



Ex post evaluation and impact assessment of funding in the FP7 NMP thematic area

Main Report

EUROPEAN COMMISSION

Directorate-General for Research and Innovation
Directorate D — Key Enabling Technologies
Unit D.1 — Strategy

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Luxembourg: Publications Office of the European Union, 2015.

ISBN 978-92-79-45413-4
doi: 10.2777/844400

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EXECUTIVE SUMMARY

In December 2013 the European Commission's DG RTD mandated Technopolis Group and the Fraunhofer Institute for Systems and Innovation Research to perform the ex post evaluation and impact assessment of the FP7 'Nanosciences, Nanotechnologies, Materials and New Production Technologies' (NMP) Theme. The report at hand presents the most important findings of this evaluation and impact assessment.

The core objective of the FP7 NMP Theme was to improve the competitiveness of European industry and generate the knowledge needed to transform it from a resource-intensive to a knowledge-intensive industry. The evaluation was commissioned in order to get insight in the impact and achievements of the NMP Theme (as is done for all other themes in FP7) but also to investigate the results of the introduction of the **Public Private Partnerships (PPPs)** in 2010. The introduction of these new directions chosen under FP7 was one of the main actions of the €200bn European Economic Recovery Plan aimed at maintaining and creating jobs and strengthening competitiveness in Europe. Launching the PPPs was one of the main actions of the Commission in this regard. Another – related – novelty was that the NMP Theme was the first theme that positioned the projects in the innovation chain using the **Technology Readiness Levels (TRL) concept**. The concept was used to outline the different research and deployment steps supporting the process of transferring ideas to the market. Due to these developments the NMP Theme became a forerunner of the approach that was adopted in Horizon 2020, with as its main characteristic the integration of research and innovation activities.

Programme rationale

Even though the forecasts project continuing growth for the areas covered by the NMP and the PPPs, 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 by the NMP Theme in search of growth. The promise of growth in these markets rests mainly on innovation and the degree to which inefficiencies and barriers can be effectively minimised.

The FP7 NMP Theme has been successful in addressing a number of important barriers to innovation in these industrial sectors, such as the fragmented supply-chain and lack of collaboration along the supply chain, competition from low-cost manufacturing countries, the limited access to natural resources and raw materials, lack of testing and quality control of techniques and processes, and organisational problems encountered in re-developing, retrofitting and renovating old buildings. The rationale for having an NMP Thematic Area 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 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 chain. 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; the programme is now better matched with the needs of the specific sectors.

Programme implementation

The NMP Theme is clearly an industry-oriented theme and this focus was even more pronounced in FP7. **The FP7 NMP has been rather successful in attracting companies.** Overall industry participation in FPs has been decreasing: it fell from 39% in FP4 to 31% in FP6 and in 2010 it accounted for only 25% in FP7. Meanwhile in the FP7 NMP, business community participation accounted for almost 40% of EC funding and compared to FP6, rose from 55% to 68% of the unique participants. SMEs – an important target group of EC policies – even accounted for two-thirds of industry participants (in FP6 NMP this was about one fifth).

After the PPPs were introduced, industry participation increased from 46% of the participations in collaborative research projects in 2009 to 53% in 2013. The large firms are active in several areas; they do not stick to one specific area but participate in projects across the range of areas to the extent the call topics fit with their internal R&D needs. Putting the N, M and P together with Industrial Biotechnology under one label (NMBP) within the **Key Enabling Technologies** in H2020 confirms this trend.

Nevertheless, **companies did not frequently take a leading role**: indeed companies coordinated only 19% of the FP7 NMP projects. Considering the introduction of the PPPs in the second half of the programme, this comes as unexpected. Explanations can be many fold; companies can favour their in-house corporate R&D staff to rather work with external partners in the co-creation of innovations, fiscal restraint in recessionary times, opportunity costs (when putting corporate R&D staff in the position as project coordinator they are less available for other tasks). Also IP considerations might play a role as most useful IP is captured at the low TRLs and IP at the process scale up stage can be diluted in large projects and harder to protect.

As in FP6, also in FP7 the community of participants is geographically concentrated. **The EC has not been successful in attracting more EU13 participants to the programme.** The EU15 represents more than 80% of the participations and funding and 78% of all unique participants. The EU13 represent only around 9% of the unique participants and around 4% of the funding. In FP6 NMP participation figures were lower, funding figures higher for EU13.

Programme efficiency

After six Framework Programmes, the functioning of the supporting system and the administrative procedures has become more professional and they support well the project teams in their work. Programme participants are satisfied with most of them, but also have points for improvement. Respondents were positive about the support services provided by the responsible project officers (POs) and by project technical advisers, but also indicated that POs can be more pro-active in stimulating communication, community building and synergies between projects. Also they were very satisfied with 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. They 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.

Programme effectiveness: Scientific results

The scientific output of FP7 NMP is mostly found in publications: scientific articles and conference papers. Most of the scientific articles generated by the FP7 NMP funded projects stem from research organisations. Companies contribute only a few percentages, except for the New Production Technologies area; here SMEs contributed to almost one-tenth of the publications. The **level of excellence** of FP7 NMP scientific articles (measured by the share of highly cited publications and taking into account the limitations of citation data) is at least as high as the average level in the whole NMP landscape in the Web of Science.

Overall, it can be concluded that most projects have been very active in generating scientific publications and also achieved a remarkable level of scientific excellence. Interesting differences in scientific output can be observed between countries, types of research organisations, NMP areas, and project types. Some of these differences - such as the focus of research activities by universities or the allocation of area relevant publications to TRLs - 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 EU13 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.

Programme effectiveness: Economic results

Although many FP7 NMP projects are still on-going **already many economic results have been achieved.** The programme already has delivered various economic outputs that will provide a contribution to competitiveness of the European economy. Of the survey participants of finished

projects 60% have developed a new or significantly improved product and half of them report that this product has already been introduced at the market. Where market introduction took place, the new product is on average 5% of the company's total turnover. Nearly half of the survey participants report the development of new or improved manufacturing processes and about 60% report new or improved services.

SMEs are relatively more productive than large firms: they report on a larger scale the development of new or significantly improved products and services reached during the project, higher improved flexibility, revenue growth and employment growth. Also they report higher increase of the projects effect on reputation and image compared to LE participants.

PPP projects are more productive than projects in other parts of the programme: PPP participants - especially those from Factory of the Future and Energy efficient Buildings projects - are relatively more productive in terms of economic outputs than participants in other parts of the programme. Three quarter of PPP project survey participants report that they already have reached the development of a new or significantly improved product. Survey participants of on-going projects (that include relatively more PPPs) report consistently higher numbers for high and medium impact as compared to the participants of finished projects (such as the number of patent applications that is already done and expected by the end of the project).

The introduction of the PPPs has contributed to a **better balance** in FP7 NMP in terms of supporting different phases in the innovation chain. The **TRLs of PPP projects are relatively higher** than in the N, M, P and I areas, which was also concluded in the final assessment of research PPPs (2013). Also **industry participation is higher** after the PPPs were introduced. **It was a good decision of EC to change the strategy during the programme.** The EC has been successful in pushing the programme, to some extent, towards higher TRLs.

Programme effectiveness: European Research Area

The FP7 NMP Theme is part of the endeavour to create a European Research Area. The programme also works that way as collaboration with organisations from other countries and regions is one of the central motivations for participating in FP7 NMP projects. Moreover, FP7 NMP supports collaboration between different types of actors. This is also reflected by the fact that 75% of the FP7 NMP publications are co-publications.

Large firms more often publish with universities (confirming other studies that indicate that they are relatively more active in basic research as compared to SMEs), while SMEs publish more often with (application-oriented) RTOs.

Surprisingly it was found that there are **more project-external co-publications than project-internal co-publications** in almost all parts of the programme, except for New Production Technologies. 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 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.

Programme effectiveness: Societal and environmental effects

Societal and environmental impacts of FP7 NMP projects are considered as an intended side-effect of economic success (rather than the other way around). Project participants report on a variety of project results with societal and environmental relevance.

Dissemination of project results in order to reach a public that is interested in these results and in their societal and environmental aspects is mainly done by traditional communication channels and mainly reaches a scientific public. However, it seems there is potential for improvements regarding accessibility of social stakeholders in the broad public, such as by using social media.

European Added Value

The concept of European Added Value (EAV) refers to the rationale for public intervention and more specifically to the need for public intervention at the European Union level (versus Member States and regions). The evaluation results indicate several aspects of EAV: pan-European challenges, coordination of national policies, the dissemination of project results at a European scale, the opportunity of having enough critical mass and the leverage on private investments.

The FP7 NMP has a positive yet modest impact on coordination of national policies thus adding to less overlap between national efforts and increased knowledge exchange and collaboration between countries. Also FP7 NMP made it possible to perform research and other activities at a scale, and combination of different types of disciplines knowledge and skills that cannot be provided by an individual country. The access to specific knowledge and networks in other countries, the continuity in EU Framework Programmes and the leverage on private investment are main added values of the FP7.

Most supporting evidence for the added value of the FP7 NMP is that only 8% of the survey participants indicate that they would have undertaken the activities anyway, e.g. by using private funding (for national programmes this is much higher).

Recommendations: stakeholders' involvement and knowledge transfer

Involvement of EU13 in H2020

The EU13 participation in FP6 and FP7 was very small and it is very likely that this will not change in the future. The problem is even intensified by the fact that the NMP programme operates at high TRLs, hence close to the competitive environment and thus closer to allegations of supporting the industry in some member states and not in others.

This would be unfortunate as our analysis showed that the level of scientific activities (in terms of NMP-related publications) of a considerable number of EU13 countries is similar to that of many EU15 countries.

It is therefore recommendable that:

- *measures are taken to encourage inclusion of new partners in the Framework Programme in general.*
- *specific measures are taken to attain a stronger inclusion of partners from EU13 countries.*

One such specific measure could be to introduce in the H2020 NMP Work Programme under Coordination Activities a new sub-programme 'Bridging the Divide' (as under the Health Theme). Such a programme should be aimed at tackling the gap between European "innovation leaders" (mostly from EU15) and "modest innovators" in EU13. This gives them also the opportunity to learn from new ways of open and commercialisation-oriented innovation processes. The new partners - research organisations and companies from EU13 - should have a significant stake in the project activities. Such inclusion also ensures a stronger and wider spread European dimension in the innovation without compromising the quality of the research.

Role of RTOs

RTOs can play an important role as linking pin between the universities and industry. RTOs translate basic research results into relevant industrial applications, which is especially important for the medium-tech SMEs (this is less the case for large firms, which have R&D capacities and work directly with university researchers). In this way RTOs have an important role in the technology transfer and the development of regional clusters. RTOs have often been project coordinators in the FP7 NMP and built consortia based on their academic and industrial networks.

The case studies investigated in this evaluation revealed that consortia succeeded in involving a variety of companies, while at the same time avoiding competition within the consortium. Several interviewees referred to this well-known trade-off. There are several examples of consortia that were too dependent on one or two firms downstream the value chain and where innovation and commercialisation would have benefited from involving additional firms, e.g. firms that are active in different geographic markets and/or downstream sectors: specialised downstream SMEs as well as large firms. Such constructions are less likely to form under H2020, as companies will get a more leading role in consortia and may be less inclined to work with other companies.

To maintain optimal composition of consortia it is recommendable that:

- *the composition of H2020 consortia are actively monitored.*
- *specific attention is paid to identify where other companies might benefit from projects in order to achieve higher dissemination of results. RTOs can play a role in identifying and contacting these companies.*

Knowledge transfer and dissemination

Firstly, the projects within the FP7 kept to traditional ways of dissemination channels and mostly reached the scientific public. Communication especially to other companies than those involved as well as to the wider public is an area that could be exploited more. There is large potential for improvements in reaching economic and social stakeholders. All projects can put larger efforts into reaching a larger and wider audience and in that process use more channels than they have thus far, for example social media. The fact that the manufacturing sector is at the heart of many national industries and thus important for the competitiveness of countries and the European Union further underlines the importance that:

- *knowledge transfer and dissemination should be significantly enhanced.*

All projects are contractually obliged to submit the Plan for Use and Dissemination of Foreground (PUDF) with their final report. These plans must include sufficient information to allow the EC to trace them, and perform related audits or reviews. In order to improve and expand knowledge transfer and dissemination and develop specific tools to support project teams in this, it is recommendable that:

- *an in-depth analysis is made of the claims made in the PUDF reports on the actual dissemination outputs, thereby answering the questions listed above.*

This will provide insight in what goes well and where these processes can be improved and what instruments are best to facilitate knowledge transfer and dissemination.

Recommendations: TRL concept

The TRL concept is a proven concept for categorising the FP7 NMP funded projects and for measuring the progress in these projects along the innovation chain. However, it suggests that projects can only go to higher levels, thereby using a linear model of innovation that does not respect the interactive and systemic character of innovation processes with feedback loops throughout the process. Large firms are well aware of market needs and required specifications. Their involvement at lower TRL allows to feedback market relevant information (and experience) into conceptual and explorative research at lower TRL by translating these information and needs into research questions/challenges.

It is therefore recommended that:

- the systemic and interactive character of the innovation process is considered when using the TRL concept to position and monitor projects' progress and in that process keep TRL thinking open, flexible and permeable.
- TRLs are used for individual work packages, as their use for a large-scale project does not sufficiently reflect the complexity of these projects.

Recommendations: Now PPPs have been introduced

The introduction of the PPPs in FP7 NMP has been successful; it has contributed to a better balance in FP7 NMP in terms of supporting different phases in the innovation chain. Such balance between activities at all TRLs should also be kept as NMP enabled innovation is driven by strong interaction between scientific activities and innovative activities; there is no short cut to innovation.

PPPs are now a well-established part of H2020. The interviews with the project participants remind of specific effects and new needs that are summarised in the following recommendations:

- *In the Nanoscience and Nanotechnologies and New Materials areas there is room for increased emphasis on higher TRLs.*
- *Maintain the increased emphasis on PPPs but also accommodate more projects that focus on standardisation and regulation (e.g. government backed-up standards, certification, European harmonisation of regulation).*
- *Intensify ESIC-type of commercialisation support as consortia may lack expertise about IPR, business models, marketing, etc.*
- *With increased emphasis on commercialisation, there is room for supporting consortia that include a range of new actors and new collaborations that are very open to emerging technologies, radical innovation and new applications areas.*

Recommendations: Evaluation of Framework Programmes

A comparison of FP7 NMP with FP6 NMP could only be made for a few aspects. It is therefore recommended that:

- *Indicators are developed for all EU Framework Programmes that allow for comparison and similar methods of data collection.*
- *Evaluations are conducted at similar periods after the start of a programme, so that results can be compared. For instance six years after the start of the first projects and another impact analysis six years after the start of the last projects.*
- *An impact assessment is performed 2-3 years after the projects' end and compared with the projects' PUDF plans and PUDF's realisation overviews that have been made immediately after the projects' end.*

1. INTRODUCTION

In this report the main results of the ex post evaluation and impact assessment of the FP7 NMP Theme are presented.

The core objective of the FP7 'Nanosciences, Nanotechnologies, Materials and New Production Technologies' (NMP) Theme was to improve the competitiveness of European industry and generate the knowledge needed to transform it from a resource-intensive to a knowledge-intensive industry. The thematic scope of the NMP also included the integration of technologies for industrial applications focussing on new technologies, materials and applications to address the needs identified by the different European Technology Platforms.

This evaluation assesses the impact and achievements of the NMP Theme, and also investigates whether the **new directions chosen during the FP7** have delivered what they were introduced for. These new directions were initiated when the economic crisis hit at the beginning of FP7. This was the reason for the European Commission to reorient the NMP Theme towards more grand economic challenges and launch the Public Private Partnerships (PPPs).

The changes to the FP7 were part of the €200bn European Economic Recovery Plan (EERP). Its main objective was to direct investment in a smart way, in order to maintain and increase jobs and stimulate competitiveness in Europe. **Launching the PPPs** was one of the main actions of the Commission in this regard. The PPPs had the specific aim to support innovation in manufacturing, in particular in the construction industry and the automobile sector, which were sectors that were hit very hard by the crisis and that faced significant challenges in the transition to a sustainable economy. Instead of establishing legal entities the Commission used a more hands-on approach that permitted the fast start-up of activities and rapid implementation of the partnerships. The three PPPs were funded through the FP7 budget of five different EC DGs (Research, ICT, Transport, Energy and Environment). DG Research and in particular the NMP Theme was the main contributor of funds to the PPPs. The three PPPs are the Green Cars initiative (GC), the Energy-efficient Buildings initiative (EeB) and - to increase the use of technology in manufacturing - the Factories of the Future initiative (FoF).

Another – related – novelty was that the NMP Theme as one of the first themes started to work with positioning the projects in the innovation chain by – sometimes implicitly – using the **Technology Readiness Level (TRL) concept**. The High Level Group on Key Enabling Technologies and the NMP Expert Advisory Group used the TRL concept to outline the different research and deployment steps supporting the process of transferring ideas to the market. The EC followed this recommendation to systematically apply this definition in order to include technological research, product development and demonstration activities within its RDI portfolio.

Due to these developments the NMP Theme became a forerunner of the approach that was adopted in Horizon 2020, with as its main characteristic the integration of research and innovation activities. For that reason it is very relevant to investigate the effects of the redirections: what have been the effects of this new approach? And: How did the implementation of the TRL concept work?

The **questions** to be answered in this evaluation address: programme strategy and rationale and programme implementation, efficiency and effectiveness. The **methods for data gathering and analysis that** applied were: strategic context analysis, composition and portfolio analysis, bibliometric and patent analyses (including network analysis), case studies and a large-scale survey. Interviews with experts from research organisation, companies and industry organisations in the field of NMP and the PPP were held to validate the results of the strategic context analysis. The 51 case studies (using desk research and interviews with the project coordinator and at least one consortium member from industry) each focus on one NMP project. 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 1 January 2014.

In the next three chapters we present the results of the evaluation following the main evaluation issues: Rationale (Chapter 2), Execution and Efficiency (Chapter 3) and Effectiveness (Chapter 4). Following the reporting framework of the EC FP7 overall evaluation, we present the results on the European Added Value of the FP7 NMP Theme in a separate chapter (Chapter 5). The report closes with conclusions and recommendations (Chapter 6). The annex report, published separately, provides more detailed information on the methodologies applied, data used and specific results.

2. PROGRAMME RATIONALE

This chapter sets out the findings related to the appropriateness of the objectives of the FP7 NMP Theme in relation to the problems, needs or issues the policy intervention originally intended to address. First, the programme objectives are presented followed by the results of the analysis in which relevance of each of the FP7 NMP Thematic Areas has been set against the related socio-economic contexts of the different industrial sectors. The objectives of the NMP Theme have been analysed based on their appropriateness in addressing the needs and the problems of the European society and industry and how well the PPPs address the needs defined in the EERP.

2.1 Programme objectives

In the FP7 NMP an **objectives hierarchy** can be distinguished with the following categories of objectives:

- *High-level objectives* of the NMP Theme, i.e. EC policy objectives defined in the Europe 2020 and ERA policies and at the Framework Programme level to which the NMP Programme and the PPPs were intended to contribute. These objectives correlate with the intended 'wider', long-term impacts of the NMP Theme.

The FP7 NMP objective at this level is: to ensure transformation from a resource-intensive to a knowledge-intensive industry.

- *Intermediate or 'strategic' objectives* are set at the NMP Programme and EERP level and correlate with the intended mid-to-longer-term impacts such a strengthening EU R&D competitiveness in NMP.
- The FP7 NMP objectives at this level are:
 - To improve the competitiveness of European industry,
 - To implement decisive knowledge for new applications at the crossroads between different technologies and disciplines,
 - To create benefits for both new, high-tech industries and higher-value, knowledge-based traditional industries, with a special focus on the appropriate dissemination of RTD results to SMEs,
 - To enable technologies which impact all industrial sectors and many other of the FP7 Themes.
- *Specific and operational objectives* are for implementing the strategic objectives at the programme level.

The specific objectives relate to the objectives as formulated in the work programmes of the NMP Theme for the areas (N, M, P and I) and the three PPPs.

The operational objectives can be found in the detailed work plans at the level of action lines within the different components of the NMP Theme.

These specific and operational objectives correlate well with the shorter-term 'outcomes' of a programme, most often to the benefit of the direct participants, as well as to the 'outputs' of the funded activities (development of new knowledge).

In addition to defining the objectives of the individual components of the NMP Theme, we noted the following **changes and evolution of objectives** over time:

- In the first years of FP7 (2007 – 2010), objectives were mainly focused on the generation of new knowledge or innovation in general, without specific prioritisation of specific application areas or domains.
- The second half of FP7 was marked by a gradual shift towards more application oriented research in various industrial sectors, starting with the nanotechnologies component. In 2010, the EERP was launched, introducing the three PPPs related to NMP.
- Finally, the last FP7 NMP work programme of 2013 provides a bridge to Horizon 2020 by incorporating an orientation towards societal challenges¹.

¹ The set of projects related to this last work programme is not included in the case studies and survey of the evaluation.

2.2 Programme relevance

In the next six sections the socio-economic context of the separate technologies and PPPs are analysed with a focus on the main barriers that slow down innovation in the industrial sectors as they find their main applications and the needs for public interventions. On the basis of this, the extent to which the FP7 NMP Theme intended to respond to these needs over time at the various levels (NMP programme, topic areas and funding schemes) is assessed.

Nanoscience and nanotechnology

Nanotechnology is a key enabling technology that can be applied in a wide range of industrial sectors such as electronics, chemicals, engineering, health and pharmaceuticals, textiles and construction, defence and energy. This recognition has driven substantial public investment towards this technology since the early 2000s, and particularly in the EU since the start of FP6 in 2002.

There are a number of barriers that inhibit the advancement of nanoscience and nanotechnology across the Member States. Literature shows that the problems that feature most prominently include: access to funding, skills shortage, collaboration along the supply chains, and regulatory and legislative issues. In addition interviewed experts mention issues concerning inconsistent definitions of nano-substances used by FP7.

In the first part of the FP7 NMP the focus in this area was on basic research; the first calls² mostly targeted nanoscience research with few attention to the use of nanotechnology and addressing societal and environmental challenges. Lack of application targets and of support to production limited the potential impact of the activities in this area on the economic growth in Europe. During the second half of the FP7 NMP, this problem was addressed by a shift towards funding of application-oriented projects.

There are large sections of the action lines and call topics devoted to safety and to improving networks, coordination and supply-chains, both of which were highlighted as key problems. Safety is identified as a key problem in the chemical industry, which, after electronics is another major growth area for nanotechnology. This makes nanosafety an especially important and pertinent area to cover. The environment, health and safety science was new at the start of the programme. Supported by the NMP programme, the NanoSafety Cluster of experts evolved to create a European NanoSafety Strategic Research Agenda that was used throughout the FP7 for building the skills and science to support management of risks and regulation. The box below gives an example of a FP7 NMP nano-safety project.

NANOMMUNE, example of a Nano-safety project

The NANOMMUNE project (2008-2011) brought together researchers from Europe and the US in the field of nanotechnology and health and safety research. The main aim of the project was to establish a panel of read-out systems for the prediction of the toxic potential of existing and emerging engineered nano-materials. The NANOMMUNE consortium successfully implemented an integrative approach, not only in terms of scientific concepts (such as 'safety by design' in nanotechnology) but most of all in the production of knowledge on the toxicology of nano-materials which was previously unavailable. This may lead to an internationally harmonised assessment of the toxicology of specific materials, which may prevent possible trade disputes.

With respect to the skills shortages problem, one specific call in the Action line 'Cross-cutting and enabling R&D' aimed at improving the skills base thus addressing to this problem.

Overall, it can be concluded that this area is well tailored to the barriers and problems encountered, with no obvious or noteworthy omissions or unexpected inclusions.

For future activities, experts indicated that new foci of interest are needed in this area in order to ensure that it stays relevant for the needs of the community. Nanotechnology is developing very fast and companies are not always able to digest all developments. Companies indicate safety and training activities, nanotechnology standardisation and awareness raising activities as topics to be covered in future projects.

² The activities in the NMP Work Programmes are classified into areas that hold a number of action lines, and the calls for project proposals are structured along these action lines.

New Materials

Improving the properties of materials is one of the most recurrent industrial innovation activities, aiming at better functionality, performance, reliability, user friendliness as well as health and environmental compatibility. Other developments of interest include more sustainable materials (such as bio-based materials), composite materials, materials with self-heating or self-repairing properties, materials with reduced energy consumption, improved energy storage and energy transmission properties. The industrial sectors that are particularly involved in materials innovations are the chemical, automotive and metals sector.

There are various barriers to research and deployment of advanced materials. Most prominent are the fragmented supply-chain (insufficient information flow across the different actors in the chain, generating coordination and collaboration problems), competition from low-cost manufacturing countries, the limited access to natural resources and raw materials, and their respective cost over time. The commercialisation of advanced material technology requires an assessment of potential health and environmental risks. Standardisation of methods for new materials and properties is a related necessity.

Some of the New Materials action lines and call topics respond especially well to the key barriers and problems identified. Two action lines specifically, are aimed at networking, integration and coordination, with several call topics and projects in both of them tackling the fragmented supply-chain 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 addressed via specific call topics and projects geared at developing new materials to substitute scarce resources, and via research into new materials.

Overall, it can be concluded that the FP7 NMP action lines and projects are well tailored to address the barriers in the new materials field.

However, there is room for improvement. The new materials challenge was tackled too much from a basic research oriented perspective (i.e. the chemistry of the specific elements) rather than taking a more applied or industrial approach, with actions that could be readily implemented. 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. However, 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 more appropriate (this was the case for nanosafety). Finally, experts consulted insisted on standardisation as a key concept in both the materials and nanotechnology areas in order to enhance Europe's competitiveness and global positioning in the NMP Theme (see the box below for an example of an FP7 NMP project on standardisation of material testing).

NANOINDENT, example of a FP7 NMP material testing standardisation project

The NANOINDENT-plus project (2012-2014) was aimed at developing a standard process for so-called nano-scratch testing. This is a material testing method for characterising the mechanical and tribological properties of thin films and nanostructures and the adhesion properties of nano-layers as a twin method to nano-indentation. In the project the three most important producers of nano-scratching instruments in Europe, two standardisation bodies and three research organisations were participating. A proposal for such a standard was developed; the proposed standard is now in the procedure that all new items for standardisation undergo.

New Production Technologies

The advanced manufacturing industry forms a substantial component of the European manufacturing industry. Specifically for advanced manufacturing, the photonics, automotive and vehicles, and machinery sectors are important. Industrial production accounts for 16% of Europe's GDP and 80% of Europe's exports are classified as manufactured products. Figures published in 2013 say that 34 million people are employed in this industry and turn-over figures are still expected to grow³. Nowadays industry accounts for about 16% of EU GDP and the EC has set its goal that industry's share of GDP should be around 20% by 2020. The New Production Technologies area is used to fast-track new innovations across the manufacturing industry.

³ Eurostat (2013) Annual Enterprise Statistics, NACE R2.

However, the manufacturing industry faces several barriers to growth including:

- The outsourcing to emerging economies;
- The lack of qualified personnel;
- The lack of investment in education and training;
- A difficulty for employers to predict relevant skillsets required;
- The lack of financial capital;
- The fragmented manufacturing value chain;
- The lack of know-how on commercialisation of RD&I developments;
- The lack of information on benefits of technology;
- Uncertainty around new market opportunities.

The New Production Technologies calls cover a relatively broad set of topics in advanced manufacturing; from chemical synthesis and the exploitation of technologies to safety management. The majority of the projects focuses across four call topics, with 'adaptive production systems' accounting for 29.3% of projects.

The New Production Technologies area tends to attract research-based projects with a focus on the increase of production efficiency and new ways of production (see the box below for an example of a project funded under this area of the FP7 NMP programme).

F³ Factory, example of a New Production Technologies project

The F³ Factory project (2009-2013) was aimed at developing faster and more flexible production methods for the European chemical industry. This included the delivery of radically new 'plug and play' modular chemical production technologies and of holistic process design methodology applying process intensification concepts and innovative decision tools. The F³ Factory consortium was made up of 25 leading chemical companies and research institutions. Because the risks and financial expenditures are very high for developing such new technology platforms for delivering innovations faster to the market in the chemical industry, the efforts are shared between partners in a consortium.

The open backbone facility that was built (by INVITE GmbH, a 50/50 joint venture between TU Dortmund University and Bayer Technology Services GmbH) is an open innovation research facility for developing and demonstrating future manufacturing technologies and also serves as an education centre.

The area also addresses problems associated with inadequate networks and poorly coordinated supply chains; they are directly addressed in several calls, lines and individual projects. Therefore, it can be concluded that the scope of the New Production Technologies area allows for a range of activities that are closely aligned with the particularities and the problems of the advanced manufacturing industry. Their evolution fits within the wider context of a framework programme more focused on applications and activities of validation and scale-up of technologies. Sustainability aspects will be key for projects and employment in the manufacturing industry in the near future and several related call topics in the current NMP Theme.

Factories of the Future

The advanced manufacturing industry is a key driver for innovation, productivity, growth and job creation. The European manufacturing industry is directly targeted by the PPP Factories of the Future (FoF) aimed at addressing important grand challenges related to this industry such as environmental friendliness and high efficiency of resources.

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 2.3). The call with the highest level of project participation (12.7%) was 'Manufacturing processes for products made of composites or engineered metallic materials'. Compared to the New Production Technologies area, which attracted relatively more research-based projects, FoF projects have a more applied focus on specific industries and for that reason the FoF had a higher level of industry participation. 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.

Furthermore, 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. The FoF PPP does not specifically address issues such as skills shortage and lack of information on new technologies and their benefits. 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.

ENEPLAN, example of a Factory of the Future project

The ENEPLAN project (2011-2014) has the aim is to deliver a manufacturing planning decision support tool for the optimisation of the plant operation that will be able to be used from the conceptual phase of the product to the final dispatch of the product to the customer. Such a system must make it possible for manufacturing companies to be able to quickly shift between diverse manufacturing operations with short transfer, program and set-up times without compromises to quality, reliability and life-cycle costs, closely adapted to the single product and with considerable energy consumption reductions (30-40%). The consortium is composed of 12 companies from the manufacturing sector (and various parts of the value chain), and five research organisations.

One important issue raised by the experts was the synergies generated by the presence of production and manufacturing topics in this PPP. Although there might be some overlap (e.g. some transport projects with manufacturing components overlapping between the New Production Technologies area and FoF PPP), this can best be considered as a positive redundancy, which at the end helped combining different approaches to solve joint challenges in the field. Overall, experts agreed that the PPPs were a positive development to the programme.

Energy efficient buildings

Apart from its economic significance⁴, the construction sector is the highest in consuming energy in the EU (about 40%) and the main contributor to greenhouse gas emissions (about 36% of the EU's total CO₂ emissions)⁵. These factors highlight the importance of research and innovation on energy efficient buildings (EeB).

The main important barriers for innovation in this field are the long time for testing, development and industry take-up of construction materials, techniques and processes, skill shortages in the contractor and professional service sectors, credit constraints for new or retrofitted energy-efficient construction projects and lack of a holistic approach to the overall building operation. There is also the problem of information asymmetries on user needs, cost-effective energy saving opportunities and the return on investments of certain key technologies. Experts indicated 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 evident.

The calls and projects in the PPP EeB focus predominantly on problems at the intersection of technological developments and user needs such as faster and efficient retrofitting, coordination of building projects and technology installation as well as cost-effectiveness. Experts did not indicate specific themes or topics relevant to this area were omitted in the PPP. With the exception of skills shortages in the sector, which this programme is not designed to overcome, all key barriers highlighted are targeted by the calls, either implicitly or explicitly. The call topics address several of the identified barriers to innovation, including:

- Developing new means of producing energy-saving technologies;
- Making products more cheaply and efficiently, through use of - for instance - new materials;
- Reducing network fragmentation;
- Access to testing and quality control of techniques and processes;
- Organisational aspects in re-developing, retrofitting and renovating old buildings.

The experts stressed that due to this PPP, the perception of innovative solutions has changed in the building sector. Also the energy efficiency perspective has evolved from an exclusive focus on the building towards a more comprehensive value-chain approach, including aspects such as maintenance and impact on tenants and landlords. This PPP is considered as an optimal setting for

⁴ 30% of EU industrial employment with 48.9 million workers directly and indirectly dependent

⁵ Compiled from different sources mentioned in: EC (2010) Energy-efficient buildings PPP – Multi-annual Roadmap and longer term strategy. Prepared by Ad-hoc Industrial Advisory Group, EC/ERA/EeB PPP.

bringing together industry, researchers and other intermediaries of the building sector and fostering joint action for change. It reduced the barriers to competition that SMEs in the sector often find when establishing new ways of collaboration among actors in the industry, working towards new energy efficiency concepts for buildings.

RESEEPE, example of an Energy efficient Building project

The RESEEPE project (2013-2017) has the aim to demonstrate the improved building performance through retrofitting. It will technically advance, adapt, demonstrate and assess a number of innovative retrofit technologies must lead to a 50% reduction of energy consumption. The consortium is composed of 25 partners, mainly companies from the building sector and their suppliers and some research organisations.

Experts indicated that a stronger emphasis would be needed on the interaction among building components and systems, contributing to a more holistic picture of the challenges in the sector. According to one of the interviewed experts the so-called lighthouse calls (large-scale demonstration - first of the kind) in H2020 are a step in this direction. However, the shift from single projects with a clear focus on various research actions to such large-scale demonstration initiatives may prove to be too challenging for some project participants because of the intensive internal communication and the 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.

Green Cars

The rationales for the development of a green car are clear, as innovations to ensure the position of Europe's automotive industry at the forefront of this global sector would be of direct economic benefit. Also, the risks and economic cost of currently existing congestion and pollution provide additional rationales for focus on innovation this field. The introduction of this PPP facilitated the transition of the automotive industry towards a more sustainable mobility mode and it especially increased the commitment from industry to electric mobility. The preparation of a joint roadmap was a major contributor to this.

Obstacles to innovation that affect the development of the green car are the high cost of producing electric vehicle batteries, uncertainty about consumer demands and concern as to long-term reliability of current solutions (i.e. batteries), skills and network related barriers, the availability of a reliable and diversified supply of metals (i.e. for electrical motors and batteries), the path dependency in the wider national transport infrastructure and the negative spill-overs (first-mover disadvantage).

The list of projects awarded has an almost exclusive focus on batteries and corresponds well with the problems that were identified: cost of production of batteries, quality of batteries, and supply of necessary metals for batteries were all key problems pointed out. Experts have some concerns regarding the strengths of the links between this PPP and research carried out elsewhere under the NMP Theme. For example, it had weak links with 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 links were stronger in projects of the mainstream NMP areas, where synergies between materials and nanotechnology call topics were common and well established.

GREENLION, example of a Green Car project

The GREENLION project (2011-2015) aims to lead to 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. It includes advanced electrode development (develop materials for cheaper, safer and eco cells), cell design and assembly process development, battery module design and development, the pilot line manufacturing of electrodes, cells and modules, a Life Cycle Assessment and development of recycling/reuse strategies and finally the demonstration of the developed battery technologies. The consortium holds eight large firms, one SME and the rest of the 17 partners are research organisations.

The ERANET Mobility (co-funded by the EC, but outside NMP, as part of the FP7 ERA-NET Plus scheme) is complementary to the GC PPP; it aims at member state's cooperation in the automotive industry. The experts indicated that the GC PPP is working rather effectively and has made considerable progress in a short period of time; the ERANET could draw some lessons from this working experience.

The skills barriers are important as electro-chemical competencies are needed in battery research and production, and Europe still is far behind Asia in this area. The experts' main concern was how to increase the currently small numbers of competent employees. The need for vocational education of employed engineers was stressed as subject matter of the PPP, in particular in the areas of e-engine and energy management as well as light construction by new materials.

Other barriers that were pointed out in our analysis, e.g. consumer awareness and path-dependencies, are not addressed by the NMP part of this PPP, but might very well be addressed in the parts of this PPP funded by the other four themes.

2.3 Conclusions

Even though the forecasts project continuing growth for the areas covered by the NMP and the PPPs, 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.

The promise of growth in these markets rests mainly on innovation and the degree to which inefficiencies and barriers can be effectively minimised. The barriers that challenge most of the NMP and PPP areas can be summarised as:

- Regulatory barriers;
- Challenges related to globalisation;
- Internationalisation and trade;
- Skill shortages;
- Network and coordination challenges (specifically across the value chain and between industry and research institutions);
- Challenges concerning access to natural resources and raw materials that feed into the production function.

The **FP7 NMP Theme has been successful in addressing a number of important barriers to innovation in relevant 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.

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 chain. FP7 NMP in its first phase was focused 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 they dealt with the specific barriers to innovation in these sectors. In the next chapters it will be shown how this has worked out.

3. PROGRAMME IMPLEMENTATION

This chapter describes how the FP7 NMP programme was implemented in terms of distribution of funds and participation patterns. It then assesses the use of the TRL concept before addressing specific aspects of programme management, such as the role of several support services, (administrative and financial) procedures and the communication between EC and project participants.

3.1 Funding statistics

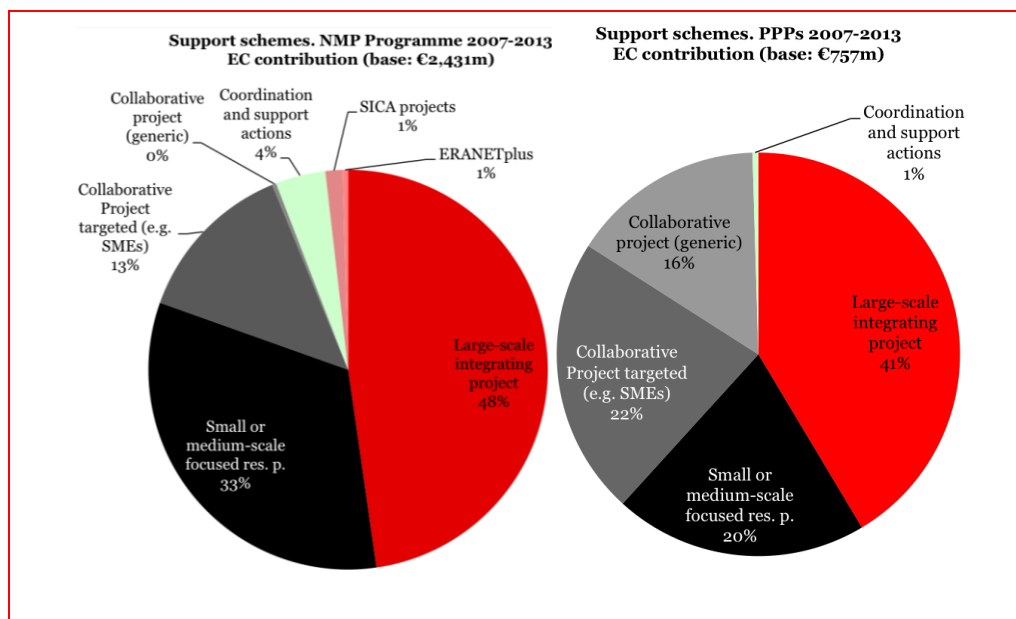
The FP7 NMP Theme comprised 799 projects, amounting to a total cost of €4,658.44m of which the EC has contributed €3,229.37m. The FP7 NMP budget represented 6.8% of the overall FP7 budget. Under FP6, EU funding for research in NMP was €1.53b, for 444 projects.

Each project in the NMP Theme belongs to a specific part of the programme. The programme is divided into four areas - N, M, P and I - and the three PPPs.

- Nanosciences and Nanotechnologies: This area makes up about 25% of all projects funded under FP7 NMP and accounts for about 23% of EC contribution, making it the largest of NMP areas.
- New Materials: This area makes up about 23% of all projects and accounts for about 21% of EC funding in FP7 NMP.
- New Production Technologies: about 13% of the projects and EC contributions are devoted to this area that is significantly smaller than the other areas but similar to the PPP Factories of the Future.
- Integration: This area comprises 19% of the EC contribution in FP7 NMP and around 20% of the projects.
- Factory of the Future PPP: About 13% of the projects and of EC contribution are devoted to this PPP. Funding by NMP theme is €400 m out of €600m EC funding; industry and EC each contribute 50%.
- Energy efficient Building PPP: This PPP accounts for about 7% of the projects and for 8% of total EC funding in NMP. Funding by NMP Theme is €250m out of total of €500m EC funding, industry and EC each contribute 50%.
- Green Car PPP: It comprises just 2% of the total number of NMP projects and 2.5% of EC funding in the NMP Theme. Funding by NMP Theme is €60m out of total of €500m EC funding; industry and EC each contribute 50%.

Projects can be funded through different support schemes. Large-scale integrating projects are at the core of the NMP Theme, with more than 45% of the overall funding (Figure 1).

Figure 1 EC Contribution across the FP7 NMP support schemes (2007-2013)



Source: eCorda data.

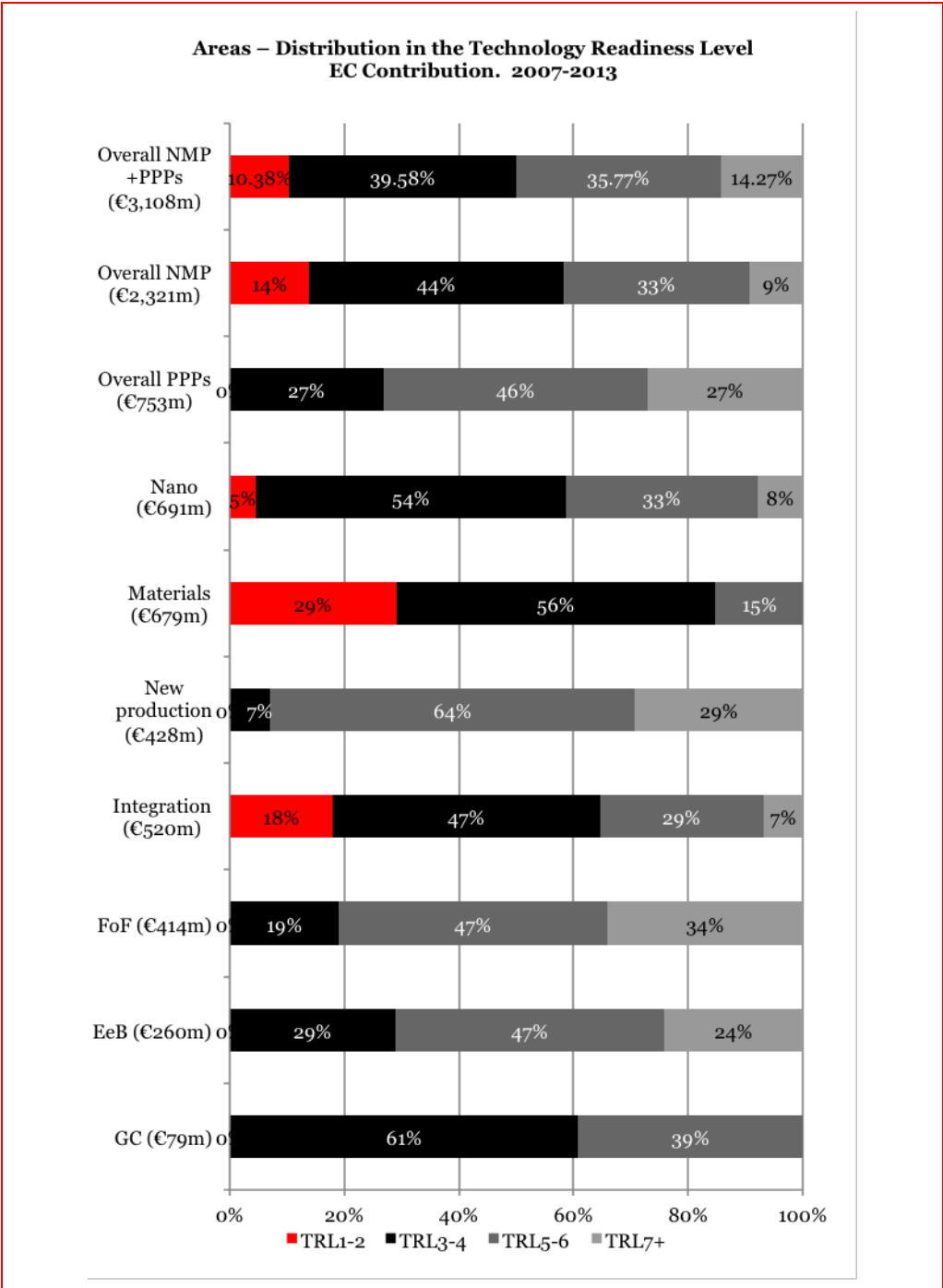
Small and medium scale research projects are the most numerous. Collaborative projects represent about a fifth of the programme, both in terms of the EC contribution and number of projects. Although Coordination and Support Actions represent around 13% of the programme in terms of projects, in terms of EC contribution their share is less than 4%. Amongst those, there are only a few ERANETplus projects.

There is a different use of the support schemes across the areas: Nanosciences and Nanotechnologies and New Materials hold a higher share of Small or medium scale focused research projects, while the Integration area contains larger shares of Large-scale Integrating Projects and Coordination and Support Actions than the others. This appears to be an appropriate use of the support schemes in the different areas, in line with their key objectives.

3.2 Technology Readiness Level of projects

The projects were categorised along their **Technology Readiness Level (TRL)**, as demonstrated in Figure 2.

Figure 2 FP7 NMP EC contribution across TRLs (2007-2013)



Source: eCorda data.

This categorisation was done based on information on the specific funding schemes, action lines and call topics for projects to which they belong. We used the nine-point TRL scale as suggested by the High-Level Group on KETs.

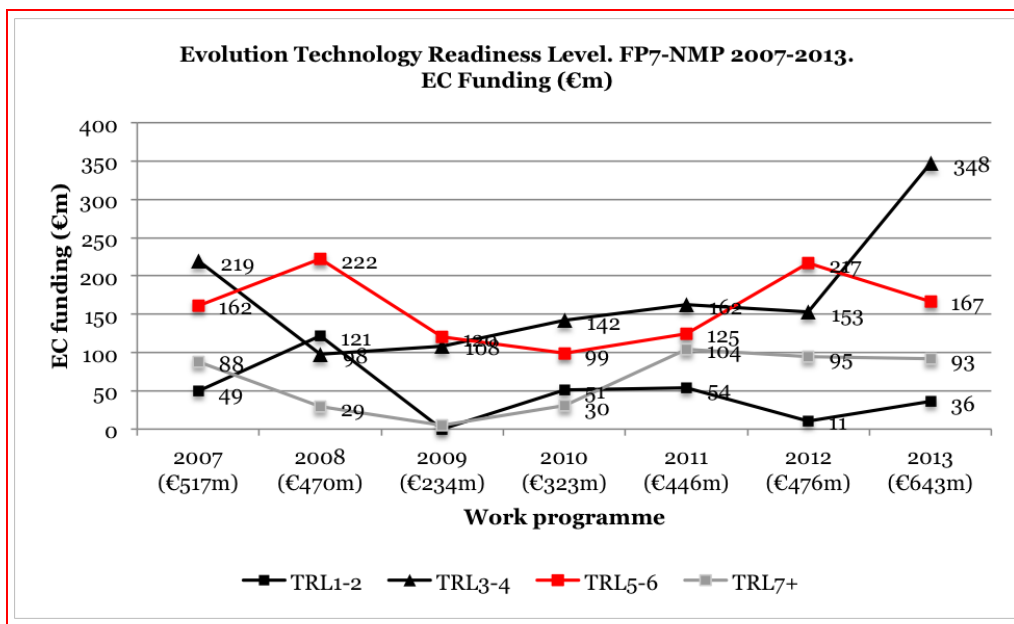
The figure shows that for the overall FP7 NMP Theme, more than 70% of the funding is for projects on TRL3-6, distributed in almost equal amounts over the TRL3-4 (lab validation/testing) and TRL5-6 categories (in situ validation/demonstration). As expected, in the N, M, P and I areas almost half of the projects and funding fall into TRL3-4 while for the PPPs the main share is in TRL5-6. The Green Car PPP is the most fundamental research oriented area within the PPPs. The New Production Technologies area has a TRL distribution that is close to that of the PPPs but with an even larger share of TRL5-6. New Materials is the area with a high share of the funding going to projects at lower TRLs. Still, the NMP Theme covers both extremes in the TRL scale too, with around 10% of the funding for projects at TRL1-2 (most Materials) and 15% at TRL7+ (New Production).

These outcomes match with those of the survey: about half of the respondents (48% of 2064) indicate that their role in the project is doing application-oriented R&D. Technology development & demonstration are less often mentioned (15%, resp. 12%).

Figure 3 shows funding allocations per work programme over the period 2007-2013. Overall, the distribution of EC funding between TRL4 and lower and TRL5 and higher remained similar (50%) across the period 2007-2013. The exception is the relatively large amount of projects at TRL3-4 funded in 2013. The 2013 NMP work programme document mentions that the emphasis of the work programme will be in demonstration and innovation activities, including pilots and scale-up to the industrial environment, while the description of the actual calls for projects shows that the technologies that are being covered are more in the lab phase than in the industrial phase, which means TRL3-4.

The case study interviews also revealed a number of **drawbacks in using TRLs** to position the projects. One project can include the development of a set of technologies that are operating at different TRLs. This is common practice in large and/or integrative projects (we found examples in at least half the PPP case studies). Also development and pilot activities in a project might give rise to the need for additional research, before a second pilot is planned, so it can happen that development of technologies at several TRLs takes place in parallel in a project.

Figure 3 FP7 NMP: Distribution of funding across annual work programmes by TRL



Source: eCorda data.

The interviews showed several examples of different interpretations of the (main) TRL of the same project. For example, interviewees mentioned the difficulties in distinguishing between different types of lab pilots, field pilots and small-scale demonstration pilots, and in positioning the pilot project at a specific point between TRL 4 and 7. To a large extent, this is due to the terminology used in the definition of the TRL concept, e.g. the nuanced differences between a technology, subsystem and system and between a relevant and operational environment.

3.3 Participation patterns

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

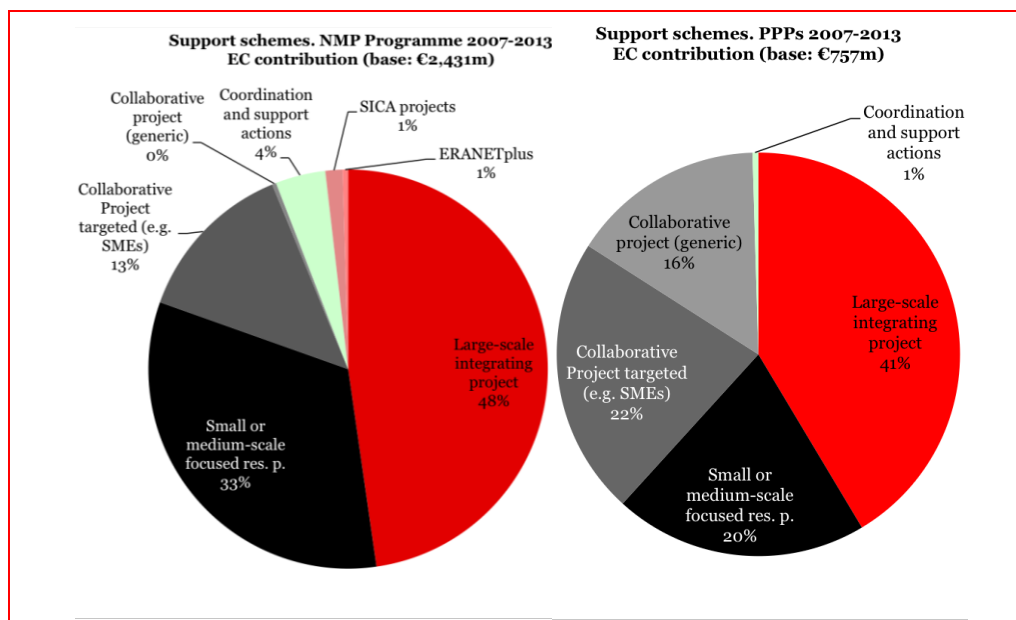
organisations within all publishing organisation in the NMP topic in the WoS (2008-2013) an estimated 4,584 unique participating organisations correspond to 1/6 - 1/10 of the total EU28 organisations publishing in NMP.

The **business community** participation accounts for almost 40% of EC funding and 68% of the unique participants (in FP6 NMP this was 55%). The share of large enterprises (LEs) involved is significant, with 20% unique participants. Small and medium-sized enterprises (SMEs) are most numerous and account for the rest of the unique industry participants (48%). In FP6 NMP about one fifth of company participation was SMEs. SMEs also received more EC contribution than LEs (Figure 4). After the PPPs were introduced (in 2010) business participation increased: from 46% of the participations in collaborative research projects in 2009 to 53% in 2013.

Research organisations accounted for 59% of the EC funding and for about 30% of the participations (34% in FP6 NMP). Participation is evenly distributed between Higher Education Institutions (HEI; universities mainly) and Research and Technology organisations (RTOs). Other types of participants - such as associations, networks and public services - are only marginally involved. Participant of RTOs dropped from 52% of the participations in collaborative research projects in 2009 to 44% in 2013.

There is a core group of 275 organisations that participated in more than six projects and 41 of them are companies (15%).

Figure 4 EC contribution across stakeholder types (2007-2013)



Source: eCorda data.

The community of participants is **geographically concentrated**. Participants from 71 different countries took part in the NMP programme, but 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; overall, Germany received almost double the funding of any other main participating EU15 country. The newer EU member states (EU13) represent only around 9% of the unique participants and around 4% of the funding. For EU13, participation figures were lower for FP6, funding figures higher.

Germany accounted for the highest share in project coordinators (18%), followed by Spain (15%), UK and Italy (just over 12%). Most project coordinators are from research organisations: from RTOs (40%) and HEIs (32%). RTOs often play a pivotal role in pre-competitive technology R&I and are a linking pin between research partners and companies. Only 19% of the project coordinators are from companies (LEs and SMEs). On the other hand, in FP6 NMP 40% of the project coordinators came from SMEs and commercial organisations. In case the latter are large enterprises and other types of companies, then the number of coordinators from industry has decreased considerably.

The areas with 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 Nanoscience and Nanotechnology and Materials. SMEs are more numerous than LEs in almost all areas except for the GC PPP. This reflects the market

structure of the industry sectors involved as well as the fact that LEs work more often at lower TRLs than SMEs. HEIs are more numerous and represent a higher share of the funding than RTOs in all areas except for the FoF and EeB PPPs. Public sector stakeholders (4.4% participations) are most present in the Integration area and EeB PPP.

A more **detailed profile of the industry participants** came from the survey. About 22% of all industry survey participants are active in technical and R&D services, 15% in the electronic, electrical and optical equipment sector, 14% in the machinery and equipment sector and 10% in the chemical sector. The other 39% are active in 13 different industrial and service sectors. The SME and LE profiles are more or less the same for the main three sectors. It was found that companies targeting a specific sector (for instance automotive) are not active in one specific area or PPP but participate in projects across the range of areas to the extent the call topics fit within their internal R&D needs.

An important aspect of the FP7 NMP Theme is that it brings together companies from different parts in the **value chain**. From the survey we learn that from the 147 industry participants (from the 313 that identified themselves as technology developers) 47% are suppliers (material, parts, components, systems), 25% are service providers and 28% are producers of finished goods.

3.4 Programme support and communication

The support services provided by the responsible project officers (POs) and by project technical advisers (PTAs) were assessed as positive by more than three quarters of participants to the survey (N=1454, resp. 1534).

The expertise, communication skills and flexibility of the POs is appreciated; the case study interviewees mentioned the quality of the PO as one of the key criteria for an efficient and effective project. But POs can be more pro-active in stimulating communication, community building and synergies between projects. As they have the overview of relevant projects they can stimulate project coordinators to liaise with other projects, exchange project results and collaborate in organising workshops and conferences. Also POs should attend more project meetings to give timely feedback about the project, advice on administrative matters, and provide early signals about changes in the EC's priorities. There is critique on the number of changes of the PO during the course of the project. PTAs were appreciated, as most of them are well-informed and constructive peers with a real interest in the project.

Less survey respondents (N=860) assessed (and probably used) the services provided by the National Contact Points (NCPs) in the member states. Most of these respondents (91%) were positive about the NCPs' services.

The EC offered Exploitation Strategy and Innovation Consultants (ESIC) services to FP7 NMP projects to enhance the positive impact of projects in terms of exploitation and innovation. The services offered included business plan development, exploitation strategy seminar, project risk analysis and assistance with patenting and standardisation issues. Respondents who used ESIC services valued them; only 11% indicated the services as poor (N=780). The case studies showed that the consortia invested in dissemination of project results to companies and other stakeholders outside consortia. Several interviewees considered ESIC services and especially the Exploitation Strategy Seminars as effective tools for supporting technology transfer and commercialisation. However, the extent to which this leads to economic impact, proved to be difficult to assess by project coordinators and other consortium members that have been interviewed.

The survey respondents were very satisfied with 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. They 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. The case study interviewees confirmed several of these findings and did several recommendations for improving procedures and support systems.

Survey respondents were satisfied with the communication with the EC; nearly the half of them said it was 'excellent' or 'very good' and another 40% said 'good' (N=1859). Case study interviews show that online communication and collaboration tools are becoming normal, but face-to-face contacts remain crucial.

3.5 Conclusions

The NMP Theme is a clearly industry-oriented theme and this focus was even more pronounced in FP7. The **FP7 NMP has been rather successful in attracting companies**. Overall industry participation in FPs has been decreasing: it fell from 39% in FP4 to 31% in FP6 and in 2010 it accounted for only 25% in FP7.⁶ Meanwhile in the FP7 NMP, business community participation accounted for almost 40% of EC funding and compared to FP6, 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. NMP is not the only theme that is successful in attracting companies; the others are Transport, Security and Energy.⁷ Nevertheless, **companies did not frequently take a leading role**; indeed companies coordinated only 19% of the NMP projects. Considering the introduction of the industry-oriented PPPs in the second half of FP7, this comes as unexpected.

The LEs are especially active in several areas; they do not stick to one specific area but participate in projects across the range of areas to the extent the call topics fit with their internal R&D needs. Putting the N, M and P together with Industrial Biotechnology under one label (NMBP) within the **Key Enabling Technologies**, in H2020 confirms this trend.

As in FP6, also in FP7 the community of participants is geographically concentrated. **The EC has not been successful in attracting more EU13 participants to the programme**. The EU15 represents more than 80% of the participations and funding and 78% of all unique participants. The EU13 represent only around 9% of the unique participants and around 4% of the funding. Similar figures applied for FP6 NMP.

After six Framework Programmes the functioning of the supporting system and the administrative procedures have become more professional and they support well the project teams in their work.

4. PROGRAMME ACHIEVEMENTS

The benefits of the NMP Theme are substantial and come in many forms, flowing through various 'exploitation channels' (scientific, economic, etc.) and also over different time scales. The direct output of the projects and their expected impact on economy and society and ultimately their contribution to the conversions into a knowledge-based economy, to European competitiveness and the objectives of ERA and the Innovation Unions is the focus of the evaluation when it comes to effectiveness. The next three sections present the scientific and economic results and the effects on cooperation and transfer of knowledge and technology. The last section presents the societal and environmental aspects of the projects.

4.1 Impact pathways: building a knowledge-based economy

Publication results

Following the intervention logic of the FP7 NMP Theme, impact pathways towards building a knowledge-based economy can be found in several types of direct outputs of the projects. Results of the survey and the case studies reveal that scientific publications are the most numerous quantifiable output of FP7 NMP funded projects. About 75% of the survey 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 on-going projects present high publication activities. Almost 50% of these projects have already achieved their publication goals and 70% of the survey participants expect that they will have several publications by the end of the project.

The FP7 NMP consortia used a broad range of publication types for generating output. These include scientific articles, conference papers, and 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.

⁶ FP7 Interim Evaluation Report.

⁷ Ibid.

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

The **national distribution** of these publications indicates that about 90% was generated by EU28 and the other 10% by non-EU countries. This distribution is similar among the difference areas. In the case of the PPPs and also Nanoscience and Nanotechnology the share of non-EU28 countries is slightly above 10%. Within EU28 most publications were contributed by organisations from Germany (16%) followed by Italy (14%), United Kingdom (12%), France (9%), Spain (9%), and Sweden (8%).

We made an analysis of the **global NMP landscape** in the Web of Science (WoS). It showed that in the period 2008-2013 worldwide 1.3 million NMP publications were produced and included in the WoS. China turns out to be the most important scientific region as measured by scientific publications (28% of all NMP publications), followed by EU28 (25%) and the US (15%). The leading role of China is most prominent in the fields Materials (31% of all publications) and New Production Technologies (28%). The US (24%) and EU28 (27%) are the worldwide leading regions in Nanotechnology; here the Chinese share drops to 21%.

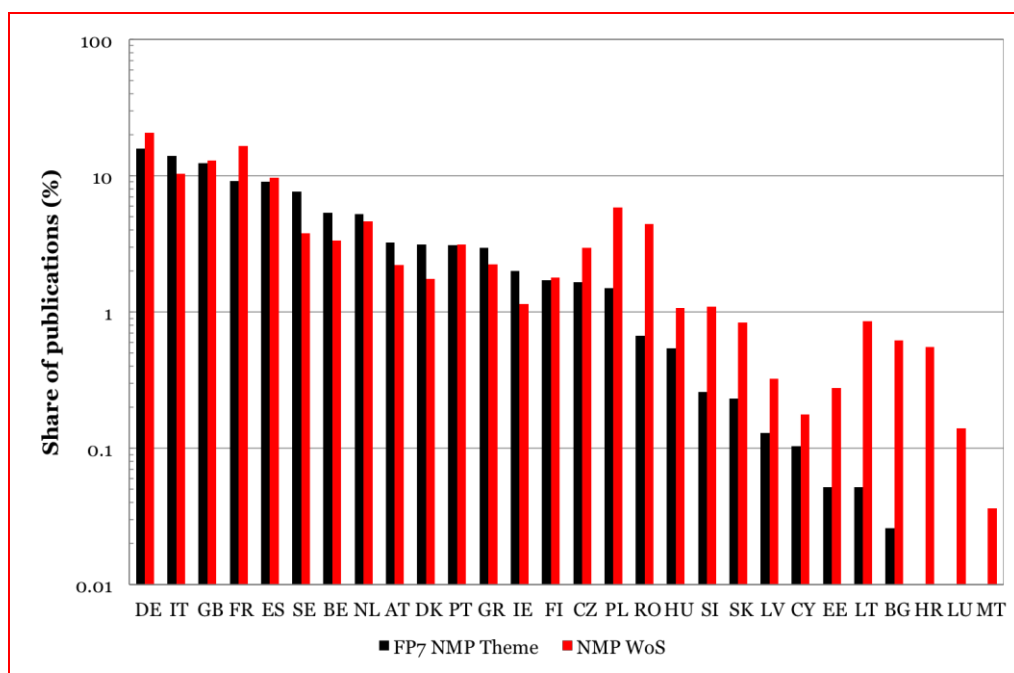
At the European level, German researchers publish most on NMP (18% of the publications) followed by researchers from France (15%), the United Kingdom (11%), Italy (9%), Spain (9%), Poland (5%) and the Netherlands (4%). A similar ranking is observed for the N, M and P areas.

A comparative analysis of the country specific publication output from the FP7 NMP funded project with this general NMP landscape (Figure 5) presents two types of countries.

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 that are less represented in FP7 NMP publications compared to the general NMP scientific landscape (in the figure the green bar is lower than violet bar). Again two subgroups can be differentiated: larger established countries which are contributing most of the publications (at the left side of the figure) and a number of smaller countries mainly from Eastern Europe which are only weakly represented in FP7 NMP (right side of figure). This general pattern is reflected also in the different NMP areas.

Figure 5 Comparison of publication activities of EU28 countries between FP7 NMP funded projects and the general NMP landscape



Source: Web of Science, SESAM database.

The observed distribution seems to indicate that there is a group of countries (Sweden, Belgium, The Netherlands, Austria, Denmark, Greece and Ireland) that was rather 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 EU13 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** not surprisingly indicates that most publications stem from universities (64%) followed by RTOs (29%). LEs 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 Nanoscience and Nanotechnology and New 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 LEs are most active compared to other area (7% of all publications). PPPs on the other hand are characterised by very strong contributions of universities and to a lesser extent SMEs while LEs and RTOs are underrepresented compared to their role in the total NMP scientific output.

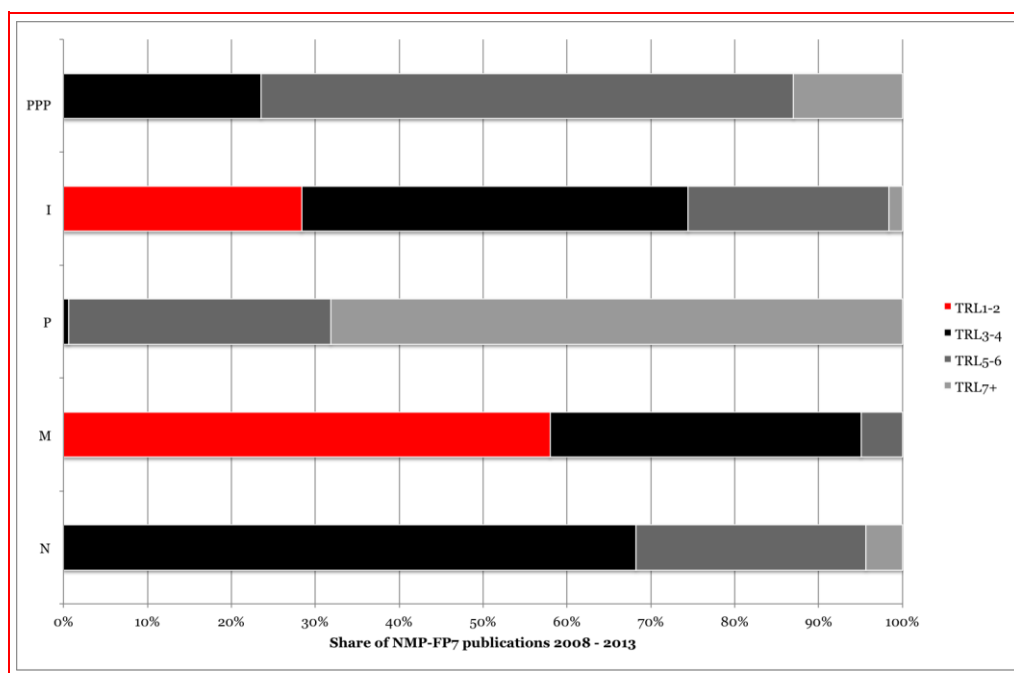
The **size of the consortia** has no clear relation with the level of publication output. The specific scientific output (publications per project) related to the number of project participants is rather robust at an average of 14 publications.

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.

Scientific output by TRL

The analysis of scientific output by TRL indicates that most publications are assigned to TRL 1-2 (30%) and TRL 3-4 (44%). 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 principals 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 area reveals a number of remarkable differences between the different topics (Figure 6).

Figure 6 Share of publications from FP7 NMP funded projects by TRL



Source: SESAM database.

Publications in the New Materials area decrease with growing TRL. They are most prominent at TRL 1-2. Publications in the Nanoscience and Nanotechnology area are mainly on medium TRLs. 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. PPPs related publications are classified to higher TRLs. This distribution reflects on the one hand the type of research activities within the different subfields: New Materials research is mainly concerned with basic questions (discovering principles and concepts); research activities in Nanoscience and Nanotechnology can be considered as more advanced in terms of TRL. Not surprisingly New Production Technologies research activities are assigned to higher TRLs.

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 6 also indicate that multiKETs-related research activities are taking place mainly at low to medium TRLs. All in all this analysis also confirms that the TRL classification is a valuable approach towards characterising scientific output of FP7 NMP funded projects.

Impact of scientific activity

The level of excellence of the scientific output was measured using highly cited papers as an indicator for excellence. 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 4,758 publications 22 publications emerged from FP7 NMP funded projects. This corresponds to 0.56% of all FP7 NMP publications. It should be noted that the citation behavior 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 a 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 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 survey participants developed thematic research databases and about 46% of these participants (in particular CSA projects) were involved in building 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 survey 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 the 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 had a temporal exchange of personnel (where this is rather common), also 19% of SME participants had. Also the projects 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, a number of barriers to impact generation were 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. 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 these 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 the three main enablers for achieving scientific and technological impacts are sufficient budgeted, continuity in funding by public and private organisations, and efficient and effective collaboration among experts and between experts and stakeholders.

Conclusions

Overall, 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 in scientific output between countries, types of research organisations, NMP areas, and project types. Some of these differences - such as the focus of research activities by universities or the allocation of area relevant publications to TRLs - 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 EU13 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.

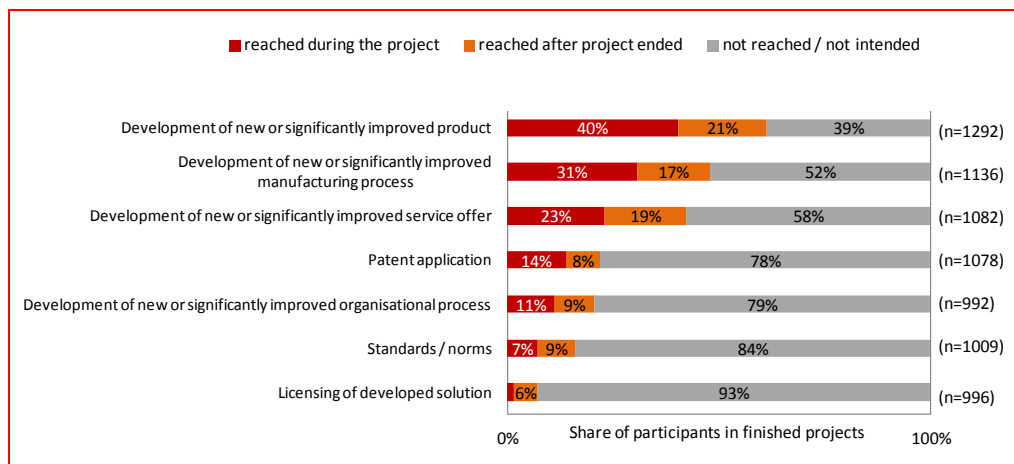
4.2 Contribution to competitiveness of European economy

New products, processes and services

The large-scale survey participants of both finished and on-going 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 7). 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. 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.

Figure 7 Economic effects of finished projects



Source: Large-scale survey. The question was: Which results were realised in the funded projects?

On average more than half of the developed services already reached market introduction. As R&D services get much quicker into the market, the output for services is higher than for developed products. 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). However, there are huge differences between the parts of the programme: services developed in projects in the New Production Technologies area are more marketed than of other parts, with the PPP projects as the least performing (which might not be surprising as these are mostly led by manufacturing companies).

The above applies for the finished products. For the on-going projects, it applies that - similar to the finished projects - many results will be reached after official project end. Nevertheless, one fourth of product developments and half of new services that have been developed in these on-going projects have already reached market introduction. Furthermore, the participants of on-going projects are quite optimistic. Half of the participants that have no market introduction yet of their finished or planned product innovation expect a market introduction within two years after project end.

SME survey participants reported on a larger scale - compared to LE participants - the development of new or significantly improved products and services reached during the project. Hence the NMP

Theme succeeded in compensating the structural disadvantages of many SMEs compared to LEs when it comes to the development of innovative solutions. Also SME participants reported higher achievements for improved flexibility, revenue growth and employment growth, than the LEs. Also they report higher increase of the projects effect on reputation and image compared to LE participants.

Differences between programme parts

If we differentiate between the separate parts of the programme 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.

Also the case studies revealed that economic impact differs between the areas and PPPs. For instance, especially in the EeB and FoF PPPs, interviewees mentioned a broader range of economic impact already realised, especially, expected economic impact after the project end. There seems to be a cut between limited economic impact areas (N, M, I and GC PPP) and more substantial or immediate economic impact areas (P, FoF and EeB PPPs). The results for FoF and EeB can be explained partly by high TRL, but one would expect such performance also for the GC PPP. It might be that this PPP has a more long-term strategy (aimed at battery building) and more short-term goals are addressed in parts that are funded by other parts of the FP (such as electronics by DG Connect).

Market introduction

One third of the survey respondents (34%) report that new and improved products developed in the finished projects are already introduced in the market. Another 13% expect that their products will be at the market in within two years after project end and 26% more than two years after the projects end. 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 turnover the companies had achieved with their new product is on average 5% of their total turnover the median share of turnover reached with the new product innovation is 5% (N=103 companies).

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

Quality, flexibility and productivity

More than half of survey participants of finished projects report 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. Relatively few improvements in productivity increases or cost savings could be realised, which is rather typical for early development stages of technology. Survey participants of on-going projects report consistently higher numbers for high and medium impact as compared to the survey participants of finished projects. The differences between the two groups probably result from the fact that the participants of on-going 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 PPPs. The SME participants in the survey report higher improvements for improved flexibility, revenue growth and employment growth, than the LEs.

Case study results confirm the survey results that there is an emphasis on quality and flexibility. Some case studies report about second-order economic impact such as increased productivity, competitiveness, employment and revenue growth.

Spin-offs

The creation of spin-offs seems to be relevant only for a small part of the survey participants, as only 6% of the survey participants of finished projects report that the project led to the creation of a spin-off. For the on-going projects this is 2% and another 10% of respondents for the on-going projects expect this to happen in the near future. Case study analysis revealed three to four spin-

offs; including a Tecnalia spin-off in the HARCO project and a Technical University of Vienna spin-off in the PHOCAM project, (see box below).

Lithoz, spin-off from PHOCAM project

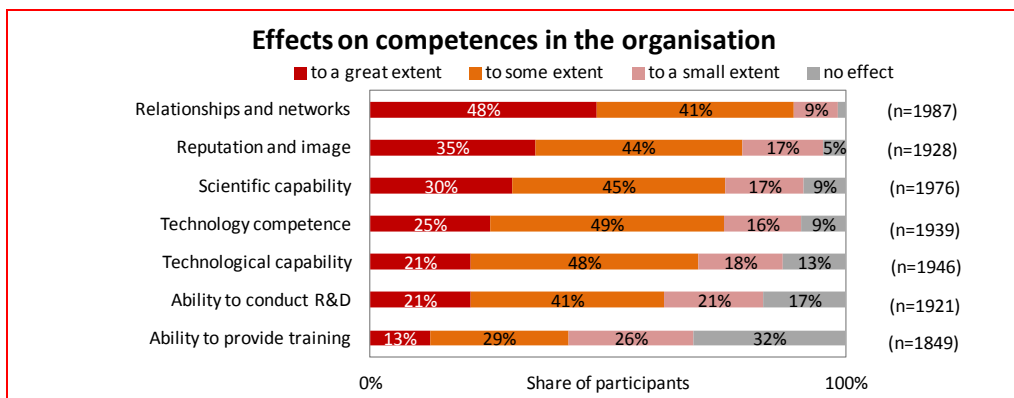
The focus of the PHOCAM project is to unite industrial know-how in the field of supply chain and quality management, software development, photopolymers and ceramics, high-performance light-sources, system integration and end-users in order to provide a fully integrated process chain at the end of the project. The consortium uses two main technologies: digital light processing (DLP) and two photon polymerisation (2PP) for the fabrication of high-resolution structures. Based on the results of the project the University of Vienna has created a spin-off, Lithoz. The company developed the patented Lithography-based Ceramic Manufacturing process and specialises in the development and production of ceramic materials and additive manufacturing systems (3D printing) for the production of high-performance ceramic prototypes, small scale series and complex parts and sells the manufacturing systems to industry clients, including consortium partner Emil Brol. Four (of the seven) partners in the project also are working on commercialisation of the project results.

Competences

The projects also contributed to the improvements of several competences of the participants: most to 'relationships and networks' (see Figure 8). This high score on relationships and networks confirms that a more innovative ecosystem makes R&D more efficient. Also it reflects the importance of open innovation and value chain in project consortia.

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

Figure 8 New competencies within the firm or research organisation



Source: Large-scale survey. The question was: To what extent did the projects' activities affect the overall competitiveness of the participating firm or research organisation?

Case studies reveal that the main barrier for achieving economic impact is a lack of commercialisation strategy at consortium level and at the level of some consortium members ('moving on to the next project'). Also, an imbalance in the consortium with very few consortium members being responsible for commercialisation or with too small or too national downstream partners is not conducive for economic success.

Results measured in change of TRL

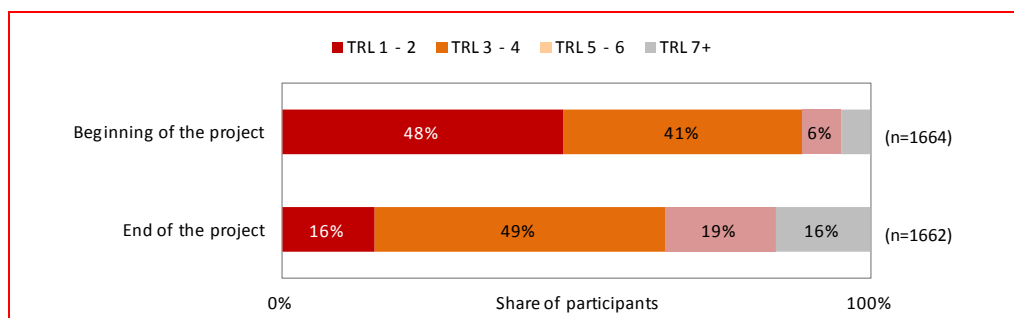
Within the scope of analysis of **economic output by TRL**, the case study results suggest that obviously economic impact is more substantial and clearer for projects with high TRLs. Case studies about the EeB and FoF PPPs describe a rich mix of output, including pilots and demonstrators. As such, high TRL projects 'add up' the different types of output, from academic publications to demonstrators. In between the 'extremes' of fundamental research 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.

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. TRL at end of project was between 5-6 or 7+ for

35% of participants. This means that overall the projects' TRL clearly increased during the project (Figure 9).

In general, at the beginning of projects there is a relatively high share of low TRL-levels, which indicate rather basic research at an early stage in the research and innovation chain. This might be right for the beginning of the NMP programme, which was a booming period of nanotechnology and the programme profited from it. If we look in detail on the areas we see that participants from New Materials are relatively often found at TRL 1-2. In New Materials basic research seems more widespread as in the other areas Nanoscience and Nanotechnology and New Production Technologies.

Figure 9 TRL at the beginning and at the end of the project



Source: Large-scale survey.

SME survey 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 LEs. Generally, SMEs are often technical process specialists when it comes to the engineering solutions of new technological solutions.

Patents

The analysis of FP7 NMP output in terms of patent applications reveals a total of 287 patents until October 2014; EU28 contributed for 90% and non-EU28 the other 10%. Survey respondents stated that most of the patent applications were filed at the European Patent Office or at national patent offices in EU member states. Patent applications in the United States or in Asian countries are not widespread. The largest share of the areas of NMP is contributed by New Materials (31%). For PPPs only eight patent applications could be identified until October 2014. Accordingly, more detailed analyses of PPP patent output are not feasible. Compared to the number of publications the number of patents is rather low. One reason for this could be the difficult release of process patents; companies tend to keep new processes secret particularly in the nanotechnology and materials areas.

In order to find out whether the role of individual countries in patenting activities based on FP7 NMP funding is similar to the global NMP patent landscape, a comparative analysis was made. Worldwide a total of 76,603 patents were filed in the field of NMP, (2008-2011). The main European countries contributing to this were Germany (43%), France (15%) and the United Kingdom (8%). Most patents were filed in the New Material (55%) followed by New Production Technologies (41%). Nanoscience and Nanotechnology (10%) and Integration (6%) had low shares of patent applications. When comparing the global NMP patent landscape with the patents based on FP7 NMP projects we observe three groups of countries. A first group is characterised by far larger shares of patent applications in the NMP landscape compared to FP 7 NMP funding. These include Germany, the United Kingdom, the Netherlands, Sweden, Austria and Finland. A second group has roughly identical shares. France represents this group. A third group of countries is characterised by higher shares of patenting activities within NMP-funded activities compared to their role in the total NMP landscape. These countries include Belgium, Greece, Ireland, Italy, Poland, Portugal and Spain. A similar situation is observed at the NMP areas level. This comparison indicates that the NMP funding was successful in motivating those countries to generate IP which are less active in the total NMP landscape.

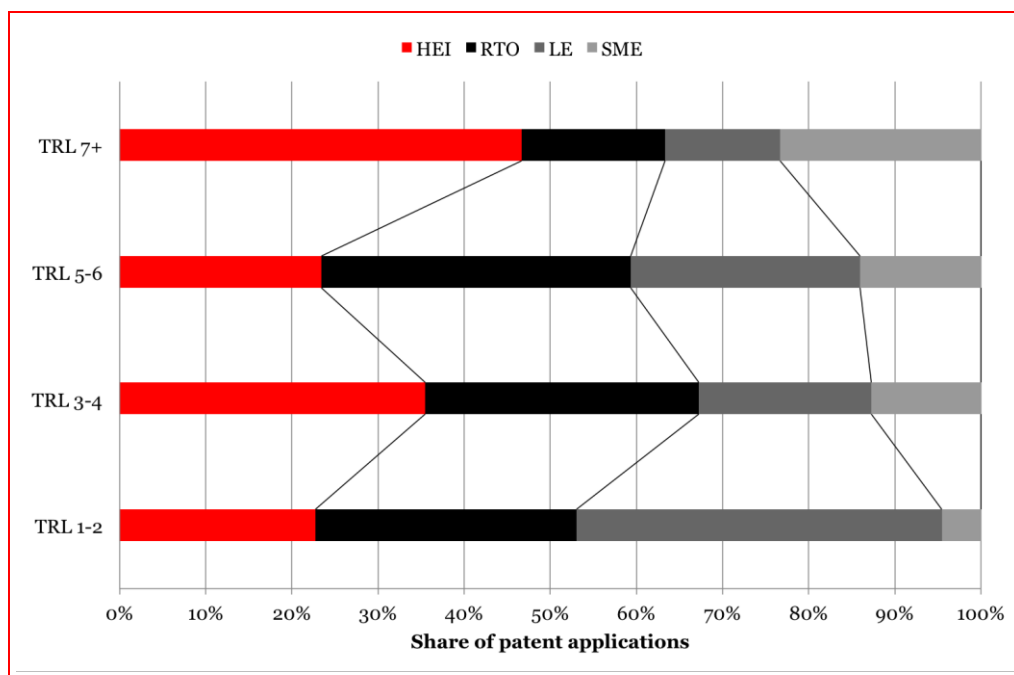
The different types of **organisations** involved in NMP-funded projects present different patenting activities. We roughly observe a one third allocation between RTOs, universities, and industry. Differentiating industry by LEs and SMEs reveals that SMEs contribute roughly 10% to the total patent output, while LEs are responsible for roughly 25%.

Patent applications may also relate to the **TRL** of the projects. Most of the patents are from projects at TRL 3-4 (41%), about 25% relate each to TRL 1-2 and 5-6 respectively and 11% relate to TRL 7+. These numbers are confirmed by survey results which showed that patent applications

are mainly done by participants in projects that are at TRL 1-2 or 3-4. The results we found for the TRL of the projects by area (Nanoscience and Nanotechnology and New Materials being more research driven, production being closer to market) is also reflected in the patenting activity. Patents on New Materials are mainly at lower TRL (1-2). Patents on Nanoscience and Nanotechnology are decreasing with higher TRL. Patents on New Production Technologies are increasing by TRL. Patents on Integration can be classified mainly to medium TRLs.

A final analysis concerning the TRL classification of patent applications included the different types of organisation (see Figure 10).

Figure 10 Patent applications by TRL and by type of participant



Source: SESAM database.

We found that patenting activities of SME increase by TRL, while large firms are mainly active at the lowest TRL (1-2). RTOs and universities are active at all TRLs.

The survey showed that the number of patents already reached and expected by the end of the project for on-going projects is much higher than for finished projects. This could be because of the higher number of PPPs in the sample of on-going projects. Involving more actively companies in project consortia of PPP's could be responsible for this result.

Lastly, when considering outputs of EU13 countries, we observe that their patenting activities are much lower compared to their publication activities.

Conclusions

We conclude that - although many FP7 NMP projects are still on-going - **already many economic results have been achieved**. A comparison with FP6 is not feasible, because the FP6 evaluation took place in the period 2009-2011, long after the programme ended (in 2006) which means that the projects' economic outputs - that take longer time to materialise than scientific - had time to do this and thus that relative more output could be measured (but also: less companies involved in smaller programme).

In general we can observe that overall more positive economic effects are achieved by still on-going projects, and - as PPP constitute most of these projects - we can conclude that **PPP's are relatively more productive**. It was a good decision of EC to change the strategy during the programme. The EC has been successful in pushing the programme more towards higher TRLs.

4.3 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

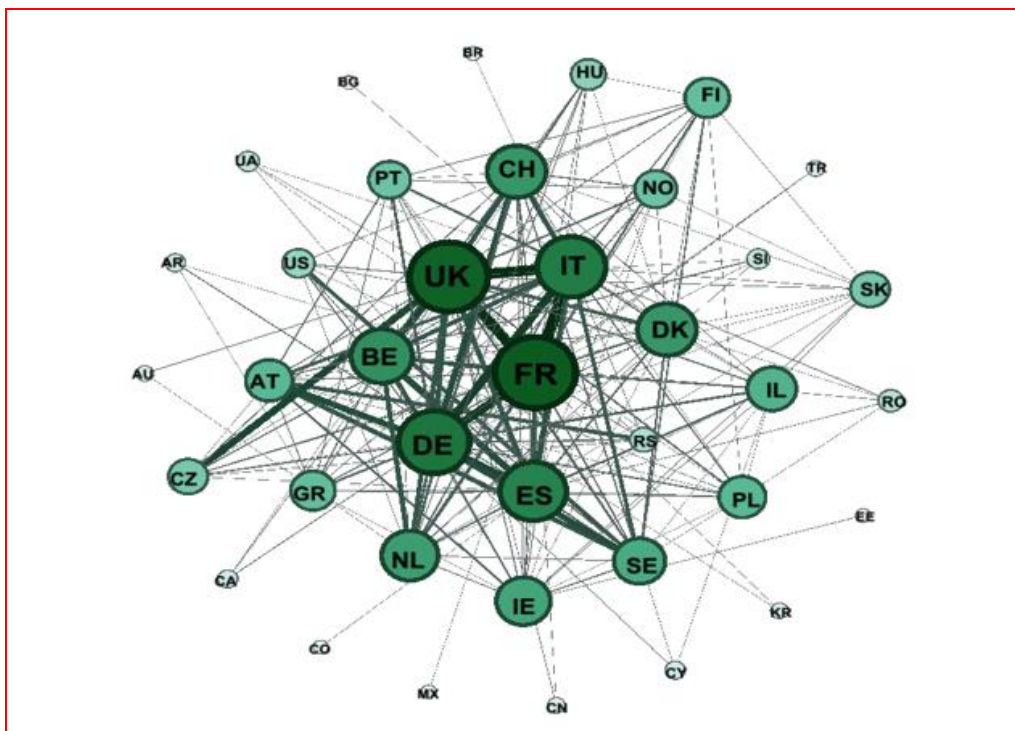
Research Area, special emphasis is put on clusters, knowledge transfer networks and strategic partnerships between universities and companies as well as the regulatory environment. The FP7 NMP Theme is part of the endeavour of the European Commission to create such a European Research Area.

Collaboration across countries

Collaboration with renowned organisations in other countries and regions is one of the central motivations for participating in FP7 NMP projects. A good indicator for international collaboration activities is scientific publications that are authored by researchers from different countries (co-publications).

The co-publication analysis of the publications produced based on the results 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 11).

Figure 11 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.

It describes effectively a three-layer research and innovation consisting of core, intermediate and outer layers. A clear core 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, GR, RS, AT, UA and CZ. Non-European countries are also part of the network, esp. US and CA, but also IL. However, cooperation with other non-European countries is rare.

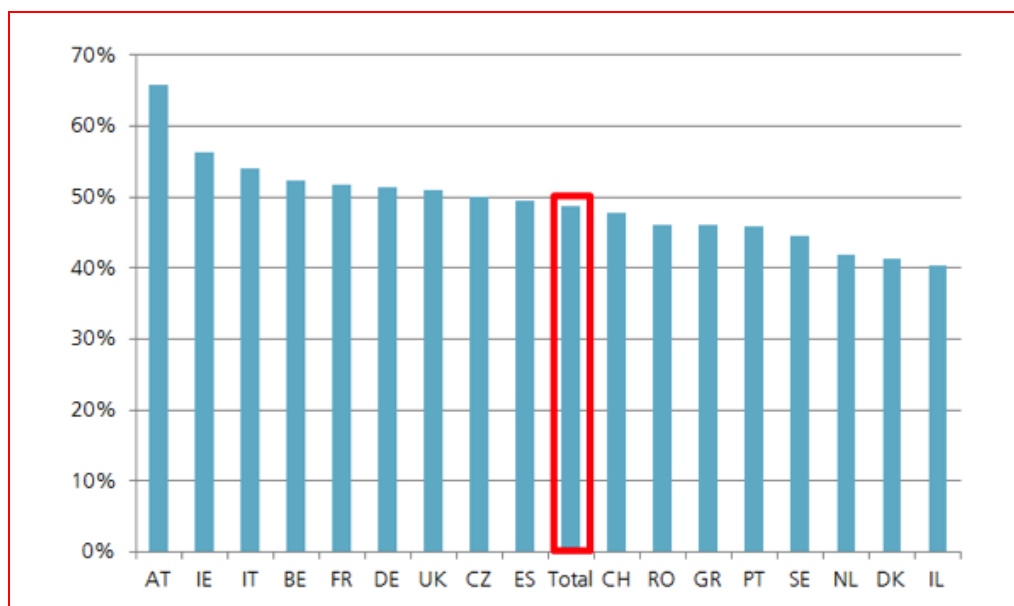
For the eight countries inside the power network, we analysed to what extent the NMP cooperation patterns match the overall scientific cooperation patterns. Interestingly, the NMP cooperation patterns for Belgium, Germany, Spain and Italy perfectly match the overall scientific cooperation patterns. The cooperation patterns of France and Switzerland match only partly and for 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 FP7 NMP programme has triggered scientific cooperation with countries which are usually not top-cooperation partners; in these countries the programme led to cooperation which clearly extended the usual network of cooperation.

In the New Materials and New Production Technologies areas (see Annex Report, Chapter 6), similar patterns evolve, with a Materials-power hub consisting of the four countries (UK, DE, IT, FR) and a Production-power hub with three countries (UK, DE and IT). However, the Nanoscience and Nanotechnology area is different: there is no clear core network; instead what evolves is a

picture of many well-connected countries and a series of special connections between Austria and South Africa, Sweden and the US, and between France and Italy.

The co-publication analysis also allows for determining countries in which the technology transfer from an 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 12 (on next page) shows that there are nine countries which show diffusion activities above the average (left of the red 'Total' bar).

Figure 12 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.

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 survey participants did cooperate in any form with their consortium partners already before the project. 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 non-European partners. Here, the case studies analysis revealed a trade-off for project coordinators. To involve non-European 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 non-European actors can be qualified as high risk, high gain**.

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 also reveals that most collaboration activities are between universities (HEI) and RTOs suggesting this axis is the engine room of NMP innovation. The next strongest link is between HEI and SMEs, possibly because of regional development factors. However, the enterprise sector (large enterprises and SMEs) 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, the extent to which they are connected to the academic field is high.

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 enterprises more often publish with HEIs (confirming other research that they are relatively more active in basic research), while SMEs publish more often with (application oriented) research organisations.

The co-publication analysis shows that in the New Materials area, large firms are a central part of the network and SMEs play a smaller role. In the Nanoscience and Nanotechnology area both large enterprises and SMEs are strongly involved. Not surprisingly, in the New Production Technologies area, industry is hardly present as this is a more application-oriented field and - as was mentioned in the section on the patents output - the manufacturing industries less tend to publish on their progress in process development.

Standardisation and regulatory bodies are a central part in the co-publication network of Nanoscience and Nanotechnology, indicating the need to research nanohazards and health impacts of nanotechnologies.

Important questions are **how 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 RTOs and LEs, and between senior management of SMEs.
- Each RTO 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 LEs 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 research and innovation collaborations.

Interestingly, the case studies also revealed that most new collaborations were made between SMEs and research organisations and between SMEs and LEs. This concerned collaboration between actors from different countries but also from the same country.

Both, the case studies as well as the online survey clearly confirmed the relevance of NMP projects for building networks and enhancing collaboration activities.

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 that were published together with partners inside and outside the consortium. We found that also partners from outside the consortia were included in the publications' authors list.

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 all areas, except for New Production Technologies. This means first of 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.

4.4 Societal and environmental objectives

The objectives of nearly all projects emphasise economic objectives and progress towards higher TRLs. Challenges and objectives related to science and technology are means to this end: the ultimate objective is to develop and commercialise new products, services and processes.

The case studies show that along the same lines, societal and environmental objectives are mentioned (safety, inclusion, energy efficiency, etc.) but phrasing often is abstract. The project documents mention that meeting societal and environmental objectives depends on meeting economic objectives. Overall, there is more attention for environmental objectives than for societal objectives. However, these societal and environmental objectives are included in the topic description of the work programmes and thus are more or less demanded by the EC and therefore these are intended project outcomes. The objectives depend on the work programme formulation. The box below lists examples of projects with **societal and environmental objectives**.

Products with aimed effects on health, safety and environment, developed in FP7 NMP projects

- Fashionable footwear for diabetic feet and fashionable clothing for wheelchair users (FASHION-ABLE project)
- Implants that reduce and neutralise toxic inorganic nanoparticles during wear (LIFELONGJOINTS project)
- Coatings that improve durability, fuel efficiency or energy efficiency (TheBarCode project)
- Lighter windows with reduced thermal conductivity (HarWin project)
- Integrated energy system consisting of mixed building types and aims at 50% reduction of the energy use and carbon emission of new and retrofitted buildings in healthcare districts (STREAMER project)
- Systems that combine air conditioning/dehumidification, by using Hybrid Liquid Desiccant systems (Nanocool project)
- New catalysts for chemical processes to convert (bio)polymers to shorter polymers without the use of critical metals (NOVACAM project)
- Recovery and recycling of rare earth materials (REMANCE project)

Source: Case studies. Project websites.

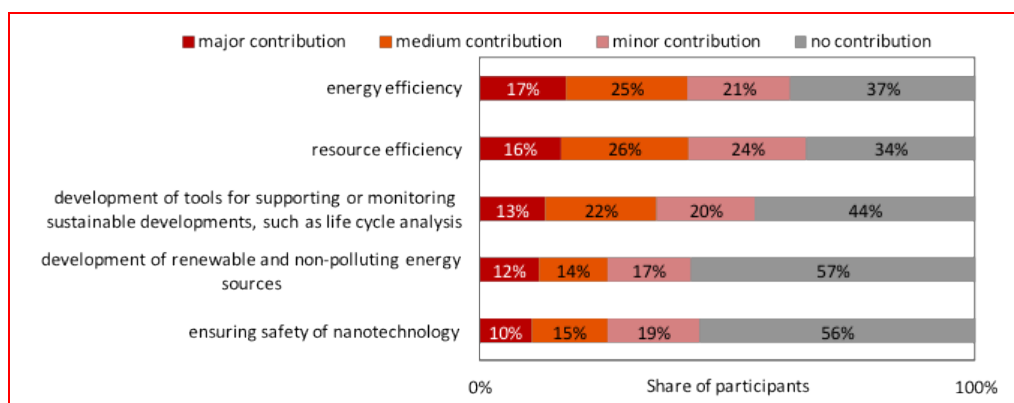
- A considerable part of the survey participants indicated that their project contributed to **environmental goals** (

Figure 13), mostly to energy and resources efficiency.

Taking into account the different parts of the programme:

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

Figure 13 Environmental effects

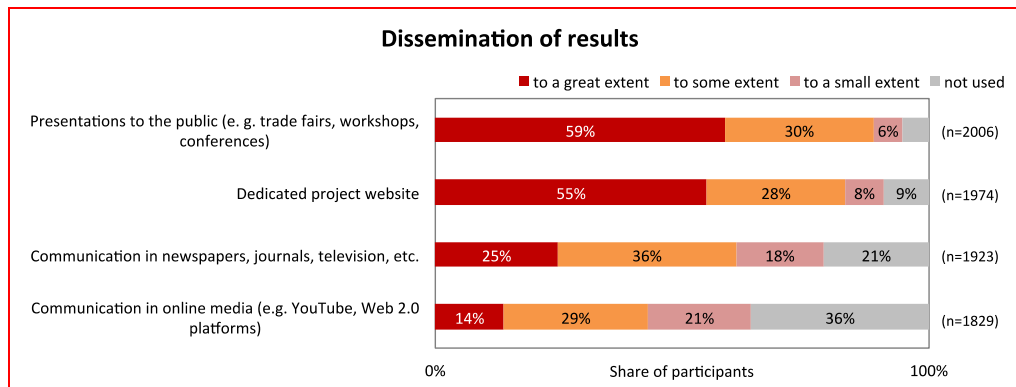


Source: Large-scale survey.

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.

Figure 14 Dissemination channels



Source: Large-scale survey, response to: Which efforts were made to include and inform social stakeholders about the research activities and results of the projects?

We **conclude** that societal and environmental impacts of FP7 NMP projects are considered as an intended side-effect of economic success (rather than the other way around). Nevertheless project participants report on a variety of project results with societal and environmental relevance. Dissemination of project results in order to reach a public that is interested in these results and in their societal and environmental aspects is mainly done by traditional communication channels and mainly reaches a scientific public. However, it seems there is potential for improvements regarding accessibility of social stakeholders in the broad public, such as by using social media.

5. EUROPEAN ADDED VALUE OF THE FP7 NMP THEME

The concept of European Added Value (EAV) refers to the rationale for public intervention (instead of relying exclusively on market forces and stakeholder initiatives) and more specifically to the need for public intervention at European Union level (instead of relying exclusively on public intervention at the level of Member States and regions). The latter not only relies on existing interventions at national or regional level but also at the competences of the EU in a specific field.

The strongest evidence highlighting the added value of the FP7 NMP is that **only 8% of the survey participants** indicate that they would have undertaken the activities without the programme, e.g. by using private funding. This level is higher for national programmes. Amongst the survey respondents, 46% would not have undertaken the research and innovation activities at all without FP7 NMP funding whilst another 46% would have looked for other funding, e.g. national programmes. Comparing participants in PPPs with the rest of the participants shows that 37% of the PPP participants would not have undertaken the R&D activities without the FP7 programme. This percentage is lower than for all projects (46%), which can be explained by the relatively higher TRL of most PPP projects. The immediate economic relevance is higher in PPPs, which increases the chance that projects would also start without FP7 NMP funding. There is thus a clear indication that significantly fewer projects would have occurred – and thus results achieved – without the programme.

- The FP7 NMP Theme furthermore addresses a number of **pan-European challenges**. Although the scientific, technological and economic objectives of FP7 NMP are the most important, they are linked to societal and environmental challenges. Section 0 showed that societal and environmental challenges are an important background rationale for the development of projects. The survey showed that a significant number of projects address energy and resource efficiency of European sectors (see

Figure 13), the building of value chains with partners in different EU countries and, to some extent, international research infrastructures and databases (30% of survey participants mentioned this) and European legislation and standards.

Coordination of national policies is about targeting public investments more efficiently and reducing fragmentation across Europe. As such, the coordination of national policies can reduce

overlap between national efforts and increase knowledge exchange and collaboration between countries. The FP7 NMP has a positive, yet modest impact on the coordination of national policies. To some extent, this reflects that there are other coordination mechanisms at work. For example, the European Technology Platforms (ETPs), but also leading universities and multinationals influence European and national policies. This increases coordination or alignment of national policies.

When asked what specific R&D objectives are reasons to participate, only 15% of the survey respondents considered "improved coordination of European research activities" to be relevant. This refers to public research and innovation programmes as well as private initiatives (e.g. coordination within multinationals). By means of comparison, 75% of participants considered exploration of new S&T knowledge to be relevant and 35% of participants considered exploitation of new knowledge to be relevant.

The case studies indicate that the FP7 NMP is complementary to national policies and programmes (in most countries) rather than leading to increased coordination of national policies (e.g. in terms of technologies and application areas). This is particularly the case in the division between the phases of innovation in which research contributes, namely:

- Basic research providing a source for innovation;
- Applied research and piloting functioning as the heart of the innovation process;
- The final steps for commercialisation.

Several interviewees indeed stressed that the FP7 NMP emphasises applied research, development and pilots, whereas national programmes in several Member States have an emphasis on basic research and on demonstrators and enablers such as cluster organisations and incubators. In these countries, EU funding is complementary to the funding of national programmes. Nevertheless, there are many exceptions. 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 but also demonstrators and commercialisation.

The analysis of national NMP policies in five Member States (see Annex Report 1) indicates that, at least in some countries, the FP7 NMP has a direct and positive impact on coordination of national policies. However, this mostly means that national policies (and programmes) also address the technologies and application areas of the FP7 NMP. For instance, the priorities, timing and procedures of national programmes in Italy were adapted in order to better match the FP7 NMP (and other parts of FP7). This approach should stimulate Italian actors to participate in the 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, the FP7 NMP is perceived as an opportunity to share Dutch experiences with public-private collaboration and work on ethical aspects of new technologies. In addition, the 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 the 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, the 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, the FP7 NMP is considered as a mechanism to increase international collaboration.

The FP6 NMP evaluation found that many participants considered this programme to be focused on basic, pre-competitive research, while national programmes had an emphasis on practical innovation and market exploration. The FP7 NMP has become more balanced in terms of supporting different phases in the innovation chain. The results of the FP6 NMP evaluation also shed the impact on coordination of national policies in a positive light. The findings of the FP7 NMP acknowledges this impact, but also highlights other mechanisms such as ERANETs that influence coordination between national and European programmes. Moreover, coordination of national policies mostly implies increased collaboration rather than prioritisation per country and reduced overlap.

The EU scale did not only play a role in access to funding or focus to an area complementary to national activities; it also **increased access to a wider range of expertise and enabled a more appropriate platform for the dissemination of research results**. The scientific results have been published in international journals, presented at international conferences and business events, shared via the project website, summarised in brochures, etc. Moreover, 46% of the survey participants are involved in building-up a research platform for improved networking

(community of interest, online forum, social media, workshop series, etc.). This percentage is slightly higher for CSA projects than for Integrated Projects.

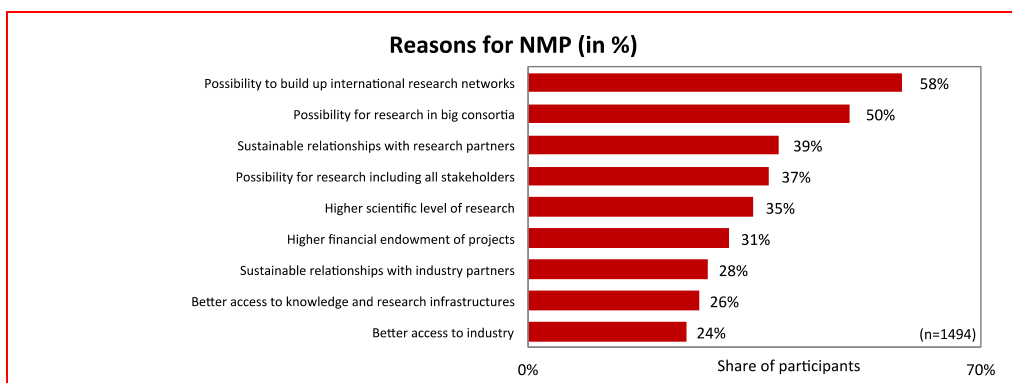
The concept of **critical mass** reflects that some research activities require the scale, complexity and combination of different types of knowledge and skills (from different disciplines and sectors) that cannot be provided by an individual country. Survey results indicate that several aspects of critical 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/enterprises and access to networks (36%) and access to R&D networks or research organisations (35%). The ArtiVase 3D project (see box below) is an example of a project in which the necessary critical mass could not be provided by national programmes alone; EC funding provided the budget for applying the multidisciplinary approach at the required large scale.

Example of added value of EC funding

The ArtiVase 3D project focuses on the design and implementation of bioartificial vascularised tissues, such as skin. The use of such tissues offers potentially great therapeutic benefits, such as replacement of skin in victims with burn wounds. The multidisciplinary approach covers micro-scale printing, nano-scale multiphoton polymerisation and electro-spinning with biological research on biochemical surface modification and complex cell culture. There are several national funding programmes on the separate topics addressed in ArtiVasc. However, the multidisciplinary approach of ArtiVasc requires a relatively large project and consortium size. Scale and interdisciplinarity are facilitated by European Framework Programmes.

The importance of critical mass also emerged from the response to the survey question on the reasons for participation in the FP7 NMP as compared to national alternatives. Participants mentioned international networks, big consortia, high scientific levels (cf. excellence) and possibilities to work with all relevant stakeholders (Figure 15).

Figure 15 Reasons for participation in FP7 NMP compared to participation in national research and innovation programmes



Source: Large-scale survey, response to: How do you assess the value added by the NMP7 programme compared to national funding programmes?

The case study results provide a similar yet richer picture with respect to critical mass, partly overlapping the survey results. In addition to the points listed above, case study interviewees mentioned:

- The FP7 and Horizon 2020 provide more continuity than national or regional governmental programmes that respond to the economic crisis by means of budget cuts in science, innovation and other policy areas.
- The FP7 NMP supports 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.
- The 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, the FP7 NMP contributes to a level playing field.
- The FP7 NMP consortia provide access to missing expertise that is available in other countries.

The EAV of **leverage on private investment** refers to the attractiveness of EU research and innovation programmes (international collaboration, excellence, etc.) and the extent to which this induces firms to invest more of their own funds compared to their investments under national programmes. This allows for continued work in big consortia, in multi-disciplinary teams, with excellent researchers, different types of actors, from different parts of the value chain and from different countries.

The importance of commercialisation within the FP7 NMP is most relevant for firms. 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%).

This was confirmed by the case studies. Because the size of specific downstream sectors and markets (such as automotive, semiconductors and energy production) differs between countries, and because many sectors and markets are spread across Europe, participation in the FP7 NMP consortia provides upstream firms from one country with access to downstream markets in other countries. As such, actors can target a larger geographic market. Case studies also revealed that from the perspective of firms (and research organisations) the FP7 NMP, in between the FP6 and Horizon 2020, provided the continuity and predictability that is needed for securing private investments. In many Member States, the financial and economic crisis led to reduced public investments in research and innovation. Again, this is a mechanism via which the FP7 NMP increased private investments in research and innovation activities.

In sum, the European Added Value of FP7 NMP is substantial. The evaluation results indicate that many projects may not have taken place without the programme. The EAV identified spans from pan-European challenges, coordination of national policies, the dissemination of project results at a European scale, the facilitation of critical mass and the leverage on private investments.

6. CONCLUSIONS AND RECOMMENDATIONS

In this last chapter the first section summarises the main findings and draws conclusions along the research questions structure. These lead to the recommendations in the second and last section.

6.1 Conclusions

Programme rationale

- The FP7 NMP Theme has been successful in addressing a number of important barriers to innovation in the industrial sectors, such as the fragmented supply-chain and lack of collaboration along the supply chain, competition from low-cost manufacturing countries, the limited access to natural resources and raw materials, lack of testing and quality control of techniques and processes, and organisational problems encountered in re-developing, retrofitting and renovating old buildings. The rationale for having an NMP Thematic Area in FP7 was and still is valid, as many of the problems identified still apply.
- Introducing the PPPs in the FP7 NMP Theme resulted in a stronger focus on economic growth, industrial innovation and creation of new jobs as technology development, and was directly linked to innovation needs in specific sectors of the manufacturing industry.

Programme implementation

- Compared to the FP6 NMP, industry participation rose from 55% to 68% of the unique participants in the FP7 NMP. After the PPPs were introduced, industry participation in collaborative research projects increased from 46% in 2009 to 53% in 2013.
- The programme has been very successful in attracting SMEs. SMEs account for two-third of the industry participants in the FP7 NMP (in the FP6 NMP about one fifth of the participating companies were SMEs).
- Companies did not take a large leadership role in the projects: only 19% of the coordinators are from companies in comparison to 40% in the FP6 NMP. Also in the PPPs in which industry does have an advanced role, the projects are often still led by research organisations. The introduction of the PPPs has not demonstrated to stimulate a leadership role for companies. Explanations can be many fold; companies can favour their in-house corporate R&D staff to work with rather than external partners when it comes to the co-creation of innovations, but also fiscal restraint in recessionary times and the opportunity costs (when putting corporate

R&D staff in the position as project coordinator they are less available for other tasks). Also IP considerations might play a role as the most useful IP is captured at the low TRLs and IP in the process of scaling-up can be diluted in large projects and harder to protect.

- As in the FP6 NMP, the community of FP7 NMP participants is geographically concentrated. The EU15 represents more than 80% of the programme participations and funding and 78% of all unique participants. The FP7 NMP was less successful in attracting research organisations from the EU13. They represented only 9% of the unique participants and only 4% of the funding.
- Programme efficiency is judged as good based on the functioning of the supporting system and the administrative procedures, which have become more professional and support the project teams appropriately in their work. Participants are satisfied with most of them, but also have points for improvement.

Programme effectiveness

- The scientific output of the FP7 NMP is mostly found in publications: scientific articles and conference papers. Most of the scientific articles generated by the FP7 NMP funded projects stem from research organisations. Companies contribute only a few percentages, except for the New Production Technologies area under which SMEs contributed to almost one-tenth of the publications.
- The level of excellence of FP7 NMP scientific articles (measured by the share of highly cited publications and taking into account the limitations of citation data) is at least as high as the average level in the whole NMP landscape in the Web of Science.
- FP7 NMP has delivered various economic outputs that will provide a contribution to competitiveness of the European economy. This includes:
 - 60% of the survey participants of finished projects have developed a new or significantly improved product;
 - Half of them report that this product has already been introduced at the market;
 - In those cases where market introduction has taken place, the turnover the companies reach with their new product is on average 5% of their total turnover;
 - Nearly half of the survey participants report the development of new or improved manufacturing processes and about 60% report new or improved services.
- A considerable share of the FP7 NMP projects has demonstrated results with societal and environmental relevance.
- SMEs are relatively very productive. Compared to large firms they report on a larger scale the development of new or significantly improved products and services reached during the project, higher improved flexibility, revenue growth and employment growth.
- The larger public is able to access project results through traditional communication channels such as project websites.

PPPs

- The introduction of the PPPs has contributed to a better balance in the FP7 NMP in terms of supporting different phases in the innovation chain. The TRLs of PPP projects are relatively higher than in the N, M, P and I areas, which was also concluded in the final assessment of research PPPs (2013). Also industry participation is higher after the PPPs were introduced.
- PPP projects are more productive than projects in other parts of the programme because:
 - PPP participants - especially those from Factory of the Future and Energy efficient Buildings projects - are relatively more productive in terms of economic outputs than participants in other parts of the programme.
 - Three quarter of PPP project survey participants report that they already have reached the development of a new or significantly improved product.
 - Survey participants of on-going projects (that include relatively more PPPs) consistently report higher numbers for high and medium impact compared to the participants of finished projects (such as the number of patent applications that is already done and expected by the end of the project).
- By changing the strategy during the programme, the EC was able to more effectively push the programme towards higher TRLs.

European Research Area

- The FP7 NMP Theme is part of the endeavour to create a European Research Area. Through its design it naturally fosters intra-EU collaboration, which has been found to be one of the most central motivations of organisations to participate in FP7 NMP projects. Moreover, FP7 NMP supports collaboration between different types of actors. This is also reflected by the fact that 75% of the FP7 NMP publications are co-publications.
- Amongst the participating organisations, LEs more often publish with universities (confirming other studies that indicate that LEs are relatively more active in basic research than SMEs), while SMEs publish more often with (application-oriented) RTOs.
- There are more project-external co-publications than project-internal co-publications in almost all programme parts, except for New Production Technologies. This means that a much larger community of research organisations and companies is involved in the FP7 NMP community than just the funded project participants and that knowledge diffusion from FP7 projects already takes place within the projects themselves.

European Added Value

- The FP7 NMP has a positive yet modest impact on the coordination of national policies by reducing overlap between national efforts and increasing knowledge exchange and collaboration between countries.
- Also the FP7 NMP provided a scale of and variation in disciplines, knowledge and skills that cannot be provided by an individual country. The access to specific knowledge and networks in other countries, the continuity in EU Framework Programmes and the leverage on private investment are the main added values of the FP7.
- The importance of the European dimension is underlined by the fact that only 8% of the survey participants indicate that they would have undertaken the activities anyway, e.g. by using private funding (for national programmes this is much higher).

6.2 Recommendations

Stakeholders' involvement and knowledge transfer

The new 'Leadership in Enabling and Industrial Technologies' (LEIT) part of Horizon 2020 will have an even stronger focus on developing European industrial technologies than the FP7 NMP had, by also including industrial biotechnology next to nanotechnology, advanced materials, advanced manufacturing and processing technologies in an "NMBP" programme. The activities in the LEIT part will be based – similar to the PPPs in FP7 NMP - on research and innovation agendas defined by industry together with the research community.

The balance within the new H2020 programme will be even more towards higher TRLs, with dedicated support for larger-scale pilot lines and demonstrator projects to facilitate industrial take-up and commercialisation. Also there is – extrapolating the trend already set in FP7 NMP – more involvement of industrial participants, and of SMEs in particular, in order to maximise the expected impact of the programme. If the preliminary results regarding the productivity of PPPs found during this evaluation will continue to be proven, H2020 is expected to gain more direct economic relevant results.

However, based on the findings of this evaluation, there are a number of weaknesses in a system in which 'the usual suspects' (the EU15 and within them the larger countries and their research organisations and the larger European manufacturing companies) lead. Whilst this is unavoidable and not necessarily negative in the sense that they are at the forefront of technological development in the manufacturing sector and contribute to a large extent to Europe's economic growth perspectives, but there are ways in which the involvement of a wider group of stakeholders can be improved and in that process be beneficial.

The recommendations are therefore divided in addressing the involvement of EU13 in H2020, the role of RTOs and the technology transfer, and the dissemination of programme results to a wider group of economic and social stakeholders.

a) Involvement of EU13 in H2020

The participation from EU13 countries in FP6 and FP7 was low and it is very likely that this will not change in the future without intervention, as the usual suspects tend to use their existing

networks. However, the level of scientific activities in terms of NMP-related publications of a considerable number of EU13 countries is similar to that of many EU15 countries. EU13 countries are in the process of directing their basic research towards applications and simultaneously changing the attitude of researchers from a more science push to a more 'market' pull approach. This process just started to take hold and it will take another 5 to 10 years before it will result in similar ways of approaching market-relevant research as the EU15 universities and research organisations currently do.

Some of these EU13 countries are developing fast and have some excellent research centres with up-to-date research facilities due to the EC Regional Operational Programmes, also in the field of NMP. When half of the financing goes to one Member State and only a marginal amount goes to the entire EU13 area the programme becomes politically unsustainable and may be a threat to the future political support for such EU programs. The problem is intensified by the fact that the FP7 NMP operates at high TRLs and hence close to the competitive environment and thus closer to allegations of supporting the industry in some Member States and not in others.

It is therefore recommendable that:

- **Measures are taken to encourage inclusion of new partners in the Framework Programme in general and,**
- **Specific measures are taken to attain a stronger inclusion of partners from EU13 countries.**

One such specific measure could be to introduce a new **sub-programme 'Bridging the Divide'** in the H2020 NMP Work Programme under Coordination Activities (under the Health Theme). Such a programme could be aimed at tackling the gap between European "innovation leaders" (mostly from EU15) and "modest innovators" in EU13. This gives the organisations from the EU13 the opportunity to learn from new ways of open and commercialisation-oriented innovation processes. The new partners - research organisations and companies from the EU13 - should have a significant stake in the project activities. Such a measure also ensures a stronger and wider spread European dimension in the innovation without compromising the quality of the research.

b) Role of RTOs

RTOs can play an important role as linking pin between the universities and industry. RTOs translate basic research results into relevant industrial applications, which is especially important for the medium-tech SMEs (this is less the case for large firms, which have R&D capacities and work directly with university researchers). In this way RTOs have an important role in the technology transfer and the development of regional clusters. RTOs have often been project coordinators in the FP7 NMP and built consortia based on their academic and industrial networks.

The case studies investigated in this evaluation revealed that consortia succeeded in involving a variety of companies, while at the same time avoiding competition within the consortium. Several interviewees referred to this well-known trade-off. There were several examples of consortia that were too dependent on one or two firms downstream the value chain and where innovation and commercialisation would have benefited from involving additional firms, e.g. firms that are active in different geographic markets and/or downstream sectors: specialised downstream SMEs as well as large firms. Such constructions are less likely to form under H2020, as companies will get a more leading role in consortia and may be less inclined to work with other companies.

To avoid a reduced level of cooperation it is recommendable that:

- **the composition of H2020 consortia are actively monitored on the basis of a balance between the industry and university in general, and,**
- **specific attention is paid to identify where other companies might benefit from projects in order to achieve higher dissemination results. RTOs can play a role in identifying and contacting these companies.**

c) Knowledge transfer and dissemination

Firstly, the projects within the FP7 kept to traditional ways of dissemination channels and mostly reached the scientific public. Communication especially to other companies than those involved as well as to the wider public is an area that could be exploited more. There is large potential for improvements in reaching economic and social stakeholders.

The fact that the manufacturing sector is at the heart of many national industries and thus important for the competitiveness of countries and the European Union further underlines the importance that:

- **knowledge transfer and dissemination should be significantly enhanced.**

All projects can put larger efforts into reaching a larger and wider audience and in that process use more channels than they have thus far, for example social media.

Secondly, all projects are contractually obliged to submit the Plan for Use and Dissemination of Foreground (PUDF) with their final report. These reports must include sufficient information to allow the EC to trace them, as well as to perform related audits or reviews. An analysis of these plans and what came out of it was not part of this evaluation but can provide useful insights and inputs in developing support instruments and measures. If conducted, such an analysis can focus on the use and results on valorisation and commercialisation for projects that made use of the ESIC services. This evaluation found that respondents were rather positive on the services, so their effect would have to be measured. Additional analysis (using interviews with project participants) can answer important questions such as: which types of organisations carry out which type of exploitation activities that lead to what types of exploitation results (such as spin-offs, products, services, etc.) and for which types of projects? What type of dissemination support (incl. ESIC) has been used, what worked well, what can be improved? Have projects IPR strategies and have parent organisations commercialisation strategies? Did HEIs claim exploitation rights, etc.?

In order to improve and expand knowledge transfer and dissemination and develop specific tools to support project teams in this, it is recommendable that:

- **an in-depth analysis is made of the claims made in the PUDF reports on the actual dissemination outputs, thereby answering the questions listed above.**

This will provide insight in what goes well and where these processes can be improved and what instruments are best to facilitate knowledge transfer and dissemination.

TRL concept

In the evaluation of the FP7 NMP, the TRL concept was used to position the projects and their output (scientific articles and patents) along the innovation chain and to measure the projects' progress made. The project coordinators validated the categorisation.

Based on this exercise, the TRL concept demonstrated to be a proven concept for categorising FP7 NMP funded projects and for measuring the progress in these projects along the innovation chain. There are no reasons why it cannot also be used for other scientific-technological programmes. However, the results of the evaluation suggests that projects can only reach higher levels thereby using a linear model of innovation that does not respect the interactive and systemic character of innovation processes with feedback loops throughout the process. Large firms are well aware of market needs and required specifications. Their involvement at lower TRLs allow for feedback market relevant information (and experience) into conceptual and explorative research at lower TRL by translating these information and needs into research questions/challenges.

It is therefore recommended that:

- **the systemic and interactive character of the innovation process is considered when using the TRL concept to position and monitor projects' progress and in that process keep TRL thinking open, flexible and permeable.**
- **TRLs are used for individual work packages, as their use for a large-scale project does not sufficiently reflect the complexity of these projects.**

Fine-tuning PPPs

The introduction of the PPPs in the FP7 NMP has been successful; it has contributed to a better balance in FP7 NMP in terms of supporting different phases in the innovation chain. Such balance between activities at all TRLs should also be kept as the NMP- enabled innovation is driven by strong interaction between scientific activities and innovative activities; there is no short cut to innovation.

PPPs are now a well-established part of H2020. The interviews with the **project participants** remind of specific effects and new needs that are summarised in the following recommendations:

- *In the Nanoscience and Nanotechnologies and New Materials areas there is room **for increased emphasis on higher TRLs**. This would allow key actors to continue developing and piloting their technologies in FPs and to involve relevant downstream actors. This is not to say that H2020 should not fund projects with low TRLs. Rather, this recommendation addresses 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.*
- *Maintain the increased emphasis on PPPs 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 on standardisation and regulation and to increase chances of commercialisation.*
- ***Intensify ESIC-type of commercialisation support** as consortia may lack expertise about IPR, business models, marketing, etc. External support serves as a reminder to timely discuss commercialisation issues between consortium members and combine this with practical advice on commercialisation.*
- *With increased emphasis on commercialisation, there is room for supporting consortia that include a range of **new actors and new collaborations** 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.*

Evaluation of Framework Programmes

During the process of this evaluation it became evident that there were few indicators to compare the FP7 NMP with the FP6 NMP. Although each Framework Programme has its specific characteristics, the main evaluation questions are more or less the same: programme relevance, implementation and effectiveness. For these three evaluation questions a core set of indicators (with set definitions and methods for data gathering) can be composed and used in evaluations of all EU Framework Programmes. This can also be reflected in the requirements for applications and the conditions for obtaining support (e.g. the obligation to report specific indicators before, during and after the projects from all participating partners).

Furthermore, there is currently insufficient information on the exploitation progress and the economic impacts of the use of project results at the company level of the companies involved and the companies to which knowledge has been disseminated.

It is therefore recommended that:

- ***Indicators are developed for all EU Framework Programmes that allow for comparison and similar methods of data collection.***
- ***Evaluations are conducted at similar periods after the start of a programme, so that results can be compared. For instance six years after the start of the first projects and another impact analysis six years after the start of the last projects.***
- ***An impact assessment is performed 2-3 years after the projects' end and compared with the projects' PUDF plans and PUDF's realisation overviews that have been made immediately after the projects' end.***

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This report presents the main results of the ex post evaluation and impact assessment of the FP7 NMP Theme. The evaluation assesses the FP7 NMP programme's strategy and rationale, the programme's 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. Evaluation of programme rationale indicates that it has been successful in addressing a number of important barriers to innovation in industry. Implementation assessment shows that the programme was successful in attracting companies although they did not frequently take a leading role. Although many FP7 NMP projects are still on-going the programme already has yielded significant results, scientific and economic. The introduction of the PPPs has contributed to a better balance in the programme between basic research and application. The evaluation showed that the Technology Readiness Level concept is a proven concept for categorising the FP7 NMP funded projects and for measuring the progress in these projects along the innovation chain. Recommendations to the Commission are made (for implementation in the Horizon 2020 programme and beyond). The Annex Report published separately provides detailed information on the methodologies applied and more and detailed results.

Studies and reports