trying to increase the social acceptance of new technologies (informing stakeholders and the general public, sometimes close to a marketing campaign).
- Continuation of CSAs is a concern, as CSA activities, output and impact require a persistent effort by experts and other stakeholders, and long-term funding by public and private stakeholders.

<u>Main barriers and enablers for achieving output</u>

Although interviewees were quite open about their project and any difficulties encountered (related to the consortium, their own role, impact, etc.), they were reluctant to mention underachievement in delivering output. Project documentation was informative and confirmed that underachievement was fairly limited. Underachievement occurred mostly in large consortia (research consortia with more than 15/20 participants and CSAs with more than 25/30 participants) and in the PPPs GC and EeB.

The main examples of underachievement are:

- Scientific publications in high impact journals, partly due to the time needed by journals, but also due a slow start of the project.
- In some cases, e.g. in projects about nanotechnologies, materials and batteries, the quality and quantity of output suffered from limited progress in addressing (persistent) science and technology challenges.
- Pilots and demonstrators that are of a smaller scale than anticipated in the project plan, partly because all preceding activities in a project took more time than planned (which 'squeezes' the work packages about pilots and demonstrators) and partly because the practicalities, complexity and funding were underestimated.

The main example of overachievement is dissemination, with nearly all case studies having a dedicated dissemination budget and a clear and rich dissemination strategy that is fully implemented. Several interviewees stressed that the dissemination strategy should target at least three distinct groups: the research community, industry and the public sector (in their role as policy makers and regulator or as a partner/user in follow-up pilots, demonstrators and implementation). Industry associations are mentioned as being relevant partners for disseminating project results and arranging follow-up events with SMEs and LEs.

However, several project coordinators and SMEs acknowledge that more innovative means can be used for dissemination to non-research actors. For example, the wider community of SMEs in specific sectors will be most interested in short documents, online visualisations and customised workshops, with crystal clear information about the potential and limitations of new technologies, products and systems.

## 3.5 Scientific and technological impact

<u>Overview of S&T impact</u>

The S&T impact that emerged from the case studies reflects the high-tech nature and the broad scope of the FP7 NMP programme. The main examples of S&T impact are:

- Discovering new materials and adding properties to materials such as nanofibres, bionanocomposites, biobased polymers, bioceramic composites, glass, high thermal coatings and bioplastics.
- Application of existing (or enhanced) materials in new application areas such as energy storage systems, electric cars, personalised medicines.
- New research methodologies, instrumentation and tools that allow for more precise measurements and simulation of potential applications of new technologies, products and systems.
- Fully and successfully testing and piloting a new prototype in a manufacturing process, office, apartment buildings or healthcare districts.
- Design and pilots for scaling up manufacturing processes, e.g. producing at a higher volume, producing larger units, producing more continuously, producing at higher temperatures or using robot swarms. See also the related concepts of process intensification, rapid manufacturing, agile manufacturing and (in chemical processing) continuous plant efficiency, consistency and scalability.
- To some extent, contributions to standardisation.

The type of S&T impact mentioned differs between low and high TRL projects and, to a lesser extent, between specific areas within the FP7 NMP programme or between funding sub schemes. For example, low TRL projects report many new methodologies, instruments and tools, whereas high TRL projects report successful technical tests and real-life pilots. Obviously, the nanotech and materials projects have a bias towards S&T impact related to materials. In terms of funding sub schemes, there are no clear differences between the S&T impact of different types of collaborative projects. The S&T impact of CSAs is small which, to a large extent, follows from the objectives of CSAs. However, interviews about CSA projects cases reveal that one specific type of S&T impact that may be expected, contribution to standardisation, is smaller than expected.

The S&T impact mentioned hardly differs between types of actors. For example, universities as well as SMEs report improvements in instrumentation or applying technologies in new application areas.

The majority of projects succeeded in moving up a technology to the next TRL. This was observed especially in case studies of TRL 5-6 and TRL 7+ projects, in collaborative projects (generic CPs and targeted CPs) and in projects within the PPPs EeB and FoF.

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| The TRANS-IND project, New Industrialised Construction Process for Transport Infrastructures based on polymer composite components, is an IP with 20 partners. The project demonstrated off-site manufacturing and on-site construction of bridges and other constructions made up of composite-based components (e.g. Fibre Reinforced Polymers). The consortium showed the construction-demonstrator to the EC, architects, construction engineers, etc. Commercialisation is hindered by the relative high price of the material/process (which will come down gradually) and by the crisis in the European construction sector. |

S&T impact, including impact achieved but also clear examples of impact expected in the short term, is in line with the objectives that are described in project plans. This applies to the majority of projects, especially for projects in the New Production Technologies area, in CSA-CA and CP-IP projects and in TRL 1-2 projects. Small Underachievement regarding S&T impact occurred in EeB PPP projects, in CSA-SA and CP projects.

Note that there were few examples of contributions to (large-scale) research infrastructures such as databases, distributed computing and shared/open development and test facilities.

Main barriers and enablers for achieving S&T impact

Interviewees mentioned few barriers for achieving S&T impact. The barriers mentioned below emerged in three to ten case studies. Barriers are:

- Insufficient budget for research and innovation activities.
- A time horizon that is too short.
- A lack of standardisation, which adds to technological uncertainty.
- Uncertainty about the application of existing regulation to new applications or about new regulations, which adds to technological and economic uncertainty, and which may also influence funding of research and innovation.
- Difficulties in collaboration between academics, business engineers and potential users, which is partly due to different terminology, incentives and priorities.
- Limited willingness to share relevant data between consortium members, which is partly due to a lack of trust and to delays or uncertainties in IPR agreements and in the implementation of these agreements.
- Inefficient collaboration in the consortium, which is partly due to a lack of alignment of the technological preferences and goals of consortium members, and differences in the level of priority that is given to the project.

For the rest, achieving S&T impact was considered to be a central, normal and risky part of a research and innovation process. Researchers may or may not succeed in adding new properties to materials; the combination of technologies may work under certain conditions but not in others (scale, application area, etc.); technical tests and real-life pilots may fail or be partially successful; etc.

The three main enablers for achieving S&T impact are sufficient budget, continuity in funding by public and private organisations and efficient and effective collaboration among experts and between experts and stakeholders.

In addition, it was mentioned that regulation could be a driver or enabler for S&T impact. Examples of such regulation that were provided are health regulation (e.g. regarding the use of nanomedicine), safety regulation for cars (e.g. regarding the use of batteries in cars), safety regulation for chemicals and nanomaterials (e.g. the 2006 REACH Directive) and resource efficiency regulation (e.g. the 2010 Energy labels Directive).

### 3.6 Economic impact

Overview of economic impact

As mentioned above, project documentation and interviewees are more explicit about economic impact than about environmental and social impact. A substantial number of projects is expected to lead to economic impact. Still, interviewees have difficulties in providing detailed, well-documented or well-motivated examples of economic impact. This is partly due to the high-tech character of the FP7 NMP programme and the long route the technology takes before it is into use (as product or process) and the economic impact can be measured (see also the concept of Key Enabling Technologies). For example, new materials and components developed in FP7 NMP may require testing and integration in systems such as car engines and wind turbines, before economic impact can be achieved. Another factor is the timing of the case studies, with around one third of the projects not being finalised yet. In addition, there is the fundamental timing issue in ex post evaluation and impact assessment studies: actors need time to create impact, whereas ex post evaluation and impact assessment studies often take place immediately after ending a programme.

The following types of economic impact were identified:

- New materials and products such as nanomedicine, adaptive components for machine tools, ceramics for Swatch watches, bioceramics for implants, textile for clothing and industrial applications and coatings for high temperature energy systems.
- New services such as Enterprise Resource Planning for high-tech manufacturing and (demonstrated) process guidelines and technological options for retrofitting of office buildings.
- New processes such as flexible production lines, high-quality 3D printing and precision manufacturing.
- Bringing all actors in the value chain together.
- Three or four spin-offs, e.g. a Tecnalia spin-off in the HARCO project (about machine tools) and a Technical University of Vienna spin-off in the PHOCAM project (about lithography-based 3D printing).

Consistent with the analysis of output, there were few statements about research infrastructures.

Only to some extent, there are indications about second-order economic impact such as increased productivity, competitiveness, employment and revenue growth. The emphasis was on quality, flexibility, new products and processes, rather than on second-order economic impact such as employment.

Several interviewees mentioned that the timing of FP7 NMP, partly overlapping with an economic crisis, implied that FP7 NMP project funding allowed organisations to limit the number of lay-offs. This applies mostly to research staff in industry.

Obviously, economic impact is more substantial, short term and/or more clear for projects with high TRLs. In this respect, the results of TRL 1-2 and TRL 3-4 projects are very similar, with a clear difference from the results for TRL 5-6 and TRL 7-8 projects.

Economic impact differs between areas. There is a clear cut between limited economic impact areas (Nanotech, New Materials, Integration and the GC PPP) and more substantial or immediate economic impact areas (New Production Technologies and the FoF and EeB PPPs). The results for FoF and EeB projects can be explained partly by high TRLs. Economic impact of Integration and GC PPP projects is less than planned. For GC, this can be explained partly by the case study sample that resulted in several case studies about batteries (with low TRLs).

Especially in the Nanosciences and Nanotechnologies area, the set of case studies includes projects with a clear focus on (basic) research. In these cases, economic impact is expected in 10 years time. In the meantime, there will be very distinct types of economic impact such as SMEs that provide instrumentation and software tools to universities, research organisations that provide access to instrumentation (as a service) and actors that obtain research funding from private organisations (actors also mentioned follow-up projects in Horizon 2020 as economic impact).

In other areas and PPPs, especially in the PPPs FoF and EeB, interviewees mention a broader range of economic impact and, especially, economic impact expectations. For instance, several Integrated projects and PPPs succeeded in running demonstrators and raising interest by stakeholders, but economic impact did not yet materialise.

<u>Main barriers and enablers for achieving economic impact</u>

The main barriers for achieving economic impact mentioned are:

- S&T impact does not yet translate into products/services and processes that lead to substantial cost reductions, energy efficiency, durability or other quality improvements for potential users. This is partly due to the minor significance of the S&T impact (in terms of changing the state-of-the-art) and normal technology adoption curves (with technologies and solutions becoming cheaper and better as the number of users increases and incremental innovations continue).

- A lack of a clear commercialisation strategy at the level of the consortium and more specific at the level of types of certain consortium members such as universities and research organisations ('moving on to the next research project').
- An imbalance in the consortium with very few consortium members being responsible for (and having a high interest in) commercialisation.
- Downstream partners that are too small for implementing an international commercialisation strategy and/or that do not cover important geographic markets inside and outside the EU.
- Limited awareness and understanding on the side of potential users/clients, which needs additional dissemination and commercialisation activities of the consortium members (and the resources to conduct these activities).
- Safety and health risks that are not addressed effectively or for which the risk perception is higher than the actual risks.
- Human capital or skills available in NMP producing and NMP using sectors, e.g. engineering skills for implementing and operating machines, and software programming skills.
- A lack of standardisation and uncertainty about regulation, or even approval/licensing not yet being possible.

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| The NANOINDENT-plus project, a follow-up of the NANOINDENT project, is a CSA-SA with eight partners and a focus on standardisation of nanoscratching. The main partners in the NANOINDENT project, with a focus on research, very much welcomed a call on standardisation in the field of nanoindentation and nanoscratching. This allowed for continuing the work in the NANOINDENT project in which one of the conclusions was that a lack of standardisation was hindering research progress and interest from manufacturers of nanoscratching instruments. |

To a large extent, the enablers for economic impact are the 'flipside' of the barriers mentioned above. For example, it was stressed that consortia that cover the value chain, including downstream sectors, have a clear potential for commercialisation.

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| The GRAFOL project, a large-scale Integrating Project with 15 partners, develops a roll-based chemical vapour deposition (CVD) machine for the mass production of few-layer graphene for transparent electrodes for LED and display applications, and adapts the process conditions of a wafer-scale carbon nanotube growth system to provide a low-cost batch process for graphene growth on silicon. The consortium covers the complete value chain, from graphene production, processing and application in microelectronics, optics, electrodes and lighting. The project minimises delivery risks by having end-users of the developed technology in different application sectors (e.g. Intel, Thales, Philips and Aixtron). This broadens and diversifies the potential routes to commercialisation. A similar value chain approach is taken in the GREENLION project, about the manufacturing of greener and cheaper Li-Ion batteries for electric vehicle applications via the use of water soluble, fluorine-free, high thermally stable binders. Partners range from nanosciences experts to material producers, battery producers and car manufacturers. |

Disseminate the results of the projects

As mentioned in the context of output, consortia invested in dissemination to companies and other stakeholders outside consortia. The extent to which this leads to economic impact, proved to be difficult to assess by project coordinators and other consortium members.

Several interviewees consider ESIC services (Exploitation Strategy and Innovation Consultants) and especially the Exploitation Strategy Seminars as effective tools for supporting commercialisation activities within projects. To some extent, it is a matter of reminding consortia that commercialisation requires timely discussions within the consortium, while everyone is tempted to focus on research. ESIC services were mentioned mostly in interviews about TRL 5-6 projects from a range of areas and PPPs.

## 3.7 Social and environmental impact

Overview of social impact

As mentioned above, social impact is closely linked to economic impact. Social challenges (or environmental challenges) may have triggered EC calls and project proposals, but the most explicit project objectives are scientific, technological and economic.

The following types of social impact are expected in the near future, in the sense that they are enabled by S&T progress and commercialisation steps taking during the project or right after project.

- Social aspects such as health and safety that are an explicit element in roadmaps that are developed in Energy-efficient Buildings roadmaps such as BUILDINGUP.
- Allergies and other health aspects that are addressed by projects on nanotechnologies, materials, nanocarriers and (nano)medicines (e.g. the NANOMMUNE project).
- Health being a focal point in projects about implants that are more durable and for which degrading/wear does not lead to toxic waste (e.g. the LifeLongJoints project).
- Creation of a Critical and Commented Database on the Health, Safety, and Environmental impact of Nanoparticles (the NHECD project created an automated database that retrieves, indexes and extracts from scientific publications results relate to the health and environmental impact of nanoparticles).
- Projects that increase the involvement of end-users (such as elderly, wheelchair users and diabetics) in the innovation process (e.g. the TAGS project and the FASHION-ABLE project).

Overview of environmental impact

Similar to social impact, environmental impact is closely linked to economic impact.

The following types of environmental impact are expected in the near future, in the sense that they are enabled by S&T progress and commercialisation steps taken during the project or right after project.

- Coatings that improve durability, fuel efficiency or energy efficiency in general (e.g. the TheBarCode project).
- Energy efficiency in apartment buildings, city districts and healthcare districts. For instance, the STREAMER project develops an integrated energy system consisting of mixed building types (i.e. hospitals and clinics; offices and retails; laboratories and educational buildings; temporary care homes, rehabilitation and sport facilities). STREAMER aims at 50% reduction of the energy use and carbon emission of new and retrofitted buildings in healthcare districts
- Stand-alone improvements of energy efficiency, e.g. the HARWIN project that develops glass windows that are lighter as well as providing more thermal insulation (and sound isolation) and the Nanocool project that develops efficient systems that combine air conditioning/dehumidification, by using Hybrid Liquid Desiccant systems. Energy savings can reach levels of 50%.
- Increased use of green polymers and other biobased materials in general. For example, the Bugworkers project develops green polymers for a range of application areas.
- Increase the efficiency of using rare earth materials and develop alternatives.

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| The REMANENCE project, Rare Earth Metal Recovery for Environmental and Resource Protection, is a CP-TP project with nine consortium members. The project develops new processes for the recovery and recycling of rare earth (RE) containing neodymium iron boron magnets (NdFeB) from a range of waste electronic and electrical equipment (WEEE). The main aim is to find a solution for these materials so that they can be recycled and used in new products and so kept in the loop rather than simply lost as waste. Challenges lie not only in the identification and separation of magnets, but also in waste logistics, micro logistics and in ensuring that the properties of recycled magnets are equivalent to those that are manufactured from primary resources. |

### 3.8 Impact on social networks and the European Research Area

Taking the initiative

In nearly all cases, one of three types of actors takes the initiative to develop project proposals and consortia: research organisations such as RTOs, large firms and universities.

In nearly all cases, one of these actors takes the lead and coordinates the proposal. Among the first partners to be invited are peers in other countries (e.g. one RTO invites another RTO) and the two other types of actors (e.g. an RTO invites a large firm and a university).

In some cases only, consulting firms play a role in the initiation phase and the first steps of a project proposal. In other cases, these firms assist in project management and in dissemination activities.

The TAGS project, Textiles for Ageing Society, is a CP-CA project with 12 consortium members. The official objective of TAGS is to bring together the elderly, social and medical care institutions, research institutions, technology transfer institutions and manufacturers to identify: specific requirements of the elderly and care institutions; latest developments in materials science and technology that will help meet these requirements; and strategies to incorporate developments in the manufacturing chain. Interviewees stress how the project is indeed increasing commercial interest by firms. In addition, the project is taking steps to clarify the requirements of textiles by incorporating the perspective of the user. Increasingly, researchers and firms understand that the user perspective is crucial for innovation and commercialisation.

Gradually, consortia and proposals develop by inviting SMEs, universities for applied science, industry associations and public sector organisations.

The case studies illustrate the continuum between consortia and projects that try to continue existing lines of research and existing collaborations ('projects looking for funding') and consortia and projects that are developed in response to the work programmes and calls in European framework programmes such as FP7 NMP ('funding that triggers projects').

<u>Building project consortia</u>

There are clear indications that the process of creating consortia often combines continuation of existing consortia and collaborations (to follow-up FP6 and national projects) and adding new partners (based on expectations about complementary scientific disciplines, technologies and application areas). As such, nearly all consortia include 'old friends' and 'new friends.' Concerns about adding to many new partners were raised in case studies about large projects and consortia.

The MUST project, Multi-level Protection of Materials for Vehicles by Smart Nanocontainers, is an integrated project with 19 partners. Of these partners, eight are from Germany and have collaborated before in European and national research and innovation projects. Consortium members include experts in nanotech and materials research, in chemicals, coating and painting, and in three application areas: aerospace, maritime and automotive (e.g. Daimler-Chrysler from Germany and FIAT from Italy).

The heart of consortia can be partners from one country or even one region (cf. clusters) or from a number of countries (in the case of a preceding FP project). In nearly all case studies, the number of partners and countries involved has increased (compared to preceding projects). This applies to all funding sub schemes but especially to CSAs, CP-Integrated Projects (CP-IP) and CP-Specific International Cooperation Actions (CP-SICA). In theses schemes, internationalisation is an explicit requirement (CP-SICA) or an implicit requirement (CSA and CP-IP).

Several mechanisms are used to identify and select new partners and create new or refresh old collaborations:

- Collaboration in previous projects about related technologies and application areas. For example, collaboration took place three to five years ago and personal relations continued after the project.
- Personal relations, e.g. between professors at different universities, between senior researchers at RTOs and large firms, and between senior management of SMEs.
- Each research organisation or university to be involved in a project invites an SME from the same country, to also join the consortium. This ensures that SMEs can trust and rely on a national partner, while increasing its international collaborations.
- Spin-offs from a university or large firm, that seeks to continue collaboration with their former parent company (and former colleagues).
- Client-supplier relations, e.g. developing a commercial relation between upstream and downstream firms into research and innovation collaboration.
- European Commission match making events and partner search websites are used to some extent only, e.g. by actors that are new to Framework Programmes.

<u>Examples of new collaborations during projects</u>

Most frequently mentioned were new collaborations made within the project consortium between SMEs and research organisations and between SMEs and LEs. This concerned collaboration between actors from different countries but also from the same country. Moreover, this concerned actors from different scientific disciplines or business sectors but also from the same discipline or sector.

In addition, there were new collaborations among actors from universities, higher education institutes and other research organisations (including RTOs). This mostly concerned collaboration between actors from different countries. Often, this concerned collaboration between actors from different scientific disciplines (to increase the level of inter- and trans-disciplinary research) but it also concerned collaboration between actors from the same scientific discipline ('peers in different countries').

Note that actors from various parts of Europe mentioned that new collaborations were also appreciated for the side effect of increased understanding of the various national cultures within Europe. As such, interviewees referred to the social-cultural and political aspects of European collaboration.

Continuation of collaborations

The overall picture is that collaboration with existing and new partners is appreciated and will be continued after the project has finished. To some extent, interviewees link this to the development of the project towards higher TRLs, for which a variety of actors is required.

The case studies did not reveal any pattern in terms of the types of actors that are most likely to continue their collaboration (e.g. collaboration between SMEs and universities or between two universities). Likewise, there is no clear pattern regarding collaboration between actors from different scientific disciplines, sectors or countries.

A trade-off emerged regarding collaboration with non-EU partners. To involve non-EU actors can provide a consortium with access to excellent knowledge, downstream partners or geographic markets. However, there have been delays and problems related to IPR negotiations and enforcement, inter-cultural collaboration and commitment. As such, collaboration with non-EU actors can be qualified as high risk, high gain.

Consortia's functioning

In general, project coordinators but also other consortium members are positive about the functioning of consortia. They refer to the collaborative spirit, effective collaboration, implementing the project plan and discussing any changes that are required.

The main point of critique concerns organisations that leave a consortium or that under-perform, which creates delays and additional work for other partners. For example, an organisation that leaves a consortium creates a challenge for the project coordinator, e.g. finding a replacement organisation and getting approval from the project officer for new consortium members and budget re-allocations. Comments about project changes and consortium changes are mostly about administrative procedures (see Section 3.10).

There were barriers at the start of the project when the partners were putting the consortium agreement together. One of the partners created problems and did not want to collaborate. The consortium was not able to vote the problematic partner out of the project. The coordinator stated that this was previously not the case as their organisation was involved in another EU project which also had issues but the coordinator for that project was able to kick out the partner who created the issues. The rules appeared to have changed and consortiums are not allowed to eliminate a partner from the project (this has not been verified by the EC, as there are likely different conditions that allow partners to leave the consortium i.e. bankruptcy). In the case of ROMEO, the problematic partner allegedly 'blackmailed' other partners in the consortium to achieve what they wanted because they were aware that they could not be eliminated from the consortium. Eventually other partners conceded to the demands of the problematic partner in order to continue with the project.

The interviews indicate that, over the years, actors have learned to collaborate in FP projects, to solve issues related to disciplinary, business-research and cultural differences, and to accept that time should be invested in aligning individual interests, creating a shared terminology and building trust.

## 3.9. European added value

Overview of EA

The set of case studies provides a rich and clear picture about the various ways in which individual FP7 NMP projects (and the FP7 NMP programme as a whole) achieve European Added Value (EAV).

- FP7 NMP project funding is more substantial than national and regional funding, which allows for large-scale projects.

- Linked to this, is that European projects can accept higher risk levels, e.g. by addressing several technologies in one project and by sharing risks between many partners.
- FP7 and Horizon 2020 provide more continuity than national or regional governmental programmes that are addressing the economic crisis by budget cuts in science, innovation and other policy areas.
- An element of FP7 NMP that is appreciated is support for inter/trans-disciplinary research and cross-sectoral innovation. In national programmes there are more 'stove pipes' and less options to include an entire value chain.
- A related point is that value chains often are international or even global, which implies that only a European or international programme can support research and innovation that involves the entire value chain.
- FP7 NMP project funding is perceived as having an emphasis on applied research, development and pilots ('the heart of the research and innovation process'), whereas national programmes in several EU Member States have an emphasis on basic research ('the source') and on pilots, demonstrators and commercialisation and enablers such as cluster organisations and incubators ('the final steps of the innovation process'). As such, in some countries EU funding is very complementary to national programmes. Note that statements about national programmes indicate large differences between countries. For example, Germany and the Netherlands were mentioned as countries that support the entire innovation process, whereas Spain, Hungary, Italy and EU accession countries were mentioned as countries with small budgets for supporting development and pilots.
- In the context of EAV and public funding in general, interviewees mentioned the persistent concerns about private funding of pilots, demonstrators, commercial roll-out and scaling up internationally. The importance of the European Investment Bank and the need for more venture capital were mentioned several times, not just by industry.
- FP7 NMP allows actors from small countries and countries that are not leading in high-tech research and sectors, to collaborate with leading countries and actors. There are fewer barriers for getting into a good consortium than for developing a one-on-one partnership with leading actors. As such, FP7 NMP contributes to a level playing field.
- A related point is that in a number of countries, specific expertise is missing. FP7 NMP consortia provide access to missing expertise and that is available in other countries.
- Because the size of specific downstream sectors and application areas (such as automotive, semiconductors and energy production) differs between countries, and because many sectors are spread across Europe, participation in FP7 NMP consortia provides firms from one country with access to markets in other countries. As such, actors can target a larger geographic market.
- A related point is that too much emphasis on intra-EU collaboration may be at the expense of collaboration with leading non-EU actors from the US, Canada, Japan, India, China, South Korea and other countries. These countries are not only relevant in terms of expertise or leadership (in selected areas) but also in terms of substantial investments in high-tech research. The difficulties in collaboration with non-EU actors are acknowledged (IPR negotiations and enforcement, cultural and geographic distance, travel costs and travel time).
- There were few statements about the influence of FP7 NMP projects on coordination of national support programmes, policies and regulation (this was only mentioned for CSAs) and very statements about international temporary staff exchange and job mobility (or job mobility in general) and about European funding being crucial for increasing human capital by formal training (e.g. funding of PhD research and training of industry researchers and process engineers).

As mentioned above, EAV partly depends on the support programmes at national and regional level. In several interviews this issue triggered a discussion about the right focus of European framework programmes in terms of TRLs, taking into account other European instruments (such as the loans and grants that are provided by the European Investment Bank), budget cuts at national and regional level, and how the need for national co-funding of European projects can lead to a self-reinforcing process in which only actors with national funding can participate in European programmes, while the knowledge and market position of actors from other countries deteriorates (which would contribute to a 'two speed Europe'). This point is made by RTOs and universities that have to match national and European project funding. For industry, the link between national and European funding is less relevant, with more flexibility to combine private and public funding of projects and project portfolios.

Synergies with company funded projects

Interviewees from industry explained that FP7 NMP projects often are part of a line of research and of a portfolio of research and innovation projects. Parts of these projects are funded by the company; part of these projects are funded jointly by a national programme and the company.

Examples were provided for FP7 NMP projects that benefited from knowledge, instruments, tools and data (and relations) that were developed in projects funded by companies. Vice versa, the results of FP7 NMP projects are used in subsequent projects funded by companies.

Crucial role of FP7 NMP funding

In line with the overall picture about EAV presented above, interviewees mentioned that FP7 NMP funding is most crucial for research and innovation that requires substantial funding, that is high risky and that combines several scientific disciplines and involves an entire value chain. This was stressed in the context of the PPPs EeB and FoF.

In addition, interviewees mentioned standardisation and regulation, for which European collaboration is crucial. However, the examples provided by interviewees were less convincing than the examples of other types of S&T output and impact.

## 3.10 Administrative procedures

Improvement of procedures and routines

The expertise, communication skills and flexibility of project officers (POs) is appreciated. They should attend more often project meetings to give timely feedback about the projects, advice on administrative matters, share information about related FP projects and provide early signals about changes in the EC's priorities. There is critique on the number of changes of POs during the course of an FP project.

Project technical advisers (PTAs) are also appreciated, as most of them are well-informed and constructive peers with a real interest in the project. The role of PTAs is expected to become more important in case as the role of POs is being handed from DGs to agencies, but this is expected not to happen very soon.

Without adding a clear value judgment, interviewees mention the trade-off between open calls and narrowly defined calls. Open calls generally mention the societal challenges and application areas, while other calls are more specific about the priorities of the EC, specific DGs and units (or even key officials) and also mention relevant technological trajectories. With open calls, proposals may 'completely miss the mark'. More narrowly defined calls create the risk that proposals are too conservative and incremental (and that competing proposals are very similar).

In terms of efficiency it was mentioned that face-to-face consortium meetings continue to be crucial, partly due to the shortcomings of conference calls with participants that speak several versions of English and that have backgrounds in various disciplines and sectors.

Statements about administrative procedures mostly concerned the complaints made by firms and universities that had to create or modify a system with time sheets (in order to comply with FP7 requirements); changes in the interface and functionalities of the FP7 participants portal (it always takes time to get used to these changes); and large research organisations being more capable of meeting administrative requirements, compared to SMEs and even LEs.

The project selection procedures can be improved by increased emphasis on the scientific criteria (new knowledge, relevance, actuality, application areas) and decreased emphasis on formal criteria (related to management, planning, etc.).

At the end of project, administrative procedures can distract actors from commercialisation. This may not be needed if procedures and information requests are streamlined throughout the entire project, e.g. by only adding additional expenses, additional time used, additional publications, etc.

Increasing the efficiency of collaborative FP projects

Interviewees were asked about any opportunities they saw for increasing the efficiency of collaborative research projects in European Framework programmes. They provided nuanced answers on the following topics.

- One of the key criteria for an efficient and effective project is the quality of the Project Coordinator. He/she needs time and resources.
- Online communication and collaboration tools are becoming normal, but face-to-face contact remains crucial.
- Project officers and the joint research centres can be more pro-active in stimulating communication, community building and synergies between FP projects. A better overview of synergies and development across projects ('an overall picture') may also help the EC itself as the sheer number of FP projects creates the risk of information overload.
- Smaller projects tend to be more efficient and equally effective than large projects, as long as small projects/consortia include the right downstream actors and other commercialisation partners.

### 3.11 Recommendations made by interviewees

This chapter presents the main recommendations made by the case study interviewees. Note that recommendations are only included when they were mentioned three times or more.

- Intensify the mechanisms (such as funding rules) for increasing SME participation, as SMEs are willing to take risks and can move fast, partly because SMEs have less vested interests and path dependencies compared to large firms.
- Add incentives and requirements for involving more end-users, i.e. client firms, organisations representing specific public interests (such as housing associations and hospitals) and non-profit organisations and individual users such as employees, consumers and citizens. This is needed given the increased emphasis on late stage development, pilots and demonstrators and the increased understanding about the importance of the contribution of users to early stage development and research.
- Reduce the number of large consortia and decrease the average number of participants per consortium. Large consortia (>20 participants) may only be needed for CSA (such as for creating European networks) and for PPPs that address several challenges at the same time (e.g. combining several scientific disciplines, business sectors and preparing for commercialisation in a range of countries). Also the call text could be clearer about the maximum size of consortia.
- In specific areas, such as Nanosciences and Nanotechnologies and New Materials, there is room for increased emphasis on higher TRLs. This would allow key actors to continue developing and piloting their technologies in European FPs and to involve relevant downstream actors. This is not to say that FPs such as Horizon 2020 should not fund projects with low TRLs (projects that are less fundamental than those funded by the European Research Council). Rather, this recommendation addressed the risk that new FPs fund 'the next big technology' instead of supporting actors that gradually and realistically develop a technology from one TRL to the next. For example, interviewees mentioned how even TRL 5-6 can mean that commercialisation still requires between five and ten years. This requires consistent EC support, instead of EC support being redirected to other technologies.
- Maintain the increased emphasis on high TRLs but also accommodate more projects that focus on standardisation and regulation (e.g. government backed-up standards, certification, European harmonisation of regulation). This allows consortia that have tested, piloted or demonstrated a product, service or process to continue their work in a follow-up project about standardisation and regulation and to increase chances of commercialisation.
- With increased emphasis on commercialisation, there is room for supporting consortia that include a range of new actors and new collaborations (instead of cliques) and, whenever appropriate, consortia that do not include the 'big names in NMP' and that are very open to emerging technologies, radical innovation and new applications areas.
- Intensify ESIC-type of commercialisation support because consortia and individual partners (or individual researchers that represent partners) may lack expertise about IPR, business models, marketing, internationalisation, etc. Moreover, commercialisation requires timely discussions and negotiations between consortium members. External support serves as a reminder that is combined with practical suggestions and advice on getting in-depth expertise about commercialisation.
- Continue investing in committed project officers. In the process of migrating the project officers from the Directorate Generals to the Executive Agencies, ensure that project officers continue to closely follow the projects and respond quickly to any issues raised by the project coordinator. Reduce the number of changes between project officers. Nearly all

case studies indicate that the project officers changed during the project, which increased coordination costs and delayed decision-making by the consortium.

- Most project reviewers, including the increased number of project reviewers from industry, have relevant expertise and experience but there still are too many reviewers that lack the right expertise and experience. Interviewees mention that the EC should continue their efforts to select the most relevant proposal and/or project reviewers.
- Despite the improvements in administrative procedures (between FP6 and FP7), there is room for further improvements. This mostly concerns procedures for implementing changes in the consortium or project, e.g. changing operational objectives, deliverables, milestones, partners and budgets per partner. There is also room to simplify the time sheet requirements, as this is a burden for SMEs.

# 4. BIBLIOMETRIC AND PATENT ANALYSES

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## 4.1 Introduction

The analysis of scientific publications (bibliometrics) and patents provides information about the scientific and economic output and impact of the NMP theme. The rational behind this approach is confirmed by the results of the survey (see Annex Report 5) and the case studies (see Annex Report 3) which reveal that scientific publications are the most numerous quantifiable outputs of FP7 NMP funded projects. About 75% of the participants in the finished projects wrote publications. Also ongoing projects present high publication activities. Almost 50% of these projects have already achieved their publication goals and 70% of the participants expect that by the end of the project publications will be achieved.

Patents represent technological development activities and due to considerable investment requirements in terms of financial and personal resources, the filing of patents also indirectly indicates economic interest. In addition, patents directly represent an economic asset indicated, for example, by license trading activities.

Against this background the main objective of the bibliometric and patent analyses is the identification of specific effects of the FP7 NMP Theme on scientific and economic output and impact. In order to achieve this objective, it is important to compare publication and patenting activities within the FP7 NMP Theme with the general scientific and patent landscape. This comparison will allow identifying similarities or/and differences which in turn will enable drawing conclusions about specific effects of the FP7 NMP Theme.

Our approach for the publication and patent analyses is based on using different indicators for characterising scientific and economic output and impact. In addition to the overall output measured as total publication or patent counts, the following indicators are used: publications and patents by:

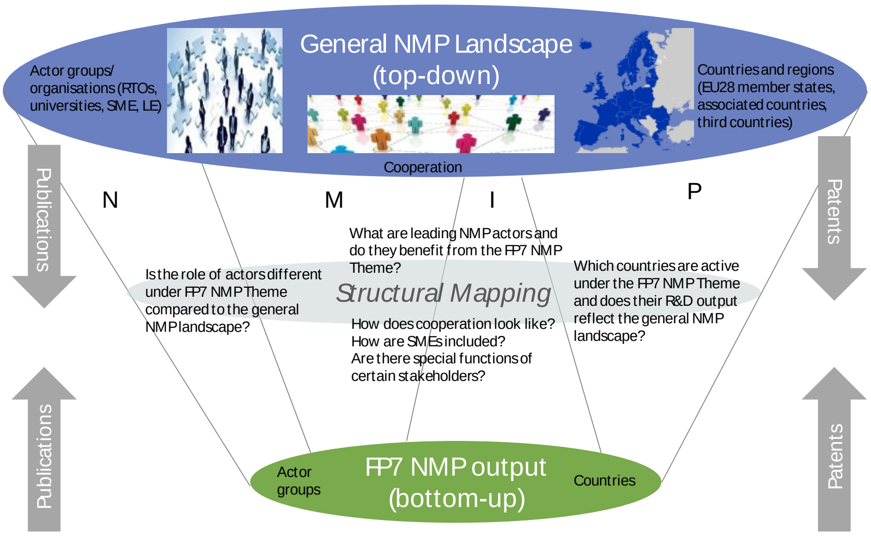
- regions and countries (EU 28 member states, associated countries, third countries),
- types of organisations (universities (higher education institutions, HEI), research and technology organisations (RTO), small and medium-sized enterprises (SMEs), large enterprises (LE)),
- NMP topics (NMP in general, Materials (M), Nanotechnology (N), New Production (P), Integration (I), PPP),
- project characteristics including type of projects and size of projects,
- TRL.

Our approach for identifying specific effects of the NMP Theme relies on combining a top-down perspective with a bottom-up perspective (Figure 19). The top-down perspective comprises an analysis of publications and patents in the general NMP landscape as represented in publication and patent databases such as Web of Science (WoS) or PATSTAT. The bottom-up perspective considers projects funded within the NMP Theme as a starting point and analyses publication and patenting activities of all funded projects. The combination of both perspectives allows for a structural mapping of scientific and economic output and impact of the NMP Theme. In specific, the following questions can be answered:

- What are leading NMP actors and do they benefit from the NMP Theme?
- Is the role of actors different under the NMP Theme compared to the general NMP landscape?
- Which countries are active under the NMP Theme and does their R&D output reflect the general NMP landscape?
- How does cooperation look like? How are SMEs included? Are there specific functions of certain stakeholders?[61]

[61] This latter group of questions is discussed in the report section about the social network analysis.

**Figure 19** Approach for bibliometric, patent and network analyses




Source: Fraunhofer ISI

## 4.2 Methods

### *4.2.1 Bibliometric analyses*

Top-down approach

As a source for the analysis of publications in the context of the top-down approach the database Web of Science (WoS) was used. A key requirement for the top-down analysis is to apply a suitable delineation of the NMP Theme including its subtopics. Different approaches have been described in the literature for delineating NMP topics. For example, the comparative scoreboard study[62] used the subject areas as indexed in the SCOPUS database as an initial starting point to define NMP categories. In some cases such as for materials engineering it was possible to translate directly to a complete SCOPUS subject category. In other cases the subject categories were used as a starting point to predefine the area of interest and narrowing it further down, for example, by adding specific keyword-based algorithms.

The delineation of nanotechnology turned out to be more difficult since due to its cross-cutting character, no clear relations to specific subject areas are obvious. However, a number of studies already defined specific search strings for the delineation of nanotechnology. Typically keyword-based approaches are used for that purpose (Hullmann and Meyer 2003)[63] and a comprehensive review of more than 120 social sciences studies in nanotechnology was published by Huang et al. (2008)[64], focussing in particular on publication data. These authors found that the keyword-based publication searches produced very similar ranking tables of the top ten nanotechnology subject areas and the top ten most prolific countries and institutions. This indicates that for structural analyses of the NMP Theme the choice of the specific search strategy is rather robust.

Taking into account this experience, we applied the following approach for the delineation: Based on the OECD Frascati Manual from 2002[65] and its revision from 2007[66] Fields of Science and Technology (FOS) have been defined. A concordance table links the FOS to WoS subject categories (to be found at InCites[67]). We have defined a further concordance table linking the WoS subject

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[62] Comparative Scoreboard and Performance Indicators in NMP Research Activities between the EU and third countries (April 2013): http://ec.europa.eu/research/industrial_technologies/

[63] Hullmann, A.; Meyer, M. (2003): Publications and patents in nanotechnology: an overview of previous studies and the state of the art. In: Scientometrics 58(3), pp. 507-527.

[64] Huang C. et al. (2008): Nanotechnology Publications and Patents: A Review of Social Science Studies and Search Strategies. United Nations University. UNU-MERIT. Working Paper Series: #2008-058 (http://www.merit.unu.edu/publications/wppdf/2008/wp2008-058.pdf).

[65] OECD, Frascati Manual: Proposed Standard Practice for Surveys of Research and Experimental Development, OECD: Paris, 2002. (OECD, 2002).

[66] OECD, Revised field of Science and Technology (FOS) Classification in the Frascati manual, OECD: Paris, 2007. DOCUMENT DSTI/EAS/STP/NESTI (2006)19/FINAL (OECD, 2007).

[67] http://incites.isiknowledge.com/common/help/h_field_category_oecd_wos.html

categories to NMP (and even the six KETs as also being relevant for the EC). The approach is thus in accordance with the NMP scoreboard approach and even further extending this approach.

Principles used are the following: Subject categories that do not relate one to one to N, M, P are excluded, e.g. unspecific, multidisciplinary subject categories could be relevant to N, M, P and even other science and technology fields and the NMP relation would be washed out. Links to application fields are excluded (e.g. connected to sectors such as aerospace, textiles etc.), since this would lead to a bias to certain sectors.

- For Nanotechnology there is a one to one mapping via the FOS 2.1.
- For Materials subject categories related to FOS 2.04 and 2.05 and additionally selected FOS 1.04 are used. Several subject categories are excluded using the principles above.
- New Production is delineated by the other part of FOS 2.02 (automation and control systems and robotics), mechanical engineering as subject category within FOS 2.03 as well as Industrial and Manufacturing Engineering under FOS 2.11.

As a result, except from individual categories from FOS 1 Natural Sciences all NMP fields are delineated by FOS 2 categories on engineering and technology.

The NMP strategies as defined in that way have the advantage that:

- All individual NMP areas are treated in the same manner and not differently (e.g. keyword-based for Nanotechnology, subject categories for Materials, mixed approaches for others). Thus, they are comparable and not biased to different directions.
- They tend to be rather focused on a one to one relation to NMP and might cover only a part of the full NMP-related publications. However, on the other hand they do not cover publications that might be out of range.

The methodology is suitable therefore, especially if comparisons across the NMP Theme should be done, if large numbers of publications will be analysed (e.g. on country, cluster, organisation level and not down to individual authors) or if network analyses are carried out and the absolute number of NMP publications is not of interest. This is the case for this project and even the structural comparison to the FP7 NMP Theme output is feasible.

<u>Bottom-up approach</u>

As the main source for analysing the scientific output of projects funded within the NMP Theme the SESAM database was used. The following information provided by this database is relevant for the publication analysis: project ID, project acronym, research programme and subprogramme, funding scheme, EU financial contribution to the project, number of participants in the project, submission date of the project, final report, publication date, publication title, and digital object identifyer (DOI). What is missing in the SESAM database are the name of organisations and the country of authors related to specific publications. This information is crucial in order to correlate each of the publications to the NMP project participants. Accordingly, the SESAM database needs to be complemented by additional sources.

In practice, each of the approximately 4,000 publications of the database was identified within the database Web of Science, where the missing information could be retrieved. The following additional information was added to the SESAM database: organisation of authors, country of authors, type of organisations (university, RTO, SME, LE). In addition, via the project ID and using the eCorda database, the TRL of each project were added, so that publications and also patents arising from individual projects could also be assigned to a specific TRL. All this information was entered into a new project database of the NMP evaluation which was used as the key source for the bottom-up analysis. Thereby countries and regions, actor groups, topics and subtopics, and TRL as well as project characteristics (size and type) could be assigned to individual publications. This project database was also used for the collaboration and network analyses based on co-publications as described in Chapter 6 of this annex report.

#### *4.2.2 Patent analysis*

<u>Top-down approach</u>

Patent data for the top-down analysis were extracted from the "EPO worldwide patent statistical database" (PATSTAT). The delineation of the NMP Theme and its subtopics could take advantage of previous studies where search strategies had been developed based on IPC classes. Important studies providing such information include the KETs observatory feasibility study[68] or even studies and information provided by the European Patent Office (EPO), which introduced a specific classification for nanotechnology[69]. The most updated and accepted delineation of NMP is available via the ongoing KETs observatory study (where Fraunhofer ISI is participating). These search strategies could be used also for the NMP evaluation (personal communication with ZEW, Mannheim, which is in charge of the KETs delineation within the KETs observatory study). This delineation of NMP, however, only allows for breakdown into the subtopics Materials, New Production and Nanotechnology. Integration as a subtopic cannot be delineated separately due to methodological reasons.

Bottom-up approach

The upgraded SESAM database as described above could also be used for the bottom-up patent analysis. The database contains information about total NMP patents and patents within all subtopics of NMP (Materials, New Production, Nanotechnology, Integration). There is also a number of PPP-related patents available via the SESAM database. However, the total number is only eight, so that more detailed analyses of PPP patents are not feasible.

## 4.3 Results

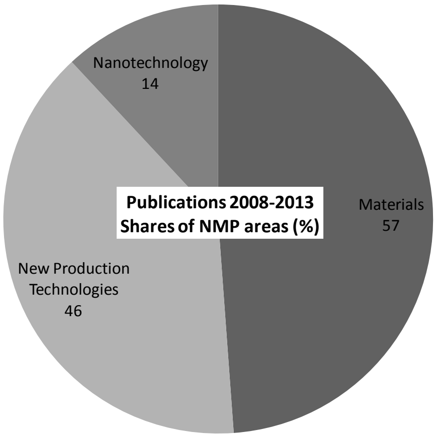
### *4.3.1 Bibliometric Analyses*

Following the intervention logic of the FP7 NMP Theme, impact pathways towards building a knowledge-based economy are firstly assessed based on scientific output using bibliometric indicators. Secondly, knowledge generation and the development of research facilities, infrastructures or instrumentation as results of research activities within FP7 NMP funded projects are evaluated using results of the case studies and the survey. The scientific output of the FP7 NMP Theme is compared with the general NMP scientific landscape in order to identify similarities or differences.

Worldwide publication activities

For the FP7 NMP relevant period 2008-2013 we identified about 1.3 million NMP publications worldwide in the Web of Science. These correspond to 12.3% of publications over all scientific fields in the Web of Science during that period. At the NMP area level most publications were generated from the Materials area (57%), followed by New Production (46%) and Nanotechnology (14%) (Figure 20, next page).

**Figure 20** Publications in NMP areas during the period 2008 to 2013. Percentage figures include double counts indicating overlap between the subfields.




Source: Web of Science, calculations by Fraunhofer ISI

68 Feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies (2012). European Commission, DG Enterprise and Industry. Report by IDEA Consult, Brussels, Belgium; Centre for European Economic Research (ZEW), Mannheim, Germany; TNO, Delft, Netherlands; CEA, Grenoble, France.

69 EPO (2013): Nanotechnology and Patents. Available at http://documents.epo.org/projects/babylon/eponet.nsf/0/623ECBB1A0FC13E1C12575AD0035EFE6/$File/nanotech_brochure_en.pdf

In order to map the role of the EU at a global level, NMP publications of EU28 countries were compared with other main world regions. As a reference, publications in all scientific fields are considered. EU28 contributed 33% of all worldwide scientific publications during the period 2008-2013 (Figure 21), followed by the US (27%), China (13%), Japan (6%) and South Korea (3%). If we compare the period 2008-2013 with the preceding six years 2002-2007, we observe no difference concerning the leading regions EU28 and the US. However, during the previous period Japan has been more active in terms of publication output compared to China. China improved its overall publication performance considerably between the two periods, increasing its share from 7% to 13%.

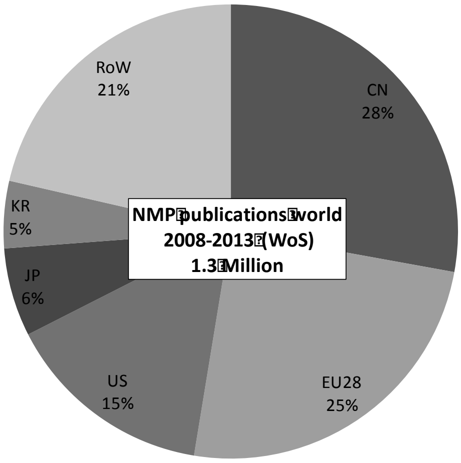
**Figure 21** Scientific publications over all scientific disciplines in different world regions

| | All WoS publications | | | |
|---|---|---|---|---|
| | 2002-2007 | | 2008-2013 | |
| | Number | Share (%) | Number | Share (%) |
| EU28 | 2.732.935 | 33 | 3.463.424 | 33 |
| US | 2.498.759 | 30 | 2.817.887 | 27 |
| CN | 571.719 | 7 | 1.347.953 | 13 |
| JP | 619.853 | 8 | 627.623 | 6 |
| KR | 197.210 | 2 | 321.012 | 3 |
| RoW | 1.621.934 | 20 | 2.035.284 | 19 |
| Total | 8.242.410 | 100 | 10.613.183 | 100 |

Source: Web of Science, calculations by Fraunhofer ISI

Focusing on NMP, China turns out to be the most important scientific region as measured by scientific publications during the period 2008-2013 (28% of all NMP publications), followed by EU28 (25%) and the US (15%) (Figure 22).

**Figure 22** Scientific publications in NMP in different world regions during the period 2008-2013

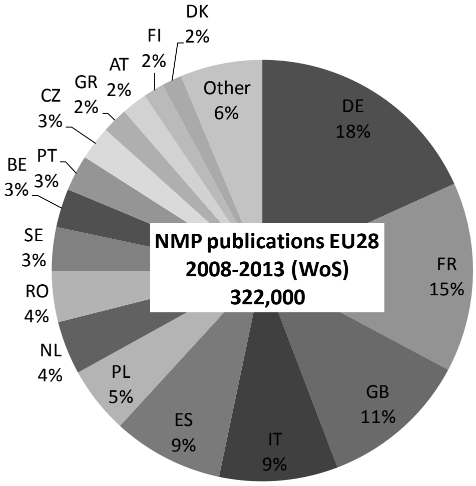



Source: Web of Science, calculations by Fraunhofer ISI

However, not only China but also South Korea is more active in producing scientific publications in NMP compared to its overall scientific activities. Comparing the publication activities of world regions in NMP between the two periods 2002-2007 and 2008-2013 clearly illustrates the changing role of China. While in the period 2002-2007 Europe (28% of all NMP publications) was producing most publications followed by the US (18%) and China (15%), in the more recent period 2008-2013 China almost doubled its publication share and developed to the most active world region in terms of producing scientific publications in NMP (source: Web of Science, calculations by Fraunhofer ISI). The leading role of China is most pronounced in the areas Materials (31% of all NMP publications) and New Production Technologies (28%). Nanotechnology is different from these two subfields; the US (24%) and EU28 (27%) are the world leading regions. The Chinese share drops to 21%.

In summary, the analysis of the worldwide NMP scientific landscape indicates that Asian countries have developed into important scientific actors in NMP during the last twelve years with China being by far most active and having a strong focus on Materials and New Production Technologies. At a European level (Figure 23) most publications in NMP are generated by German researchers (18%) followed by France (15%), the United Kingdom (11%), Italy (9%), Spain (9%), Poland (5%) and the Netherlands (4%). A similar ranking is observed for each of the NMP areas.

**Figure 23** Scientific publications in NMP in EU28 countries during the period 2008-2013




Source: Web of Science, calculations by Fraunhofer ISI

At the level of individual organisations within the EU28 the most active organisation is CSIC from Spain, followed by the Max Planck Society (Germany) and Delft University from the Netherlands (see Figure 24). Taking into account that CSIC and the Max Planck Society as well as CNRS from France are larger research organisations including a number of different individual research institutes, Delft University (the Netherlands), the University of Cambridge (United Kingdom), the Imperial College London (United Kingdom), the Karlsruhe Institute of Technology (Germany), the University of Lyon (France) and the University of Toulouse (France) are the most active individual organisations in terms of generating scientific publications.

**Figure 24** TOP 10 organisations based on NMP publication activities in the EU28 (2008-2013 normalised to strongest organisation by subfield (= 100) and summed up without weighting factor)

| TOP Organisations Publications (2008-2013) EU28 | N | M | P | NMP (max 300) | Rank |
|---|---|---|---|---|---|
| CSIC (ES) | 95 | 100 | 72 | 267 | 1 |
| MAX PLANCK SOCIETY (DE) | 100 | 100 | 36 | 236 | 2 |
| DELFT UNIVERSITY OF TECHNOLOGY (NL) | 43 | 39 | 100 | 182 | 3 |
| CNRS (FR) | 60 | 64 | 56 | 180 | 4 |
| UNIVERSITY OF CAMBRIDGE (UK) | 62 | 48 | 59 | 168 | 5 |
| CNR (IT) | 67 | 56 | 39 | 162 | 6 |
| IMPERIAL COLLEGE LONDON (UK) | 37 | 40 | 84 | 161 | 7 |
| KARLSRUHE INSTITUTE OF TECHNOLOGY (DE) | 38 | 37 | 55 | 130 | 8 |
| PRES UNIVERSITY OF LYON (FR) | 32 | 43 | 55 | 130 | 9 |
| PRES UNIVERSITE DE TOULOUSE (FR) | 25 | 30 | 71 | 126 | 10 |

Source: Web of Science, calculations by Fraunhofer ISI

The FP7 NMP projects community counts a total of 10,089 participating organisations. They correspond to 4,584 unique participant organisations. Based on an analysis of EC funded organisations within all publishing organisation in the NMP topic in the WoS (2008-2013) an estimated 4,584 unique participating organisations correspond to 1/6 to 1/10 of the total EU28 organisations publishing in NMP.

<u>Publication results of the FP7 NMP Theme</u>

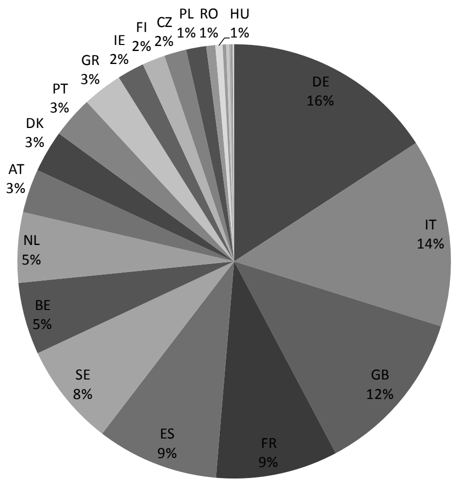
Results of the survey and the case studies reveal that scientific publications are the most numerous quantifyable outputs of FP7 NMP funded projects. About 75% of the participants in the finished projects wrote publications. Most of these were generated in a collaborative way (88% co-authored). Interestingly nearly half of these co-authored publications involve an industrial partner.

Also ongoing projects present high publication activities. Almost 50% of these projects have already achieved their publication goals and 70% of the participants expect that by the end of the project publications will be achieved. FP7 NMP consortia are using a broad range of publication types for generating output. These include conference papers, scientific articles, articles in business press, flyers, brochures and also videos. Moreover, most of the consortia have been able to generate the scientific output according to plan.

The bibliometric analysis of data in the SESAM database showed that 3,936 publications generated by the FP7 NMP funded projects until October 2014 could be identified also in the Web of Science (WoS). Most of these publications can be assigned to the Materials area (1,816), followed by Nanotechnology (1,211), Integration (455), and New Production (328). The three PPPs produced 126 publications until October 2014.

The national distribution of these publications indicates that about 90% of them were generated by EU28 countries and the other 10% by non-EU countries. This distribution is similar across the different NMP areas. In the case of the PPPs and also Nanotechnology the share of non-EU28 countries is slightly above 10% (source: SESAM database, calculations by Fraunhofer ISI). Within EU28 (Figure 25) most publications were contributed by organisations from Germany (16%) followed by Italy (14%), United Kingdom (12%), France (9%), Spain (9%), and Sweden (8%).

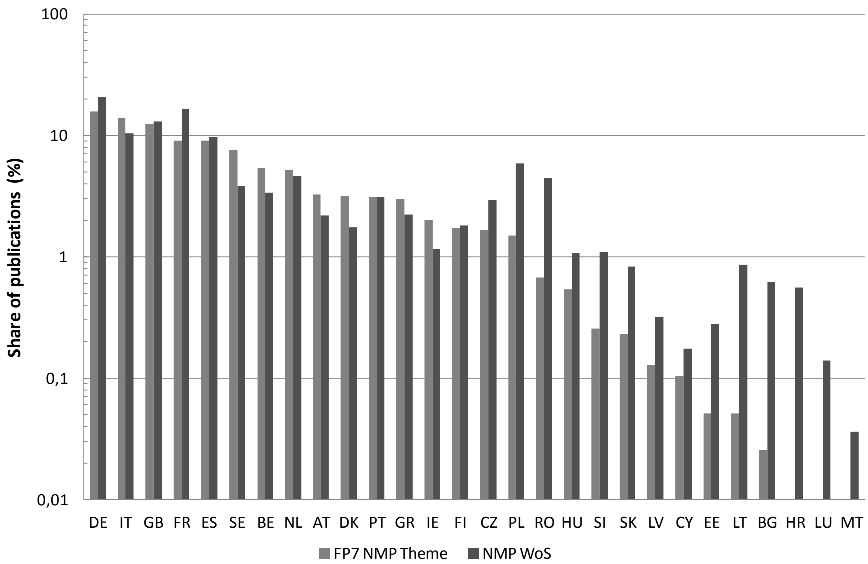
**Figure 25** National distribution of FP7 NMP publications based on a total of 3,936 publications




Source: SESAM database, calculations by Fraunhofer ISI

A comparative analysis of the country specific publication output from the FP7 NMP funded project with the general NMP landscape – as presented above – presents two types of countries (Figure 26).

**Figure 26** Comparison of publication activities of EU28 countries between FP7 NMP funded projects and the general NMP landscape

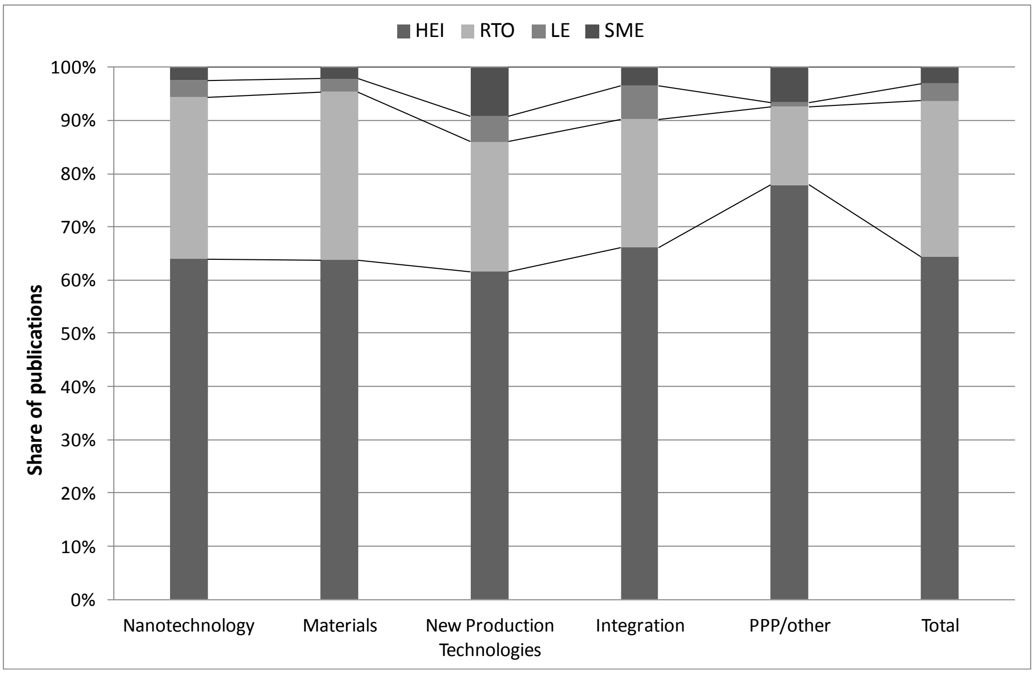



Source: Web of Science, SESAM database, calculations by Fraunhofer ISI

Firstly there are countries with stronger representation in FP7 NMP funded publication activities compared to their role in the general NMP landscape. This group includes three countries which recently faced economic problems – Italy, Greece, and Ireland – but also several countries without such difficulties during the last years (Sweden, Belgium, the Netherlands, Austria, and Denmark). Secondly, we observe countries which are less represented in FP7 NMP publications compared to the general NMP scientific landscape (WoS publications). Again two subgroups can be differentiated: larger established countries which are contributing most of the publications (Germany, United Kingdom, France, and Spain), and a number of smaller countries mainly from Eastern Europe which are only weakly represented (the Czech Republic, Poland, Hungary, Slovenia, Slovakia, Latvia, Cyprus, Estonia, Lithuania, Bulgaria, Croatia, Luxembourg, Malta). This general pattern is reflected also in the different NMP areas. The observed distribution seems to indicate that there is a group of countries (Sweden, Belgium, The Netherlands, Austria, Denmark, Greece and Ireland) which was quiet successful in generating scientific output from FP7 NMP funded projects compared to their role in the general NMP landscape. On the other hand it is not surprising – giving their low participation figures – that most of the Eastern European members states are largely underrepresented in terms of generating scientific publications from FP7 NMP funded projects.

The differentiation of scientific output by type of organisation (Figure 27) not surprisingly indicates that most publications stem from universities (64%) followed by research and technology organisations (29%). Large firms and SMEs contribute only about 3% each to the scientific output. Considering the different areas of NMP some interesting deviations from this distribution are detected. While Nanotechnology and Materials roughly present the same pattern, in the case of New Production Technologies SMEs are more active contributing almost 10% to all publications. Integration is the area where large enterprises are most active compared to other areas (7% of all publications). PPPs on the other hand are characterised by very strong contributions of universities and to a lesser extent SMEs, while large enterprises and research and technology organisations (source: SESAM database, calculations by Fraunhofer ISI) are underrepresented compared to their role in the total NMP scientific output.

**Figure 27** Scientific output of FP7 NMP funded projects by type of organisation




Source: SESAM database, calculations by Fraunhofer ISI

The size of the consortia has no clear relation with the level of publication output. The specific scientific output (publications per project) related to the number of project participants is rather robust at an average of 14 publications (source: SESAM database, calculations by Fraunhofer ISI).

Scientific output varies per project type. CSA projects produce fewer publications (1.8 per project) than CP projects (5.7 publications per project). Within CP, small or medium scale focused research projects present the highest publication output (7.4 publications per project) followed by large scale integrating projects (5.8). Targeted projects are far less active compared to the others (0.9), which might be explained by the SME focus of these projects (source: SESAM database, calculations by Fraunhofer ISI).

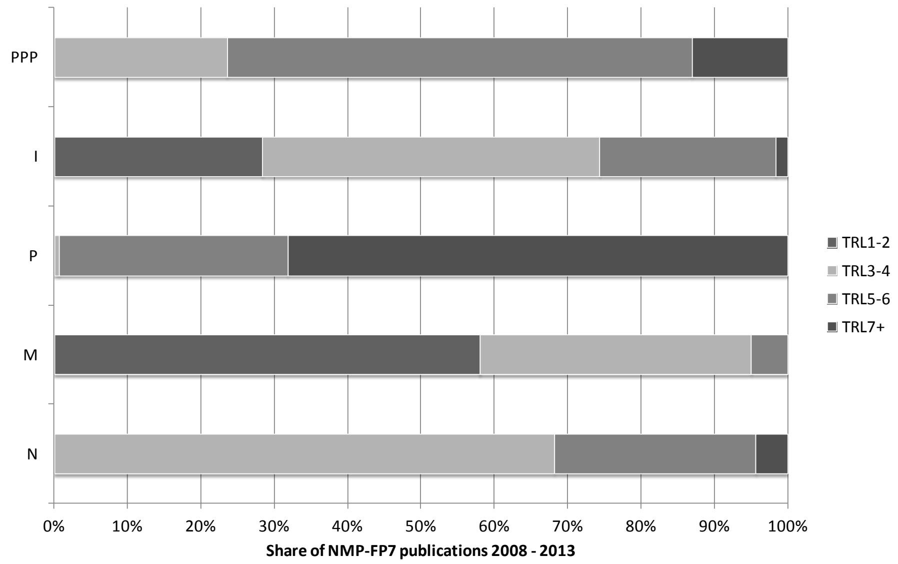
Scientific output by Technology Readiness Level

The analysis of scientific output by TRL indicates that most publications are assigned to TRL 1-2 (30%) and 3-4 (44%) (Source: SESAM database, calculations by Fraunhofer ISI). 18% of the publications are classified to TRL 5-6, 8% to 7+. This distribution basically reflects the nature of research activities at the different TRL. TRL 1-2 are characterised by exploring principles and concepts, while TRL 3-4 are concerned with lab validation and testing. Obviously these activities are most relevant to generating results for scientific publications.

The analysis of TRL by NMP areas reveals a number of remarkable differences between the different areas (Figure 28).

Publications in the Materials area decrease with growing TRL. They are most prominent at TRL 1-2. Publications in the Nanotechnology area are mainly on medium TRL. Scientific output in the New Production Technologies area is increasing with higher TRL being most important at TRL 7+. Publications in the Integration area are observed mainly from low to medium TRL (1-6). PPPs related publications are classified to higher TRL. This distribution reflects on the one hand the type of research activities within the different subfields: Materials research is mainly concerned with fundamental research questions (discovering principles and concepts); research activities in Nanotechnology can be considered as more advanced in terms of TRL. Not surprisingly New Production research activities are assigned to higher TRL. The Integration area could also be considered as a "precursor" of the multiKETs concept, where several key enabling technologies (KETs) are used in combination. Taking this perspective, the results presented in Figure 28 also indicate that multiKETs-related research activities are taking place mainly at low to medium TRL. Finally, this analysis also confirms that the TRL classification is a valuable approach towards characterising scientific output of FP7 NMP funded projects.

**Figure 28** Share of publications from FP7 NMP funded projects differentiated by TRL and NMP area




Source: SESAM database, calculations by Fraunhofer ISI

Impact of scientific activity

The level of excellence of the scientific output was measured using highly cited papers as an indicator for excellence (source: Web of Science, SESAM database, calculations by Fraunhofer ISI). In the Web of Science 0.36% of all NMP publications since 2008 obtained more than 100 citations and are considered as "highly cited". Within this group of in total about 4,758 publications, 22 publications emerged from FP7 NMP funded projects. These correspond to 0.56% of all FP7 NMP publications. It should be noted that the citation behaviour might be influenced by a number of different factors which are not directly related to scientific excellence. These include for example the size of partnerships and thus the trend towards self-citation, which might be higher in EC funded projects, or a higher visibility of publications stemming from EC funded research. More in depth-analyses would be required to explore the role of such factors in detail. Taking into account such limitations of citation data we consider the presented comparison as first hint for the notion that the level of excellence of FP7 NMP publications as measured by the share of highly cited publications is at least as high as the average level in the whole NMP landscape.

The analysis of scientific impact based on results of the survey and the case studies indicates that building up thematic research databases or research platforms for improved networking as well as developing new instrumentation and new research methods are main impact dimensions generated by FP7 NMP funded projects. For example, about one third of the participants in the FP7 NMP programme developed thematic research databases. About 46% of the participants and in particular CSA projects were involved in building up a research platform for improved networking of stakeholders. On the other hand, contributions to setting up large-scale infrastructures were rather low. Almost 50% of participants indicate that development or substantial improvement of facilities or infrastructures was not at all achieved. In summary, most of the impact achievements were in line with the objectives set by the different projects.

The FP7 NMP projects stimulate the mobility of project team members. 41% of survey respondents stated that the project has led to a temporal exchange of personnel with one or more project partners. While 53% of research organisations participants reported a temporal exchange of personnel, also 19% of SME participants indicated exchange. Projects also contributed to improving the career prospects for young researchers (e.g. PhD programmes in research or talents promotion in industry), as 66% of the survey participants stated. This mostly applies for research participants (77%) but also for SME participants (44%).

However, also a number of barriers to impact generation was identified in the case studies. These include insufficient budgets for research and innovation activities, too short time horizons, a lack of standardisation which adds to technological uncertainty, uncertainty about the application of existing regulation to new applications or about new regulations, which adds to technological and economic uncertainty and which may also influence funding of research and innovation activities. In some cases difficulties in collaboration between academia, business and potential user were identified, for example, due to using different terminologies, having available different incentives or setting different priorities. The willingness to share relevant data between consortium members in some cases also impeded impact generation. This is partly due to a lack of trust but also to delays or uncertainties in IPR agreements and the implementation of such agreements. Ineffective collaboration within consortia is also mentioned, partly due to a lack of alignment of the technological preferences and goals of consortium members, and differences in the level of priority that is given to the project. However, in more than half of the case studies achieving science and technology, impact was considered to be a central, normal and risky part of the research and innovation process.

Complementary to these barriers to impact generation, according to the case studies the three main enablers for achieving scientific and technological impacts are sufficient budget, continuity in funding by public and private organisations, and efficient and effective collaboration among experts and between experts and stakeholders.

### *4.3.2 Patent analyses*

Worldwide patenting activities

During the period 2008-2011 837,506 transnational patent applications at the EPO over all technological fields were identified in the PATSTAT database (Figure 29). Most of these patents were contributed by EU28 countries (37%), followed by the United States (28%) and Japan (20%). China (7%) and South Korea (6%) contributed considerable lower shares to the total patent landscape. However, if we compare patent applications during the most recent period with the period 2002-2007, it becomes obvious that China increased its share by a factor of more than 3.

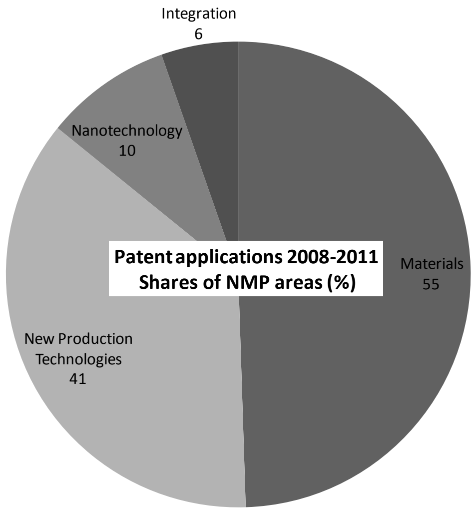
**Figure 29** Patent applications over all technological fields in different world regions

| | Patent applications in all fields | | | |
|---|---|---|---|---|
| | 2002-2007 | | 2008-2011 | |
| | Number | Share (%) | Number | Share (%) |
| EU28 | 437.028 | 39 | 312.151 | 37 |
| US | 373.970 | 33 | 232.205 | 28 |
| JP | 208.703 | 19 | 169.419 | 20 |
| CN | 24.792 | 2 | 55.632 | 7 |
| KR | 45.467 | 4 | 47.217 | 6 |
| RoW | 30.282 | 3 | 20.882 | 2 |
| Total | 1.120.242 | 100 | 837.506 | 100 |

Source: PATSTAT, calculations by Fraunhofer ISI

In the field of NMP a total of 76,603 patents were filed worldwide during the period 2008-2011, corresponding to 9% of the total number of patents over all technological fields. By far most of these patent applications have been filed in the Materials area (55%) followed by New Production Technologies (41%), Nanotechnology (10%), and Integration (6%) (Figure 30).

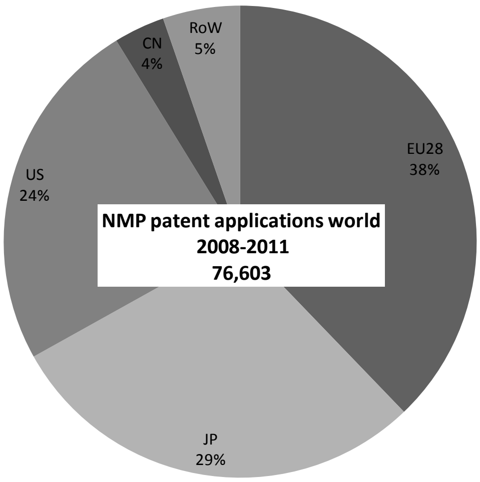
**Figure 30.** Patent applications in NMP subfields during the period 2008-2011. Percentage figures include double counts indicating overlap between the subfields.

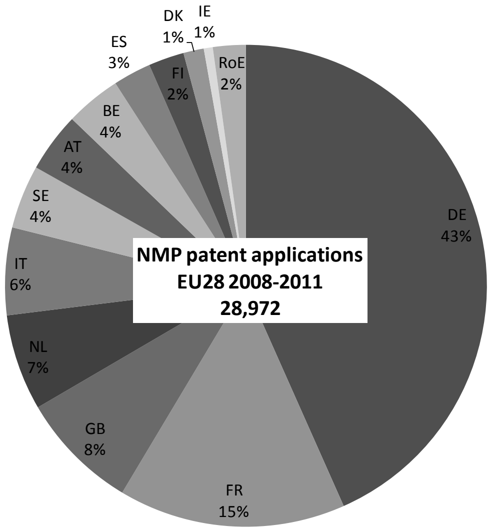



Source: PATSTAT, calculations by Fraunhofer ISI

Comparing the contributions of different world regions to the total patent landscape (Figure 31) reveals that the largest share of the NMP patents (38%) over the period 2008-2011 was contributed by EU28 countries. Japan is following on a second place with 29%, the United States contributed 24%. The share of China in the NMP field is 4%, which is considerably lower compared to the role of China in patent applications over all scientific fields (compare Figure 29).

**Figures 31 and 32** Contribution of different world regions and EU 28 countries to NMP patent applications in 2008-2011




Source: PATSTAT, calculations by Fraunhofer ISI

The main European countries contributing to the world NMP patent landscape over the period 2008-2011 have been Germany (share of 43%), France (15%), the United Kingdom (8%), the Netherlands (7%), and Italy (6%) (Figure 32). More than 50% of EU28 countries contributed less than 1% to all EU28 patent applications (total number: 28,972).

Patenting results of the FP7 NMP Theme

Patents are one type of intellectual property rights (IPR). In general, IPR are legal rights aimed at protecting the creations of the intellect, such as inventions, appearance of products, literary, artistic, and scientific works and signs among others. Types of IPR include the following: patents and utility models, which are referring to inventions; registered designs referring to product appearance; trademarks referring to signs words, phrases, symbols or designs of combinations of these which are used as brands of goods and services; copyright, referring to literary artistic and scientific works, and other related rights or neighbouring rights referring to performance of performing artists, phonogramme recordings by producers, and rights of broadcasters over radio and TV programmes.

An overview of IPR generated as result of projects funded under the FP7 NMP Theme is shown in Figure 33. Until October 2014, 321 projects have been finished with a final report. 41% of these projects generated at least one type of IPR. In total, 354 IPR were reported. Most of these (81%) are patent applications.

**Figure 33** IPR generated as result of FP7 NMP funded projects

| | Projects with final report | Projects with min. 1 IPR | | Projects without IPR | Reported total IPR | IPR reported as patent applications | |
|---|---|---|---|---|---|---|---|
| | Number | Number | % | % | Number | Number | % |
| Nanotechnology | 89 | 34 | 38 | 62 | 76 | 62 | 82% |
| Materials | 92 | 39 | 42 | 58 | 100 | 88 | 88% |
| New Production | 69 | 26 | 38 | 62 | 75 | 59 | 79% |
| Integration | 70 | 32 | 46 | 54 | 103 | 78 | 76% |
| NMP Total | 321 | 131 | 41 | 59 | 354 | 287 | 81% |

Source: SESAM database, calculations by Fraunhofer ISI

Comparing the different areas of the NMP Theme indicates that the highest IPR rates (IPR per project with final report) were generated in the Materials (42%) and the Integration area (46%), the share of patent applications within total IPR is highest within the Materials area (88%) and lowest in the Integration area (76%).

The different types of IPR generated out of FP7 NMP Theme funded projects are summarised in Figure 34. Accordingly, besides 287 patent applications trademarks (17) are the most important other type of IPR. In addition, registered designs and also utility models have been generated, as well as a larger number of other not specifically defined IPR. Trademarks were most important within the New Production Technologies area (8) and the Nanotechnology area (5). Other types of IPR, not specified in detail, have also been reported mainly by the New Production Technologies area.

**Figure 34** Different types of IPR generated as results of FP7 NMP funded projects

| | IPR | Patents | Trademarks | Registered Designs | Utility Models | Other IPR |
|---|---|---|---|---|---|---|
| Nanotechnology | 76 | 62 | 5 | 1 | 0 | 8 |
| Materials | 100 | 88 | 2 | 1 | 2 | 7 |
| New Production | 107 | 78 | 8 | 4 | 0 | 17 |
| Integration | 71 | 59 | 2 | 0 | 0 | 10 |
| NMP Total | 354 | 287 | 17 | 6 | 2 | 42 |

Source: SESAM database, calculations by Fraunhofer ISI

The analysis of FP7 NMP output in terms of patent applications reveals a total of 287 patents[70]. EU28 contributed for 90% and non-EU28 the other 10% of the total (source: SESAM database, calculations by Fraunhofer ISI). Confirming these results, survey respondents stated that most of the patent applications were filed at the European Patent Office or at a national patent office in EU member states. Patent applications in the United States or in Asian countries are not wide-spread. The largest share of the different areas of NMP to patent applications is contributed by Materials (31%), followed by New Production Technologies (27%), Nanotechnology (22%), and Integration (21%). Until October 2014 for PPPs only eight patent applications could be identified in the SESAM database. Accordingly, more detailed analyses of PPP patent output are not feasible.

Compared to the number of publications (3,936), the number of patent applications is rather low. One reason for this could be the difficult release of process patents, which in general would be important for the NMP Theme. However, companies tend to keep new processes secret, particularly

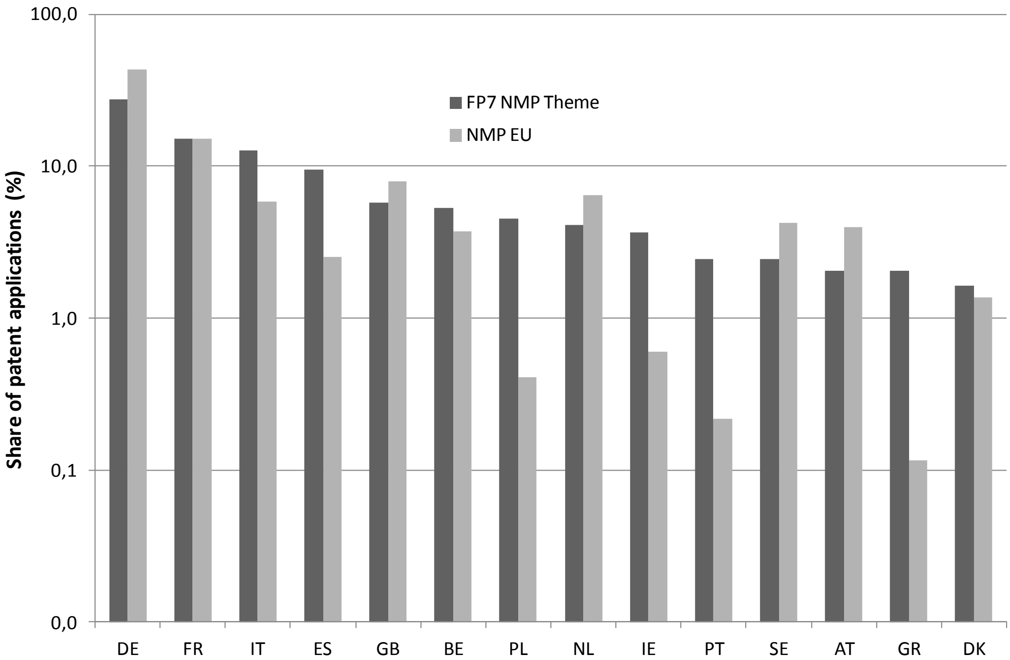
[70] For comparison, the recently finished NMP patent study (Tender RTD-NMP-2013-patents) identified 270 patents in the SESAM database. The difference to the present study could be explained by the lower number of projects already covered by the SESAM database in the case of the NMP study (290 compared to 321)

in the Nanotechnology and Materials fields (result of case study interviews). In addition to the secrecy issues the NMP patent study (footnote 70) identified lacking available resources and the ease to invent around the claim once a patent application has been published as other important obstacles to patenting.

However, according to the NMP patent study the SESAM database presents a non-trivial underestimate of the real patent output of projects which is estimated to range between 56% and 15% of all project patents. Therefore conclusions based on the total number of patents retrieved from the SESAM database should be taken with care. In the following we only analyse structural features of patenting activities which should be rather robust against a too low coverage of the SESAM database since a differentiation of coverage by the considered structural criteria seems unlikely.

In order to find out whether the role of individual countries in patenting activities based on FP7 NMP Theme funding is similar to the global NMP patent landscape (see above), a comparative analysis was made. Results indicate that there are three groups of countries (Figure 35).

**Figure 35** Comparison of patenting activities of EU28 countries between FP7 NMP funded projects and the general NMP landscape. The figure presents results for countries which contributed at least 1% to the total FP7 NMP Theme patent output.



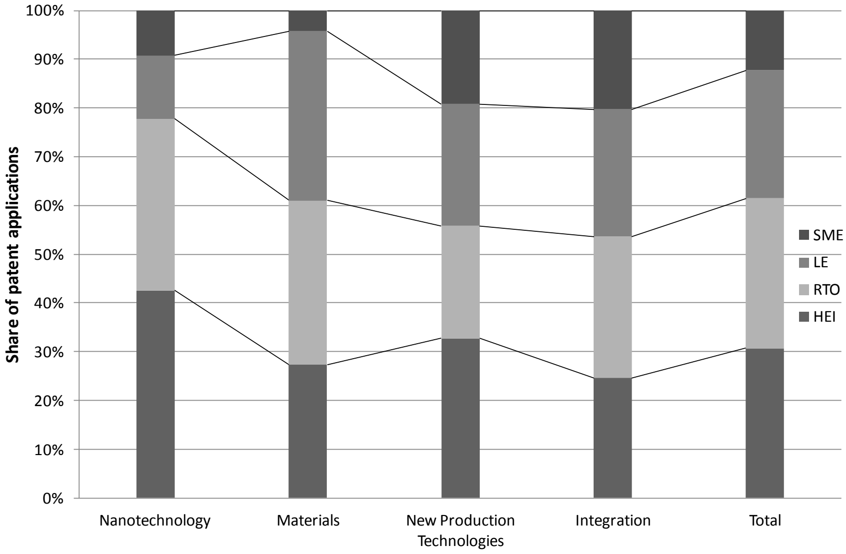

Source: PATSTAT, SESAM database, calculations by Fraunhofer ISI

A first group of countries is distinguished by far larger shares of patent applications in the NMP landscape compared to FP7 NMP funding. These include Germany, the United Kingdom, the Netherlands, Sweden, and Austria. A second group has roughly identical shares of patent applications, France represents this group. A third group of countries is characterised by higher shares of patenting activities within NMP funded projects compared to their role in the total NMP landscape. These countries comprise Italy, Spain, Belgium, Poland, Ireland, Portugal and Greece. A similar situation is observed at the NMP Theme areas level (source: PATSTAT, SESAM database, calculations by Fraunhofer ISI). This comparison indicates that the NMP funding was successful in motivating those countries to generate IPR in forms of patent applications which are less active in the total NMP landscape.

The different types of organisations involved in NMP funded projects present different patenting activities (Figure 36, next page). We roughly observe a one third distribution of patent applications between research and technology organisations, universities and industry (SMEs plus LEs). Differentiating industry by large firms and SMEs reveals that SMEs contribute roughly 10% to the total patent output, while large firms are responsible for roughly 25%. Within NMP areas SMEs are focussing in terms of patent applications on Integration and New Production Technologies. Large firms present a relatively high share of patent applications within the Materials area.

Patent applications may also relate to the TRL of the projects. As shown in Figure 37 (next page) most of the patent applications from FP7 NMP Theme funded projects can be classified to TRL 3-4 (41%). About 25% relate each to TRL 1-2 and 5-6, respectively and 11% relate to TRL 7+. This distribution of patent applications along the TRL scale is confirmed by results of the survey, which showed that patent applications are mainly filed by participants of projects that are at TRL 1-2 or 3-4.

**Figure 36** Patent applications of FP7 NMP funded projects by type of organisation



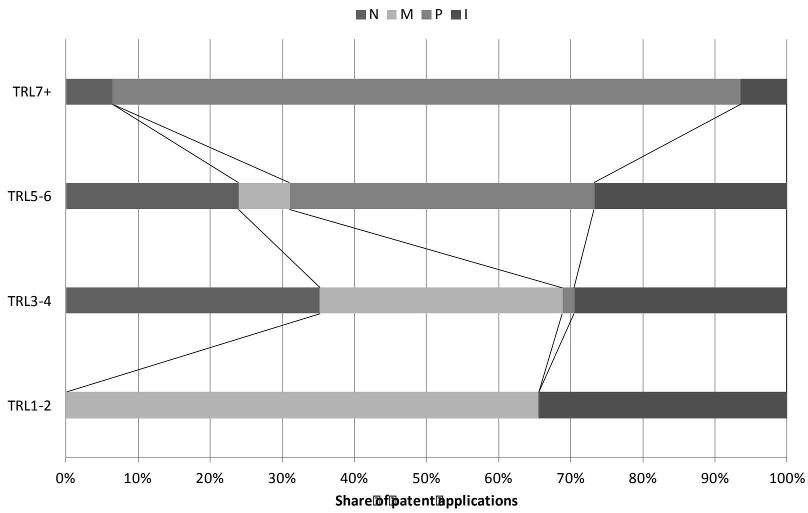

Source: SESAM database, calculations by Fraunhofer ISI

**Figure 37** Patent applications of FP7 NMP Theme funded projects differentiated by TRL

| | Patent applications | |
|---|---|---|
| TRL | Number | Share (%) |
| TRL 1-2 | 66 | 24 |
| TRL 3-4 | 110 | 41 |
| TRL 5-6 | 64 | 24 |
| TRL 7+ | 30 | 11 |
| Total | 270 | 100 |

Source: SESAM database, calculations by Fraunhofer ISI

**Figure 38** Patent applications of FP7 NMP funded projects by TRL and by NMP area

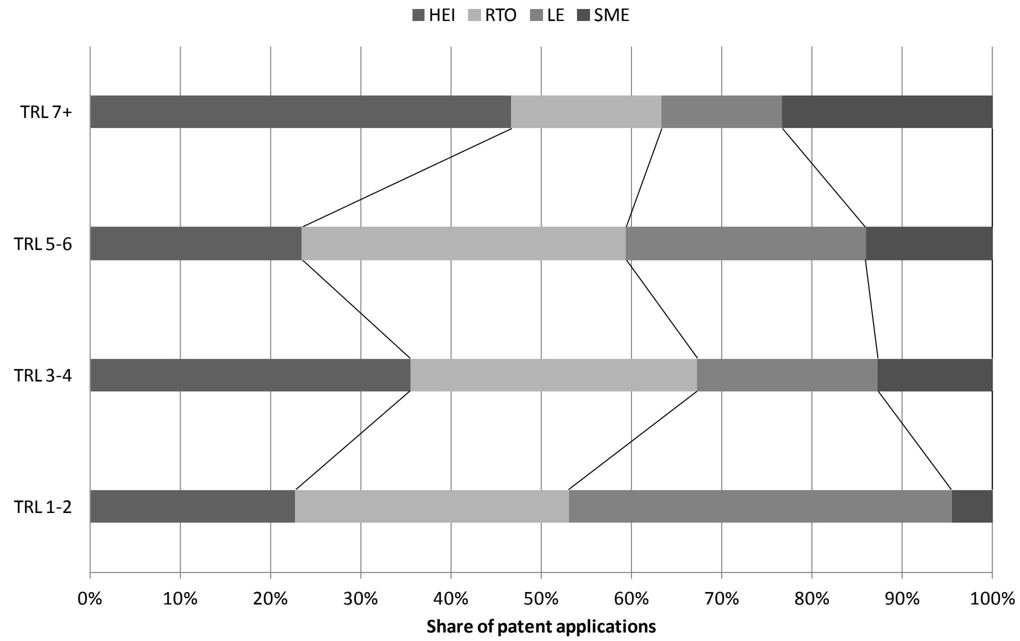



Source: SESAM database, calculations by Fraunhofer ISI

The results which we found for the TRL of the projects by NMP area, namely Nanotechnology and Materials being more research driven, Production being closer to market, are also reflected in the patenting activity. Patents on Materials are mainly at lower TRL. Patents on Nanotechnology are decreasing with higher TRL. Patents on New Production Technologies are increasing by TRL, and patents on Integration can be classified mainly to medium TRL (Figure 38 above).

A final analysis concerning the TRL classification of patent application considers the different types of organisations (Figure 39, next page). Accordingly, patent applications by SMEs are increasing with TRL. Large firms on the other hand are mainly active at lower TRL. Research and technology organisations and universities are active at all TRL, universities interestingly seem to have a stronger focus on high TRL (TRL 7+).

**Figure 39** Patent applications of FP7 NMP funded projects by TRL and by type of participant




Source: SESAM database, calculations by Fraunhofer ISI

## 4.4 Conclusions

As a system of reference for the analysis of scientific publications and patent applications out of the FP7 NMP Theme a worldwide mapping of the NMP related scientific and patenting landscape was carried out. Considering scientific activities, we observe remarkable shifts in the contributions of different world regions over the last 10 years. In particular, Asian countries have developed into important actors and China emerged as the most active region with a strong focus on publications about Materials and New Production technologies.

Focusing on the FP 7 NMP Theme, we can conclude that most projects have been very active in generating scientific publications and also achieved a remarkable level of scientific excellence. We observe interesting differences between countries, types of research organisations, NMP areas, and project types in terms of scientific output. Some of these differences - such as the focus of research activities by universities or the allocation of area relevant publications to TRL - confirm general understandings of the nature of NMP research activities. The interpretation of other observations such as the national distribution of scientific output raises questions. In particular the low representation of countries from Eastern Europe compared to their role in the worldwide NMP science landscape seems to indicate that the FP7 NMP programme was less successful in attracting research organisations from these countries. Applying the TRL scale to scientific output also allows a mapping of the different NMP areas to TRL. Accordingly Materials research is positioned mainly at TRL 1-2 indicating that fundamental research questions are prevalent. Nanotechnology is concerned with more advanced research issues at medium TRL, New Production related research is closest to the market mainly at TRL 7+.

Impact of scientific activities within the FP7 NMP Theme can be considered as relatively high and is achieved via different routes: scientific excellence, building up thematic research databases, setting up research platforms for improved networking, developing new research methods and instrumentation, stimulating mobility of team members, and improving career perspectives of young researchers. Main barriers to impact generation include insufficient budget for R&I activities, too short time horizon, lack of standardisation contributing to technological uncertainty, uncertainty about regulation, difficulties in collaboration between academia, business and potential users, lacking willingness to share data, ineffective collaboration within consortia. On the other hand sufficient budgets, continuity in funding, and good collaboration practices were identified as main enablers.

The worldwide patenting landscape in NMP indicates interesting differences to the scientific landscape with respect to regional contributions. Namely, currently the role of China is far less pronounced in NMP related patenting compared to all fields. However, taking into account China's very active role in the scientific landscape and assume that scientific activities are preceding patenting we would expect that China will increase its patenting shares considerably over the next few years. The analysis of patent applications generated out of FP7 NMP Theme funded projects indicates that the absolute number of patent applications is rather low compared to the absolute number of publications. One explanation for this difference is the incomplete coverage of project patents by the SESAM database. In addition, the nature of technology development activities within the NMP Theme could also contribute to low patenting activities. In particular process development is an important element. As results of the case studies showed, companies are hesitating to file patents for new processes. Rather they prefer to keep them secret in order to secure competitive advantages. The analysis of patenting activities of different types of organisations along the TRL scale indicates that SMEs are mainly involved in higher TRLs closer to the market. This makes sense from the value chain perspective; however it also raises the questions, whether there is a risk, that SMEs might get disconnected from earlier TRL stages and fundamental research knowledge, which in turn might impede their innovation activities in the long run.

# 5. LARGE SCALE SURVEY

*Authors: Matthias Gotsch, Oliver Som and Nadezda Weidner, Fraunhofer ISI.*

## 5.1 Methodology

### *5.1.1 Survey sample composition*

Primary data on the participant level of the FP7 NMP theme was collected by means of a large-scale online survey. The large-scale survey was held under all participants of the 508 projects that were finished or that had passed the mid-term assessment at January 1st, 2014.

In detail, the online survey addressed all projects funded in the NMP thematic area, which

- were finished at 01.01.2014 = 324 projects ;
- passed the mid-term assessment at 01.01.2014 = 184 projects;
- which is in total = 508 projects.

Although the provided database was composed of 508 projects with altogether 6375 participants, the sample was reduced to 5280 contact persons after filtering out 1095 duplicates, which are individuals who took part in several projects or represent two organisations in the same project.

After these contact persons were identified, the online survey was launched on the 2nd September 2014. In a first invitation round, emails with invitation to take part in the survey were sent to all 5280 participants representing the projects. A quite high number of emails could not be delivered since the email address provided in the SESAM database didn't exist. Even after contacting alternative contact persons from the database there remained a final number of 467 emails which could not be delivered. Finally an adjusted total sample of 4813 addresses remained, which could be contacted.

Before the first reminder was sent out, there were 1206 responses received, among them 1012 completed questionnaires. Then the first reminder was sent on the 16th September 2014 only to participants who have not started the survey or have not completed it to that point of time. Additionally, all participants, who explicitly refused to take part, were excluded.

A second reminder was sent on the 29th September 2014 to participants who have not started the survey or have not completed it to that point of time. Due to the end of the holiday season, this second reminder activated also participants, who just arrived after their holidays back in the office, to join the survey. Finally, the online survey was closed at 3rd October. To sum up, 2077 out of 5280 addressed participants have completed the survey. This made a return rate of almost 40%, which is a relatively high response rate.

The composition of the survey participants reflects the composition of the whole population, which will be shown more in detail in the Section 5.1.3.

**Figure 40** Sample description

| | **Count** |
|---|---|
| Original database (participants of 508 projects) | 6375 |
| Duplicates (persons in several projects or representatives of two organisations in the same project) | - 1095 |
| Addressed participants (whole population) | 5280 (100%) |
| E-mail could not be delivered | - 467 |
| Adjusted total sample | 4813 |
| Non-response or survey suspended | - 2736 |
| Survey completed | 2077 (39.3%) |

### *5.1.2 Survey content specifications*

In preparation of the large-scale survey, several restrictions were involved. For instance, it was the goal that the duration to fill-in the questionnaire should not exceed 20 minutes for the interviewee in order to achieve high response rates. As common language of the online survey English was chosen.

To encourage the willingness of participants to complete the questionnaire and minimise the drop-out rate, the wording of questions was adjusted to reflect the particularities of different stakeholders (e.g. business enterprises or research organisations). Additionally, a necessary distinction between finished projects and projects which passed the midterm was made, reflecting in four different survey versions with adjusted formulations:

- Finished projects: Research participant;
- Finished projects: Industry participant;
- Ongoing projects: Research participant;
- Ongoing projects: Industry participant.

For original questionnaire programming the online tool EFS Globalpark was used. A pretesting of the questionnaire was conducted to ensure a common understanding of the questions under different cultural constraints and to enable comparability of results across countries.

In the field time of the large-scale survey in September 2014 personalised links were sent to 5280 addressed participants, which were the responsible project managers of the funded projects. To ensure a high response rate, an accompanying letter from the European Commission was attached to especially motivate companies to participate in the survey.

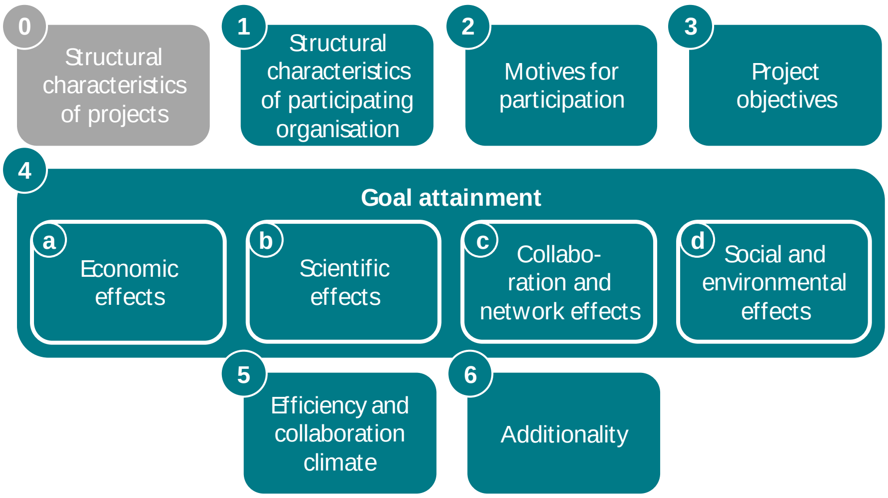
After collecting of the data, several data cleaning and harmonisation activities (missing values, outliers, etc.) were performed.

Based on the evaluation goals, the following topics were covered by the questionnaire:

- Effectiveness: participant-level analyses;
- Efficiency: programme-level analyses (administrative and financial level);
- Structural characteristics of funded entities and projects.

The complete content of the online survey consisted of 6 modules whose composition is illustrated in Figure 41. The figure shows an overview about the whole survey, the detailed content of the modules is presented in the following tables.

**Figure 41** Overview of large-scale online survey content




<u>Module 0: Structural characteristics of project</u>

Because the large-scale survey did not ask anything which could be made available through other means or databases, the structural characteristics of the project (Module 0) were extracted from the SESAM project database and matched with the survey results. In this way, it was managed to avoid asking the interviewees project characteristics.

The SESAM Database allowed access to detailed information on FP7 NMP projects, including statistics on participants, aggregated statistics on proposals by applicants ID, country and thematic and a number of other criteria.

The module addressed content concerning the structural characteristics of the project:

| | |
|---|---|
| • Number of partners<br>• Composition of partners | • Budget<br>• Status |

Module 1: Structural characteristics of organisation

The first module addressed the following content regarding the structural characteristics of the questioned organisation:

| | |
|---|---|
| • Size<br>• Industry affiliation (firms)<br>• Scientific discipline (research)<br>• Project role (firms)<br>• Type of R&D organisation<br>• Part of bigger company (firms) | • Firm age<br>• Previous participation in funding programmes at EU/national level<br>• Number of people involved<br>• ... from which departments/functions<br>• ... juniors/seniors |

Module 2: Motives for participation

The second module addressed the following content in respect to the different motives for participation:

| | |
|---|---|
| • Access to capital<br>• Networking<br>• Access to knowledge (technological, market, …)<br>• Development of new products, new processes, new services, ...<br>• Opening-up new markets | • Exploring new customers<br>• Development of completely new business area<br>• Scientific interest<br>• Solving scientific problem<br>• Contributing to scientific advancement |

Module 3: Project objectives

The third module addressed the following content in regard to the project objectives on project and organisational level:

| | |
|---|---|
| • R&D goals<br>• Type of development: product, process, service<br>• Innovation goals | • Degree of novelty of developed solution<br>• Commercialisation goals |

Module 4: Goal attainment

The fourth module addressed the following content concerning the degree of goal attainment, structured in economic, scientific, collaboration & network, and social & environmental effects:

| | |
|---|---|
| 4a) Economic effects<br>• Patent application (planned)<br>• Patents licensed (planned)<br>• Product market /service innovation (# and $)<br>• Process innovation<br>• Cost saving / productivity increase<br>• Standards/norms<br>• Market share<br>• Opening-up new markets<br>• Which economic effects are expected in the nearer future:<br>- for midterm projects - till the end of project | 4b) Scientific effects<br>• Creation or substantial improvement of research instrumentation / facilities /infrastructures<br>• Extra income from contract research contracts based on project results<br>• Number and character of technological and scientific breakthroughs with long-term impact<br>• Capacity effects: new competences<br>• TRL after project finished |

| | |
|---|---|
| - for finished projects - in the next 3 years<br>• Expected time to market/series implementation | |
| 4c) Collaboration & network effects<br>• New collaborations between SMEs / large enterprises and research organisations<br>• Increased intensity of knowledge transfer between SMEs / large enterprises and research organisations during the project<br>• Continuation of collaboration of SME / large enterprises and research organisation after the project<br>• Continuation of existing cooperation between actors from two or more academic disciplines<br>• New cooperation between actors from two or more academic disciplines<br>• Continuation of existing cooperation between actors from two or more industrial sectors<br>• New cooperation between actors from two or more industrial sectors | 4d) Social & environmental effects<br>• Development of new/improved product, service or process addressing social needs<br>• Improved environmental impact of new product, service or process<br>• Development of tools for supporting/monitoring sustainable developments (LCC)<br>• Improvements in energy efficiency, resource efficiency<br>• Dissemination activities, such as publications in newspapers, presentations to the public, organising/participating in (public) debates, involving social stakeholders etc.<br>• Number and character of project activities aimed at ensuring the safety of nanotechnology and new or advanced materials<br>• Personnel exchange / mobility of researches<br>• PhD / talent development<br>• Distribution of man vs. woman in the project team<br>• Gender issues addressed in the project |

Module 5: Efficiency & collaborative culture

The fifth module addressed the following content in respect to administration & communication efficiency and collaborative culture:

| **Efficiency** | **Collaborative culture** |
|---|---|
| Administrative efficiency:<br>• Overall performance of coordinator<br>• Necessary adjustments along the running project (time, work, goals, partners, …)<br>• Appropriateness of financial and temporal framework<br>Communication efficiency:<br>• Communication with EC<br>• EC information on NMP funding programme<br>• Adequacy of expectations and requirements | • Agreement procedure on joint project goals<br>• Collaboration climate in the consortium<br>• Conflict solving<br>• New collaboration with same partners |

Module 6: Additionality

The sixth module addressed the following content concerning additionalities:

| |
|---|
| • Strategic importance of project in overall R&D/innovation portfolio<br>• Volume of R&D budget in the organisation<br>• What would have happened without the granted funds<br>• Impulses for other R&D projects in the organisation<br>• Continuation of activities after official project end |

### *5.1.3 Analysis of response to survey*

Participants of the survey were compared with all potential respondents to ensure that there is not a non-response bias. To conduct a non-response analysis, following relevant structural characteristics were considered in the analysis:

- „Type of participant" (SME, LE, Research);
- „Project status" (ongoing, finished);
- „Region" (EU 15, EU 13, outside EU);
- „Funding scheme" (CP, CSA);
- „Thematic area" (N, M, P, I, PPP).

Figure 42 shows the analysis of responses by type of participant. While research participants have a share of 55% in the whole population, they are represented by 60% in the completed survey, which is slightly higher.

**Figure 42** Analysis of responses by type of participant

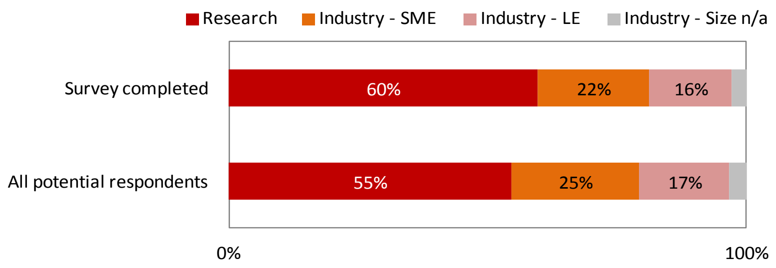



Figure 43 shows the analysis of responses by project status. While participants from ongoing projects have a share of 25% in the whole population, they are represented by 28% in the completed survey, which is slightly higher.

**Figure 43** Analysis of responses by project status

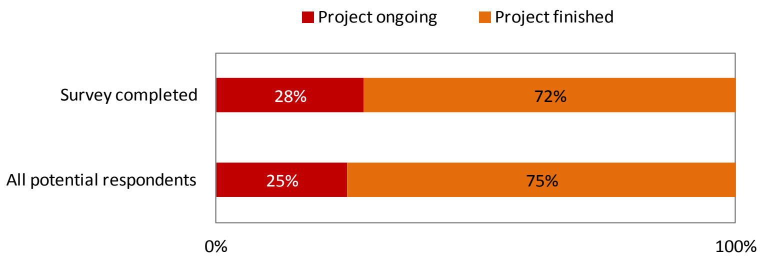



Figure 44 shows the analysis of responses by participants region. There are no differences between all potential respondents and survey participants visible. The apparently differences for participants outside of the EU is due to rounding differences.

**Figure 44** Analysis of responses by region

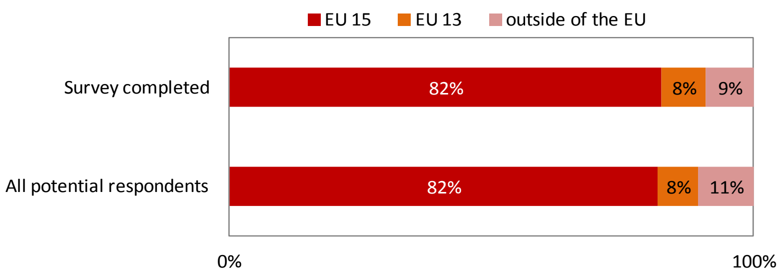



Figure 45 shows the analysis of responses by the funding scheme. Both, CP and CSA projects are represented in the survey identical to their representation in the whole population.

**Figure 45** Analysis of responses by funding scheme

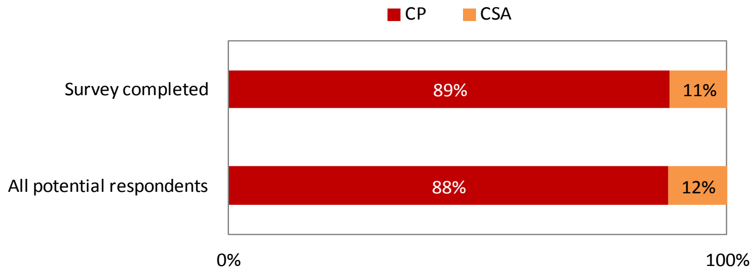
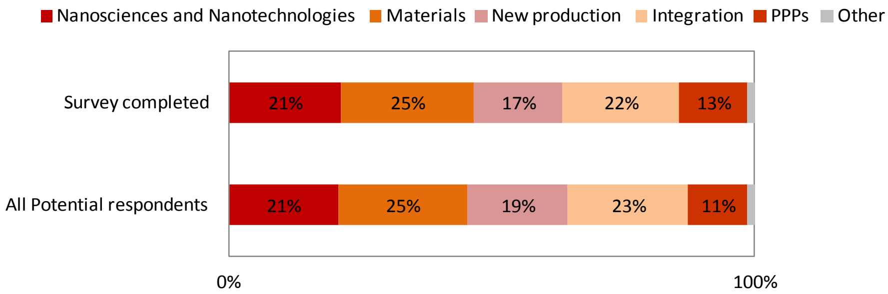



Figure 46 shows the analysis of responses by area (N, M, P, I, PPP). There are no visible differences between all potential respondents and survey participants regarding their area.

**Figure 46** Analysis of responses by area




All in all, the composition of survey participants reflects the composition of the whole population (all potential respondents). Only marginal differences could be found regarding the type of participant and project status:

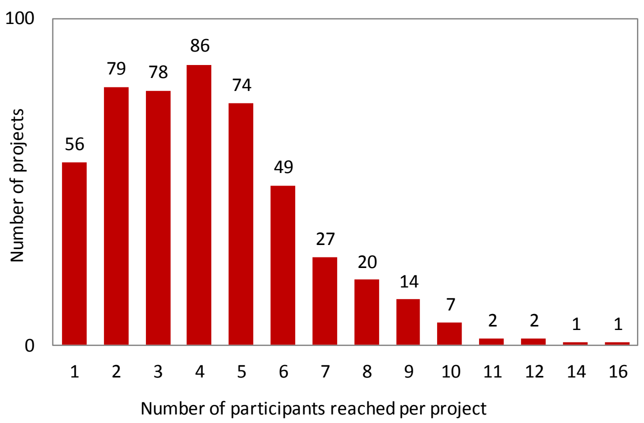
- The share of research partners is slightly higher among the respondents, than in the whole population;
- Participants in ongoing projects showed higher response rate than in already completed projects.

No structural differences regarding following characteristics can be stated:

- Region (EU-15, EU-13, outside EU);
- Funding scheme (CP, CSA);
- Thematic area (N, M, P, I, PPP).

Regarding the question if all projects are included, it can be stated that 496 out of 508 projects were reached by the survey. At least one participant per project was reached for these 496 projects. The exact number of participants reached per project can be found in Figure 47.

**Figure 47** Projects reached by survey



## 5.2 Large-scale survey results

Survey results are clustered to six thematically sections, which are presented in the following:

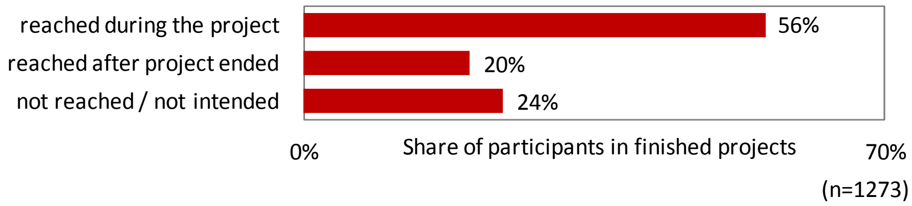
- Scientific output and impact;
- Economic output and impact;
- Networking and collaboration;
- European Added Value;
- Societal and environmental output and impact;
- Programme efficiency.

### *5.2.1 Scientific output and impact*

What is the range of the scientific publication activities?

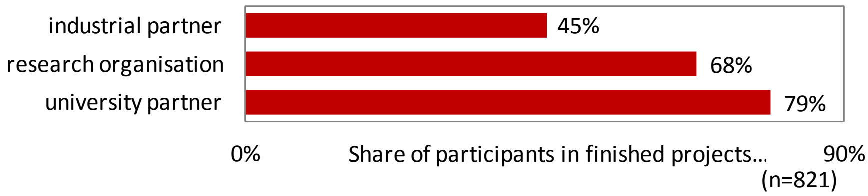
Survey results show that about 75% of participants in finished projects worked on publications during or after the project. Therefore, publications are undoubtedly an important exploitation and dissemination channel of NMP projects. In detail, 56% of participants published during project running time and another 20% published after the project officially has ended. Only 24% have not published at least one publication (see Figure 48).

**Figure 48** Publications of finished projects



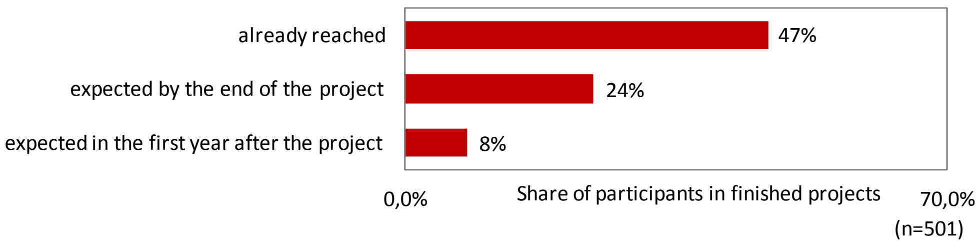

If we look on the publications of finished projects more in detail, we observe that 88% of the publications were co-authored. In 79% of the publications a university was involved, in 68% a research organisation. Both numbers are not surprising. Highly welcomed also in nearly half of the co-authored publications an industrial partner was involved, which is remarkably high (Figure 49).

**Figure 49** Co-authored publications of finished projects



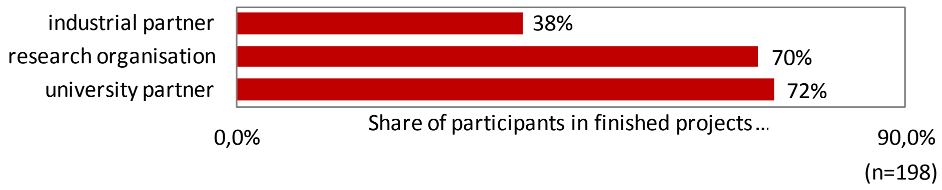

Survey results also show that about 70% of the participants in ongoing projects will have a publication by the end of the project. 47% have already published, while additional 24% expect to publish by the end of the project. Another 8% expect to publish in the first year after official project end (see Figure 50).

**Figure 50** Publications of ongoing projects



If we look at the publications of ongoing projects more in detail, we can observe that 87% of the publications are co-authored. In 72%, respectively 70%, a university partner or a research organisation is involved in the publication, which is comparable to finished projects. Additionally, in 38% of the co-authored publications an industrial partner is involved (see Figure 51).

**Figure 51** Co-authored publications of ongoing projects




What additional results were obtained?

Participants were asked if they were involved in building-up a thematic research database or a research platform for improved networking.

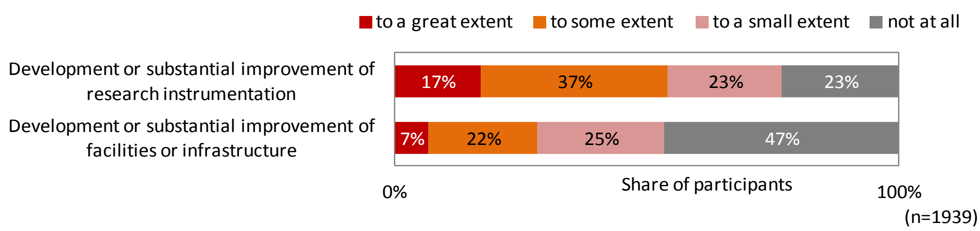
Overall, 32% of participants were involved in building-up a thematic research database. It seems that especially participants of CSA projects and of ongoing projects are active in this activity. About the half of the participants of CSA projects were involved in building-up a thematic research database, compared to only 30% among participants of CP projects. 39% of participants in ongoing projects are involved in building-up a thematic research database, compared to only 29% in finished projects.

Regarding the involvement in building-up a research platform for improved networking the numbers are similar. In general, 46% of participants were involved in building-up a research platform for improved networking of stakeholders. However, about two third of the participants of CSA projects were involved in building-up a research platform for improved networking, compared to only 43% among participants of CP projects. Additionally, 54% of participants in ongoing projects are involved in building-up a research platform, compared to only 43% in finished projects.

Therefore, the special tasks of CSA projects seem to be reflected by the involvement of CSA participants in building-up thematic research databases and platforms for improved networking.

Additionally, about a half of the participants could develop or substantially improve their research instrumentation. A significantly lower number of participants could develop or substantially improve their facilities or infrastructure in the project (see Figure 52).

**Figure 52** Creation or substantial improvements of research infrastructure



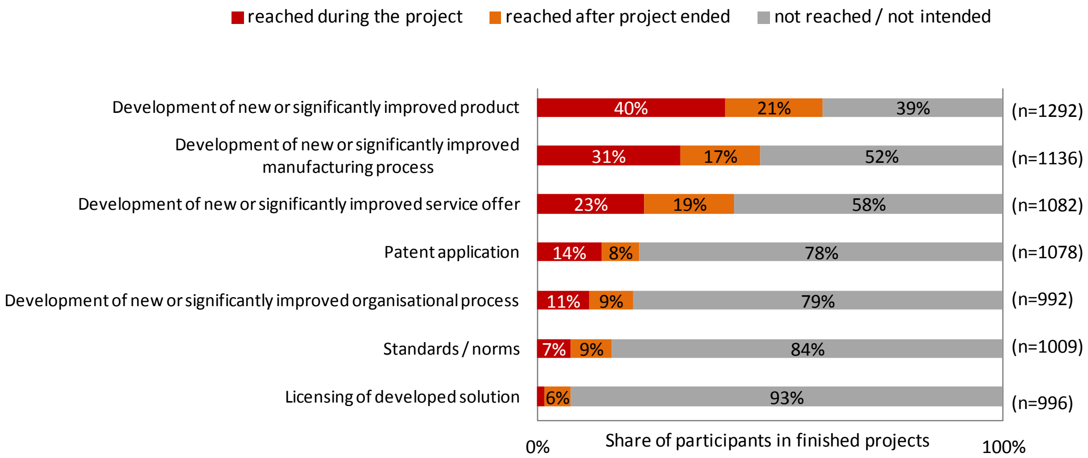

### *5.2.2 Economic output and impact*

Which results were realised in the funded projects?

The project participants of both finished and ongoing funded projects reported many different economic results, varying from new or significantly improved products and services, patents and spin-offs to higher flexibility and new competencies in specific fields.

Survey results show that about 60% of the participants of finished projects developed a new or significantly improved product (Figure 53). Examples of new or significantly improved products are: new materials and products such as nanomedicine, adaptive components for machine tools, ceramics for Swatch watches, bioceramics for implants, textile for clothing and industrial applications and coatings for high temperature energy systems.

**Figure 53** Results realised in finished projects



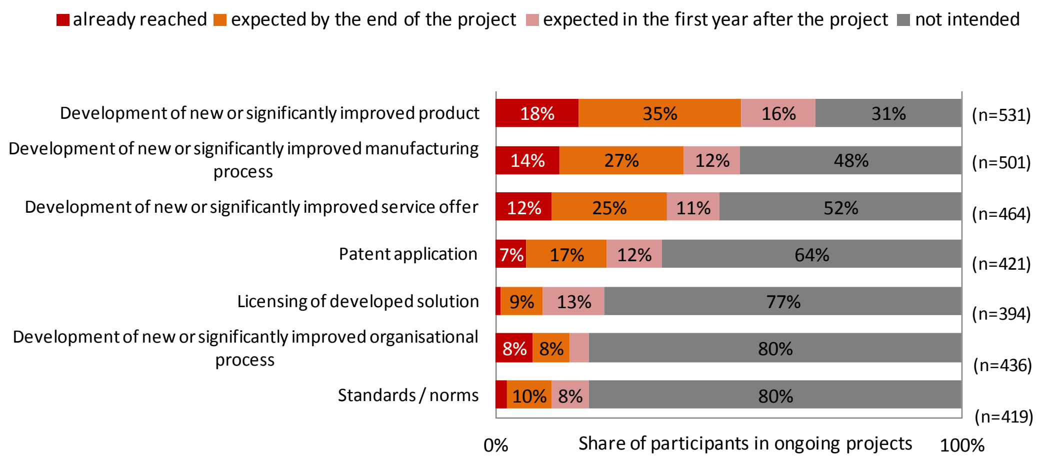

Simultaneously, the development of new or improved manufacturing processes, such as flexible production lines, additive manufacturing or high performance manufacturing, was reported by nearly the half of the participants from the finished projects. New services, such as Enterprise Resource Planning for high-tech manufacturing, demonstrated process guidelines or technological options for retrofitting of office buildings, were developed by about 40% of the participants. In general, many economics impact will be achieved only after the official project end, which could be a hint that the project duration is either too short or the expectation to reach a market-ready solution within 3 years is too optimistic. Economic effects by participants from P are relatively often reached after the official project end compared to participants from N, M or I.

SME participants reported on a larger scale - compared to large firm participants – the development of new or significantly improved products (44% vs. 27%) and services (22% vs. 9%) reached during the project. Hence the NMP Theme succeeded in compensating the structural disadvantages of many SMEs compared to LE when it comes to the development of innovative solutions.

If we differentiate between the different parts of the thematic areas it is striking that more than three quarters of the participants from PPP projects report that they already have reached the development of a new or significantly improved product. This could be related to the fact that PPP projects are focused on research and development subjects that are positioned later in the value chain and/or that the PPP participants are more efficient in their development processes.

Participants with a TRL between 3-4 or 5-6 at the beginning of the project are a bit more successful in developing a product or service during or after project than participants of other TRL stages. Surprisingly, they are even more successful than TRL 7+. A possible reason for this could be that earlier TRL stages leave more room for product and service development.

**Figure 54** Results realised in ongoing projects

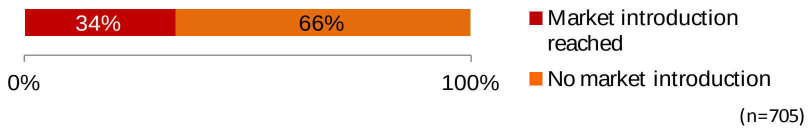



The above applied for finished projects. For the ongoing projects, it applies that, similar to the finished projects, many results will be reached after official project end. However, up to 70% of the participants already have or expect to develop a new or significantly improved product.The development of a new or improved manufacturing process is expected by nearly the half of the participants from ongoing projects. New services are already developed or are expected to be developed by about 48% of the participants (see Figure 54).

How is the market maturity of the developed products assessed?

If we examine the economic results of finished projects in more detail particularly with regard to the market introduction of the developed products and services, one third of the respondents from finished projects (34%) report that a new and improved product developed in the finished projects is already introduced at the market (see Figure 55).

**Figure 55** Product innovation - market introduction (Finished projects)



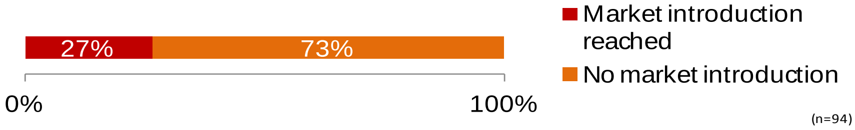

In the cases without a market introduction yet (n=380), participants say it will be at the market in within two years after project end (21%) or more than two years after the project end (43%). When interpreting the figures it must be remembered that the technologies developed in NMP projects are often integrated in larger systems (e.g. complex manufacturing systems) and in this case the whole system has to be ready for market introduction.

In those cases where market introduction has taken place, the median share of turnover reached with the new product innovation by the offering company is 5% (n=103 companies).

There are obviously differences between areas. The participants of Production projects are by far leaders in terms of market introduction (44% compared to only 23% in Materials projects and 26% in Nanotechnology projects). Concluding, the areas Materials and Nanotechnology seem to be more away from the market, while the area Production seems to be the most nearest to the market.

If we look on the ongoing projects, we see that one fourth of product developments in ongoing projects have already reached market introduction (see Figure 56).

**Figure 56** Product innovation - market introduction (Ongoing projects)

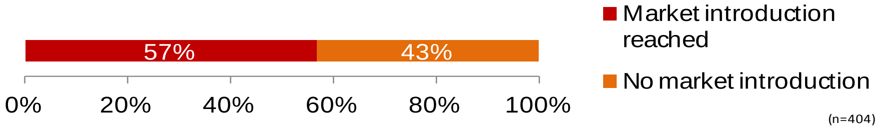



Participants of ongoing projects are quite optimistic. Half of participants with finished or planned product development (but without market introduction yet) think that the market introduction will be within two years after project end. Given the success rate of finished projects, this finding may indicate that the participants are far too optimistic at this point of time or are not able to reasonably anticipate upcoming difficulties and barriers.

How is the market maturity of the developed services assessed?

On average more than half of the developed services in finished projects already reached market introduction. As R&D services get much quicker into the market, the output for services is higher than for developed products (see Figure 57).

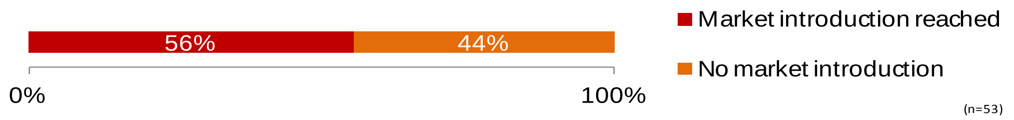
**Figure 57** Service innovation - market introduction (Finished projects)




In the cases without a market introduction yet (n=145), participants say the market introduction will be up to two years after the project has ended (31%) or more than two years after the project has ended (34%). Simultaneously 35% state that a market introduction is not planned at the moment. For those cases where market introduction of the new service has taken place, the median share of turnover reached with the new service is 3% (n=58 companies). Again, there are huge differences between the areas: services developed in projects in the Production area (66%), are more marketed than for other area, with the PPP projects (27%) as the least performing. This might be not surprising as these are mostly led by manufacturing companies.

If we look on the ongoing projects, one can state that more than half of service innovations of ongoing projects already reached market introduction (see Figure 58). In two-third of the cases without a market introduction yet, a market introduction is planned within two years after project end.

**Figure 58** Service innovation - market introduction (Ongoing projects)




What is the range of the patent activities?

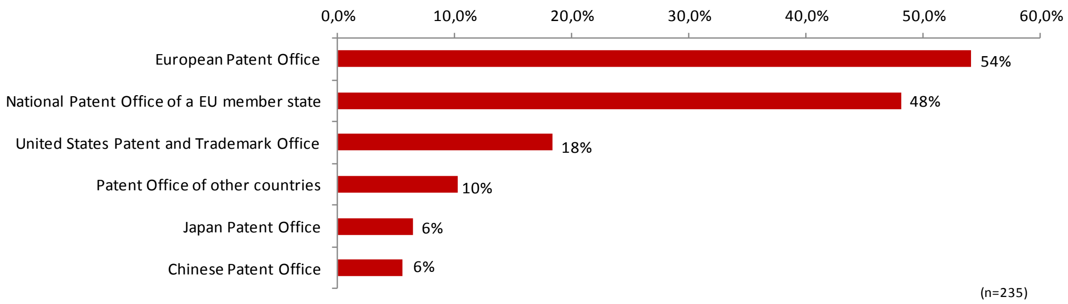
Most of the patent applications were filed at the European Patent Office or at national patent offices in EU member states. Nearly one fifth of the participants stated that they filled in a patent application in the United States Patent and Trademark Office. Patent applications in Asian countries are not widespread. Therefore, the EU single market seems to be the most important target market of NMP developments (see Figure 59).

A half of participants stated that in a patent application at least one project partner was involved. In the cases in which a project partner was involved in the patent application, it was a

- University or higher education institution (HEI) (involved in 64% of the cases);
- Industrial partner (involved in 50% of the cases);
- Research and technology organisation (RTO) (involved in 45% of the cases).

Surprisingly equal shares of different co-patenting partners might be an indicator of well-functioning collaboration and knowledge transfer between the R&D and industry partners.

**Figure 59** Patent application - location




Did the project lead to a spin-off?

6% of the participants of finished projects state that the project led to the creation of a spin-off. Simultaneously, 2% of the participants of ongoing projects state that the project led to the creation of a spin-off so far.

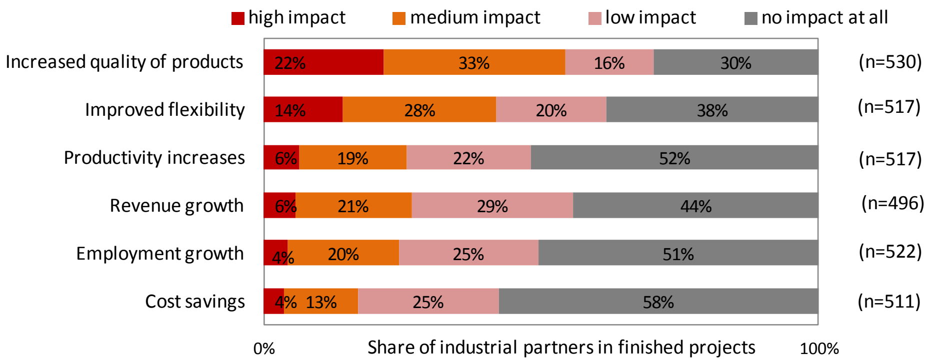
Another 10% of the participants of ongoing projects state that they expect that the project will lead to the creation of a spin-off by the end of the project. Summarising, the creation of spin-offs seems to be relevant only for a very small part of the participants.

To what extent did the projects' activities affect the overall competitiveness of the participating organisations?

More than half of participants of finished projects report in the survey a high or medium increase in the quality of their products. For European companies which are more in quality as in price competition, this makes sense.

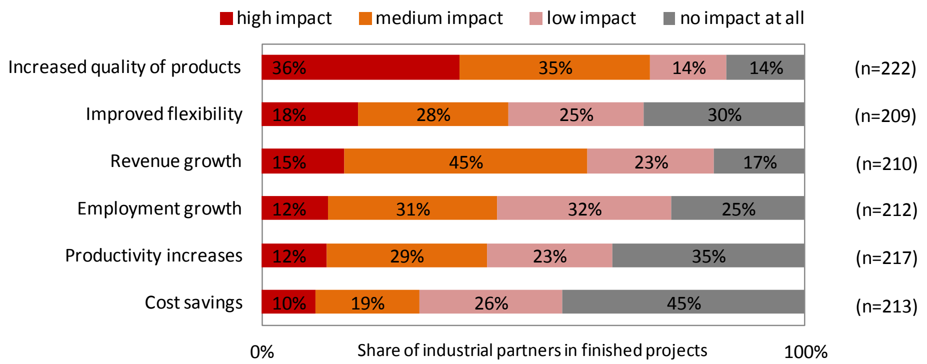
42% report a high or medium increase in flexibility within their organisation. But relatively few improvements in productivity increases or cost savings could be realised, which is rather typical for early development stages of technology (see Figure 60).

**Figure 60** Improvements within the organisation (finished)




Participants of ongoing projects report consistently higher numbers for high and medium impact as compared to the participants of finished projects. For instance, more than 70% report a high or medium increase in the quality of their products (see Figure 61).

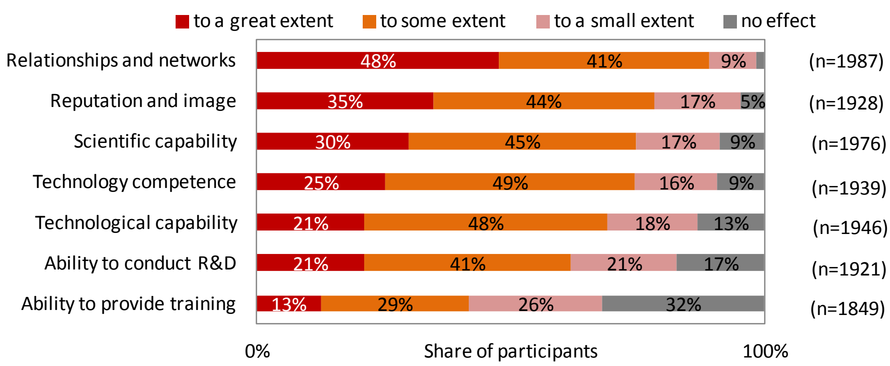
**Figure 61** Improvements within the organisation (ongoing)




The differences between the two groups probably result from the fact that the participants of ongoing projects also considered their (perhaps a bit too optimistic) expectations until the project end. However, increase of flexibility and productivity are important parts of the PPP FoF. Therefore, the overall more positive effects for on-going projects could also reflect the newly introduced PPP content of the programme. The SME participants (both for finished and ongoing projects) report higher improvements for improved flexibility, revenue growth and employment growth, than the large enterprises.

The projects also contributed to the improvements of several competences of the participants: most to "relationships and networks". This high score on relationships and networks confirm that a more innovative ecosystem makes R&D more efficient. Also it reflects the importance of open innovation and value chain in project consortia. Besides "relationships and networks" (48%) also "reputation and image" (35%) and "scientific capability" (30%) was named often by the participants as effect which benefited by a great extent (see Figure 62).

**Figure 62** Effects on competences in the organisation



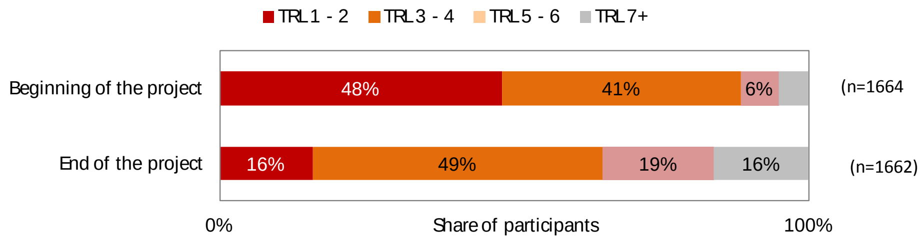

For the three most affected competences (relationship and networks; reputation and image; scientific capability) the effects for participants of research organisations are consistently higher as for industry participants. This means that especially research participants could improve their internal competences through the projects, while the effect for competence building in industry firms is weaker.

SME participants of the large-scale survey report higher effects for "reputation and image" compared to participants from LE.

<u>To what degree did the project activities contribute to an increase of the participant's TRL?</u>

Survey results reveal that participant's self-estimated TRL at the beginning of their project was between 1-2 or 3-4 for over 88% of participants. Participant's TRL at the end of project was between 5-6 or 7+ for 35% of participants. This means that overall the participant's self-estimated TRL clearly increased during the project (see Figure 63).

**Figure 63** TRL over time




Maybe, TRL increases mainly because of learning effects stimulated by cooperation with external partners and rather not due to firm-internal competence building. The improvement in „relationships and networks"(compare Figure 62) was rated as important effect, while the importance of „technology competence" was not outstanding. If we look in detail on the areas we see that participants from the Materials area are relatively often found at TRL 1-2. In Materials basic research seems more widespread as in the other areas.

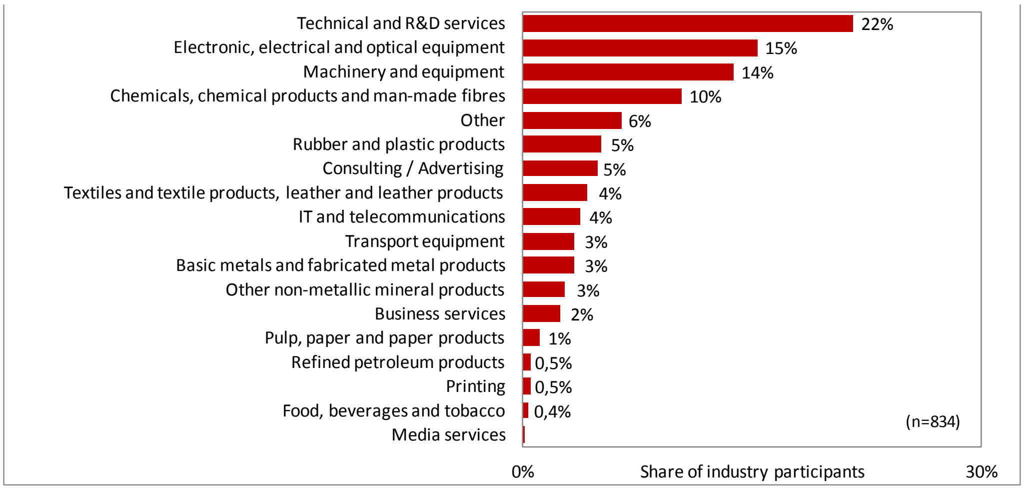
SME participants are comparably more often active at TRL 5-6 or 7+, indicating that they are stronger involved in the later stages of the R&D process, and less in basic research activities as compared to large firms. Generally, SMEs are often technical process specialists when it comes to the engineering solutions of new technological solutions.

### *5.2.3 Networking and collaboration*

<u>What are the (typical) structural characteristics of the participants?</u>

If we look at the different backgrounds of participants, it can be stated that most of industry participants are from rather R&D-intensive sectors. The four most represented sectors stand for more than 50% of all industry participants (see Figure 64).

**Figure 64** Industry affiliation of industry participants




22% of industry participants are from technical and R&D services, 15% are producers of electronic, electrical and optical equipment, another 14% belong to machinery and equipment and finally 10% to Chemicals, chemical products and man-made fibres. But maybe, potentials of the connection of whole supply chains are given away in this way. Additional, more process-specialised sectors should be involved as users of the developed solutions.

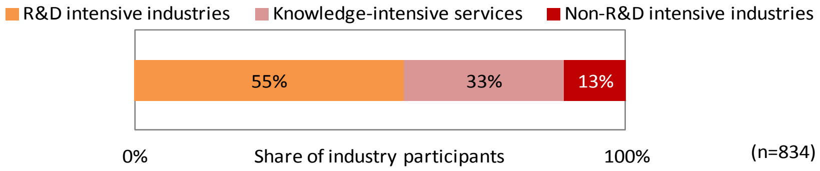
The picture gets even clearer if we use a categorisation of the industry affiliations in the following 3 categories:

- Non R&D intensive industry
  - Food, beverages and tobacco
  - Printing
  - Pulp, paper and paper products
  - Textiles and textile products, leather and leather products
- R&D intensive industry
  - Basic metals and fabricated metal products
  - Other non-metallic mineral products
  - Refined petroleum products
  - Rubber and plastic products
  - Chemicals, chemical products and man-made fibres
  - Electronic, electrical and optical equipment
  - Machinery and equipment
  - Transport equipment

- Knowledge intensive services
  - Business services
  - Consulting / Advertising
  - IT and telecommunications
  - Media services
  - Technical and R&D services

Analyses show that 55% of industry participants are from R&D intensive industries, in the same time 33% are knowledge-intensive services and only 13% belong to non-R&D intensive industries. In sum, nearly 90% of industry participants are from R&D intensive industries and from knowledge intensive service (see Figure 65).

**Figure 65** Industry affiliation (categorised)




If we consider especially the most named industry affiliations of SME participants, the picture changes only a little. 23% of SME belong to technical and R&D services, 16% to electronic, electrical and optical equipment and 15% are from machinery and equipment sector. All other sectors are represented by one-digit percentages (see Figure 66, next page). Besides industry participants' affiliation, also the research participants were asked what their main area of application was. Results show that almost one half of the research participants (44%) are active in the application area "Materials, chemistry, chemical processes". At a distance follow "Healthcare" (11%), "Machinery and manufacturing equipment" (9%), "Energy generation, conversion, storage and distribution" (7%) and "Electronics and telecommunication" (7%).

In the same time, management and business administration services (non-technical innovations, e.g. business models) or other social sciences (acceptance of new solutions) are not well represented in the researcher's application areas (see Figure 67, next page).

**Figure 66** Industry affiliation of SME participants

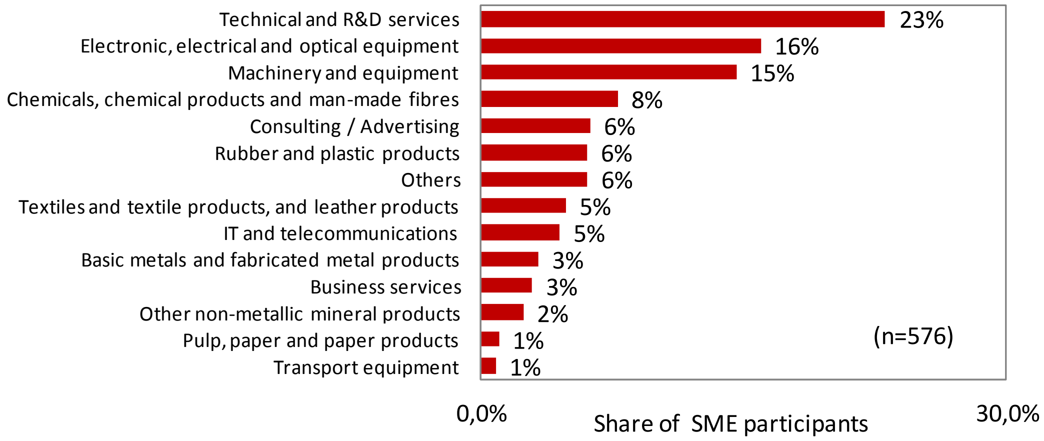
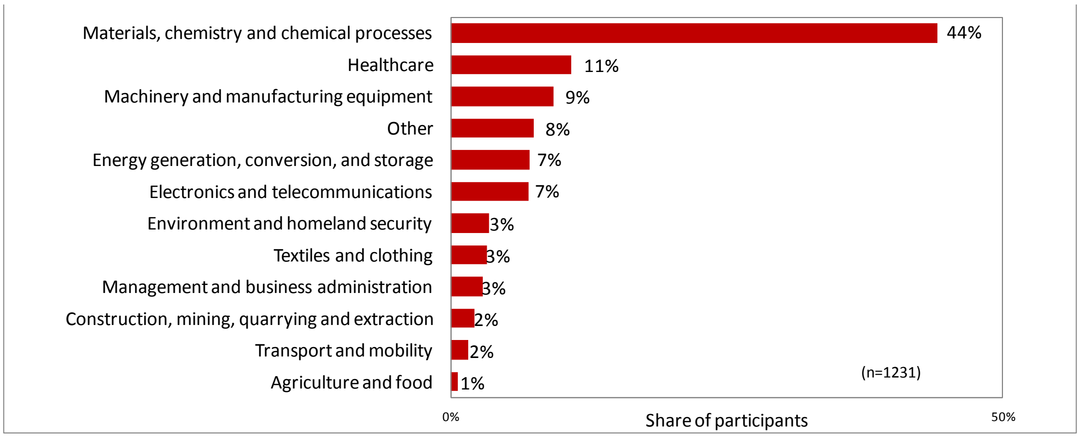
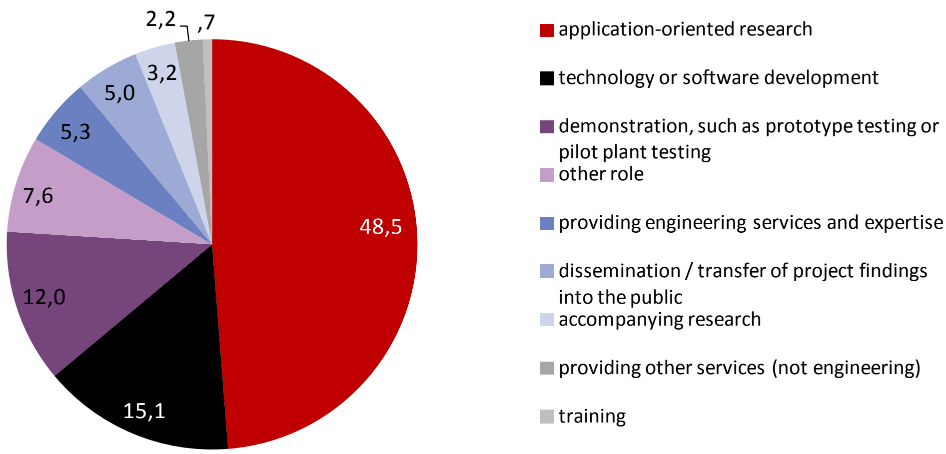



**Figure 67** Area of application for research participants




When looking at the specific role of the participants in their project, we see that nearly half of participants are doing application-oriented research in the project. Another 15% state, that their main role in the project is technology or software development. In sum, two third of participants are active in R&D activities during the project (see Figure 68).

**Figure 68** Project role

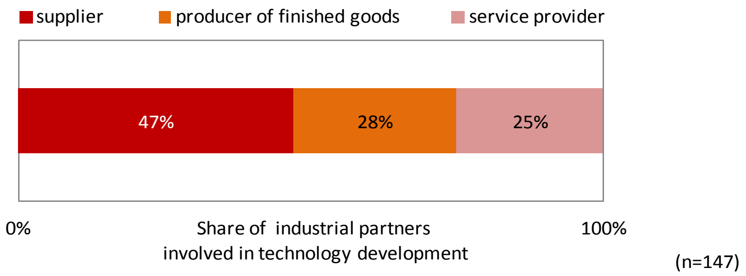



(n=2064)

Demonstration and dissemination activities seem to be underrepresented. Maybe, a more challenge driven approach with more potential user and customer involvement could be better.

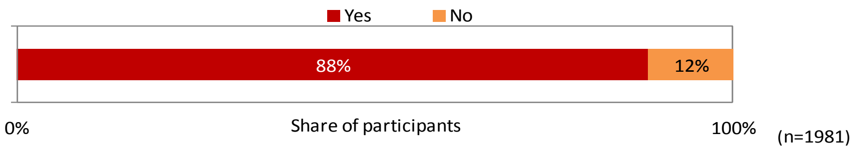
Another important aspect of the FP7 NMP Theme is that it brings together companies from different parts in the value chain. From the survey results we learn that from the 147 industry participants (from the 313 that identified themselves as technology developers) 47% are suppliers (material, parts, components, systems), 28% are producers of finished goods and 25% are service providers (see Figure 69). If we look on SME participants in detail, we can see that their value chain position is quite similar. 44% of participating SMEs are suppliers, 27% are producers of finished goods and 29% are service providers.

**Figure 69** Position in the value chain of participants




Regarding earlier participation in funding programmes, 88% of participants state that they already participated in another funding programme before. For only 12% of the survey respondents it was the first time to participate in a funding research project (see Figure 70).

**Figure 70** Participation in funding programme before

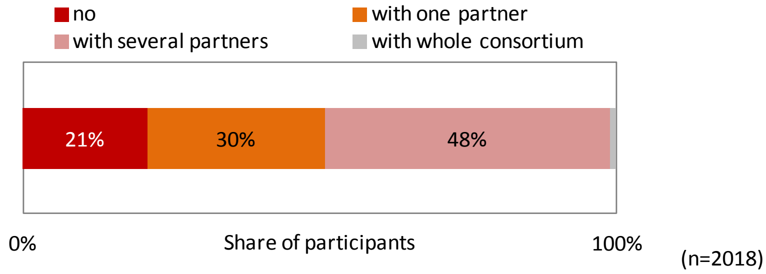



When considering geographic location of the participants it appears that 90% of participants from «old » EU countries (EU 15) have already participated in another funding programme. But in the same time, also 83% of participants of «new » EU countries (EU 13) have already participated in another funding programme before.

Could new collaborations be established between the participants?

Survey results show that only one fifth (21%) of participants did not have any cooperation with their consortium partners before the project. Most of participants already had existing cooperation with their consortium partners (see Figure 71).

**Figure 71** Existing cooperation partners

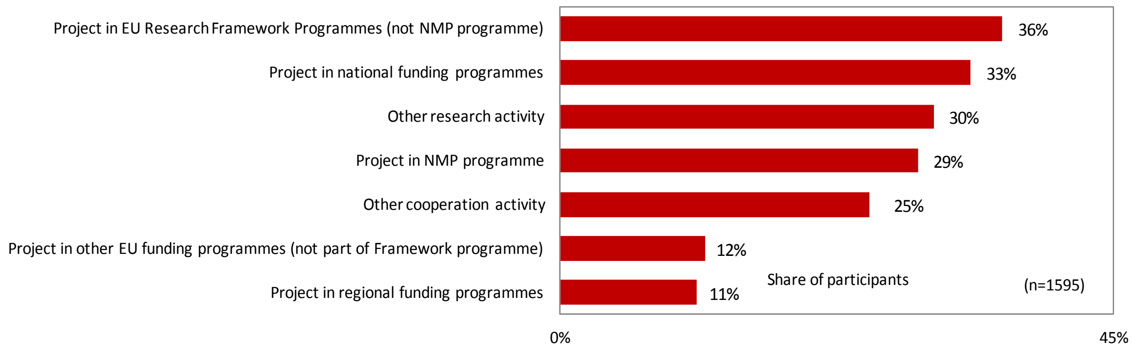



It seems there are always the same who get funded and also in similar consortiums. With only a few new participants, thereby only little new impulses in the consortiums can take place. Better inclusion of new EU member countries could improve building up new networks. A lot of participants already had existing cooperation with their consortium partners within other EU or national funded programmes. More than one third of participants has worked together with their current project partner in another EU FP project, one third in a national project and 29% of participants stated that they even have worked together in a finished FP NMP project (see Figure 72).

Therefore, on can conclude that cooperation and resulting networks seem to be:

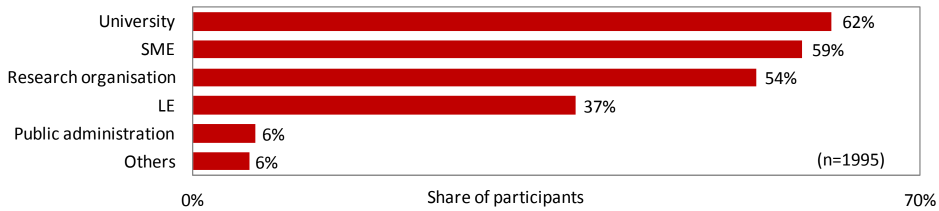
- sustainable (positive aspect), but simultaneously
- impermeable for new partners (negative aspect).

**Figure 72** Existing cooperation – type of projects




However, also important is the question if the participants also could establish new cooperation during their participation in FP7 NMP funding and with whom. Most of the participants, which could establish new cooperation in the project, cooperated with a new university partner. Also, high number of new cooperation with SME, which means that SME get included in networks, could be established (see Figure 73).

**Figure 73** New cooperation - type of partner




Controlled by type of participant (SME, LE, research) no reportable differences were found, except for the fact that SMEs (compared to LE and research) are a little bit below average for new cooperation with universities.If a research participant declared to have established cooperation with a new research partner, we additionally asked for the academic discipline in order to check for interdisciplinary:

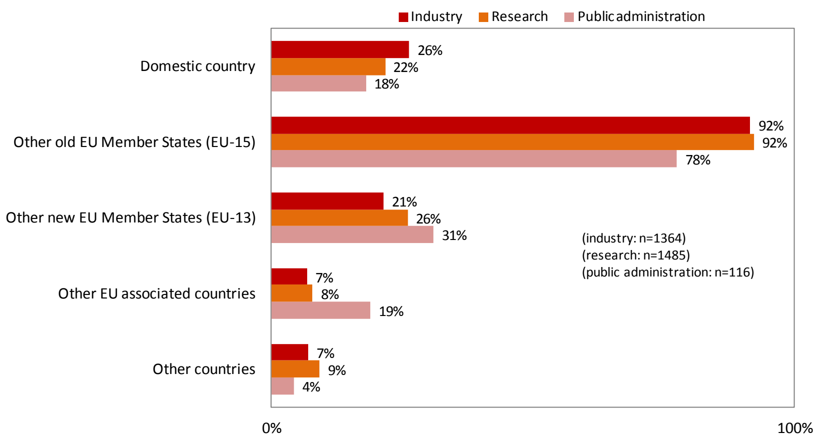
- 75% of new research partners are working in another academic discipline.

If an industry participant declared to have established cooperation with a new industry partner, we additionally asked for the industrial sector:

- 84% of new industry partners operate in another industrial sector.

Therefore, FP7 NMP programme build a good fundament for interdisciplinary cooperation across all disciplines and industries. Innovative solutions often are developed at interdisciplinary interfaces. An important fundament for future challenges, e.g. key enabling technologies, maybe can be established in this way. Most of new cooperation partners (independent if public administration, research or industry partner) are from EU-15. Only in a fourth of the cases the new cooperation partner is in the domestic country, which shows that cross-border cooperation are supported, but mainly inside the EU-15 (see Figure 74). Cooperation's and resulting networks again seem to be sustainable, but simultaneously impermeable for new partners from outside.

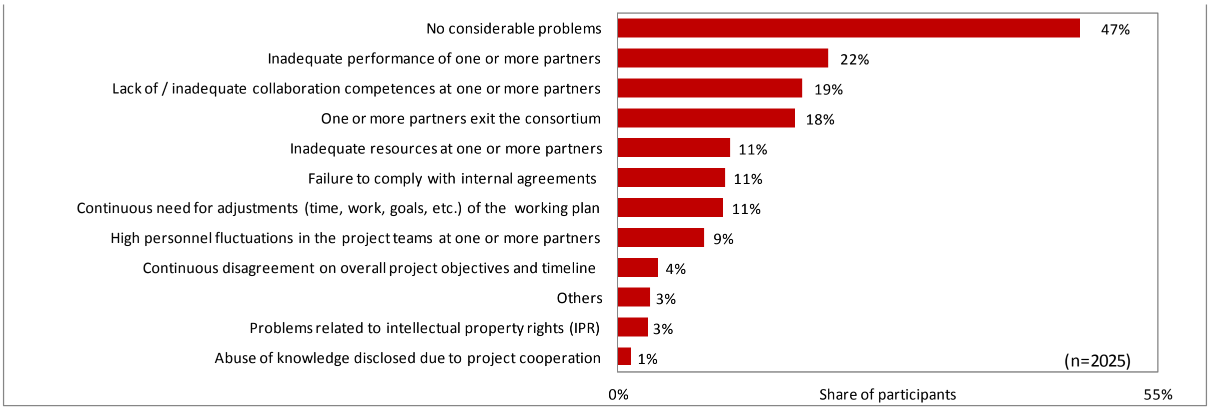
**Figure 74** New cooperation - countries



Which, if any, collaboration problems did most frequently occur in the project consortiums?

About the half of participants have no considerable or serious cooperation problems (see Figure 75). However, one fifth mentioned an inadequate performance of partners, which seems quite high and one fourth complained about missing collaboration competences respectively the consortium exit of other partners. The reasons why there are almost no IPR problems within the consortium are unclear.

**Figure 75** Collaboration problems

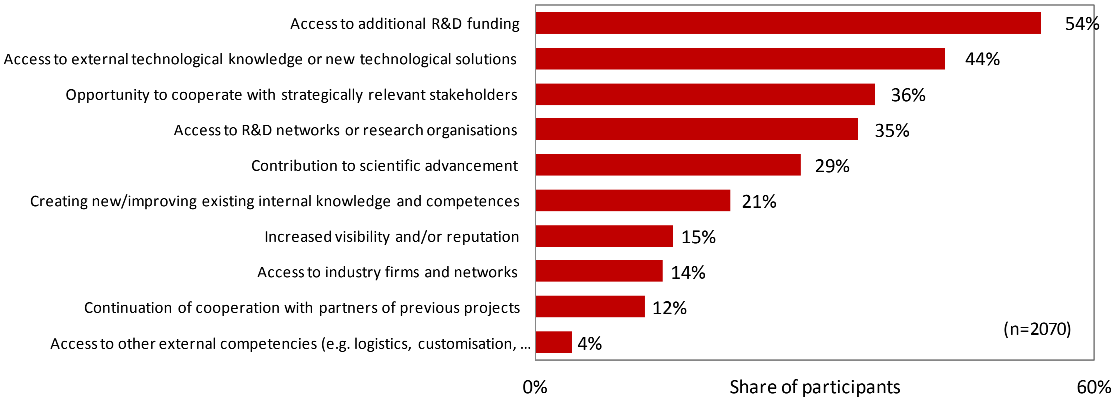



### *5.2.4 European Added Value*

What were the most important motives and objectives of the participants?

Survey results indicate that several aspects of critical mass are considered relevant as a motivation for participating in FP7 NMP. Most specifically, this concerns access to additional funding (54%), to external knowledge (44%), the opportunity to work with strategically relevant research units or enterprises and access to networks (36%) as well as access to R&D networks or research organisations (35%) (see Figure 76).

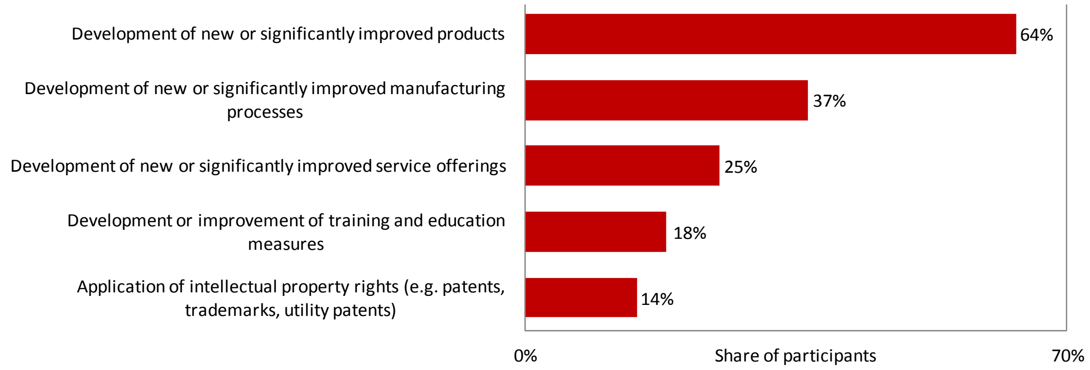
**Figure 76** Motives for participation




The participation motives of SMEs only slightly distinguish. The access to external technological knowledge or new technological solutions outside the organisation (59%) is the most named motive, followed by access to additional R&D funding (45%) and access to R&D networks or research organisations (38%) as well as the opportunity to cooperate with strategically relevant research units and enterprises (36%).

Asked for their individual innovation goal, the development of products seems to be by far the most important innovation objective. Application of IPR is surprisingly weak (corresponding to no cooperation problems on IPR). Also, organisational process innovations are obviously not in the focus (see Figure 77). However, new EU funding guidelines also include non-technical innovations as important enabler of new technologies, which is not reflected here.

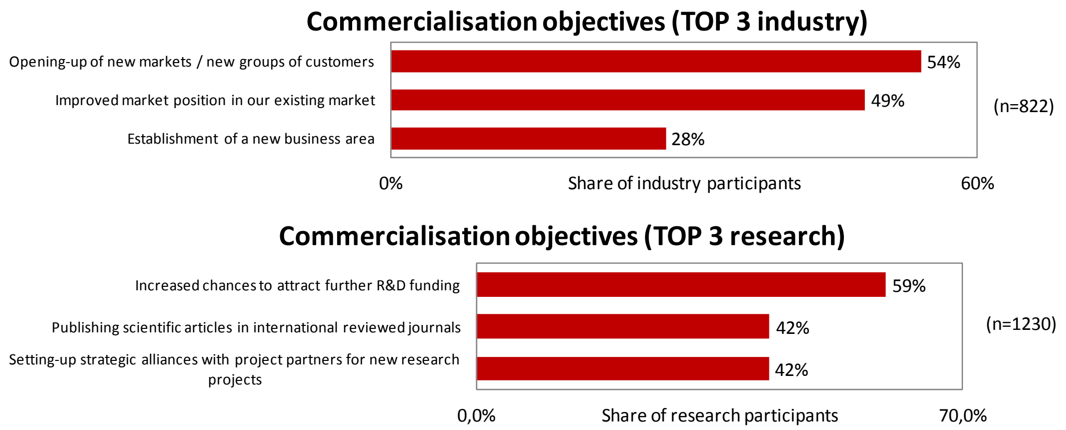
**Figure 77** Innovation objectives




The innovation objectives for SMEs are quite the same. The most important objectives for SME were the development of new or significantly improved products (74%), development of new or significantly improved manufacturing processes (38%) and development of new or significantly improved service offerings (27%) as well as the application of intellectual property rights (17%).

Besides innovation objectives, the participants also were asked about their commercialisation intentions regarding the project results. The importance of commercialisation within FP7 NMP seems to be most relevant for industry participants. The survey revealed that for firms specifically, three commercialisation objectives are highly or moderately important: opening-up new markets or new groups of customers (54% of the 822 industry participants that answered this question), improved market position in our existing market (49%) and establishment of a new business area (28%) (see Figure 78).

**Figure 78** Commercialisation objectives



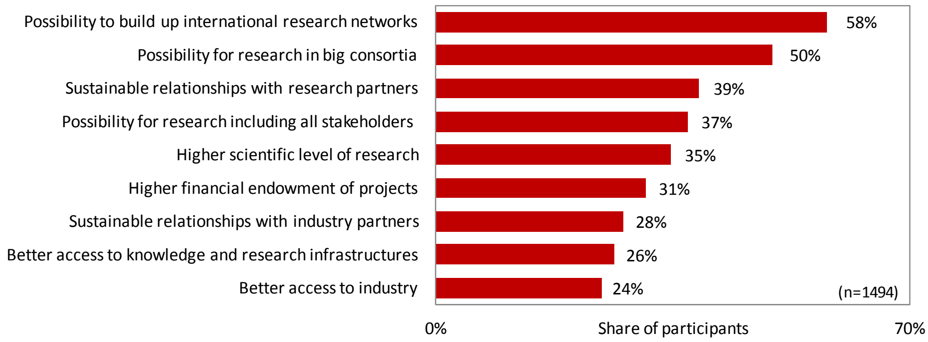

Most mentioned commercialisation objectives of industry and research participants are completely different. But there are no conflicting commercialisation objectives in industry-science cooperation. Synergies and convertibility of commercialisation objectives should be present.

<u>How do the participants assess the value added by the NMP7 programme compared to national funding programmes?</u>

About 78% of participants have stated that they have a comparable national funding programme in their country. Controlled by region no reportable differences were found between the „old" EU member countries (EU 15), the „new" EU member countries (EU 13) and participants from countries outside the EU.

Results show that advantage of NMP programme is not financial endowment, but international networks and bigger consortia (expectations to build-up networks are mostly fulfilled). The access to industry and relationship to industry partners seems to be not so important (see Figure 79). Projects are not dealing with market introduction and competition, but with R&D questions. This could be maybe problematic, if market ready solutions are expected by EC.

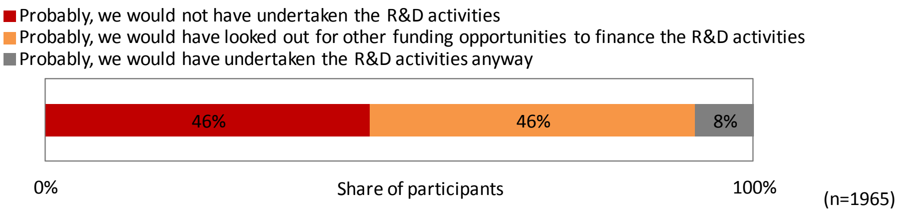
**Figure 79** Reasons for participation in FP7 NMP




<u>What would have happened if the project was not funded under FP7 NMP?</u>

An overall assessment by participants is that 46% of them would not have undertaken the research and innovation activities without FP7 NMP funding and another 46% would have looked for other funding, e.g. national programmes. Only 8% indicates that the respondent would have undertaken the activities anyway, e.g. by using private funding (this figure is much higher in evaluations of national programmes). Therefore, task of funding seems to be mostly fulfilled. The support of activities which are too risky and too expensive to be undertaken without funding has taken place. Also, the free-rider effect is very small (see Figure 80).

**Figure 80** Without granted funds under FP7 NMP



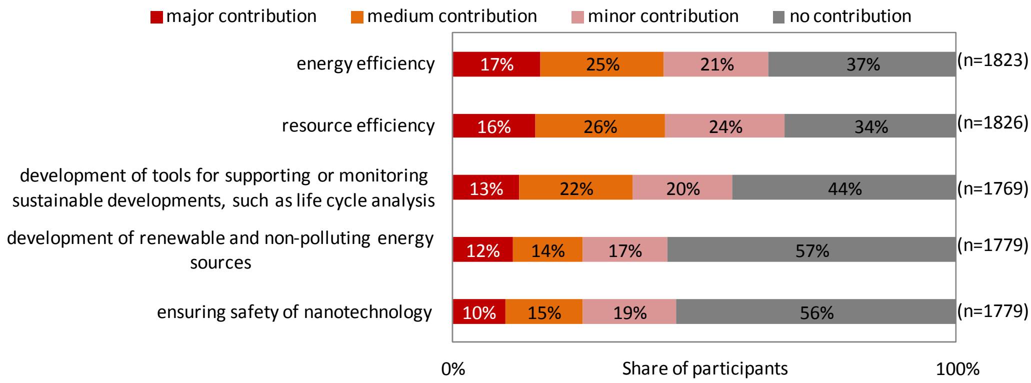

No reportable differences between the areas were found; except for participants in PPPs as 37% of the participants in PPP project teams would not have undertaken the R&D activities. This percentage is lower than for all NMP projects (46%); this can be explained by the relatively higher TRL of most PPP projects. The immediate economic relevance is higher which increases the chance that projects would also start without FP7 NMP funding.

### *5.2.5 Societal and environmental output and impact*

<u>How did the funded projects contribute to address societal and environmental challenges?</u>

A considerable part of the survey participants being asked about their project's contribution to societal and environmental goals, say that they contribute to energy and resources efficiency (63%, resp. 66%) and development of tools for sustainable development (56%). Contributing to better nanosafety is also considerable: almost 45% participants mention this (N=1800). In general, less than half of participants contributed with a major or medium contribution to the societal and environmental challenges (see Figure 81).

**Figure 81** Environmental effects




Taking into account the different areas, the participants in the three PPPs and Nanosciences and Nanotechnologies contributed above-average on specific indicators. Especially participants in the

PPPs contributed above-average to the four most addressed environmental effects. For energy efficiency PPP's scored 39% versus all the other areas 17%; for resource efficiency this was 29% versus 16%; for the development of tools for supporting or monitoring sustainable developments this was 23% versus 13% and for the development of renewable and non-polluting energy sources: 22% versus 12%. Participants in Nanosciences and Nanotechnologies contributed above-average to ensuring safety of nanotechnology by 24% versus 10% and to ensuring safety of new or advanced materials, including industrial safety (20% compared to 14%).

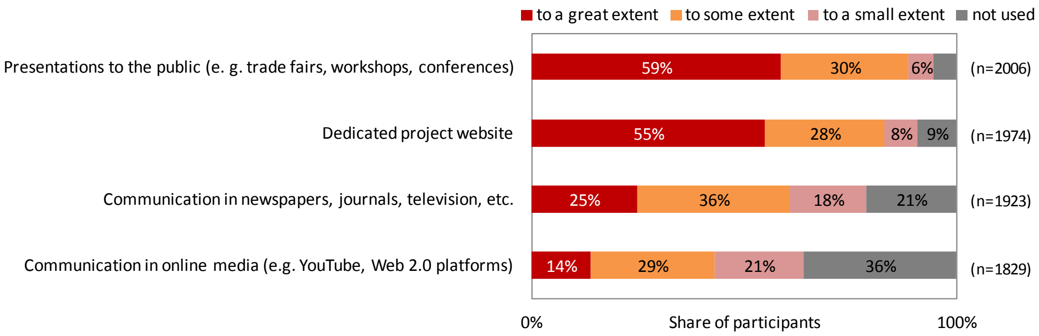
How did the funded projects contribute to stimulate the mobility and career options of researchers?

The FP7 NMP projects stimulated the mobility of project team members. It showed that 41% of survey respondents state that the project has led to a temporal exchange of personnel with one or more project partners. While 53% of research organisations participants had a temporal exchange of personnel (where this is rather common), also 19% of SME participants had. Also the project contributed to improving the career prospects for young researchers (e.g. PhD programmes in research or talents promotion in industry), as 66% of the survey participants stated. This mostly applies for research participants (77%) but also for SME participants (44%). Considering the shortage of skilled professionals in many areas, career aspects in industry should be increased.

Which efforts were made to include and inform social stakeholders about the research activities and results of the projects?

To include and inform social stakeholders about the research activities and results of the projects, the participants especially used presentations to the public and dedicated project websites to disseminate their results ("traditional channels"). Dissemination channels, which rather reach the broad public and non-professionals, are used less (see Figure 82). There seems to be potential for improvements regarding accessibility of social stakeholders in the broad public.

**Figure 82** Dissemination



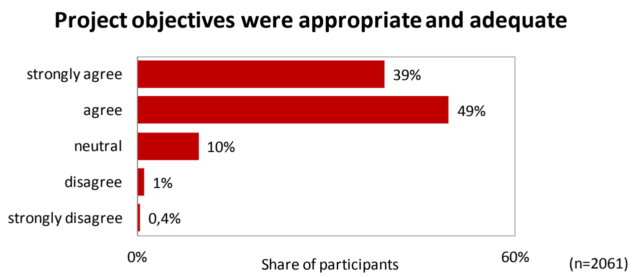

On average, 18% of the participants were actively involved in integrating relevant social stakeholder groups into the project. In detail, only 15% of the participants of CP were actively involved in integrating relevant social stakeholder groups. But 40% of participants of CSA projects were actively involved in integrating relevant social stakeholder groups. Participants of CSA projects seem to take their special project task seriously.

### *5.2.6 Programme efficiency*

Were the objectives defined at the beginning of the project adequate?

About 90% of participants agree on the statement that their project objectives were appropriate and adequate (see Figure 83). Nevertheless, "agree" could also mean, that single objectives are nonetheless regarded as inadequate, but in general the participants seem to be satisfied.

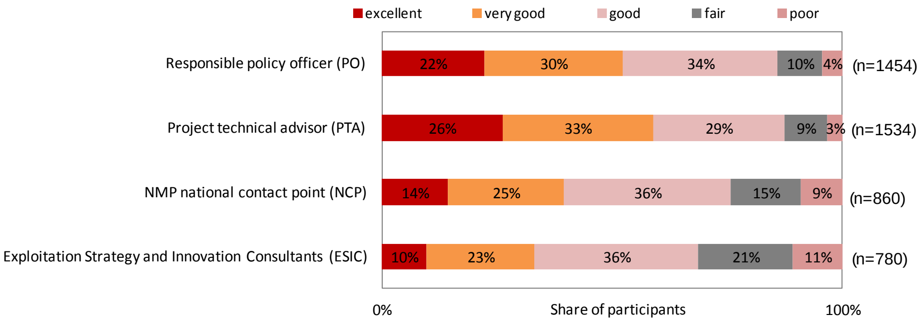
**Figure 83** Project objectives



How do the participants assess the administrative frame conditions of the NMP programme?

The support services provided by the responsible policy officers (POs) and by project technical advisers (PTAs) were assessed as very positive by more than three quarters of participants of the survey. Less survey respondents (N=860) assessed (and probably used) the services provided by the National Contact Points (NCPs) in the member states. Most of them (91%) were very positive about the NCP's services (from excellent, very good, good to fair). Those who used the services of ESIC (Exploitation and Strategy and Innovation Consultants) made similar assessments. Only 11% indicated the services as poor (N=780) (see Figure 84).

**Figure 84** Assessment of support services




Communication with the European Commission was assessed "excellent" or "very good" by nearly the half of the participants. More than 80% of the participants assess the communication at least as "good" which indicates more or less satisfaction on the side of the participants (see Figure 85). Asked for implementation aspects, the survey respondents were very satisfied about networking opportunities, the quality of the call documents, project duration, financial endowment of the project related to project objectives, contractual conditions and the appropriateness of the funding conditions of FP7 NMP Theme. Particularly, the networking opportunities are assessed exceptionally positive (assessed by over the half as "excellent" or "very good"). Survey respondents were less satisfied with the administrative requirements, the time frame between project selection and formal start of the project and the transparency of the selection procedure (see Figure 86).

**Figure 85** Assessment of communication with EC

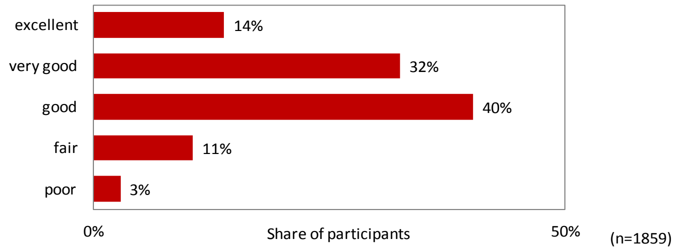
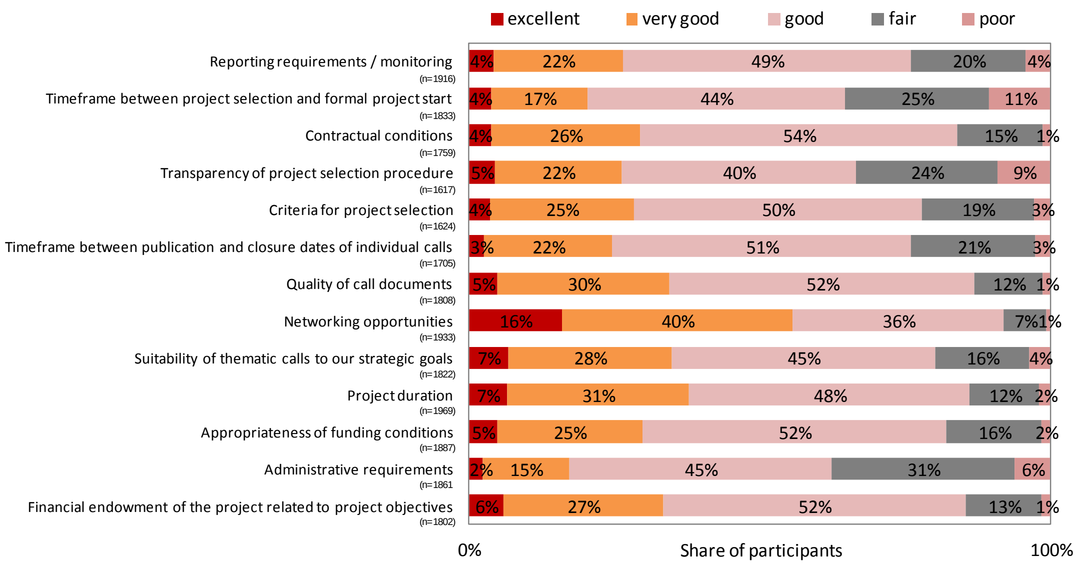



**Figure 86** Assessment of implementation aspects



# 6. SOCIAL NETWORK ANALYSIS

*Authors: Bernd Beckert, Matthias Gotsch, Axel Thielmann and Thomas Reiss, Fraunhofer ISI.*

## 6.1 Social Network Analysis of FP7 NMP participation based on the composition of project consortia

### *6.1.1 Introduction*

Social Network Analysis (SNA) has its origins in classical sociology and is a useful instrument for measuring the nature and extent of collaboration activity among interacting entities. It generally implies the study of social structure and its effects, whereas social structure is regarded as a social network which consists of a set of actors and a set of relationships that connect the actors. Hence, SNA concentrates on relationships between actors and explores the availability of resources and the exchange of resources between these actors[71]. As SNA identifies information sharing patterns and the structure of communities, thus pointing to key actors as well as to actors that are less integrated in the community, it is a good instrument for analysing the social structure of FP7-NMP participation.

### *6.1.2 Methodology and data set*

A network is usually described by a graph consisting of nodes and lines. Consequently, SNA treats the so-called actors as nodes and the relationships between them as lines[72]. In this context, the following two network characteristics are used for our subsequent analyses. First, degree centrality implies that central actors must be the most active in the sense that they have the most relations to other actors in the network. Degree centrality is defined as follows:

$$C_d = d_i / (g - 1)$$

$C_d$ Degree-centrality

$d_i$ Number of linkages (degree)

g Number of actors of the network (size of the network).

The higher the degree centrality the more active is the actor within the network and can use its position to influence others or to get more information.

Second, betweenness centrality measures the extent to which an actor is needed as a link in the chains of contacts, facilitating the spread of information through the network. It counts how often one actor lies on the shortest path between two other actors, hence, taking into account the connectivity of the node's neighbours, giving a higher value for nodes which bridge clusters[73]. The value of betweenness centrality is defined as follows:

$$C_b(n_i) = \sum_{j \neq n \neq k} g_{jk}(n_i) / g_{jk}$$

$g_{jk}$ ($n_i$) Number of shortest path between two nodes j and k (geodesics) where node ni is involved.

$g_{jk}$ Number of shortest paths between two nodes j and k

$C_b$ ($n_i$) Betweenness centrality

The higher the value of betweenness centrality the more important is the actor within the network, i.e. the actor possesses a strong transmitter function within the network so that he is for example strongly needed for the diffusion of information.

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71 See Scott, J. (1991): *Social network analysis: A handbook.* London: Sage; Reid, N.; Smith, B. W. (2009): Social network analysis: Its use in local economic development. *Economic Development Journal*, pp. 48-55.

72 See Wasserman, S., & Faust, K. (1994): *Social Network Analysis: Methods and Applications.* Cambridge: Cambridge University Press.

73 Nooy, d. W., Mrvar, A., & Btagelj, V. (2005). *Exploratory Social Network Analysis with Pajek.* Cambridge: Cambridge University Press.

As outlined in the NMP portfolio and composition analysis, the Commission's eCorda database containing all the FP7 NMP projects awarded since the start of FP7 can be used for our subsequent analyses. Hence, a total of 799 projects and 10.089 participants are our subject of study. Thereby, each project belongs to a specific area of the theme. The four areas of NMP are nanosciences and nanotechnologies (N), materials (M), new production technologies (P) and integration (I) while the private public partnerships (PPPs) include energy efficient buildings (EeB), factories of the future (FoF) and green cars (GC).

Figure 87 illustrates the overall structure of the FP7 NMP projects pointing to the number of projects as well as to the number of participants differentiated by the areas above mentioned.

**Figure 87** Number of FP7-NMP projects and participants, by area

| ***Areas - Number of FP7-NMP projects and participants*** | | | | |
|---|---|---|---|---|
| | **No of projects** | **%** | **No of participants** | **%** |
| ***NMP*** | ***620*** | ***100*** | ***7,828*** | ***100*** |
| Nanosciences and nanotechnologies | 191 | 30.8 | 2,307 | 29.5 |
| Materials | 182 | 29.4 | 2,088 | 26.7 |
| New production technologies | 92 | 14.8 | 1,336 | 17.1 |
| Integration | 154 | 24.8 | 2,087 | 26.7 |
| Other | 1 | 0.16 | 10 | 0.13 |
| ***Other*** | ***8*** | ***100*** | ***99*** | ***100*** |
| ***PPP*** | ***171*** | ***100*** | ***2,162*** | ***100*** |
| EeB | 52 | 30.4 | 742 | 34.3 |
| FoF | 102 | 59.6 | 1,197 | 55.4 |
| GC | 17 | 9.94 | 223 | 10.3 |
| ***Grand Total*** | ***799*** | | ***10,089*** | |

Source: eCorda database

As can be seen from Figure 87, the NMP theme embodies around 75% of the NMP areas in terms of number of projects and participants. Hence, the remaining projects and participants belong to the three PPPs. Regarding the four areas of the NMP theme, N is the largest area in terms of number of projects as it covers 30% of the NMP projects, followed by M with 29%, I with 24% and P with 15%. Within the group of the three PPPs, FoF accounts for the largest share with almost 60%.

**Figure 88** Institutional distribution of the FP7 NMP participants, by area

| ***Areas - Institutional distribution of the FP7-NMP participants*** | | | | | |
|---|---|---|---|---|---|
| | **HES** | **OTH** | **PRC** | **PUB** | **REC** |
| ***NMP*** | ***2,227*** | ***202*** | ***3,228*** | ***278*** | ***1,893*** |
| Nanosciences and nanotechnologies | 769 | 57 | 820 | 54 | 607 |
| Materials | 747 | 44 | 762 | 49 | 486 |
| New production technologies | 321 | 24 | 741 | 10 | 240 |
| Integration | 387 | 77 | 902 | 165 | 556 |
| Other | 3 | - | 3 | - | 4 |
| ***Other*** | ***28*** | ***1*** | ***34*** | ***16*** | ***20*** |
| ***PPP*** | ***359*** | ***49*** | ***1,282*** | ***23*** | ***449*** |
| EeB | 97 | 22 | 442 | 21 | 160 |
| FoF | 206 | 25 | 737 | 2 | 227 |
| GC | 56 | 2 | 103 | - | 62 |
| ***Grand Total*** | ***2,614*** | ***252*** | ***4,544*** | ***317*** | ***2,362*** |

Source: eCorda database

Figure 88 refers to the institutional distribution of the FP7 NMP participants differentiating again between the areas. As the figure illustrates the group of private commercial (PRC) accounts for the largest share in terms of all FP7 NMP participants with a percentage share of 45%. The groups of higher education and research organisations possess similar shares, occupying second and third place with around 25% each. Within the different subgroups, the institutional distribution of the FP7 NMP participants is similar compared to the total picture.

### *6.1.3 Results*

As mentioned above the FP7 NMP data provided by the Commission Services are a good starting point to show early interactions between participants with a degree of collaboration affinity for one another which might potentially lead to further interesting results through additional common project work. In order to shed light on the overall structure of the community, the following analyses illustrates the FP7 NMP networks pointing to key actors as well as to actors that are less integrated into the community. Regarding the whole portfolio of the NMP Theme (except of the category "Other") 790 projects are covered by our analyses. Thereby, the 790 projects include 4,617 different actors (nodes) and 65,989 relations (lines). The average degree centrality of this network is 28.58528, i.e. each actor has about 29 different project partners.

In order to present an overview of the most active actors within this network, the following Figure 89 shows the Top-10 FP7 NMP participants regarding their values of degree and betweenness centrality. The Top-10 participants originate from the EU15-countries including Germany, the Netherlands, Italy, Spain, Finland, France and Denmark.

**Figure 89** The values of degree and betweenness centrality of the Top-10 FP7 NMP participants

| FP7-NMP participant | Participant type | Rank | Degree centrality | Rank | Betweenness centrality |
|---|---|---|---|---|---|
| FRAUNHOFER (DE) | Research Institute | 1 | 1,674 | 1 | 0.225666 |
| TNO (NL) | Pub. Research Gov. | 2 | 785 | 2 | 0.060637 |
| CNR (IT) | Research Institute | 3 | 767 | 3 | 0.065436 |
| TRECNALIA (ES) | Research Institute | 4 | 724 | 4 | 0.046282 |
| VTT (FI) | Research Institute | 5 | 692 | 5 | 0.043049 |
| CEA (FR) | Research Institute | 6 | 672 | 6 | 0.039999 |
| CNRS (FR) | Research Institute | 7 | 652 | 7 | 0.038277 |
| DTU (DK) | Higher Education | 8 | 617 | 8 | 0.031038 |
| ACCIONA (ES) | Bus. Enterprise LE | 9 | 528 | 9 | 0.025611 |
| CRF (IT) | Bus. Enterprise LE | 10 | 506 | 10 | 0.023572 |

Source: eCorda data base

As Figure 89 shows, the Fraunhofer society occupies the first place with more than 1,600 unique project partners being far ahead of the other participants. The same accounts for the value of betweenness centrality which is with 0.225666 by far the largest one. This means that the Fraunhofer institutes possess the strongest transmitter function within the network as it is highly involved in the spreading of scientific information. Regarding the value of degree centrality, the other nine participants rank between 785 (Nederlandse Organisatie voor Toegepast Natuur-wetenschappelijk Onderzoek - TNO) and 506 (Centro Ricerche Fiat SCPA) unique project partners.

It has to be noted that these calculations are based on absolute numbers. Thus, it is not astonishing that "FRAUNHOFER" - being the largest research organisation for applied science in Europe - has the most connections with other actors. As the database only allows for aggregated numbers we cannot say which specific Fraunhofer institutes are the most active ones. The same applies to CRNS or CRN institutes. Being interested in specific research collaboration patterns, this is of course unsatisfying, however, the numbers in Figure 89 gives a first overview of who the central actors are and how intensely they are connected with other actors.

Referring to the participant type, it is striking that out of the top-ten participants six belong to the group of research institutes, even though the group of private commercial (Bus. Enterprise LE in Figure 89) accounts for a much larger share in terms of total number of FP7 NMP participants with a percentage share of 45% as already outlined above ("PRC" in Figure 88). It can be concluded that RTOs have a strong and obviously important role as integrator of other actors (especially companies).

The frequency of FP7 NMP collaboration also highly differs on a country level. The following Figure 90 shows the Top-10 involved participant countries measured by degree and betweenness centrality. It is not surprising that Germany again holds first place regarding the number of project partners who come from most different countries as the German Fraunhofer institutes have the largest number of unique project partners. Overall, Germany cooperates with project partners coming from 68 unique countries. Germany cooperates most often with project partners coming from Italy, the United Kingdom and Spain. The United Kingdom holds second place with project partners coming from 65 unique countries, followed by France, Spain and Italy with 63 unique countries each. Overall, regarding the whole portfolio FP7 NMP theme, the project partners come from 71 unique countries.

**Figure 90** The values of degree and betweenness centrality of the top-ten FP7 NMP participant countries

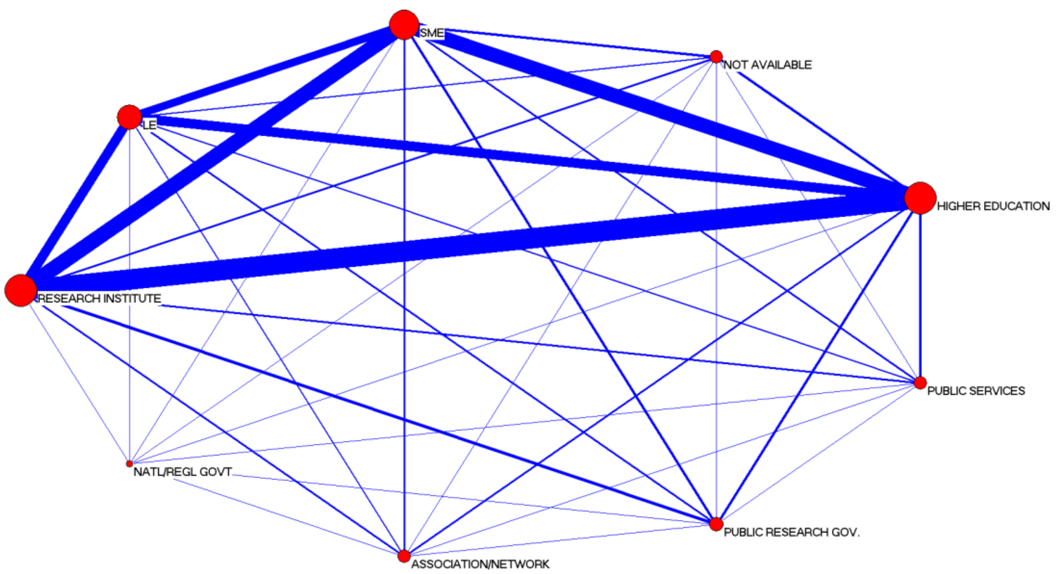
| FP7-NMP participant country | Rank | Degree centrality | Rank | Betweenness centrality |
|---|---|---|---|---|
| Germany | 1 | 68 | 1 | 0.068680 |
| United Kingdom | 2 | 65 | 3 | 0.052827 |
| France | 3 | 63 | 5 | 0.043246 |
| Spain | 4 | 63 | 4 | 0.044822 |
| Italy | 5 | 63 | 3 | 0.047406 |
| Belgium | 6 | 58 | 6 | 0.030456 |
| Netherlands | 7 | 57 | 7 | 0.030321 |
| Switzerland | 8 | 54 | 11 | 0.016577 |
| Sweden | 9 | 54 | 9 | 0.018347 |
| Austria | 10 | 52 | 13 | 0.014061 |

Source: eCorda database

When looking at the distribution of organisations (stakeholder types) coming together in a FP7 NMP project, the following picture evolves: Overall, the most cooperations were realised between research organisations and universities ("Higher Education"). But there are also strong links between research organisations and SMEs as well as between universities and SMEs. Large enterprises (LE) are involved in the network to a smaller degree but to both universities as well as research organisations.

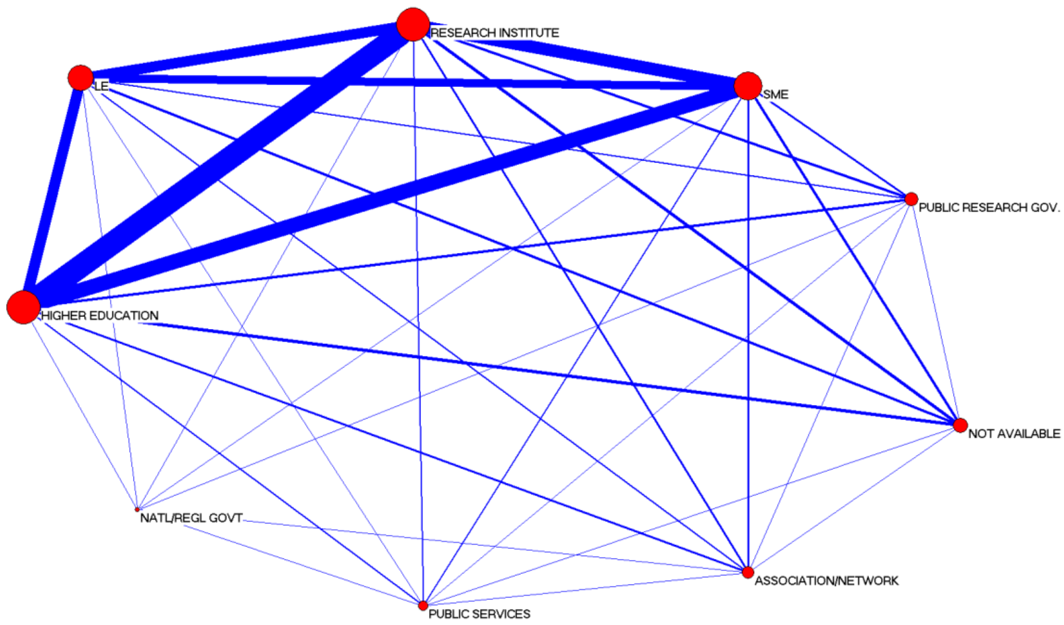
Looking at the different areas of the FP7 NMP programme, the pattern is the same in N, M and P where most cooperations are between research organisations and universities whereas SMEs and large enterprises follow with smaller numbers. However, in the fields of integration and PPPs it is the other way round: There, the enterprise sector plays a more important role (see Figures 91 to 95).

**Figure 91** Stakeholder type network of the N area



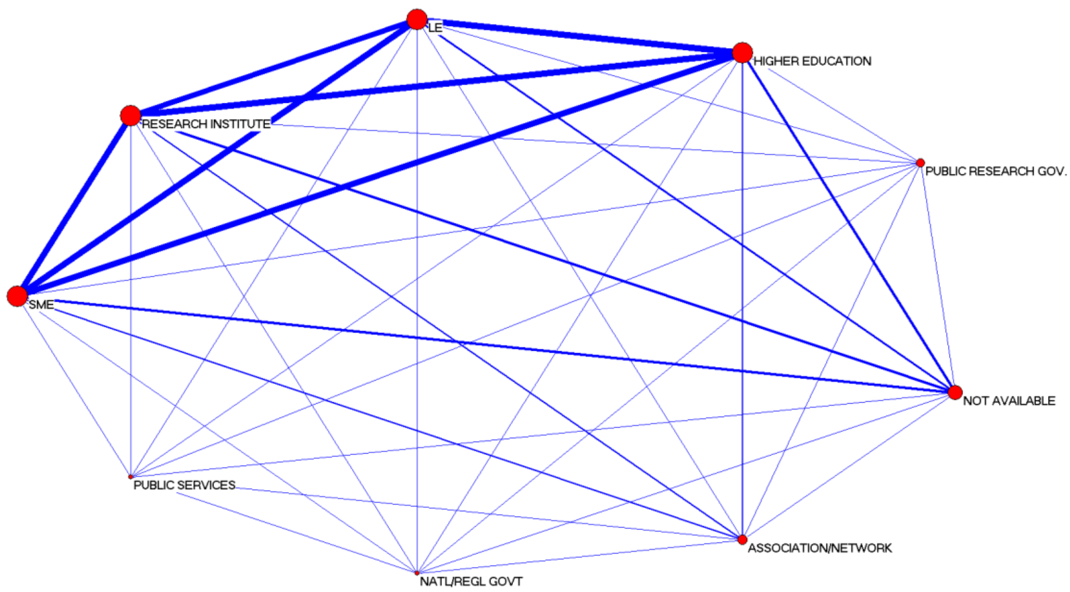

Source: eCorda database

**Figure 92** Stakeholder type network of the M area



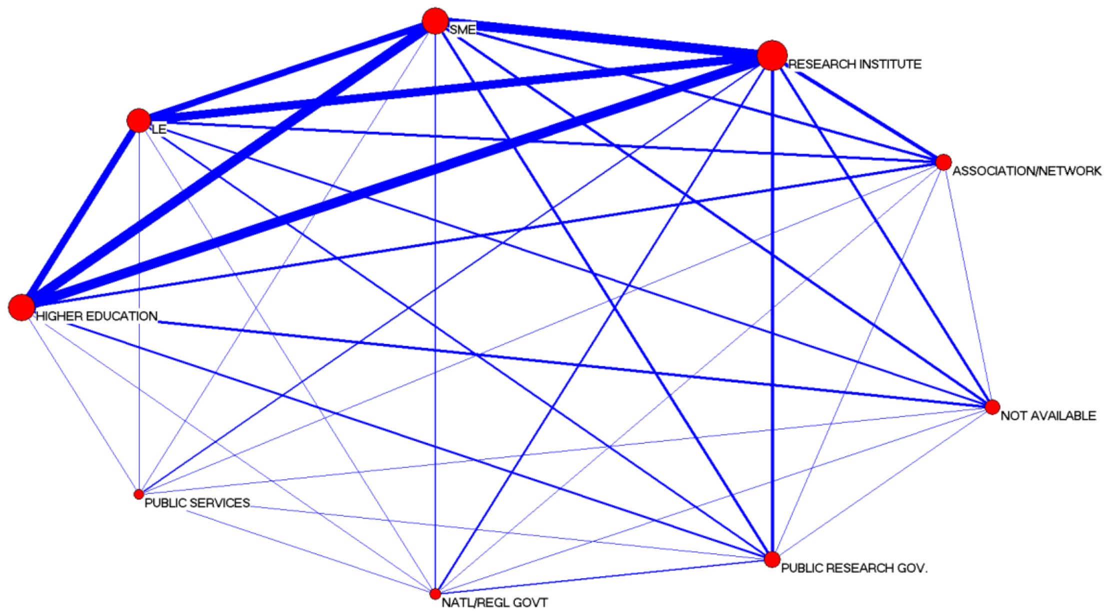

Source: eCorda database

**Figure 93** Stakeholder type network of the P area



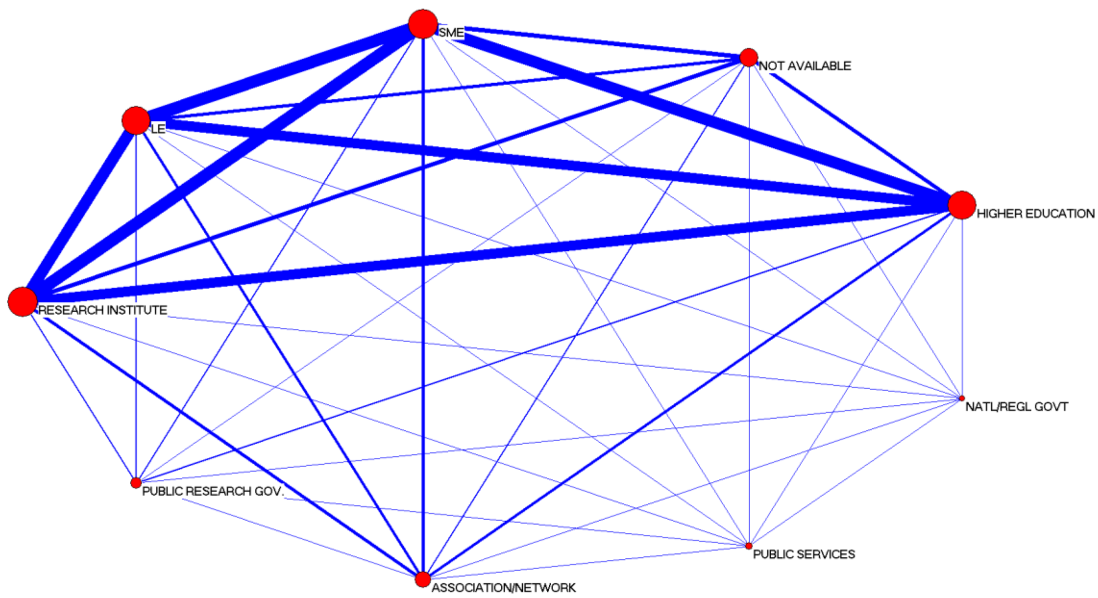

Source: eCorda database

**Figure 94** Stakeholder type network of the I area




Source: eCorda database

**Figure 95** Stakeholder type network of the three PPPs




Source: eCorda data base

In order to provide a more in-depth view on the cooperation patterns of the FP7 NMP participants differentiated by area, the following table illustrates some key facts of the differently FP7 NMP networks.

Regarding the portfolio of the FP7 NMP programme, 620 projects are covered with more than 7,800 participants. Thereby, the projects include 3,774 different actors (nodes) and 53,859 relations (lines). The average degree centrality of this network is 28.54425, i.e. each actor has on average almost 29 different cooperation partners as it holds for the entire FP7 NMP network including the three PPPs. Taking into account the different areas as outlined in Figure 95, it is nanosciences and nanotechnologies with the most relations between its involved project partners, while the projects within the area of integration have the most unique actors. While the area of new production technologies constitutes the smallest network in terms of nodes and lines, it possesses the highest value of density[74], while the network of the area of materials possesses the lowest value of density. The PPP network is equipped with most actors compared to the number of actors of the subgroups of the NMP Theme but possesses comparably little connections. This is the reason for the low value of density.

**Figure 96** FP7 NMP Network characteristics by area

| Areas - FP7-NMP Network characteristics | | | | |
|---|---|---|---|---|
| | Nods | Lines | Average Degree | Density |
| *NMP* | *3,774* | *53,859* | *29* | *0.00756* |
| Nanosciences and nanotechnologies | 1,318 | 16,384 | 25 | 0.01888 |
| Materials | 1,269 | 12,743 | 20 | 0.01583 |
| New production technologies | 965 | 11,339 | 24 | 0.02438 |
| Integration | 1,406 | 15,732 | 22 | 0.01593 |
| PPP | 1,341 | 13,223 | 20 | 0.01472 |

Source: eCorda database

Regarding the most active actor within the different sub-networks, the Fraunhofer society possesses the most unique project partners as well as it is Germany with project partners coming from most different countries with one exception; within the PPP network, Germany has as many project partners from different countries as Italy (38 each).

Whereas the first part of the social network analysis looked at the composition of projects and analysed their networks in terms of country coverage, involvement of stakeholder types (research organisations, SMEs, large enterprises, etc.) and number of unique partners in the different areas, the following section will analyse the output dimension of the cooperations. It will use co-publications as a methodological base to trace actual cooperation patterns originating from FP7 NMP projects.

## 6.2 Social Network Analysis of FP7 NMP Participation based on co-publications

### *6.2.1 Introduction*

The second part of the Social Network Analysis deals with the output dimension of cooperations and uses data from the co-publication analysis and the co-patenting analysis. In the Draft Final Report of November 2014, this analysis was put under the heading "European Research Area". The European Research Area is a central part of the European innovation strategy. Its aim is to foster excellent science and research across borders and to strengthen knowledge transfer from the scientific field to the field of applications and technology development. To create a European Research Area, special emphasis is put on clusters, knowledge transfer networks and strategic partnerships between universities and businesses as well as the regulatory environment. The FP7 NMP Theme is part of the endeavor of the European Commission to create such a European Research Area.

### *6.2.2 Methodology and data set*

In order to find out about collaboration patterns which were initiated or extended by FP7 NMP-projects we use co-publication analyses. In a first step, publications and patents associated with an NMP-project had to be identified. This information already existed in the eCorda-database. An in-depth-analysis of bibliometrics is given in the Draft Final Report in the Sections 4.1 (Impact pathways) and 4.2 (Contribution to competitiveness). The available database did not provide co-publication information according to country and organisation type. Thus, in a second step, it had to be looked up individually for each publication, which organisations were involved in writing the

[74] Density represents the proportion of direct links in a network relative to the total number of possible links.

article. Since co-publications often involve partners which are not part of the project, in a third step, it was important to identify those organisations in order to be able to analyse scientific diffusion patterns of FP7 NMP projects. Approximately 4,000 publications had to be looked up in the Web of Science database and authors had to be assigned to organisations involved in the project or marked as "External" (yellow line in Figure 97).

Based on this groundwork, a detailed network analysis on the basis of co-publications became possible. The data allows for a comprehensive analysis of collaboration networks triggered, sustained or enlarged or by FP7 NMP-projects.

### 6.2.3 Results: Collaboration across countries

Collaboration with renowned organisations in other countries and regions is one of the central motivations for participating in NMP projects. A good indicator for international collaboration activities is scientific publications that are authored by researchers from different countries (co-publications).

**Figure 97** Co-publication database: Assigning organisations to publications

| ID | Participant Legal Name | Parti | Externa | Title | DOI | Nr | P480 | P481 | P482 | P483 | P484 | P485 | P486 | P487 | P488 | P489 | P490 | P491 | P492 | P493 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 213345 | POLITECNICO DI MILANO | IT | | | | | 1 | | | | | | | | | | | 1 | | |
| 213345 | TEKNOLOGIAN TUTKIMUSKESKUS VTT | FI | | | | | | | | | | | 1 | | 1 | | | | | |
| 213345 | BRITISH TELECOMMUNICATIONS PUBLIC LII | UK | | | | | | | | | | | | | | | | | | |
| 213345 | EUROPEAN UNION OF THE NATURAL GAS II | BE | | | | | | | | | | | | | | | | | | |
| 213345 | ELECTRICITE DE FRANCE S.A. | FR | | | | | | | | | | | | | | | | | | |
| 213345 | DET NORSKE VERITAS AS | NO | | | | | | | | | | | | | | | | | | |
| 213345 | COMITE EUROPEEN DE NORMALISATION | BE | | | | | | | | | | | | | | | | | | |
| 213345 | D'APPOLONIA SPA | IT | | | | | | | | | | | | | | | | | | |
| 213345 | INSTITUT NATIONAL DE L ENVIRONNEMEN | FR | | | | | | | | | | | | 1 | | | | | | |
| 213345 | GDF SUEZ | FR | | | | | | | | | | | | 1 | | | | | | |
| 213345 | EUROPEAN VIRTUAL INSTITUTE FOR INTEGI | DE | | | | | | | | | | 1 | | | | | | | | 1 |
| 213345 | INSTITUT JOZEF STEFAN | SI | | | | | | | | | | | | | | | | | | |
| 213345 | UNIVERSITAET STUTTGART | DE | | | | | | | | | | 1 | | | | 1 | | | | |
| 213345 | NATIONAL CENTER FOR SCIENTIFIC RESEAF | GR | | | | | | | | | | | | | | | | | | |
| 213345 | CONSIGLIO NAZIONALE DELLE RICERCHE | IT | | | | | 1 | | | | | | | | | | | 1 | | |
| 213345 | STIFTELSEN SINTEF | NO | | | | | | | | | | | | | | | | | | |
| 213345 | ASSOCIATION POUR LA RECHERCHE ET LE D | FR | | | | | | | | | | | | | | | | | | |
| 213345 | UNIVERSITA DEGLI STUDI DI ROMA LA SAPI | IT | | | | | | | | | | | | | | | | | | |
| 213345 | DANMARKS TEKNISKE UNIVERSITET | DK | | | | | | | | | | | | | | | | | | |
| 213345 | RIJKSINSTITUUT VOOR VOLKSGEZONDHEID | NL | | | | | | | | | | | | | | | | | | |
| 213345 | JRC -JOINT RESEARCH CENTRE- EUROPEAN | BE | | | | | | | | 1 | | | | | | | | | | |
| 213345 | COMMISSARIAT A L ENERGIE ATOMIQUE ET | FR | | | | | | | | | 1 | | | 1 | | | | | | |
| 213345 | IMPERIAL COLLEGE OF SCIENCE, TECHNOLC | UK | | | | | | | | | | | | | | | | | | |
| 213345 | ATOS SPAIN SA | ES | | | | | | | | | | | | | | | | | | |
| 213345 | ALMA MATER STUDIORUM-UNIVERSITA DI | IT | | | | | | 1 | 1 | 1 | 1 | | | | | | | 1 | | |
| 213345 | UNIVERSITA DEGLI STUDI DI PADOVA | IT | | | | | | | | | | | | | | | | | | |
| 213345 | External | | yes | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 213345 | | | | CFD model simulation of LPG dispersion in | | 480 | | | | | | | | | | | | | | |
| 213345 | | | | Addressing emerging risks using carbon cap | | 481 | | | | | | | | | | | | | | |
| 213345 | | | | Release of Hazardous Substances | 10.1016/j | 482 | | | | | | | | | | | | | | |
| 213345 | | | | A Model for Process Equipment D | 10.1016/j | 483 | | | | | | | | | | | | | | |
| 213345 | | | | Lessons learnt from Toulouse anc | 10.1111/j | 484 | | | | | | | | | | | | | | |
| 213345 | | | | Search for the "European way" of | 10.1080/1 | 485 | | | | | | | | | | | | | | |
| 213345 | | | | UML modelling concepts of HAZO | 10.1080/1 | 486 | | | | | | | | | | | | | | |
| 213345 | | | | First steps in developing an autor | 10.1080/1 | 487 | | | | | | | | | | | | | | |
| 213345 | | | | Approaches towards a generic me | 10.1080/1 | 488 | | | | | | | | | | | | | | |
| 213345 | | | | Risk governance and emerging te | 10.1080/1 | 489 | | | | | | | | | | | | | | |
| 213345 | | | | IRGC's approach to emerging risk: | 10.1080/1 | 490 | | | | | | | | | | | | | | |
| 213345 | | | | Public awareness promoting new | 10.1080/1 | 491 | | | | | | | | | | | | | | |
| 213345 | | | | Remote operation in environmer | 10.1080/1 | 492 | | | | | | | | | | | | | | |
| 213345 | | | | iNTeg-Risk project: concept and f | 10.1080/1 | 493 | | | | | | | | | | | | | | |

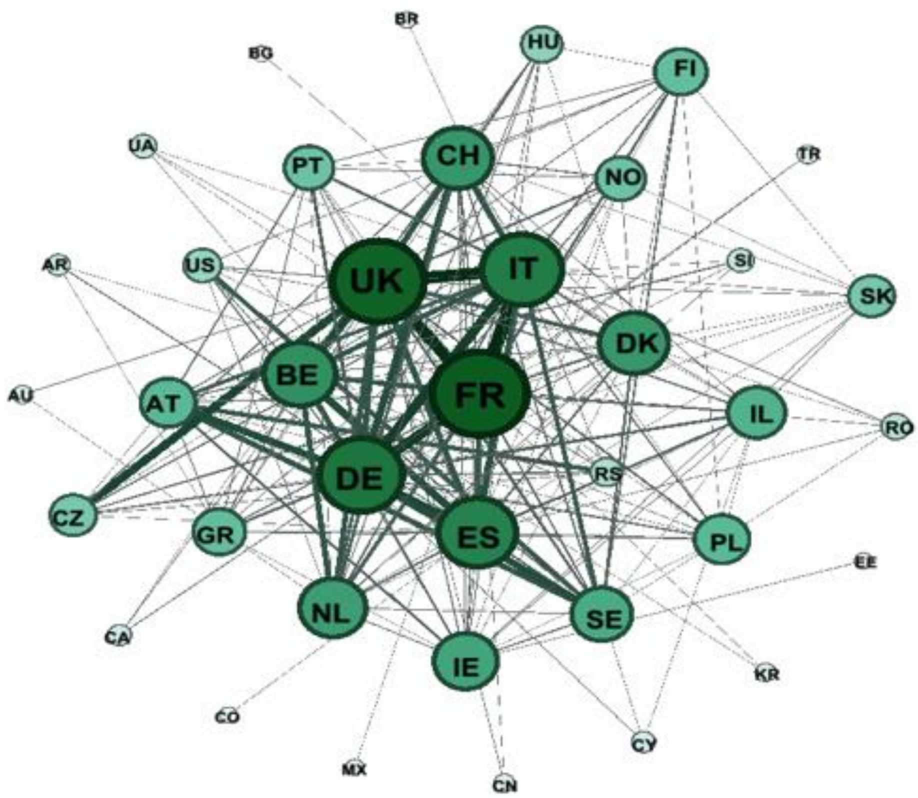
Source: Co-publication database. Green: Project partners, "P480" in top row stands for publication number 480, in orange are the titles of the assigned articles.

The co-publication analysis of the publications written on the basis of the FP7 NMP projects shows that 75% of these publications are co-publications. This is not surprising because the aim of the project is to combine expertise and to jointly develop new technologies. However, looking more closely at co-publication patterns, interesting facts evolve (see Figure 98).

Taking the areas together, a clear power network of knowledge transfer shows up between eight countries: Belgium, Denmark, Germany, France, Italy Spain, Switzerland and the UK. These countries can be regarded as NMP collaboration hubs because most co-publications originate from there. Countries with weaker ties to the core network are: PT, NO, HU, FI, SK, PL, SE, IE, NL, RS, UA, GR, AT, and CZ. Countries from outside Europe are also part of the network, esp. US and CA, but also IL. However cooperation with other non-European countries is rare.

Similar to the project partnership patterns presented earlier, here we are looking at absolute numbers of co-publications. A normalisation of the numbers according to a countrys´ general participation activity was not possible at this stage. As such, Figure 98 presents the actual picture of total collaborations and does not provide a comparison of relative collaboration activities on a country level.

**Figure 98** Co-publication activities showing collaboration patterns across countries




Source: Co-publication analysis. Included are project-internal co-publications without same-country-co-publications. Total co-publications: 1356. Size of bubble indicates number of outward connections; thickness of line between bubbles indicates strength of connection between two countries.

For the eight countries inside the power network, we analysed in how far the NMP cooperation patterns match the overall scientific cooperation patterns. For the comparison we used a Web of Science database analysis in which co-publications in all of science and for selected countries were counted (Denmark is not part of the data set). Figure 99 shows how the results match.

**Figure 99** Comparing NMP-power networks with overall co-publication patterns (match or no match)

| | Belgium | Germany | France | Italy | Spain | Switzer-land | UK | Most important co-pub partner |
|---|---|---|---|---|---|---|---|---|
| Belgium | - | yes | yes | yes | Yes | yes | yes | NL |
| Spain | yes | yes | yes | yes | - | yes | yes | BE, IT |
| Germany | Yes | - | Yes | Yes | yes | yes | Yes | AT, CH, NL |
| Italy | yes | yes | yes | - | yes | yes | yes | CH (high numbers in all fields) |
| Switzer-land | yes | yes | no | no | no | - | No | DE (low numbers in all fields) |
| France | yes | no | - | no | no | yes | No | BE (low numbers in all fields) |
| UK | no | no | no | no | no | no | - | BE, CH (low numbers in all fields) |

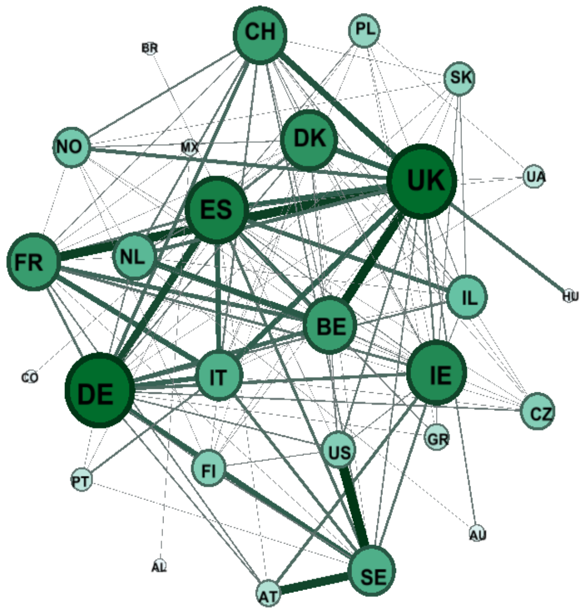
Source: Co-publication analysis against overall co-publication activities as being counted by the 2014-Report on the monitoring of the Pact for Research and Innovation (PFI) of the Federal German Ministry for Education and Research (BMBF). See: http://www.gwk-bonn.de/fileadmin/Papers/GWK-Heft-38-PFI-Monitoring-Bericht-2014.pdf.

Interestingly, the NMP ooperation patterns in Belgium, Germany, Spain and Italy perfectly match the overall scientific cooperation patterns, the cooperation activities in France and Switzerland match only partly and in the UK they do not match at all. The results of our analysis show that in

France and Switzerland, and especially in the UK, the NMP programme has triggered scientific cooperations with countries which are usually not top-cooperation partners; in these countries the NMP-programme motivated cooperations which clearly extended the usual line of cooperations.

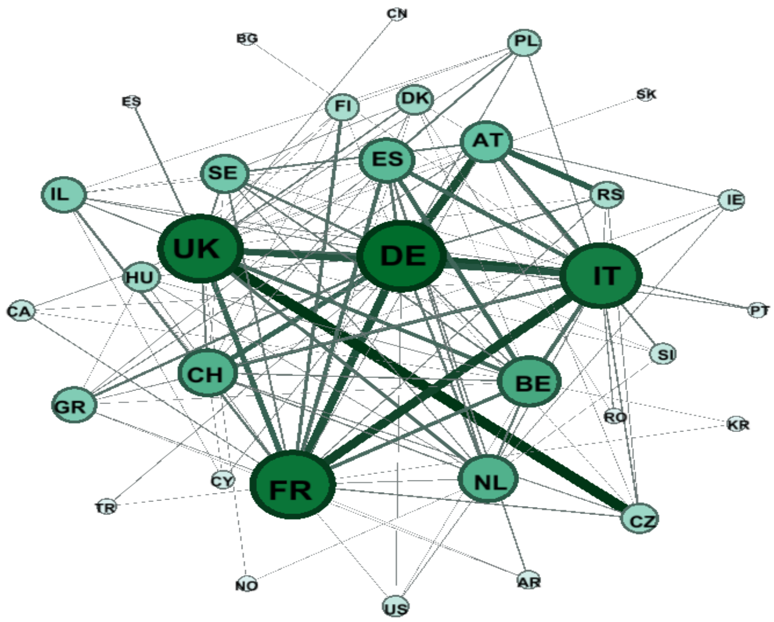
Looking at the separate areas of Materials and New Production Technologies, similar patterns as in Figure 98 evolve. The Materials power hub consists of the four countries (UK, DE, IT, FR) and a Production power hub comprises the three countries UK, DE and IT. However, the Nanotechnology area is different: there is no clear core network, instead here evolves a group of many well-connected countries. Slightly more outward connections in this field can be found from Germany, Spain and the UK, but the difference to other countries is small. Also, a series of special connections characterises the nanotechnology network chart, for example between South Africa and Austria, Sweden and the US, and between France and Italy. Figures 100-102 display the respective networks in detail.

**Figure 100** Co-publication activities in the nanoscience and nanotechnology area



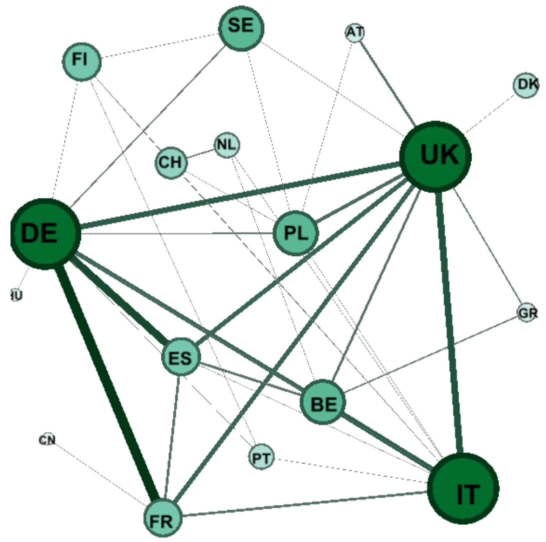

Source: Co-publication analysis.
Total internal co-publications in the field of N: 436
without same country co-publications.

**Figure 101** Co-publication activities in the materials area




Source: Co-publication analysis.
Total internal co-publications in the field of M: 581
without same country co-publications.

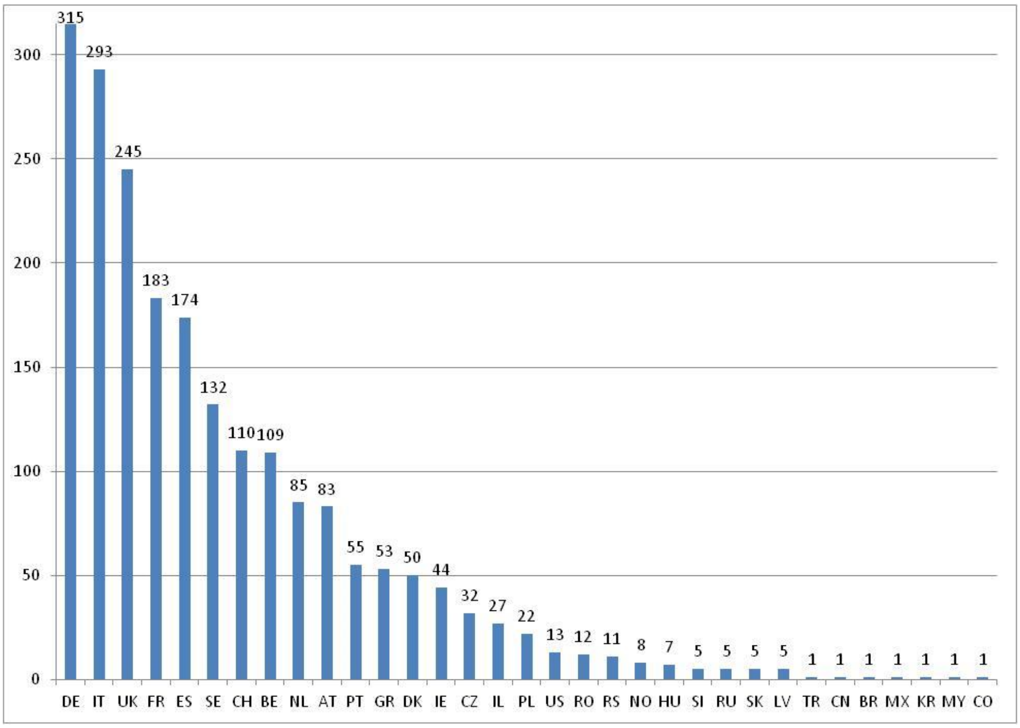
**Figure 102** Co-publication activities in the new production technologies area




Source: Co-publication analysis.
Total internal co-publications in the field of P: 107,
without same country co-publications.

The co-publication analysis also allows for determining countries in which the technology transfer from a FP7 NMP project into the existing research network worked especially well. This can be found by counting co-publications with project-external partners. Project-external partners can be located in other countries as well as in the same country. To co-publish with organisations which were not in the project consortium but which belong to the wider scientific and economic network indicates the relevance of the project results and signals the level of diffusion activities. Figure 103 shows in which countries the co-publication activities with external partners are especially relevant in absolute numbers.

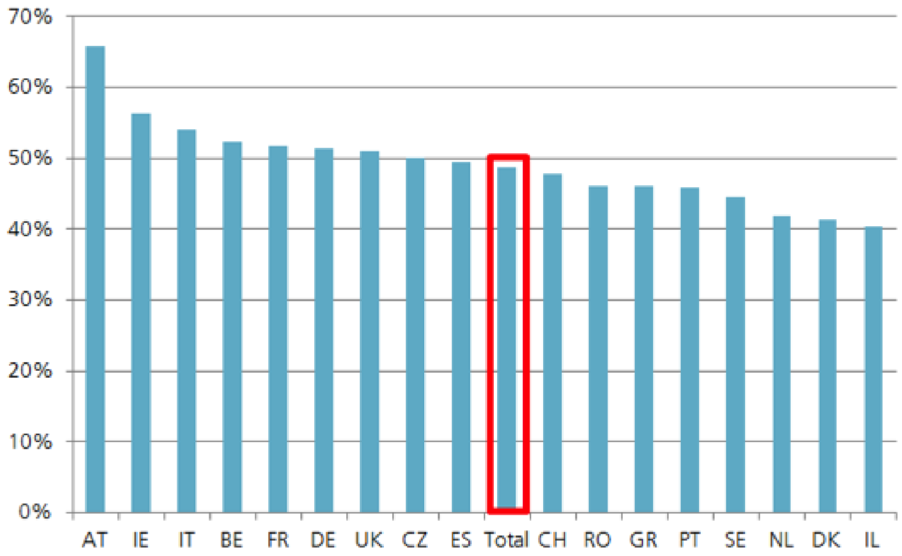
**Figure 103** Participation in co-publications with external partners in all fields




Source: Co-publication analysis, absolute numbers

Normalised to the total number of co-publications per country, Figure 104 shows that there are nine countries which display diffusion activities above the average (left of the red 'Total' bar). The main result of this analysis is that knowledge transfer to external researchers works especially well in AT, IE, IT, BE, FR, DE, UK, CZ and ES. These countries are above the average percentage of project-external co-publications as measured against all co-publications. Countries below the average focus more on project-internal co-publications.

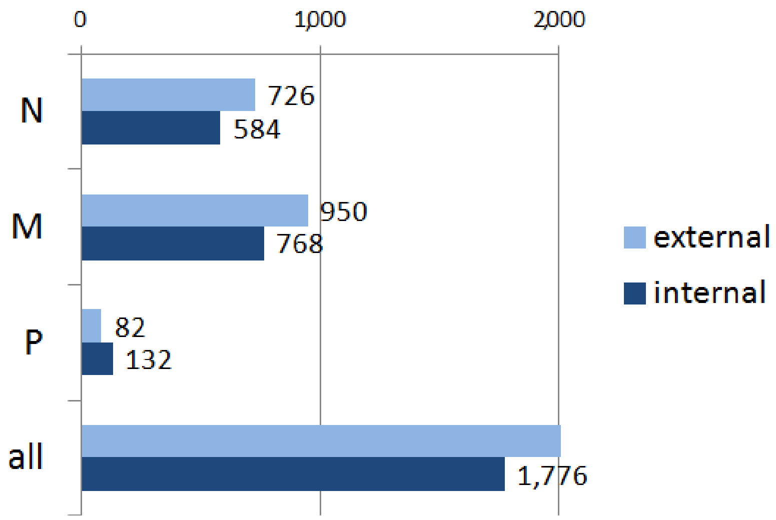
**Figure 104** External co-publications as an indicator for above-average diffusion activities




Source: Co-publication analysis, Percentage of project-external activities as measured against total number of co-publications in selected countries.

Looking at the aggregated data comparing internal and external co-publications it can be said that the diffusion of ideas, concepts and applications triggered by EU projects works well (Figure 105).

**Figure 105** Participation in co-publication activities comparing the N, M and P areas




Source: Co-publication analysis. Note: „internal" means: co-authors belong to organisations who collaborate in the respective EU-project (project-internal co-publications), „external" means: co-authors belong to an organisation not involved in the EU-project. „Internal" as well as „external" numbers include same-country co-publications, number of „all" co-publications higher than addition of N, M and P because of missing co-publication numbers in the remaining areas of I and PPPs.

There are more project-external co-publications than project-internal co-publications altogether and in almost all fields (with the exception of P). Project partners use existing research networks and build new connections to disseminate project results or develop ideas further. Project participants are generally well connected with their scientific peers and use the EU-projects to strengthen and extend their connections.

Other than in the N and M areas, in the P area there are more internal than external cooperations. This may indicate a strong core of actors who rely on outward cooperations to a smaller extent. However, the numbers are small, therefore interpretations have to be cautious.

Interesting facts concerning collaboration patterns across countries also come from the case studies and the online survey. There we have analysed how projects and consortia build on previous activities in the EU context. It turned out that creating new consortia often means to continue existing consortia and collaborations (to follow-up FP6 and national projects). In fact, 79% of the project participants did cooperate in any form with their consortium partners already before the project (survey). But projects also included new partners which were selected for their complementary scientific expertise or technological competence or because of application area coverage. Wherever new partners were asked to participate in the consortium, roughly 80% came from another country (20% from the same country. As such, nearly all consortia include 'old friends' and 'new friends'.

The heart of consortia can be partners from one country or even one region or from a number of countries (in the case of a preceding FP project). In nearly all case study projects, the number of partners and countries involved in such successive projects has increased. This applies to all funding schemes, especially to those where internationalisation was an explicit (CP SICA) or implicit requirement (CSA and CP IP).

A special point is collaboration with partners outside Europe. Here, the case study analysis revealed a trade-off for project coordinators. To involve such actors can provide a consortium with access to excellent knowledge, downstream partners or geographic markets. However, there have been reported delays and problems related to IPR negotiations and enforcement, inter-cultural collaboration and commitment. As such, collaboration with actors outside Europe can be qualified as high risk, high gain.

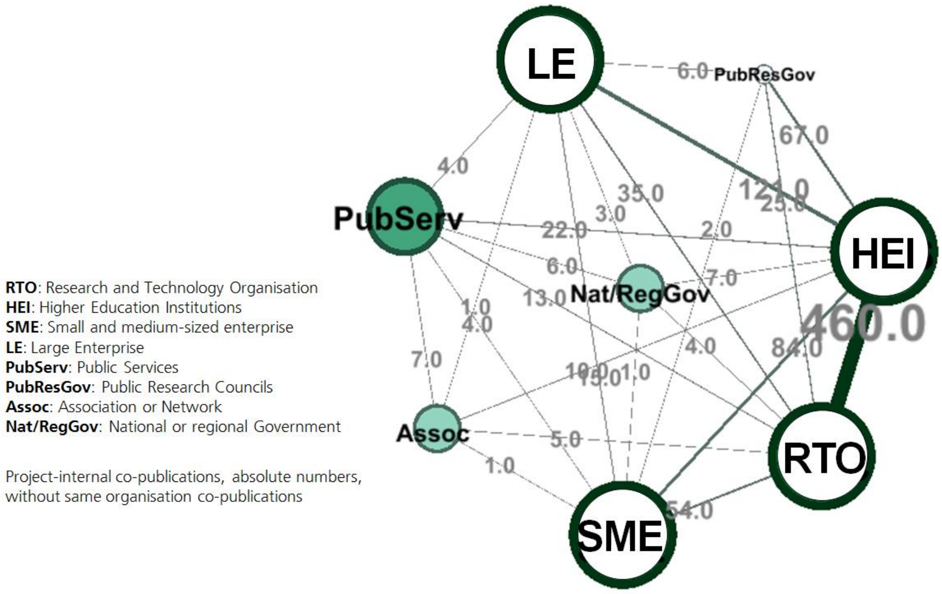
### *6.2.4 Results: Research-industry collaboration and technology transfer*

The successful diffusion of ideas, concepts and new technologies from research to industry is one important prerequisite to transform science into applications and finally into commercial products. One indicator for intended impacts of the NMP Theme is the collaboration of research organisations with firms in NMP projects. The co-publication analysis reveals that most collaboration activities are between universities (HEI) and research organisations (RTO).

However, the enterprise sector (LE and SME) also participates substantially in co-publication activities. Large enterprises as well as SMEs have manifold connections to academia and the regulating environment; they are an active part in the peer-network of NMP researchers. Although the number of co-publications in which industry is involved is significantly lower (thinner lines), the extent to which they are connected to the academic field is high (same size of bubbles in Figure 106).

Industry has a certain preference for universities when it comes to co-publications: 205 industry-universities co-publications were counted, against 89 industry-research organisation co-publications. Large firms more often publish with universities (confirming other research that they are relatively more active in basic research), while SMEs publish more often with (application oriented) research organisations.

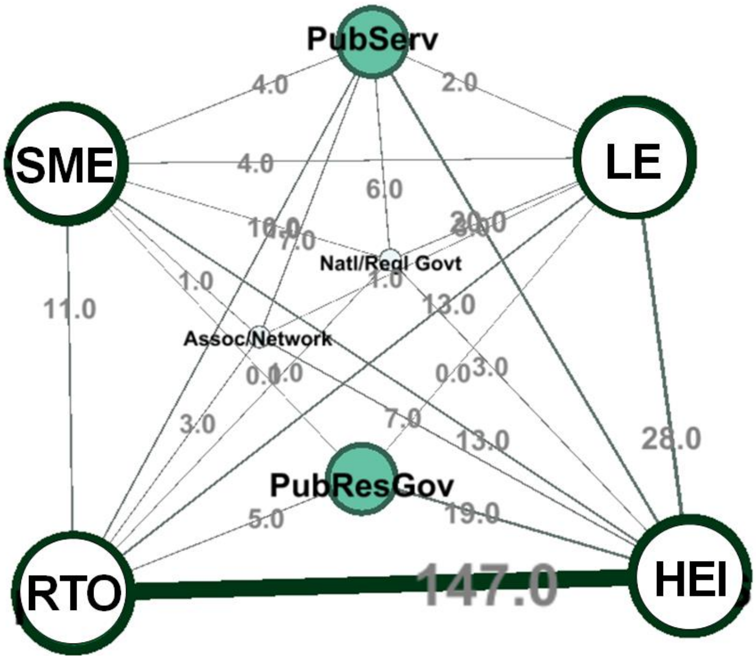
**Figure 106** Co-publication activities showing collaboration patterns across organisations (network chart)




Source: Co-publication analysis.

The co-publication analysis shows that in the materials area, LE are a central part of the network and SMEs play a smaller role. In the nanotechnology area both LE and SME are strongly involved. Not surprisingly, in the new production technologies area, industry is hardy present as this is a more application-oriented field and the manufacturing industries are less inclined to publish on their progress in process development (see Figures 107-109).

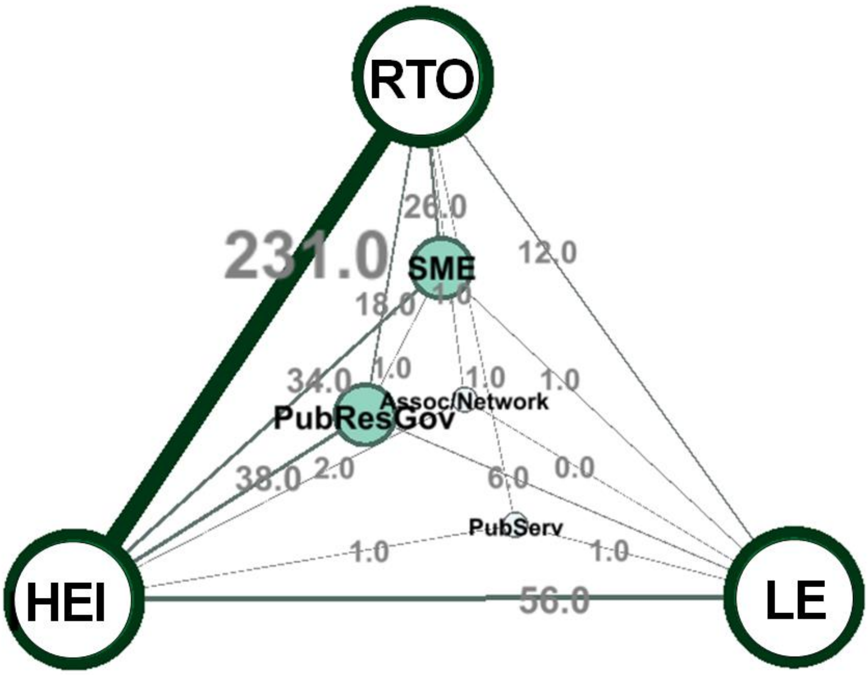
**Figure 107** Co-publication activities across organisation types in the N area




Project-internal co-publications. Total internal co-publications in the N area: 310 (without same country co-publications). Source: Co-publication analysis.

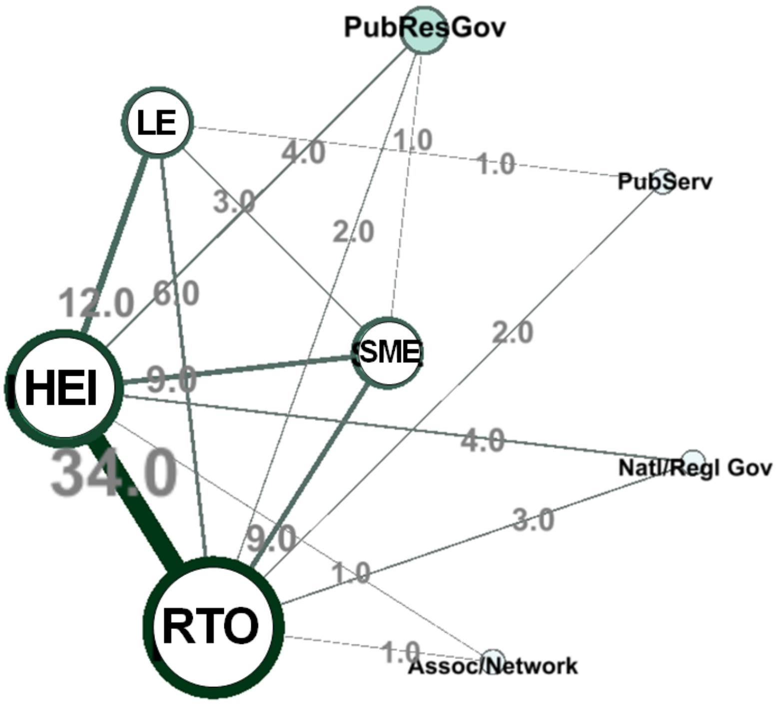
Standardisation and regulatory bodies are a central part in the co-publication network of nanotechnology, indicating the need to research nanohazards and health impacts of nanotechnologies.

**Figure 108** Co-publication activities across organisation types in the M area




Project-internal co-publications. Total internal co-publications in the M area: 429 (without same country co-publications). Source: Co-publication analysis. Note that REC is RTO and HES is HEI in official labeling.

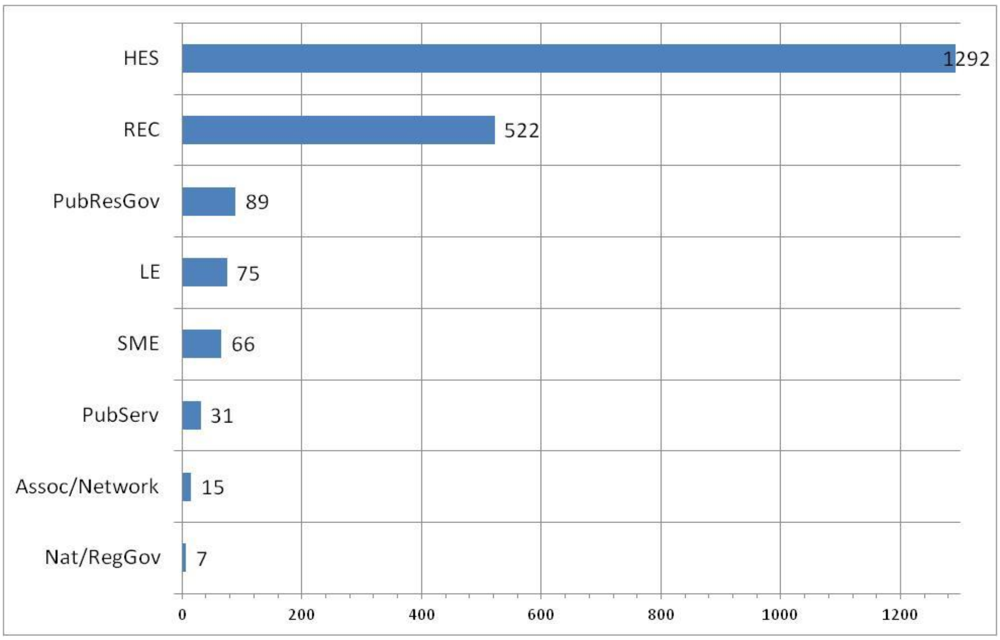
**Figure 109** Co-publication avtivities across organisation types in the P area




Project-internal co-publications. Total internal co-publications in the field of P: 92 (without same country co-publications). Source: Co-publication analysis.

Interesting patterns arise when looking at co-publication activities with project-external partners. As could be expected, academic organisations (HEI and RTO) have most external co-publications (Figure 110). Knowledge transfer within academia works well.

**Figure 110** Participation in co-publications with external partners in all fields




Source: Co-publication analysis, absolute numbers. Note that REC is RTO and HES is HEI in official labeling.

The high number of project-external co-publications of SMEs shows that also private enterprises are very active in sharing their knowledge from EU-projects with partners outside the project context. This means that results from EU-projects have not been kept inside the consortium but were dissemmiated and further developed by involving external partners from existing networks or by establishing new contacts.

Important questions are, how knowledge transfer networks come about and what mechanisms are used to identify and select new partners or refresh old collaborations at the beginning of a project. The case studies give us the respective hints. Of relevance for the forming of project consortia are:

- Personal relations, e.g. between professors at different universities, between senior researchers at research organisations and large firms, and between senior management of SMEs.
- Each research organisation or university to be involved in a project invites an SME from the same country, to join the consortium. This ensures that SMEs can trust and rely on a national partner, while increasing its international collaborations.
- Spin-offs from a university or large firm that seek to continue collaboration with their former parent company (and former colleagues).
- Client-supplier relations, e.g. developing a commercial relation between upstream and downstream firms into a research and innovation collaboration.

Interestingly, the case studies also revealed that most new collaborations were made between SMEs and research organisations and between SMEs and large firms. This concerned collaboration between actors from different countries but also from the same country.

The relevance of NMP projects for building networks and enhancing collaboration activities is confirmed by the survey results. These show that the respondents rate this effect as the most important in terms of effects of the projects on the organisation's competences.

#### *6.2.5 Conclusion*

Collaboration with renowned organisations in other countries and regions is one of the central motivations for participating in NMP projects. We investigated what the effect was of FP7 NMP on collaboration by analysing the publications and patents that were published together with partners inside and outside the consortium.

From analysing the co-publication patterns it can be concluded that the diffusion of ideas, concepts and applications triggered by EU-projects outside the involved community works well. There are even more project-external co-publications than project-internal co-publications in almost all areas, except for New Production Technologies. This means first at all that a much larger community of research organisations and perhaps companies is involved in the FP7 NMP than just the funded project participants and secondly that project partners use existing (research) networks and that they build new connections to disseminate project results or to develop ideas further.

# APPENDIX A: LIST OF INTERVIEWED EXPERTS

| Name | Function | Organisation | Field of expertise | Role in NMP-related groups |
|---|---|---|---|---|
| Miimu Airaksinen | Research Professor of Eco-efficiency of the Built Environment | VTT | Energy efficiency on building systems | E2BA board member as a representative of VTT |
| Chris Decubber | EFFRA, Research Programme Manager | EFFRA FoF Research Association | Manufacturing and production | Member manufacture implementation board |
| Karl-Heinz Haas | Deputy spokesman of the Fraunhofer Nanotechnology Alliance | Fraunhofer ISR | Nanotechnology, Nanosciences | Coordinator in FhG for Nanoactivities |
| Gereon Meyer | EFFRA, Research Programme Manager | VDI/VDE-IT | Green Car | Member of the PPP board |
| Herman Schoo | Senior Research Fellow | TNO | Production Process | -- |
| Bertrand Fillon | European VP | French Alternative Energies and Atomic Energy Commission | N, M, P and Integration | -- |
| Bastien Caillard | Project manager | European Virtual Institute for Integrated Risk Management | N, M, P and Integration | -- |
| Andrea Lazzari | Associate Professor | University of Pisa, Department of Chemical Engineering | N, M, Integration and PPP (GC) | -- |
| Ineke Malsch | Director | Malsch Techno Valuation | N, M, P and Integration, Social and ethical aspects | -- |
| Alexei Antipov | Manager on Nanomaterials | PLASMACHEM PRODUKTIONS-UND HANDELGMBH | N, M, P and Integration | -- |
| Birgit Bittmann | Technologietransfer | Institut für Verbundwerkstoffe GmbH | N, M, P and Integration | -- |
| Andrea Maria Ferrari | Unit Manager | D'Appolonia | N, M, P and Integration | |
| Dmitry Kashanin | CTO | Cellix Ltd | N, M, P and Integration | -- |

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This report is the annex to the Main Report with the main results of the ex post evaluation and impact assessment of the FP7 NMP Theme. The evaluation assesses the FP7 NMP Theme's strategy and rationale, programme implementation, efficiency and effectiveness. Also, it investigates whether the new directions chosen during FP7 – the launch the Public Private Partnerships (PPPs) - have delivered what they were introduced for.

This Annex Report holds six chapters, with the results of the six methodological parts of the evaluation study: Strategic context analysis, Portfolio and composition analysis, Case studies, Bibliometric and patent analyses, Large-scale survey and Social Network analysis. Each chapter can be read as separate document, with an introduction, explanation of the methods used and the results.

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