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Strategy Definition & Road Mapping for

Industrial Technologies

to Address Grand Challenges

Final report

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EUROPEAN COMMISSION

Strategy Definition and Road Mapping for Industrial Technologies to Address Grand Challenges

Final report

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INTRODUCTION

In mid-April 2011 the project regarding preparation of the report on "Strategy Definition and Road Mapping for Industrial Technologies to Address Grand Challenges" was assigned to Oxford Research by the European Commission, Research Directorate-General – Industrial technologies.

The main aim of this project is to assess the links and relevance of present Nanosciences, Nanotechnologies, Materials and new production technologies (NMP) activities to the major technical issues and bottlenecks associated with Grand Challenges, providing a set of operational recommendations.

The title of the study is to some extent misleading. The detailed description provided in the Terms of Reference underlines that the development of technological roadmaps is outside the scope of this study. The study is also not a summary of roadmaps for different industries. The word 'strategy' is also not fully appropriate for the content. By strategy we would normally understand a set of strategic objectives associated with a number of programmes and projects described with a defined split of tasks and measurable monitoring indicators. **This study is in great part focused on analysing bottlenecks and defining possible approaches to solving them through the use of identified policy options.** From this analysis a number of recommendations are proposed, which we believe will create a discussion regarding the future of the NMP programme. Finally, the timeframe of the project did not fit planning processes at the Commission. Horizon 2020 impact assessment was developed before this project was in fact contracted, therefore its outcomes cannot be used for planning, but rather for adjusting the future of community funding schemes.

The structure of the report is shaped following the Terms of Reference requirements for the contract. First **the Grand Challenges and their bottlenecks are analysed.** Then the report discusses the **role, strengths and weaknesses of FPs. Finally policy options are proposed, described and analysed in more detail**, bringing in stakeholders' views.

The research team would like to thank all experts and stakeholders engaged for their valuable input to the data collection, workshop participation and comments received during the report preparation process. We would like to express special thanks to our main contact persons from the European Commission: Mr Jesús-Maria Alquezar-Sabadie, Ms Kristiina Urpalainen and Mr Michel Poireau. We thank them for their smooth co-operation.

Norway, 16.01.2012

Harald Furre
CEO, Oxford Research AS

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EXECUTIVE SUMMARY AND RECOMMENDATIONS

The current study was commissioned by the DG Research and Innovation, Industrial Technologies unit, with the aim to assess the links, relevance and role of the present NMP[1] activities in overcoming critical bottlenecks associated with solving the Grand Challenges. The study is to provide **insight, analyses and recommendations on strategy definition and produce a road map for industrial technologies**. The material from the study is to be used in the European Commission's work with setting priorities, defining targets, measuring pathways, and monitoring future R&D activities that address the Grand Challenges with the help of industrial technologies.

It shall be noted that the present study is prepared **in the context of Horizon 2020 preparation process** and reflects also to the work undertaken by the High Level Expert Group[2] on Key Enabling Technologies.[3]

The study employs an extensive survey of policy documents; industrial technologies studies and road-maps; past, current and on-going evaluation work on FP5, FP6 and FP7; and foresight studies, as well as international reports on innovation and R&D policies in Europe and worldwide. Two workshops were conducted in autumn 2011 successfully bringing together experts, researchers, and engineers from academia, industry research centres, EU and national organizations that work with NMP, competence centres, and ETPs. Thirty-five interviews were carried out with researchers, experts, engineers and policy makers; all informants are active in EU and national associations that deal with industrial technologies, in universities and research centres, national research councils, EU joint undertakings PPPs, and the industry. In addition Oxford Research representatives attended two international conferences: Planning Research for the Future (October 2011, Berlin) and The Innovation Convention (December 2011, Brussels).

We synthesized the existing literature on Grand Challenges to describe and analyse their interrelations, and consider the current and potential contribution of NMP to solve them. These **Grand Societal Challenges are defined** as:

- health, demographic change and wellbeing;
- food security, sustainable agriculture, marine and maritime research, and the bio-economy;
- secure, clean and efficient energy;

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[1] Industrial technologies are most of all represented in European Framework Programmes under the 'NMP' theme, covering nanosciences, nanotechnologies, materials and new production technologies.

[2] http://ec.europa.eu/enterprise/sectors/ict/key_technologies/kets_high_level_group_en.htm

[3] Key Enabling Technologies (KETs) include nanotechnologies, micro- and nanoelectronics, biotechnology, photonics, advanced materials, and a cross selection of all the above advanced manufacturing systems.

- smart, green and integrated transport;
- climate action, resource efficiency and raw materials;
- inclusive, innovative and secure societies.

Specifically, this study identifies a **list of critical bottlenecks**. We have identified a group of R&D, legal and market obstacles for each set of Grand Challenges and found that some of these are political in nature. Resolving issues such as EU political fragmentation, shortsightedness of political decisions, lack of legal and market regulatory mechanisms, and the gap between fundamental research and industrial applications are essential for removing the rest of the bottlenecks.

These **underlying bottlenecks need to be addressed first**, in order to be able to set out constructive development processes in the context of the Grand Challenges. Many identified bottlenecks cannot be addressed within the scope of the NMP programme itself. They require concentrated cooperation with other Directorates of the Commission as well as policy initiatives on a higher level.

This study also addresses the role, strengths and weaknesses of the FPs in general and NMP theme in particular with regard to solving the Grand Challenges. We found that conditions for the framework programmes have evolved over three decades, but the eminence, pervasiveness and complexity of today's Grand Challenges require a revision of the framework conditions themselves. We followed the work on Horizon 2020 and found that this **process of revision was largely undertaken as Horizon planning progressed**. Similarly we see the need for a committing strategy that sets up the framework conditions under which EU and the Member States jointly address the Grand Challenges. Specifically, how can Member States use political, legal and market mechanisms to ensure that the strategic solutions provided by the R&D are effectively exploited in a timely way. This finding also implies that a clear and binding connection between Europe 2020 and Horizon 2020 should be established and pursued, as many of the bottlenecks that the Member States commit themselves to remove according to the Europe 2020 strategy are directly relevant for achieving the objectives of Horizon 2020.

The present euro area economic crisis will affect the ability to assure funding to complete many of the projects related to the Grand Challenges. It needs very strong leadership from the European Commission to say that this is **exactly the right time to invest in new innovation and technology, so that Europe is in a strong competitive position post-euro crisis** to benefit from solutions to Grand Challenges.

In addition we emphasise that **the current EU R&D system is complicated, comprising a variety of activities**. It is difficult to have an overview of the different initiatives, mechanisms and instruments that are living 'their own lives'. It is further difficult to have a clear picture of each and every one of them within the R&D system, including their role in addressing the Grand Challenges. We concur with others that rather than creating more new instruments the Commission should instead consider **making use of the existing successful instruments**, mechanisms and initiatives such as JTI/Joint Undertakings, PPPs, and ERA-NETs, while **defining their concrete roles, expectations and output** in relation to the Grand Societal Challenges.

This study assessed the experience of various Member States and third countries in defining their R&D and industrial technologies policies along the Grand Challenges. We clearly **observed a shift towards priorities addressing the Grand Challenges across the OECD and third countries**. The issues that remain high on the agenda of many national STI (Science, Technology and Innovation) strategies are environment and energy, new and emerging technologies, and food security. In addition, issues such as health sciences, sustainable high-tech transport, aging and urbanisation rank high in national STI strategies.

Based on document studies we found that the **majority of countries have allocated budgets and established programmes addressing Grand Challenges**. However **these programmes vary in their focus on research, innovation and technologies**; whilst a number of countries have developed programmes that support scientific and technological R&D in many or all of the Grand Challenges, far fewer countries have developed programmes of innovation support.

An important part of this study develops **three policy options** and assesses their potential economic, social and environmental impacts. The policy options are: **'Business as usual',** which is a continuation of FP7; **'Gradual evolution',** which resembles the Horizon 2020 set-up, and **'Radical reorientation',** which gives European competitive clusters the power to manage and implement R&D projects. The policy options were thoroughly discussed in our experts' interviews, raising questions, new ideas, fears and scepticism in some and optimism in others. The comparison between the different policy options and their impact analyses has shown that 'Business as usual' has least potential to address the needs imposed by the Grand Challenges, nor learn the lessons drawn out of past and current FPs' organization and outputs. The 'Gradual evolution' option was advocated by most interviewees. This study shows that 'Gradual evolution' is very likely to make a bigger impact than the 'Business as usual' option, given that political, legal and market regulatory mechanisms are in place. **'Radical reorientation' awoke curiosity and inspiration but also fear and scepticism** in the interviewees. Through adopting a set-up similar to Horizon 2020, we assessed 'Radical reorientation' as having considerable potential to address the Grand Challenges. **Encouraging competitive clusters that manage and implement R&D projects would be a strong strategy to address the needs for more**

commercialization and higher competitiveness.

Below we present a list of main policy recommendations that result from this study. The list of recommendation is detailed and complemented with **other recommendations from the workshops and interviews in Chapter 10. of this report**.

Main recommendations for the European Commission

Effective policies and policy instruments

Recommendation: The design of more effective policies and policy instruments for the benefit of European innovation and economic growth should **build on more comprehensive and well-informed social and economic studies** than has hitherto been the case. Such investigations should assess links and look into the relative strength and internal workings of science-technology fields and subfields in the EU, and, furthermore, have a **high level of detailed analysis.**

Increase private financing for R&D

Recommendation: Policy measures should aim at strengthening European corporate actors, and find ways to support decreasing levels of R&D funding by European companies.

This would include **predictability of regulatory regimes, tax credit schemes, and other investment incentive**s. In return for such more continual policies underpinned by the European Parliament and Council and preferably in collaboration with national governments, individual leading – and often globally present – companies should adhere to equally **stable commitments to invest in enhancing skills, innovation and infrastructure** within the confines of the European Union.

Patent rights in NMP theme

Recommendation: In the light of the foreseen unified European patent litigation system, it is of paramount importance that the EU continues to strike a balance so as not to either deprive many patents of their value or drive research offshore and out of jurisdictions that narrowly construe the defence.

Meeting Europe 2020 strategy

Recommendation: In order to meet the target goals set up in the Europe 2020 growth strategy, the European Commission shall **focus on technologies already close to the market today**, searching for demonstration and scaling up solutions. The EC shall support actions for regulatory tools to implement existing technologies in need of a bigger market to become competitive.

Create an open Venture Capital (VC) market

Recommendation: As already pointed out in the Europe 2020 strategy, **undertake actions create an open European VC market.** Then stimulate VC through European Commission agencies and European Investment Bank mechanisms supporting availability of large scale projects financing. Only large investments will enable innovation players in Europe to finance second stage development of innovative, complex and expensive technologies.

Recommendation: In the view of the cluster-oriented policy option described in the chapters above, the European Commission shall consider introducing a new actor for industrial technologies under Horizon 2020. The new approach shall include **cluster-driven, large scale regional programmes**. By adjusting existing mechanisms of FP7, clusters may contribute to solving the Grand Challenges through a focus on research commercialization. This may especially be supported by using pre-commercial public procurement on a regional level as well through extensive use of equity financing and RSFF mechanisms.

The European Commission shall consider **concentrated investments in limited number of excellence centres in Europe with a clear focus to create intensive innovative growth agglomerations**. The intervention can integrate all available European Commission mechanisms on a limited geographical area. The scope shall cover such elements as: general infrastructure, research facilities, SME support projects (incubators), venture capital market support, access to finance support through RSFF, education facilities, educational programmes, labour market intervention, concentration of demonstration projects, cultural activities and other social and economic dimensions.

Take a more proactive role in addressing Grand Challenges

Recommendation: Act more proactively as facilitator in the context of the Grand Challenges while attracting and **pooling more national funds for joint activities in the area of key enabling technologies**. This mechanism shall be intensified in the NMP theme and shall not only be declaratory but also contain formal commitments from both the European Commission and the Member States.

Cope with societal fear of new emerging technologies

Recommendation: Societal fear about advanced technologies has to be addressed through NMP programme financed projects. Knowledge diffusion about KETs and their possible influence on humans must be obligatory and inherent in close-to-market projects financed by the European Commission, with a strong PR dimension. Separate projects related to **awareness building, testing and education need to be cautiously financed** across Europe.

Recommendation: The European Commission shall consider financing European-wide projects oriented towards **integrating innovation results with cultural expression and social science investigation**. This can be undertaken in the form of joint calls or different new forms of cooperation with other relevant

Directorates General, including Education and Culture and Information Society and Media.

Commercialisation of R&D results:

Recommendation: Each FET consortium should commit to and help **develop a substantial, operational exploitation initiative** intertwined with the scientific work throughout the project's life time. It is crucial that such a commercialisation programme does not just launch an inert commercialisation board, but instead includes professionals with proven effective skills in the translation of research into market-relevant solutions. This includes researchers with experience of both academic research and industrial R&D, entrepreneurs, venture capitalists, and seasoned legal counsellors.

Support for frontier science

Recommendation: Sustain or intensify support for frontier science projects that do not have any expectation to immediately impact the market. Results of **frontier research projects should undergo screening** by skilled engineers and other relevant professionals in the relevant field *before* publication, as there is a risk of intellectual property leakage. There is no contradiction in both patenting and publishing, but if publishing occurs first, the novelty element of the idea is ruined and the patentability is lost.

Support science that addresses critical problems directly stemming from Grand Challenges

Recommendation: Support for market-oriented public-private partnerships should be specifically implemented in areas that show strong science-technology linkages, such as chemicals, drugs, instrumentation and electronics, or other that may surface during thorough assessments of different research fields.

Recommendation: Partners participating in EC funded collaborative efforts to, e.g., solve Grand Challenges, should also sign up to a detailed and committing exploitation plan before embarking on the project, all the way down to who will build pilot and implement the manufacturing process. A stronger focus on- and commitment to exploitation of project results with clear orientation towards the market have already been introduced under schemes in FP7 and should be further promoted in the subsequent framework programmes.

CHAPTER 1. GRAND CHALLENGES' UNDERSTANDING, INTERRELATIONS AND CURRENT BOTTLENECKS

In this chapter we give an overview of the Grand Challenges and their interrelations.

Grand Challenges

The Grand Challenges reflect Europe's issues, current and future trends and the policies being developed in response.

This important discussion joins the future of the Community with Community spending, **since Key Enabling Technologies development may influence our future ability to answer the Grand Challenges**. The Lund Declaration[4] identifies a set of themes in urgent need of solution. The Declaration emphasises the necessity for the European research community to respond. Following this declaration, the European Commission (EC) Research and Innovation DG published a report on 'The Role of Community Research Policy in the Knowledge-Based Economy',[5] prepared by the European Research Area Expert Group (ERA-EG). It has identified ways to maximise the efficiency of Community research policy in the post-2010 period. Among its most important recommendations is a call for concentrated research efforts to solve the major problems it terms 'Grand Societal Challenges'.

Later on, the European Commission Research and Innovation DG published 'Strengthening the role of European Technology Platforms in addressing Europe's Grand Societal Challenges'[6]. This report summarises the work of an expert group on European Technology Platforms (ETPs), convened by DG Research in early 2009. The expert group examined how the current 36 European Technology Platforms should evolve in the near future. This report proposes that all ETPs be encouraged to work in flexible clusters focused on addressing the key problems facing Europe. These clusters should involve all relevant stakeholders, work across all aspects of the knowledge triangle (innovation, research, education), and be responsible for implementing potential solutions.

In October 2010 the Europe 2020 **Innovation Union Flagship initiative** appeared. The initiative first of all provides a list of over 30 action points that are to be reached in order to direct European research

[4] Lund Declaration, 'Europe Must Focus on the Grand Challenges of Our Time', Swedish EU Presidency, 8 July 2009, Lund, Sweden. http://www.se2009.eu/polopoly_fs/1.8460!menu/standard/file/lund_declaration_final_version_9_july.pdf.

[5] Report of the European Research Area Expert Group on 'The Role of Community Research Policy in the Knowledge-Based Economy', [Online] http://ec.europa.eu/research/era/index_en.html.

[6] Report of the European Technology Platforms Expert Group. 'Strengthening the role of European Technology Platforms in addressing Europe's Grand Societal Challenges'. http://www.ectp.org/groupes2/params/ectp/download_files/27D1047v1_ETP_ExpertGroup_Report.pdf.

into new and better services and products with the main target to remain competitive on the global marketplace and improve the quality of life in Europe.

On 4 of February 2011, at the first European Council to place innovation at the top of the political agenda, EU leaders recognised that the Innovation Union initiative is a crucial strategy for European future economies. They gave strong backing to a series of proposals to turn the EU into a true Innovation Union.

Just recently, on 30 November 2011 the European Commission published officially its plans for Horizon 2020, its omnibus R&D programme. The main idea behind this plan is to make funding of research simpler and more economically productive. Under this proposition a number of radical changes were signalled. The Framework Programme as we know it today will in fact disappear, as the entire internal structure of financing will change and only some of the internal FP-originated tools and mechanisms are to be maintained.

The biggest change in the context of this report is reflected through a new focus of strategic priorities of Horizon 2020. The biggest part of the programme (43% of the total allocation of almost EUR 88 billion) will be dedicated to Grand Societal Challenges.

Each of the Grand Challenges raises significant issues for the future, while potential solutions may be linked to key enabling technologies (KETs).

During the planning of future research activities, the European Commission formulated differently the set of Grand Challenges, which was subject to change at least three times during the flow of this project. The final list was published together with the **Horizon 2020 proposal** and contains:

- **health, demographic change and wellbeing;**
- **food security, sustainable agriculture, marine and maritime research and the bio-economy;**
- **secure, clean and efficient energy;**
- **smart, green and integrated transport;**
- **climate action, resource efficiency and raw materials;**
- **inclusive, innovative and secure societies.**

Sections below discuss these challenges.

1.1.1 Interconnections between Grand Challenges

When defining the Grand Challenges it is important to clarify what the Commission has decided are the most important areas for focused research. Equally important is to point out the interconnections between the different challenges. That interconnectedness becomes clear when examining the specific needs of each challenge area, identifying the technologies, present and future, that may be applied to solving the challenges, and assessing the particular bottlenecks presented by each challenge. Here we will give some examples of how

the challenges are synergistically linked.

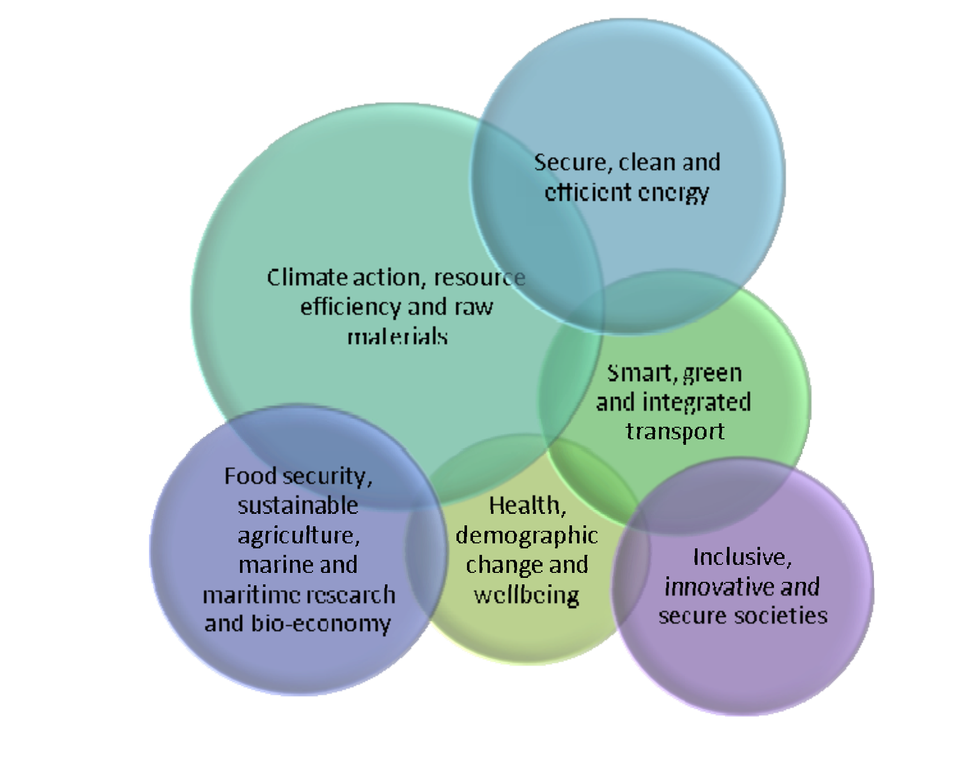
One obvious example is seen in the intertwined needs, actions and consequences between climate action, resource efficiency and raw materials, and secure, clean and efficient energy. Since our energy consumption is a major source of climate pollution, addressing the issues of energy efficiency will also go a long way toward solving the climate crisis. In the same way, inefficient energy storage technologies is a critical bottleneck related to both smart green and integrated transport, and secure, clean and efficient energy. When scientists one day manage to make batteries that last radically longer and recharge radically faster than the batteries of today, this breakthrough will have a major impact on the possibilities for both the realization of green transport and for secure and efficient energy. At the same time this will be an important step for climate action.

Health, demographic change and wellbeing focus on empowering older persons (among other issues). There are many different aspects contained in this goal, but for the sake of example, the challenge of making society inclusive, innovative and secure is undoubtedly important. By promoting digital inclusiveness, older people may be able to solve more of the problems of everyday life without help from others. The same goes for smart and integrated transport that includes the needs of older people. Considering the demographic changes Europe is going through, the empowerment of elders may have an important impact on the economies of Member States.

Food security, sustainable agriculture, marine and maritime research and bio-economy are all intricately part of climate action, resource efficiency, health and wellbeing. Healthy oceans and the technology to use the marine resources in a sustainable way will have a huge impact on the environment. At the same time it’s without question that the quality and the quantity of the food available have a major impact on human health.

The Societal Grand Challenges are connected in many ways. So too, breakthroughs within one KET may have a huge impact on several other of the Grand Challenges. The model below shows (in a very simplified manner) a few ways in which the different Grand Challenges are linked.

Figure 1: Interrelations between Grand Challenges



1.1.2 Health, demographic change and wellbeing

Eurostat's 'Demography report 2010', clearly indicates the EU's demographic picture: **continental growth is fuelled mainly by immigration, whereas the population is becoming older and more diverse**. Europe is bracing for the social and economic impacts of a retiring 'baby boom' generation. But the ageing of the population is not a temporary European trend — it is a long-term and global development, one that will be felt for generations to come. Paradoxically, perhaps, the new technologies to some extent add to longevity, as medicine, sanitation, and agricultural production have improved. Life expectancy around the world has risen and continues to rise. This, combined with falling birth rates, is causing what experts call the **'demographic transition'—the gradual change from high to low levels of fertility and mortality**.[7]

In highly developed countries, including most of the EU Member States, this demographic transition

[7] Caldwell, John C.; Bruce K Caldwell, Pat Caldwell, Peter F McDonald, Thomas Schindlmayr (2006). Demographic Transition Theory. Dordrecht, The Netherlands: Springer. p. 239. ISBN 1-4020-4373-2.

began in the 18th century and continues today. In less developed countries, this demographic transition started later and is still at an earlier stage.[8]

One of the most important implications of this transition is that the elderly constitute a much greater share of the total population than before. Europe has seen both mortality and fertility fall since the 19th century. Since the 1960s, however, fertility has declined even more dramatically.[9]

The EU population ages at varying speed. Populations that are currently the oldest, such as Germany's and Italy's, will age rapidly for the next twenty years, then stabilise. Some populations that are currently younger, mainly in the East of the EU, will undergo **ageing at increasing speed** and by 2060 will have the oldest populations in the EU. [10]

Gradual but nonetheless major changes are affecting the population of Europe already. Two main positive trends are emerging: a slight increase in fertility and greater life expectancy. The modest increase in fertility reported by Eurostat in 2010 results from somewhat new family building patterns in EU countries: fewer marriages, more cohabitation, more divorces and an older average age of women at childbirth who tend to have higher fertility rates. Indicators observed just before the recession suggest that fertility seems to be increasing again, albeit only slowly. Life expectancy keeps rising. The labour force keeps growing and EU-27 has attracted large numbers of migrants.

The most recent large wave of immigrants, that has swollen the cohorts of foreigners in Mediterranean countries such as Greece, Italy and Spain, abated in 2008. Immigrants tend to be less well-educated and employed in jobs below their qualifications. [11]

According to Eurostat estimates**, immigration may reach 40 million in 2050** and could offset the effects of low fertility and extended life expectancy.

In its October 2006 communication entitled 'The demographic future of Europe — from challenge to opportunity',[12] the Commission presented its views on the demographic challenges the EU faces and options for tackling them, underlying the role of employment and productivity

[8] "Demographic transition", Geography, About. http://geography.about.com/od/culturalgeography/a/demotransition.htm

[9] Growing Old; Valdis Wish¸ Knowledge Allianz 2009; http://knowledge.allianz.com/demographics/aging/?214/global-population-aging-growing-old

[10] Demography report 2010; European Commission

Directorate-General for Employment, Social Affairs and Inclusion, Unit D.4

Eurostat, the Statistical Office of the European Union, Unit F.1. March 2011.

[11] Ibidem.

[12] http://europa.eu/legislation_summaries/employment_and_social_policy/situation_in_europe/c10160_en.htm

directly linked with development of European industry.

Nevertheless, ageing populations will create a number of challenges for current and future governments. One is how to sustain public pension/social security systems as a larger proportion of people reach retirement and enjoy a longer life. New technological solutions including **KETs may be used to cope with some problems related to old age and frailty**, and most of all to health-related challenges.

Another dimension related to industrial technologies is the education, employment and integration of migrants in order to assure a qualified workforce for European industry in the years to come. Over the next 20 years, Europe will in fact have to attract a qualified labour force from outside in order to meet the needs of its labour market. It is also the task of the Union to promote diversity and combat prejudice in order to facilitate the economic and social integration of immigrants.

Finally the demographic changes will influence the way we live today, creating new types of societies with different working models, changes in city/rural design and density, and especially new modalities of living. Some aspects of this future trend can be observed now with current statistics. Today in Europe rural areas are losing the young generation faster than urban areas. Cities are attracting residents of all ages. Although in 2001 rural areas had on average an older population than intermediate or urban areas, from 2001 to 2006 the share of the old age group grew faster in urban areas.[13]

Theories of post industrial societies argue that the current era of industrial society is coming to an end, and services and information are becoming more important than industry and goods.[14] In 'Wikinomics', Don Tapscott and Anthony Williams taught the world how mass collaboration was changing the way businesses communicate, compete, and succeed in the new global marketplace.[15] The principles of wikinomics seem now more powerful than ever. Recent presentations at the European Innovation Convention prove that **networked intelligence, businesses and communities are bypassing crumbling institutions**. Humanity is altering the way our services and governments operate. Social media trigger revolutions and build public awareness. Key enabling technologies are a fundament for all these changes.

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[13] Population and social conditions, Michael Goll; Statistics in focus 26/2010, Eurostat.

[14] Sztompka, Piotr, Socjologia, Znak, 2002, ISBN 83-240-0218-9, p.509-511.

[15] http://anthonydwilliams.com/2010/03/10/wikinomics-and-the-era-of-openness-european-innovation-at-the-crossroads/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+anthonydwilliams+%28anthonydwilliams.com%29

Public health and pandemics

The main consideration in public health issues is to provide medical care to everyone while minimising discrimination.

One of the main priorities within KETs is drug research, important to public health and official responses to pandemics.

1.1.3 Food security, sustainable agriculture, marine and maritime research and the bio-economy

Malnutrition affects 2 billion people in the world today. With the predicted growth in population, by 2025 this number likely will increase vastly (especially in Africa and South Asia), as food demand in emerging countries increases. Moreover, supply is likely to be reduced and food prices may prove prohibitive for the poorest groups because of the reduction of agricultural land, irrigation problems and the general effects of climate change. Key enabling technologies **supporting agriculture production may be an important factor in future solutions**.

One of the immediate and overwhelming concerns of the food sector is the global increase in food prices. During the first three months of 2008, international nominal prices of all major food commodities reached their highest levels in nearly 50 years while prices in real terms were the highest in nearly 30 years.[16]

In addition, the challenges of climate change are increasingly urgent. The Intergovernmental Panel on Climate Change makes it clear that warming of the climate system is 'unequivocal', as observations of increases in air and ocean temperatures, widespread melting of snow and ice, and sea-level rise have made evident.[17] Agriculture will therefore have to cope with increased climate variability and more extreme weather events. **Agriculture has to find ways to feed the world while being environmentally, socially and economically sustainable**. All these aspects can be addressed by key enabling technologies in the future, as the business-as-usual scenario of industrial farming with its input and energy intensiveness, collateral damage to the environment and marginalization of small-scale farmers is no longer tenable.

In this context special attention in Horizon 2020 was given to seas and oceans as a potential source of response to the food challenge.

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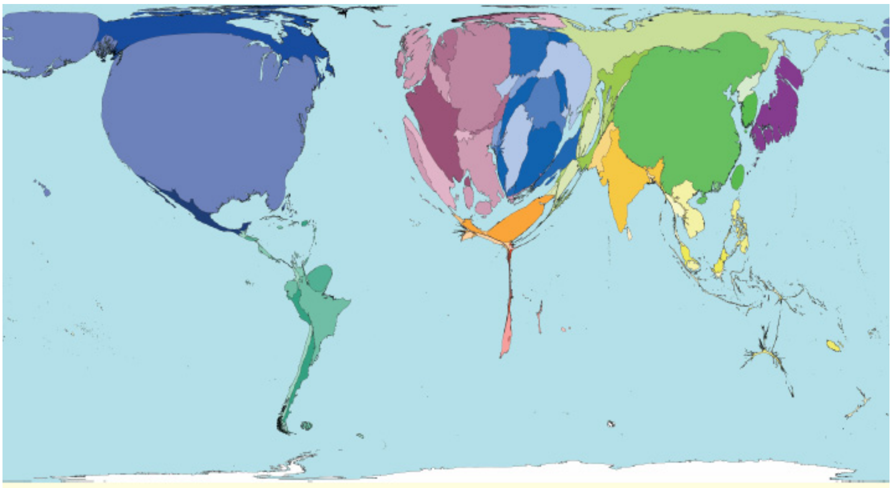
[16] FAO. 2008. Soaring food prices: Facts, perspectives, impacts and action required. HLC/08/INF/1. High Level Conference on World Food Security: The Challenges of Climate Change and Bioenergy, Rome, 3-5 June 2008.

[17] IPCC. 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland.

Figure 2: Industrial Water Use



Source: SASI Group (University of Sheffield) and Mark Newman (University of Michigan); 2006. Data are sourced from the World Bank's 2005
World Development Indicator: data presented in proportional relation of cubic metres of water for industrial use, annual average per

Water

The need for water will increase sharply with the increases in world population and the rise in the standard of living and expectations in emerging countries. Six billion people depend on this supply and a significant portion of the world's population now face water shortages. Today 31 countries representing 2.8 billion people, including China, India, Kenya, Ethiopia, Nigeria and Peru, confront chronic water problems. Within a generation, the world's population will climb to an estimated 8 billion people.

Yet, the amount of water will remain the same.[18]

Use of freshwater resources varies from one country to another. In low-income

countries, almost 90% of freshwater is used for agriculture, 8% for industry and only 5% for households. In high-income countries, industry uses 59%, agriculture 30% and households just 11%.[19] This **high level of industrial-related water consumption must gain a special focus among technologies developed in the area of NMP**, as the industrial processes might be refined in the search for more efficient and sustainable technologies. It is estimated that 22% of worldwide water use is industrial.[20] Major industrial users

[18] Safe Drinking Water: The need, the problem, solutions, and an action plan;

Report of the Third World Academy of Science 2002.

[19] Ibidem.

[20] WBCSD Water Facts & Trends; 2009; http://www.wbcsd.org

include hydroelectric dams, thermoelectric power plants that use water for cooling, ore and oil refineries that use water in chemical processes, and manufacturing plants that use water as a solvent. Water withdrawal can be very high for certain industries, but consumption is generally much lower than that of agriculture.

There are in general two main factors to be described here in the context of future water shortages. First of all total withdrawals of freshwater have increased dramatically and doubled over the past 40 years.[21] Inefficient irrigation practices that have played such a large role in groundwater depletion not only waste water but degrade soil quality and reduce farm productivity.

Secondly the relentless rise in population in various parts of the world, particularly in developing countries, will result in reduction of available freshwater per person per year by 40%.

Strong tensions may emerge, as the quantities available are likely to decrease due to above mentioned factors as well as climate change and non-sustainable consumption.

In order to meet this challenge industrial technologies will have to propose new ways of **fresh water 'production' and reuse.**

Desalination plants may proliferate around the Mediterranean, in Asia, Australia and California. Early plants first located in the Middle East today produce half of the world's desalinated water.[22] Such first-generation desalination technologies use a great deal of combustion energy. Thus current methods of desalinisation will contribute to increased CO_2 emissions and exacerbate problems in the natural hydrologic cycle.

Industrial technologies are to play a role here with regard to **enhancement of the existing desalination techniques**, but also regarding the use and reuse of water in private and industrial environments. Another field of potential interest here is delivery of efficient and low cost sewage treatment technologies.

Marine and maritime research[23]

Marine research addresses flora and fauna of the seas as well as their interaction with coastal territories and the atmosphere. Nowadays, one of the major concerns of marine research is the preservation of marine ecosystems.

Preservation of the marine environment is crucial to our own ability to survive on the planet and is directly linked to another Grand Challenge: climate action. Oceans absorb approximately one-third of the CO_2 produced by humans, which while beneficial for the atmosphere,

[21] Ibidem.

[22] The World in 2025 , European Commission; Directorate-General for Research; 2009 http://ec.europa.eu/research/social-sciences/pdf/the-world-in-2025-report_en.pdf

[23] EU Strategy for Marine and Maritime Research; MEMO/08/553 Brussels, 3 September 2008.

has detrimental effects on the marine environment.[24]

Strategies and techniques for marine conservation tend to combine theoretical disciplines, such as population biology, with practical conservation strategies, such as setting up protected areas. Other techniques include developing sustainable fisheries (including fish quotas) and restoring the populations of endangered species through artificial means, where again KETs may bring extensive responses.

Maritime research aims at technologies and innovative solutions for better exploitation of sea and ocean resources. This includes the design, building and operation of vessels, harbours, oil platforms and more widely any kind of human-related activity centred around sea and ocean resources (such as tourism).

This particular sector is extremely important for the European economy, as 90% of external trade and 40% of internal trade in the EU is seaborne and served by more than 1200 European ports.

Employment is important in understanding the dimensions of this challenge, with shipbuilding accounting for 0,8 million direct and indirect highly skilled jobs, fisheries and aquaculture with 0,5 million jobs and maritime tourism about 3 million jobs.

Additional sectors appear also in this context with high growing potential in the future like for example **'new resources and blue biotechnology' being an emerging sector**, where marine and freshwater organisms are used for purposes such as **increasing seafood supply and safety, controlling the proliferation of noxious water-borne organisms**, and developing new drugs.

In the context of the energy challenge, the most important aspect of marine technologies is potential energy production. Seas and oceans offer an underexploited resource to use alternative energies such as tidal and wave power and offshore wind farms. Maritime research within key enabling technologies may offer solutions such as the **design, building and operation of offshore wind turbines, wave and tidal energy generators, sea and undersea exploitation technologies.**

1.1.4 Secure, clean and efficient energy

There is an increasing tension between rapidly growing demand and restricted supplies of petroleum-based resources (oil, gas). Their polluting nature is a complicating factor, which holds true for a resource that is still abundant: coal. These tensions have caused an almost constant rise in energy prices. Increased use of renewable energy, as well as progress in the reduction of energy consumption, may help to contain price rises. But opinion is divided over the scope of possible change, and how and when this might happen.

[24] http://www.fis.com/fis/worldnews/worldnews.asp?monthyear=&day=21&id=40659&l=e&sp ecial=&ndb=1%20target .

Despite our technological sophistication, in 2025 the world's energy demand will have increased by 50 per cent (relative to 2005) and will reach the equivalent of 15 billion tons oil. Oil production will have peaked, and some experts believe coal will become the prime energy source between now and 2050. Possibly, oil will still largely be in the lead in 2025.[25] **The security of energy supplies increasingly will be called into question in Europe**. If policy does not change the EU of the future will be more dependent on external sources than in 2005. In 2030, the Union will import almost 70% of the energy it needs.

New dimension for the energy discussion appeared in 2011 with the Fukushima Daiichi nuclear disaster, following the Tōhoku earthquake and tsunami on 11 March 2011. This, the largest nuclear disaster since Chernobyl in 1986, caused an extremely important change in the thinking of several developed countries' governments. The findings of our investigation within this study reveal a **large shift in such leading technologically advanced countries as Japan and Germany from nuclear energy production to alternative sources**. This trend is claimed to impact the entire European research and industry, forcing key enabling technologies to deliver responses to crucial bottlenecks described later in this document.

25 International Energy Agency foresight.

1.1.5 Smart, green and integrated transport

'Transport is rightly considered (...) as a key societal challenge. It should be also kept in mind that transport is a key condition for competitiveness.'[26]

The issue of transportation and the environment is paradoxical in nature. On one side, transportation activities support increasing mobility demands for passengers and freight, which range from urban commuters to international trade. On the other side, transport activities have resulted in growing levels of pollution and congestion. As a result, the transportation sector is becoming increasingly linked to environmental problems. With a technology relying heavily on the combustion of hydrocarbons, notably the internal combustion engine, the impacts of transportation on environmental systems has increased with motorization. This has reached a point where **transportation activities are a dominant factor behind the emission of most pollutants and thus their impacts on the environment**.[27]

26 Informal discussion with stakeholders on the transport component of the next common strategic framework for research and innovation, Brussels, 16 June 2011.

http://ec.europa.eu/research/horizon2020/pdf/workshops/smart_green_integrated_transport/summary_report_workshop_on_16_june_2011.pdf#view=fit&pagemode=none

27 The Environmental Impacts of Transportation; Authors: Dr. Jean-Paul Rodrigue and Dr. Claude Comtois http://people.hofstra.edu/geotrans/eng/ch8en/conc8en/ch8c1en.html

Innovative solutions for transport address materials and manufacturing processes for lower fuel consumption and development of **alternative fuel sources**. Materials science is engaged in developing new construction materials for roads and rail roads, as well as materials for transport security. Such processes will be critical to strengthen the global competitiveness of the European transport industry.

The 'green' aspect of transport is very much aligned with two other Grand Challenges described here– 'climate action, resource efficiency and raw materials' and 'secure, clean and efficient energy'.

1.1.6 Climate action, resource efficiency and raw materials

Global warming is no doubt one of the most serious problems facing humanity today. Two separate dimensions of global warming correspond to different kinds of advanced technologies under discussion. First is the prevention of the global warming itself (reduction of emissions, clean production, less pollution in general). Second are the technological efforts to mitigate the consequences of global warming (natural disasters such as flooding, forest fires, hurricanes, desertification).

Global warming is also connected with other Grand Challenges, as it will have an impact on the long-term health and economic well-being of current and future generations.

In order to prevent a downward spiral, the current strategy underlines the need to **reduce emissions of heat-trapping gases by using the technology, know-how, and practical solutions already at our disposal**. Secondly the strategy pursues promising new technologies, including new materials, that will enable us to produce highly efficient products with less pollution, thanks to knowledge-intensive production processes.

The European Commission has followed this strategy to tackle global warming since the introduction of climate-related initiatives in 1991, when it issued the first Community strategy to limit carbon dioxide (CO_2) emissions and improve energy efficiency. Several important directives were introduced at that time, including those to promote electricity from renewable energy, voluntary commitments by car makers to reduce CO_2 emissions by 25% and proposals on the taxation of energy products. All those fields benefit from implementation of solutions offered by KETs. Examples include filters, protection and isolation films, **new combustion sources, energy storage and electricity grids**.

However, it is clear that action by both Member States and the European Community need to be reinforced, if the EU is to succeed in cutting its greenhouse gas emissions to 8% below 1990 levels by 2008-2012, as required by the Kyoto Protocol. On the political level this was supported by the EU Council of Environment Ministers, who acknowledged the importance of taking further steps at the Community level by asking the Commission to put forward a list of priority actions and policy measures. The Commission responded in June 2000 by launching the European Climate Change Programme (ECCP). The political dimension and commitment later was strengthened through the engagement of the European Commission in the development of technologies, particularly in the context of the framework programmes (FPs). Industrial technologies play a crucial role in the Commission's portfolio of tools, and are strongly represented in European FPs, especially with the NMP priority in FP6 and FP7.

The second European Climate Change Programme (ECCP II), which launched in October 2005, is still influencing the shape of the strategic dimensions of research conducted in FP7.

In spite of all political actions, the most important source of CO_2 emissions worldwide is caused by the transportation of goods and people. **Fossil fuel combustion generates more than 90 per cent of the world's CO_2 emissions**.

After fossil fuel combustion the next two areas with high CO_2 emission impact are **iron/steel and cement production**.

Supply of raw materials

Supplies of raw materials are not a key subject of this study, but over recent years has appeared as one of the fundamental bottlenecks in development of KETs in the future. New materials in this context shall be developed as alternatives for raw materials. In fact, current problems with raw materials availability have put industrial technologies into the forefront of political discussion.

The European Commission claims that 14 critical raw materials used for high tech products such as mobile phones, laptop computers and clean technologies are in danger of shortage. Increased recycling of products containing these materials will be needed in the future. The list includes cobalt, gallium, indium and magnesium. They are increasingly used for 'emerging technologies' but are mined in only a few countries such as China, Russia and Mongolia. These countries could either manipulate the supply of these critical materials or take environmental action that may jeopardise EU imports.

After recent problems with materials availability from China, EU is working to secure supplies of these minerals from outside the EU, such as from Latin America, Africa and Russia. The EU also started stockpiling— to better profit from the material that we have here.[28]

Demand from emerging technologies for materials (including rare earths) is expected to increase significantly by 2030, according to EU estimates.[29]

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[28] Andrea Maresi, press officer for EU Industry Commissioner Antonio Tajani.

[29] Report of the Ad hoc group on defining critical raw materials, June 2010, Brussels. http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/report-b_en.pdf ,

According to secondary sources of this study, research and industry deployments in the nearest future will focus on:

- improved physical methods for minerals concentration (enrichment of non-ferrous ores, froth flotation);
- new technologies for production of precious metals;
- development of chloride metallurgy;
- processing systems for re-use and recycling;
- innovative use of alternative energy sources for processing raw materials and metals recovery.

1.1.7 Inclusive, innovative and secure societies

This Grand Challenge is in fact composed of three separate issues. The openness of societies is hardly connectable with discussion of enabling technologies, being of a social science nature. Horizon 2020 documents which are to give some indication regarding possible action in the area of research indicate that 'Actions supporting smart, sustainable, inclusive and equilibrate growth' are to be financed. Still, no further information is given in this regard.

The connection between openness and security of societies is more easily observed — in a larger context, security is fundamental for society's ability to stay open.

An **innovative society, meanwhile, is the overwhelming factor motivating this study**, addressed and described in policy options later on. Therefore in this section we will only address the security issues that can be directly addressed with key enabling technologies.

Current developments in the Arab countries in Northern Africa, mass migrations influencing southern European countries and growing terrorist risks put security in the forefront of research in industrial technologies and novel materials. The European security strategy, 'A Secure Europe in a Better World', endorsed by the European Council in December 2003, outlines the global challenges and key threats in this area.

The Commission Communication from 2003 on 'The European Defence and industrial and market issues – Towards an EU Defence Equipment Policy' emphasises the need for effective cooperation between national research programmes in the field of global security. The idea is to concentrate on a few carefully selected subjects of advanced technology accompanied by specific measures.

Security is an evolving issue that presents many challenges to the EU. It impacts a wide range of existing and emerging EU policies (competitiveness, transport, environment, energy, health,

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http://europa.eu/rapid/pressReleasesAction.do?reference=IP/10/752&format=HT and http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/10/263&format=HTML&aged=0&language=EN&guiLanguage=en

consumer protection, finances, trade, space and telecommunications). It is a critical consideration of the Common Foreign and Security Policy and the European Security and Defence Policy. Research policy plays a cross-cutting role to target threats and reduce citizens' concerns, helping to protect against terrorist threats.

Special attention within this challenge is to be given to information society being important part of our future. An important part of modern society development is based on the security of information systems. ICT (Information and Communications Technology, one of KETs) is one of the disciplines where a lot is to be done in order for Europe to feel secure.

Cyber-security is now a serious issue, especially in the view of cyber-attacks conducted against countries in the past. The most serious and far-reaching consequences occur from information infrastructure disruptions at the global, national and regional level. Secret intelligence operations are currently conducted using existing internet technologies and can be vulnerable. Taking the above into consideration European defence services will require extensive support from the available technologies and, most of all skilled specialists need to be available at the European market.

The Union needs to use a range of instruments to deal with such current hazards as terrorism, proliferation of weapons of mass destruction, failed states, regional conflicts and organised crime. Industrial technologies can give the necessary assistance, offering scientific innovations in the area of detection, monitoring and early warning systems and technologies.

Technology itself cannot guarantee security, but security without the support of technology is impossible. It provides information about hazards, helps to build effective protection and, if necessary, enables designated agencies to neutralize dangers. In other words: technology is a key 'force enabler' for a more secure Europe. Space technologies are a perfect illustration of this. A decision as to whether global positioning or earth observation systems are to be used for defence and security purposes is primarily political in character, not technological. When the decision is made — implementation is of purely technical nature.

CHAPTER 2. BOTTLENECKS

Dividing bottlenecks

Bottlenecks are obstacles that in different ways hinder the attainment of our goals. In this section critical hindrances have been identified and grouped.

This study identifies a large number of problems through document studies, interviews and workshops. In this chapter we hope to present a final, short, and readable outcome of our research and analysis. To identify the most critical hindrances we used two criteria: 1) those mentioned by several experts, and 2) those that impact an entire area (that is, above project level).

Since the **obstacles identified touch a variety of issues of different nature and operate at different levels**, we decided to split them into four different areas:

- technology and R&D related,
- political,
- legal,
- market.

Many issues of the identified bottlenecks intersect with the Grand Challenges as well as the above listed areas, an observation we term their 'cross-cutting' nature. The crucial obstacles will be seen to appear across several themes and challenges. This stubborn ubiquitousness is in part why these issues can be seen as hindrances.

In the following sections these crosscutting obstacles are described. Then our analysis presents their connections to the Grand Societal Challenges.

2.1.1 Cross-cutting bottlenecks

General

The interview data demonstrate that a range of critical issues need to be addressed in solving the Grand Challenges. While some of the bottlenecks are specific to an individual Grand Challenge, there are a few that concern the general political, legal and market framework conditions for research and development in the EU. These underlying congestions need to be addressed first, in order to be able to set out constructive development processes in the context of the Grand Challenges. Many identified obstacles cannot be addressed within the scope of the NMP programme itself. They require concentrated cooperation with the DGs as well as policy initiatives on a higher level. The clear directive coming out of the interviews is that in order for the FPs to contribute their knowledge and technologies towards solving the Grand Challenges, these **underlying issues should be solved first**.

In the following we present the general bottlenecks brought up in the interviews.

Political fragmentation

There is not enough political will (understanding, focus) in the EU for concrete actions that should and must be undertaken in order to address the Grand Challenges in a coordinated and committed way at the Community level.

Political fragmentation in Europe is a multi-dimensional issue. Most important in this context seems to be the Member States' traditional approach whereby **national policies prevail over common, long-term perspectives and European interests**. The Member States' political election agendas, which influence decision making on the national and community levels, are an additional factor to be considered here. Finally competition in particular areas leads Member States towards continued game plays.

A lack of- and unwillingness to think in terms of EU common interests leads Members States towards bilateral agreements with third countries, which are still preferred instead of playing with a common strong EU position. For example bilateral agreements regarding energy with Russia, or with China concerning raw materials supplies, are preferred by the Member States instead of a joint European approach on these strategic matters. This hurdle points out the short-term perspective in politics at the national level.

In addition, industry and civil organizations with contradicting interests try to influence the political reality. Extensive lobbying more and more influences powerful decision-making bodies of the European Union. Already in 2000, about 2,600 interest groups had permanent offices in downtown Brussels, of which European trade federations comprise about a third, commercial consultants a fifth, companies, European NGOs (e.g., in environment, health care or human rights) and national business or labour associations each about 10%, regional representations and international organizations each about 5%, and, finally, think tanks about 1%.[30]

Finally, **lack of coordination and integration between legislation on national levels** as well as between EU policies must be underlined in this context. Clear examples of such hinders are national and regional health policies that are not influenced by the common European approach. An even more striking and essential example of the EU's difficulties with full integration is the stalled creation of a single market for trade and services. This flagship European effort is still hindered, after many years of continuous efforts, by contradictory and market-limiting regulations.

Political myopia

The politics of today at the EU level is characterized, according to our interviewees, by **short-sightedness and a 'what-can-I-have-out-of-this' approach**. This is seen as a major bottleneck that permeates the politics in the EU and influences the joint efforts to address mutual problems. Factors such as strong lobbying on the national, EU and international levels, limited political mandate, and power games work to the detriment of solving the Grand Challenges.

[30] 'Lobbying in the European Union: current rules and practices'. Directorate-General for Research Working Paper, 2003.

Gap between research and industrial application

Although steps have been made to address the gap between science and industry, there is still a lot to be done. It is a positive factor that the industry has been increasingly involved in the FPs, but this gap persists. The **FPs created a positive matrix to bring together industry and academia**, however the reality is that the researchers still care mostly about their publications and the industry still can't see many applications that they can commercialize. As one of the interviewees put it: '*The problem in Europe is not about creating new knowledge, but it is about exploiting this new knowledge*.'

Bottlenecks linked to Grand Challenges

The presentation of obstacles in the table below is mainly focused on the vertical split into four categories, while basic interconnections have been maintained along the table's horizontal rows. Thus the bottlenecks are in most cases also thematically interconnected when reading from left to right.

2.1.2 Health, demographic change and wellbeing

The challenge is to improve the life-long health and wellbeing of all while maintaining economically sustainable care systems.

In order to shape future developments in this field, a non-exhaustive list of technological challenges based on the analysis of identified existing industrial roadmaps, strategies and other planning documents is provided below, divided into thematic subcategories.

Health:

Challenges which are to be addressed by **KETs within 'health' theme**[31]:

- Creation of effective single dose vaccines that can be used soon after birth;
- Production of vaccines that do not require refrigeration;
- Needle-free delivery systems development;
- Production of devise reliable tests in model systems to evaluate live attenuated vaccines;
- Need for antigens for effective, protective immunity;
- Knowledge regarding which immunological responses provide protective immunity;
- Need for development of a biological strategy to deplete or incapacitate a disease-transmitting insect population;
- Development of a chemical strategy to deplete or incapacitate a disease-transmitting insect population;
- Creation of a full range of optimal, bioavailable nutrients in a single staple plant species
- Development of drugs and delivery systems that minimize the likelihood of drug resistant micro-organisms
- Implementation of therapies that can cure latent infection,
- Unrevealing of immunological methods that can cure chronic infections
- Implementation of technologies that permit quantitative assessment of population health status
- Assessment of multiple conditions and pathogens at point-of-care
- Research on biomarkers of health and disease
- Unfolding new ways to achieve healthy birth, growth, and development.

Wellbeing

Listing of the barriers hindering possible responses in this area must be as complex as the entire 'wellbeing' itself. This chapter is presenting hindrances identified from various secondary documents.

One of the most commonly used enabling technologies, impacting our 'wellbeing', not that much explicit in other challenges, is definitely ICT. Many of the obstacles listed below are very sector-specific and of technical nature aligned with information technologies.

Micro- and nanoelectronic systems:

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[31] Following http://www.grandchallenges.org/Pages/Default.aspx

- Societal need to **include sensors and actuators to nano- or microelectronic systems** is created, but **ethical issues arise** in this context, creating possible development barriers.
- There exists an unmatched need to master the design of heterogeneous systems that combine digital and non-digital functions used in everyday use devices.
- Broadening of the product portfolio and products manufacturability using existing wafer technology and production lines is hindered by **fierce competition and high investment costs**. It is not easy to ensure business profitability by producing commodity integrated circuits (ICs).
- For fabrication of wafers used in the integrated circuits and other micro-devices: Stronger interaction is needed between designers, process engineers and providers of design tools in order to relax the lithographic constraint of printing features 'as-designed' onto the wafer.
- For electronic systems production: The development of **structural in-line metrology** (accurate 3D measurement of different patterns, overlays etc.), **fast and sensitive defect detection and classification**, structural off-line characterization (including morphological, physical and chemical analysis of 3D nano-meter-sized structures made of complex material stacks), and methods of assessing the sources of process variability, are all challenging fields requiring large focus over coming years in order to enable sector development.
- For microprocessors and memories used in our electronic devices: As the critical dimensions of CMOS transistors are scaled down, leakage currents and the associated static power consumption become a major issue for the researchers.
- For the electronic imaging used in electronic devices of everyday use: Lowering the pixel size is mainly driven by cost at the device and system levels. However, it is becoming **a real challenge to detect photons while decreasing pixel size**. For non-visible imaging, different technologies are needed for different wavelength ranges. In addition to performance improvements that are common to all imagers, such as better sensitivity, dynamic range and endurance and lower noise and pixel-to-pixel crosstalk, there is a definite **need for multi-spectral analysis using a single sensor technology**.
- For the general design of the advanced microelectronic systems: Among other things, the success of MtM[32] technologies depends on the availability of system-level co-design methods and tools. Even for digital IC technology, which has a long history of electronic design automation (EDA), we are far from using the capabilities of the latest CMOS processes effectively. The productivity gap between what you can put onto silicon and what you can design onto silicon is still growing. The reality is even

[32] MtM - More than Moore- technology where added value to devices is provided by incorporating functionalities that do not necessarily scale according to "Moore's Law“. Moore’s law is a rule of thumb in the history of computing hardware whereby the number of transistors that can be placed inexpensively on an integrated circuit doubles approximately every two years. http://en.wikipedia.org/wiki/Moore's_law

worse for MtM technologies, because there is not only a digital design gap but also a multi-domain aspect to consider. State-of-the-art MtM design tools must therefore be a mix of tools that cover all technologies used in a single product, and are therefore likely to come from different vendors and have different levels of maturity.

- For the general design of the advanced microelectronic systems: The success of MtM will depend on a profound understanding for the properties and behaviour of materials and their interfaces under manufacturing, qualification testing and use conditions, and on the ability to tailor the material design for the requirements of specific applications. This issue is already acute for MtM technologies, where multi-scale size effects and multimaterial compatibility, stability and reliability will be key to success. Among the many challenges, characterisation and modelling of materials and their interface behaviour need more attention, especially for multi-scale, multiphysics and time dependent situations.

- For heterogeneous integration of future nanoelectronic systems used in every day applications: Interconnection, packaging and assembly are major bottlenecks for future nanoelectronics technology and business development.

- For design methods and tools used in nano and micro-electronics: Future design environments will have to cope with a number of major challenges. There will be a large impact from 'More than Moore', through the functional, topological and technical complexity of extremely integrated and heavily compacted systems. In addition, future design environments will be impacted by MtM side effects, notably the evermore serious fabrication and cost constraints associated with continuous downscaling of CMOS technologies and increasing process variability. The whole situation is seriously aggravated by the fact that software now has to be taken into account as part of the integrated design process.

- Reliability of the electronic devices: Unfortunately, the on-going downscaling of semiconductor technologies aggravates the design of highly reliable integrated circuits, because decreasing component dimensions such as oxide thicknesses or wire diameters have a negative influence on ageing. They cause **accelerated wear out of important reliability parameters in integrated circuits** such as thermal behaviour, breakdown voltages, electro-migration and device matching.

- Equipment and materials used for production of electronic devices: Historically, (poly)-silicon, silicon dioxide, silicon nitride and aluminium have been the materials of choice for semiconductor devices. In the last decade, however, it has proven impossible to further extend dimensional scaling with this set of materials alone. A multitude of new high-performance materials with specially engineered electrical, mechanical and chemical properties must be introduced to extend Moore's Law and allow fabrication of scaled devices that operate at higher speed and/or lower power. A huge material science effort is required to deliver the necessary properties, involving the selection, demonstration and integration of appropriate chemistries.

Embedded systems[33]

- For assuring the robustness, autonomy, and mixed critical systems ability to serve humans: Embedded applications with different dependability and real-time requirements will share the same network and hardware components. This can be concluded from several of the scenarios, such as in supportive transportation or care at home and everywhere. This convergence leads to the new challenge of mixed criticality systems and components, of incremental and evolutionary systems and of new architectures to support this mixed criticality. Such systems and components must be able to **simultaneously serve different applications dependably, in real time, and meet energy requirements**. The components and systems must, furthermore, be adaptable since the requirements may change over time. It will not be possible to provide the required robustness and dependability at all times. In such situations, the local embedded system must be able to work autonomously on local resources and data. Autonomy is also increasingly important to adapt to changing application contexts and network environments.
- For production and integration of the future embedded systems in our everyday use: The major challenge in the field of embedded system architecture relates to development of a **generic framework that supports the interoperability** of a set of pre-validated components while making minimal assumptions about the internal structure and implementation of the components.
- For production and integration of the future embedded systems in our everyday use: The major challenge in the area of system design is to develop design methodologies and their associated tools to respond to the ever-increasing complexity of large systems. System analysis methods have to provide a usable suite of analysis methods covering all phases and all viewpoints in the development of safety critical embedded systems, including cross-viewpoint dependencies, enabling cost-efficient certification.
- For validation of the future embedded systems: The major challenge in the area of validation is the reduction of the overall effort required to demonstrate convincingly that a given quality level of a system service has been achieved. At present, the effort for validation and certification amounts to a substantial fraction of the development cost of large embedded applications.
- Major challenges in the area of dependability of embedded systems include the provision of a generic framework that supports secure and dependable, reliable and timely system services despite the accidental failure of system components and the activity of malicious intruders. This

[33] An embedded system is a computer system designed for specific control functions within a larger system, often with real-time computing constraints. It is embedded as part of a complete device often including hardware and mechanical parts. By contrast, a general-purpose computer, such as a personal computer (PC), is designed to be flexible and to meet a wide range of end-user needs. Embedded systems control many devices in common use today. Source: http://en.wikipedia.org/wiki/Embedded_system

requires **technologies for the dynamic reconfiguration of nearly autonomous sub-systems**.

- For communication between the embedded systems of everyday use: The major challenge in the area of communication is the provision of ubiquitous wireless connectivity under the constraints of minimum power consumption and limited bandwidth. The vision of ambient intelligence depends critically on the availability of such an information infrastructure.
- Regarding the knowledge used for production of embedded systems: The major challenge in the area of silicon scaling from the system perspective is to elevate the design abstractions to such a high level that the effective reuse of large and proven Intellectual Property Blocks can be realised. The determinism of the chips must be maintained in order to support **effective system-level validation and certification**. The key to success in the embedded systems market is how to connect system knowledge with IC knowledge.

Materials:

A totally different issue presented in this paragraph is discussing obstacles in the context of materials used in such areas as construction or transport in our everyday applications. Due to its cross-cutting nature it is presented in the wellbeing area.

- Corrosion leads to an increased use of materials and energy, and to larger amounts of waste, and therefore is an important factor for KETs to be addressed.
- Inadequate R&D efforts are made in **tribology applications (friction, lubrification and wear between surfaces**) leading to inefficiency in terms of consumption of energy due to: friction and reduced efficiency, maintenance costs, replacement of materials and components, machines and plants shutdowns, increased lubricant consumption.

Construction:

- The existing building stock has a long life-time and solutions to retrofit existing buildings are lacking. For existing buildings, technical possibilities to create a more energy-efficient structure are poorer and most of them remain to be invented. **Low-intrusive retrofit techniques are lacking**; affordability is still a major problem, and social demand and acceptance are not very well known.

Finally the table below presents an overview of major issues which will influence possible response to the challenge in scope. The table content is based on results obtained during project workshops

Table 1: Health, demographic change and wellbeing – bottlenecks

Technology and R&D	Political	Legal	Market
Lack of integrated systems/technologies. **Much is unknown about nanotechnology's effects on humans** and there's a lack of connections between the different disciplines.	The **national health systems are too different from each other** and strongly lobbied.	Lack of common international or European standards, and lack of a strategy to coordinate the interdisciplinary research.	Time to market (and therefore the time to the patient) is too long. Lack of single market for health services and elderly services.
Lack of common standards and conformity assessment procedures. This hampers existing and new services and technologies such as smart homes, integrated health and social care ICT systems, and assistive technologies. Lack of common standards makes it difficult to reach mass markets and deliver opportunities for competitiveness.	Lack of knowledge of relevant needs for different groups of people in a range of work, home, leisure and care settings, including those with impaired cognitive, sensorial or motor capacity. Most existing guidelines are based on old studies or simply on estimations.	The assistive technologies industry is fragmented, and users' organisations small. Differences in social and health care reimbursement schemes within Member States and uncertainties about the legal requirements of medical certification for ICT-enabled services.	Access, accessibility and user-friendliness of assistive ICT is not sufficiently addressed by the industry, especially regarding the elderly. **Markets alone do not possess the necessary incentives to guarantee interoperability and modularity across different devices and services**, thus increasing costs to final users, missing economies of scale, and hampering the internal market for ICT and aging.

Long-term behaviour of smart materials (temperature sensors, electrodes for cardiology monitoring, motion and respiration sensors) when used as textiles still is a key issue. Biological, chemical and acoustic sensing still requires more research.		**Ethical and psychological issues: assistance vs. autonomy and free choice**.	Lack of a systematic approach to market development leading to high costs for research and market validation and the lack of exchange of practical experiences because of market barriers.
Global health concerns face bottlenecks in fields such as smart biomaterials, biochips and microfluids and electronic imaging, and are field specific. Photonic systems such as lasers, sensors and actuators and biosensors are each posed with field-specific technological challenges.			The focus of industry is not on innovative technologies for the developing world. The challenge is to develop **cheap medical technologies**, but also technologies that are tailored for the specific challenges that low- and middle-income countries face.
Water desalination technologies are expensive, insufficiently effective and polluting.	Increase in world population and urbanisation leads to soil sealing, which dramatically reduces the capacity of soil to absorb and filtrate rainwater, leading to reduced aquifers.	Responsibility for managing floods and drought in regards to disaster relief may reside at different levels in different countries, from national organizations and regional authorities to local muni-cipalities and city councils.	

Source: Oxford Research AS

A critical R&D bottleneck is that **interdisciplinary research and development are not strong enough** to have a lasting effect on the development of industrial technologies and their integration. The interdisciplinary teams in this area still speak different languages – the languages of their respective disciplines. Another critical problem is the **safety issue of using the enabling technologies** (for example nanotechnology) upon the human body.

Finally a critical hurdle lies at the political level, where there are highly different health systems across Europe and a lack of common standards.

Introduction of smart systems face obstacles such as **ethical questions raised by nanomedicine (**privacy, non-discrimination, informed consent, respect of human dignity and integrity). The impact of nanoparticles on humans, animals and the environment is not known as there are very few studies regarding the issue. Pervasive healthcare systems and applications set demanding requirements regarding energy, size and weight, cost, mobility, connectivity, and coverage of smart systems. These systems are very critical in meeting future health needs, and therefore they raise high standards regarding reliability, scalability, privacy enhancement, interoperability, and configurability, among other challenges.

2.1.3 Food security, sustainable agriculture, marine and maritime research and the bio-economy

The challenge is to secure sustainable supplies of safe and high-quality food and other bio-based products by providing productive, resource-efficient and resilient production systems, while accelerating the conversion towards the low-carbon and sustainable bio-based European industries of the future.

NMP theme was **not very much oriented towards the food and agriculture under FP6 and FP7** as other thematic priorities dealt with research challenges to this regard. The possible bottlenecks for KETs in this context are mostly linked to other challenges.

Agriculture

In general it must be stated that in the future the development of automation technology for highly productive and efficient production processes will determine development trends of agricultural machinery.

Finally the table below presents an overview of major issues which will influence possible response to the challenge in scope. The table content is based on results obtained during project workshops.

Table 2: Food security, sustainable agriculture, marine and maritime research and bio-economy – bottlenecks

Technology and R&D	Political	Legal	Market
Safety of certain KETs still not proven.	Lack of a global political framework for food distribution.	Lack of safety-related regulations on international level especially within nano enhanced products.	**Safety issues in context of KETs causing lack of trust among consumers.**
Lack or limits of sustainability in current systems of food manufacturing, preservation, storage, processing, packaging, transportation and distribution and retail. **Lack of integrated systems for food packaging.**		Valuable food raw materials are wasted — the consequence is overproduction in the primary sector.	Reduction of agricultural land for food production (linked to increased use of land for the production of renewable energy sources and to urbanisation encroaching on agricultural land). Waste and overproduction of food. Lack of economical systems to track food from production to the consumer.
Technology for efficient local water treatment and reuse technologies is not entering the user market (too expensive).	Aging infrastructure leads to significant water leakage. Ineffective water pricing policies do not reflect sensitivity of water resources	Inadequate pan-European regulation hindering water reuse.	Lack of consciousness in daily water use. Globalisation and wealth growth, leading to extensive agriculture (irrigation and pollution) and consumption habits with a high water footprint.
	Lack of knowledge and information that is required for decision-making and	Issues of water allocation and competition between the water users (home,	High investment and operational costs associated with the collection / distribution and treatment of the

	long-term planning in regards to managing water resources.	industry, agriculture and environment).	municipal drinking water and wastewater, as well as water resource management. Need for smaller scale, adaptable, local infrastructure systems is immense.
Advanced facilities, emerging technologies, industrial engineering concepts and new added-value products and services to **improve utilization of food and non-food raw materials and waste**.			Bottlenecks specific in Europe: **food production system depends heavily on fossil fuels**, with both production and distribution sensitive to fuel prices. Strict regulation on genetically modified crops delays private investment.
Source: Oxford Research AS			

Despite adequate global food production, many still go hungry because increased food supply does not automatically mean increased food security. What is important is who produces the food, who has access to the technology and knowledge to produce it, and who has the purchasing power to acquire it.[34]

The main hurdle in this area **is the lack of knowledge about the impact of the current economies upon the global seas and oceans.** According to the interviewees there is no holistic approach in exploiting the seas and oceans today; actions in this area are done in isolation. There are numerous advanced technologies that are used on the seas and oceans today, but there is little knowledge about their effects upon the marine ecosystems and biodiversity. Also, the lack of political and legal frameworks concerning the use of technologies on the seas and oceans lead to the situation where countries do not take responsibility for the eventual damages and negative impacts caused.

[34] Pretty, J. and Hine, R. 2001. Reducing food poverty with sustainable agriculture: a summary of new evidence. UK: University of Essex Centre for Environment and Society.

2.1.4 Secure, clean and efficient energy

The challenge is to ensure the transition to a reliable, sustainable and competitive energy system, in the face of increasing resource scarcity, increasing energy needs and climate change.

In order to shape future developments in this field, a non-exhaustive list of technological challenges based on the analysis of identified existing industrial roadmaps, strategies and other planning documents is provided below, divided into thematic subcategories.

Non-fossil energy sources:

- Nuclear energy has its own unique technical challenges related to issues like material & fuel handling, fusion, fission & radiation damage as well as decommissioning & storage. Waste management issues.

Photovoltaic energy:

- **PV systems lack cost-efficiency.** To stay competitive in the longer term, need to lower the cost of each unit of electricity generated, which requires more efficient cells and better productivity.
- The key technological challenge for the development of solar-heated buildings is to reduce the volume of the heat storage.
- For solar thermal, **storage of heat is a major bottleneck**. Further advances in seasonal and compact storage will have a major impact on the use of solar thermal energy.

Wind energy:

- Wind power variability and forecast errors impact the power system's short-term reserves.
- Sub-structures represent a significant proportion of offshore development costs. Thus, novel sub-structure designs and/or improved manufacturing processes that reduce costs will be critical to improving the economics of offshore developments.
- **Offshore wind farms installation is very costly**, requires efficient transport links, large drop-off areas and good harbours, and installation takes place in a hostile offshore environment.
- The manufacturing and installation of the cables represent a significant cost in offshore developments and have proved to be high-risk areas during installation and operations The integration of offshore wind into the grid represents a major challenge. The current grid infrastructure will not allow the full potential of offshore wind to be realised. This potential can only be realised through the construction of interconnected offshore grid systems and regulatory regimes that are better able to manage the intermittency and flexibility of wind power generation.

- Turbines: addressing marine conditions, corrosion and reliability issues creates new challenges in the offshore sector. The key factors affecting the deployment of offshore wind are the current shortage of turbines, and their reliability.
- **Non-storability and energy loss prevent the electricity market from spreading globally**.

Biofuels:

- Largely driven by government support and high energy cost: **need for better efficiency in terms of biomass yield,** nutrient and water use and energy conversion.
- Sustainable and reliable supply of feedstocks will be a critical success factor for the long-term perspective of biomass-based technologies on a large scale. This relates to efforts in improving productivity in these sectors, in developing reliable supply chains that open up the feedstock potentials, certification issues, and prevention of excessive disturbances in agricultural and forest commodity markets. These challenges, which are not specific to bioenergy and biofuels use of biomass, should be addressed in a coherent effort shared with the relevant stakeholders and initiatives.
- Because of the variety of potential feedstocks at global and EU levels, different conversion technologies are needed based on mechanical, thermochemical, biological and chemical processes.
- Algae: Cost reduction and scale-up are critical challenges.

Geothermal energy:

- The key challenge for widespread direct use of geothermal heat will be the ability to reliably engineer the subsurface heat exchangers (using technique known as "EGS" – Enhanced Geothermal System) in a reproducible way to harness the heat flux at the required temperature.
- Fundamental research is required to bring about a significant breakthrough in **compact, efficient storages.**

Hybrid district heating and cooling:

- To reach high penetrations of Renewable Energy Sources (RES) in district heating requires the **development of source systems that can draw on a variety of heat and cold sources to meet customer demand at any time**.

Control and automation of systems:

- One major challenge that should be tackled is related to the control and automation of systems. As an hybrid system is not simply an addition of two (or more) separate systems, specific research should be carried on the best way to control the combined system taking into account the stochastic nature of sunlight availability (if it is used in the hybrid system) as well as climate conditions, heating and/or cooling demand forecasting. This research should also address energy performance monitoring as well as early fault diagnosis for continued high performance over the system's lifetime.

Fossil energy sources: exploration and extraction

- Ultra deep offshore reservoirs need new materials to alleviate platform structure, new technologies to guarantee flow assurance, **new sub sea robotics**, a better understanding of well bore stability, sealing techniques, fit for purpose completions, high temperature high pressure sensors, imaging deep reservoir structure, etc.

Electricity distribution networks:

- The intermittency and variability of renewable generation whether wind, photo-voltaic or other technologies can create considerable effects on power system operation. This can impact quality of supply and security margins and consequently operational costs. This clearly requires comprehensive understanding and, in some situations integrated control, of both central and distributed generation and potentially of demand resources, at all voltage levels. A large number of micro-generators, uncertainties in distributed generation output (due to intermittent availability of some renewable energy sources or dependence of distributed generation operation on other services such as heat demand driven CHP), changes in power flows, especially in distribution networks.
- Apart from the external challenges, caused by new connections and bulk energy transfers, internal European grids will need to be modified fundamentally. Large amounts of bulk power will enter mainland Europe at specific points, often where there are no, or very limited, electric power grids available. Similar problems for planning and operations of the electricity networks of the future will arise when nuclear fusion might become available, leading to power plants with a unit size of several GW. Due to on the one hand very ambitious objectives for renewable and distributed energy resources, and on the other hand possibilities for extremely large power plants, **grid development will enter a high degree of uncertainty**. Transmission of these extremely high power values (perhaps in the order of tens of GW) to the demand centres presents what is at present an undefined but very real technical challenge. Software development for modelling grid frequency and voltage support with large amount of power generation outside the actual synchronous area will be needed.
- The active networks of the future will **efficiently link small and medium scale power sources with demand,** enabling efficient decisions on how best to operate in real time. The level of control required to achieve this is significantly higher than found in the present transmission and distribution systems.
- Transmission: grid congestion. In this regard, uniform data exchange formats are essential

for efficient communication between European system operators, for both normal and contingency situations. The options for establishing a pan European control layer are to be developed and assessed for achieving improved power system coordination.

- Transport systems of the future may include electric vehicles that require rapid recharging, placing new and considerable demands on grid infrastructure, supply quality and network control.

Finally the table below presents an overview of major issues which will influence possible response to the challenge in scope. The table content is based on results obtained during project workshops.

Table 3: Secure, clean and efficient energy – bottlenecks

Technology and R&D	Political	Legal	Market
Inefficient large energy storage technologies.	Countries are sensitive about assuring energy security.	**Different grids standards in Member States**.	Inefficient use of energy.
Lack of efficient energy storage technologies hinders development of many alternative sources.	Smart grids are related both to electricity distribution and energy management; bottlenecks include the lack of harmonizing procedures, national standards and interconnection standards for the European grid system.	Lack of harmonization of grid connection requirements, as well as the incompatibility of fault protection systems and metering, limits the penetration of Distributed Energy Resources (DER) in today's power systems.	As the penetration of variable renewable energy sources increases, maintaining system reliability may become more challenging and costly. Levelized cost of energy for many renewable energy (RE) technologies is currently higher than existing energy prices, though in various settings RE is already economically competitive.

The intermittency and variability of renewable generation, whether wind, photo-voltaic or other technologies, can create considerable effects on power system operation which can impact quality of supply and security margins and consequently operational costs.	Apart from the external challenges caused by new connections and bulk energy transfers, internal European grids will need to be modified fundamentally. Large amounts of bulk power will enter mainland Europe at specific points, often where there are no, or very limited, electric power grids available.		The demand for electricity varies throughout the day and across seasons, which poses difficulties in regards to electricity distribution networks.
Too energy-intensive production processes. Climate change will have impacts on the size and geographic distribution of the technical potential for RE sources, but research into the magnitude of these possible effects is nascent.	Short-term thinking. Gap between political will and technology.		The contribution of different drivers (e.g., R&D, economies of scale, deployment-oriented learning, and increased market competition among RE suppliers) to cost reduction is not always understood in detail.
Smart grids can improve electricity system reliability and efficiency, but their use of new ICT also introduces vulnerabilities that jeopardize reliability, including the	**Lack of interoperability is a critical obstacle to the development.**		The costs associated with RE integration, whether for electricity, heating, cooling, gaseous or liquid fuels, are contextual, site-specific and generally difficult to

potential for cyber-attacks.			determine.
Source: Oxford Research AS			

In the energy area, even as long political processes are ongoing, it is still **difficult to agree and commit globally on actions**. Many of the interviewees pointed out that there are advanced technologies in place today, but that the critical weight lies on the political, legal and market blocks. When these bottlenecks are solved, the R&D-related impediments will be addressed as well. As one of the interviewees put it, '*There is a gap between the political will now and the technology possibilities that are lying in the future*.'

A critical R&D-related congestion is the **inefficient use of energy in various forms**. A lot of primary energy is wasted, either in electricity transportation or in electricity generation. For example, in vehicles a lot of energy is wasted in the way energy is extracted from the batteries and transmitted to the active parts. Energy is lost when transformed and distributed, giving a low yield of energy use even in the most modern cars.

Another critical issue discussed in the interview is the **energy-intensive industrial production processes**. Energy efficiency in industrial production has been a focus of the Commission and this is considered to be a positive step in addressing the challenges in this area.

2.1.5 Smart, green and integrated transport

The challenge is to achieve a European transport system that is resource-efficient, environmentally-friendly, safe and seamless for the benefit of citizens, the economy and society.

In order to shape future developments in this field, a non-exhaustive list of technological challenges based on the analysis of identified existing industrial roadmaps, strategies and other planning documents is provided below, divided into thematic subcategories.

Decarbonisation of transport:

- Maritime transport: exposition to future fuel oil shortage and rising prices because of today's oil-based propulsion systems. Long-life ships require new technologies to be retrofitted to existing ships to reduce fuel consumption and CO_2 reduction.
- Rail transport: technical barriers to **interoperability and intermodality**. high levels of maintenance costs, acting as brakes for the financial performance of rail operations.
- Electric vehicles: need to store the electricity onboard the vehicle in such way that it can compete with hydrocarbon fuels

in terms of the required energy density.

- Road transport: Replacement of conventional gasoline or diesel by alternative fuel will cause high wear, friction and increased thermal loading due to lack of lubricating properties of bio-fuels, reduced compatibility with engine oils and with seal material as well as increased risks of corrosion. Existing solutions cannot cope with these problems resulting reduced engine reliability and component life time, e.g., existing PVD coating were out during component run-in phase (too thin) or do not possess resistance against fatigue (existing thick layers produced by thermal spraying).
- In the future **fuel cells will play an important role in assuring the mobility of vehicles and electrical devices** (laptops, mobile phones, etc.). One of the largest hurdles encountered in the development and production of fuel cells is their relatively low efficiencies. Naturally the catalyst used plays a significant role in determining the efficiency of the cell, but the inability of the membranes used to selectively transport protons between segments of the cell also impacts on the performance.
- Air transport: consumes a lot of fuels and is responsible for many CO_2 and NO_x emissions. Manufacture, maintenance and disposal of aircrafts and related products has a negative environmental impact.

Finally the table below presents an overview of major issues which will influence possible response to the challenge in scope. The table content is based on results obtained during project workshops.

Table 4: Smart, green and integrated transport – bottlenecks

Technology and R&D	Political	Legal	Market
Batteries for electric vehicles not efficient enough.	Transport systems of the future may include electric vehicles that require rapid recharging, placing new and considerable demands on grid infrastructure, supply quality and network control.	**Lack of sufficiently defined regulatory framework for decarbonisation and CO_2 storage.**	Expensive technologies for green cars and competition with traditional cars.

	Lack of international collaboration on issues regarding decarbonisation of transport.	Structural problems in the supply and distribution chains of different commodities, including the availability of transport infrastructure and services.	Lack of proper infrastructure. Issues of accessibility, comfort and perceived security are of great importance to elderly travellers.
Lack of technological breakthrough enabling massive migration from fossil fuel transport.	Oil is the main political world-ruling factor.		New alternative technologies are still too expensive or ineffective
Source: Oxford Research AS			

Bottlenecks in transportation are to large extent dependent on those in the energy area. When the problems within energy generation and supply in transport are solved, it will have an effect upon all the issues connected to the smart and green transportation. A market-related obstacle is the **high cost and low efficiency of smart / green cars**, which make it difficult to enter the market.

In terms of R&D impediments, it is difficult to pinpoint any concrete example. However, it is critical that a breakthrough technology is developed – a technology that would replace the current technologies based on fossil-fuel combustion. An example would be a high efficiency battery enabling long distance, low weight electric vehicle construction.

2.1.6 Climate action, resource efficiency and raw materials

The challenge is to achieve a resource efficient and climate change resilient economy that meets the needs of a growing global population within the natural limits of a finite planet.

In order to shape future developments in this field, a non-exhaustive list of technological challenges based on the analysis of identified existing industrial roadmaps, strategies and other planning documents is provided below, divided into thematic subcategories.

CO2 absorption:

- CO_2 Capture and Storage (CCS): **High costs and risks still outweigh the commercial benefits.** A need to further develop CO_2 capture techniques and reduce the energy consumption of oxygen production and CO_2 treatment, as well as increase the efficiency of both CO_2 capture and the power plant in order to reduce energy consumption (which the capture process can increase).

Post-combustion technology CCS:

- Insufficient experience for power plant application on a large-scale and special requirements due to flue-gas conditions.
- High energy demand/penalty for regeneration of the solvent and energy requirements for CO_2 compression.
- Full process integration and optimisation for power generation.
- Absorption system with high-throughput under oxygen environment is unavailable today.

Pre-combustion technology CCS:

- Scale-up issues in designing and developing a highly reliable industrial-scale power plant with CO_2 capture
- Scale-up of gasifiers
- Highly efficient gas turbines for hydrogen combustion.
- Energy losses by shift-reaction and CO_2 capture process must be compensated.
- **Full process integration and optimisation for power generation**.

Oxy-fuel combustion technology CCS:

- No commercial gas- or coal-fired power plants currently exist which operate under oxy-fuel conditions
- Only tests being performed are in laboratory-scale rigs and experimental boilers up to a size of a few MWth.
- There are uncertainties as to what are acceptable impurities in the CO_2 rich flue gas.
- CO_2 rich flue gas treatment is not yet developed.

Raw materials:

- Low recycling rates of critical raw materials partly because of inadequate innovation in recycling.
- **Low substitutability of critical raw materials** (high tech metals such as cobalt, platinum, rare earths, and titanium).
- Facilities, emerging technologies, industrial engineering concepts and new added value products and services to improve utilization of food raw materials and waste via emerging technologies into new materials (food and non-food).

Finally the table below presents an overview of major issues which will influence possible response to the challenge in scope. The table content is based on results obtained during project workshops.

Table 5: Climate action, resource efficiency and raw materials – bottlenecks

Technology and R&D	Political	Legal	Market
Lack of systems for raw materials recycling. **Lack of technologies ensuring full life cycle of products.**	**Raw materials resources concentrated in countries outside Europe.** Protectionist trade policies, including export restrictions, which create market distortions, exacerbate price fluctuations and lead to strategies that tighten the supply (stockpiling, long-term contracts or price hedging).	Lack of international legal framework to regulate colonialisation of raw materials	Market for many critical raw materials is small and lacks transparency. Expensive new materials. Main customer base is not in Europe. High dependence on a small number of countries for some critical materials (e.g. rare earth, 97% from China).
A need to further develop CO_2 capture and treatment technologies. Inefficiency of greenhouse gas (GHG) capture technologies.		**Lack of sufficiently defined regulatory framework for CO_2 storage and for decarbonisation.**	High cost of producing new materials and high cost. New CO_2 emissions due to extraction activities.
New materials production is very expensive, while more KET research brings bigger consumption of the raw materials		Low recycling and low sustainability of critical raw materials requires implementation and enforcement of relevant recycling	Inefficiency in terms of consumption of energy due to friction and reduced efficiency, maintenance

already in scarcity.		legislation.	costs, replacement of materials and components, machine and plant shutdowns, increased lubricant consumption.
Bottlenecks regarding resource-efficient buildings include: expensive new energy-efficient structures, well-known and well-managed techniques are preferred in contracts instead of innovative techniques.	Lack of harmonizing and realistic specifications regarding the impact of construction materials on human health and environment: air, soil, underground water, for example. Greatest barrier of all innovation lies in national liability regimes in many EU Member States and the way in which they are insured.	Lack of legal clarity for defining when reprocessed waste can be reclassified as a product; illegal export as dumping waste.	In construction the stock has a long life-time and solutions to retrofit existing buildings are lacking.
Smart systems need low cost and high performance materials. Autonomy of smart systems depends upon their ability to scavenge energy from their environment, store it and use it efficiently.			

Need for a consistent architecture for smart environments characterized by three equally important trends: multivendor interoperability, dynamic device configurations and extreme scalability.			
State-of-the-art knowledge in a large number of production-related areas is required to be competitive in running state-of-the-art micro- and nanoelectronic systems.			
	Conflict between forest protection and benefits of use of forest for industrial use.	Exploration and extraction face competition from different land uses and a highly regulated environment (e.g.: Natura 2000).	
Source: Oxford Research AS			

In climate action the congestions are very much of political, legal and market nature than a R&D nature. As in the energy challenge, the research and technology development is advanced and has a strong potential, but **there is a lack of- or insufficient political, legal and market framework conditions to govern climate protection efforts, which would allow the technological potential to unleash**.

In terms of legal impediments, there is a **lack of international**

regulations to govern the phenomenon of buying critical raw materials or exclusive access to critical raw materials from the developing countries. The fact that most of the new materials are extremely expensive and costly on the market makes that a critical bottleneck in commercializing new materials and the technologies using these materials.

2.1.7 Inclusive, innovative and secure societies

The challenge is to foster inclusive, innovative and secure European societies in a context of unprecedented transformations and growing global interdependencies. The objective of 'inclusive societies' is to support policymakers in designing policies that prevent the increase in inequalities, as well as the development of various forms of divisions in European societies and with other world regions.

In order to shape future developments in this field, a non-exhaustive list of technological challenges based on the analysis of identified existing industrial roadmaps, strategies and other planning documents is provided below, divided into thematic subcategories.

Sensors and actuators:

- The integration aspects (monolithic/hybrid) of sensors and actuators will be an important challenge and focus for the years to come. This will include the development of sensors and actuators based on materials other than silicon that offer new functionality or lower cost, as well as arrays of sensors and actuators of the same or different functionality. In addition, new sensor types such as nanowires and carbon nanotubes with potential for improved sensitivity need to be investigated and fabrication processes have to be developed to integrated such new sensing elements into devices, systems and applications.
- The major challenge in the area of sensors and actuators relates to the support of huge amounts of input and output data envisaged in the application contexts with minimal power requirements and fail-safe operation.
- The technical challenges for smart systems and environments may be summarised as how to create a consistent architecture for smart environments characterised by three equally important trends: **multivendor interoperability, dynamic device configurations and extreme scalability**.

Heterogeneous integration:

- Wafer-level integration: Ultra high-density wafer-level integration technologies must be able to successfully combine different technologies while also meeting yield and cost requirements.
- Module integration: Future board and substrate technologies have to ensure cost-efficient integration of highly complex systems, with a

high degree of miniaturisation and sufficient flexibility to adapt to different applications.

- 3d integration: a technology that enables different optimised technologies to be combined together and that has the potential for low-cost fabrication through high yield, smaller footprints and multi-functionality.

Finally the table below presents an overview of major issues which will influence possible response to the challenge in scope. The table content is based on results obtained during project workshops

Table 6: Inclusive, innovative and secure societies – bottlenecks

Technology and R&D	Political	Legal	Market
Dispersion of effort and a lack of coherence in security research, especially in regards to security systems, lead to enormous difficulties for interoperability between 'security users'.	**Defence remains the domain of Member States and cooperation is difficult even in research.**	The differences between national laws, especially concerning security applications.	Growth in security systems is hampered by the high costs of installing and operating the systems.
Lack of adequate information on European level to be able to recognise and react to ICT threats in due time. ICT is increasingly used in cybercrime and politically motivated attacks.	Communication between different communities and agencies dealing with cyber security within Europe is far from being optimal.		
Need for more efficient lasers (more light output for a given energy input), longer-lasting components that can be readily recycled, maintenance-free manufacturing equipment, new light sources, new processing strategies and new photon			

transmission systems, better integration of the system components. Need to consider environmental impacts of new components, processes and products. Interdisciplinary research efforts in manufacturing technologies, microsystem engineering, nanotechnology, telecommunications and optics required to overcome physical and technical limitations.			
Main reason for the slow market penetration is the huge fragmentation in integration technologies, most of which have been developed and fully optimised for specific applications. Due to this fragmentation most technologies address a market that is too small to justify further development into a low-cost, high-volume manufacturing process. And new technology development or optimisation is required for each new application, which makes the entry costs high.		Lack of European guidelines for performance-based and innovative design relating to natural disasters (e.g. earthquake-resistant structures, tsunamis, flood and erosion, landslides, etc.).	

	There is a dividing line between defence and civil research funding. An absence of specific frameworks for security research at the European level, limited cooperation between Member States and **lack of coordination between national and European efforts,** exacerbate the lack of public research funding and present major obstacles to achieving cost-effective solutions.	Information vs. personal privacy. From the security point of view, guaranteeing the anonymity of users, trusting the information, availability of services and the scalability of security applications are important long-term considerations.	
New technology components in space have to be tested in real conditions before being adopted in operational satellite systems. Satellite services need continuous development to provide more power and bandwidth in space, in order to enable cheaper, smaller user terminals, as well as lower utilisation costs, and enhanced, higher data rate services.	In space, technology is characterized by high technical risks that the private sector cannot bear alone. In addition, the European-level R&D space framework is mainly addressing the civilian environment, without much focus on the defence requirements.		Unlike terrestrial networks — where extra capacity can be installed incrementally, following market demand — satellites have to be ordered far in advance of the market if they are to be deployed on time for new services.
Source: Oxford Research AS			

As mentioned at the beginning of this study this Grand Challenge — inclusive, innovative and secure societies — is separated into at least three separate dimensions.

First of all, we consider the social security dimension, characterized today by a number of political, economic and legal obstacles. **Europe is struggling with assuring a fully integrated social security system while responding to the needs of increased social mobility**. This particular hurdle is still hindering actions undertaken within the European Research Area. Uncertainty to this regard is still to some extent influencing creation of a real single market for research.

The second challenge in this context is the issue of external migrations, currently and in the future. Social tensions are born in Europe especially in the time of financial crisis, while countries are and will be struggling with employment problems in coming years. On a longer time scale **external migration shall be seen as a major response to the future situation on the labour market in Europe**. Ageing societies and raising percentage of retired will impact the labour market resulting especially in a potential shortage of qualified workers. Challenges here appear in the long term within education, training and integration of newcomers.

Current uncertainty caused by the global financial crisis and euro area problems are negatively influencing political solutions and legislative actions, as well as social dialogue in this regard.

All these factors are interlinked with the geo-political situation. **Terrorism and global conflicts** are challenging areas for industrial technologies. In the future **KETs will have to deliver solutions for security, detection and monitoring systems of different kinds**. Of course also military applications are of key importance in this field.

An extremely challenging, and relatively new dimension is the functioning of virtual networks and their interrelations with reality.

Finally **ICT security is a demanding field** where many of KETs will be expected to deliver solutions in the future.

CHAPTER 3. CURRENT ROLE, STRENGTHS AND WEAKNESSES OF FPS VIS-À-VIS GRAND CHALLENGES

Policy context — overview

In this chapter we provide an overview of the policy areas covered by DG Research through the past framework programmes to create a contextual background for the new generation of research programmes – the Horizon 2020.

3.1.1 Policy context – historical developments

After the Second World War a number of European nations that had previously been world powers were faced with the reality that their influence had been greatly diminished. Countries such as France, Germany and Great Britain no longer had the prominence in international affairs they had formerly enjoyed. A significant aspect of this desire for global importance seems to have centred on economics. A unified Europe would provide European companies with a domestic market rivalling that of the United States in size, and enable lower cost production of goods and services, impacting directly development of industrial technologies. Integration meant re-asserting main European countries as significant players in the world's economy. During the Cold War few nations outside the two superpowers had the resources to drive big science. Countries wishing to compete with them had to pool resources. Reconstruction requirements, Cold War dilemmas and insecurity, competition from the United States, and an understanding of limitations combined with the politics of European unification[35] provided the setting for the emergence of a European common research policy.

Therefore technological development was one of the fundaments of European integration starting at the end of the 1950s. The transformation from economies highly dependent on agriculture and food production to economies much more dominated by modern industry gained significant importance. Both the European Coal and Steel Community and 'Euratom' treaties — in the fields of coal and steel, and nuclear energy respectively — aimed at building modern European industry (with 'nuclear' being the buzz word for research at that time). The baseline political idea at that time was to start and maintain cooperation between European nations, which in the long term was to safeguard the post-war security and assure industrialized economic development. This approach was intended **to assure that Europe would catch up with United States** – the only strong market economy of that era — and to assure prosperity of future generations to come. Quite

[35] "Multinational laboratories - Sputnik, History of CERN" Solomon's House Revisited. The Organization and Institutionalization of Science.

http://science.jrank.org/pages/49302/multinational-laboratories.html surprisingly **after 50 years this subject is still in the agenda.**

However the treaty signed at the beginning of the integration process (establishing the European Economic Community) did not create any solid base for joint research policy in the area of industrial technologies. Still, during the 1960s and 1970s a certain number of research programmes in areas considered priorities at the time, such as energy, the environment and biotechnology, were financed from the communities' budget.

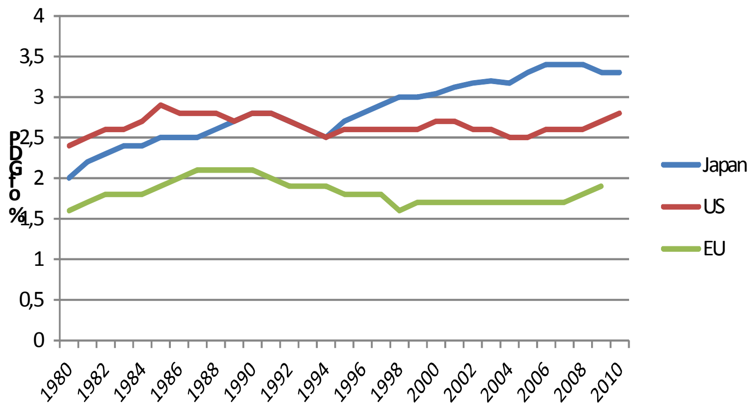
Over the passing years the situation in Europe began to change. The transformation of European industries continued and the knowledge-intensive industries started to influence the scene, including the actors creating the future ICT-sector. At the end of 1970s appeared strong driving forces for development of new industrial policies and joint R&D under management of the European Communities. The main needs for this policy at that time were to:[36]

- reduce the technological gap to other leading economies,
- reduce the dependency on the US,
- stop brain drain,
- go beyond the policy of national champions,
- build synergies in Europe.

[36] "Research, quality, competitiveness, European Union technology policy for the knowledge based society" ISBN: 978-0-387-79264-4 by Attilio Stajano, Second Edition, Springer, 2009.

The main argument for the initial Framework Program was that Europe lagged behind the US and Japan. This was seen in quantitative terms, measured by per capita, and in terms of cooperation between universities and industry.

Figure 3: Historical overview of R&D funding to GDP



Sources: "Research, quality, competitiveness, European Union technology policy for the knowledge based society" ISBN: 978-0-387-79264-4 by Attilio Stajano, Second Edition, Springer, 2009.; OECD Science, Technology and Industry Scoreboard 2011 http://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2011_sti_scoreboard-2011-en; http://www.battelle.org/aboutus/rd/2011.pdf
Note: data for EU 27 start from 1998.

The critical mass for producing front end research was too small in the Member States and accordingly cross-European collaborative research was to be encouraged, together with industry/university collaboration, in order to reach the policy targets. Today, after years of implementing framework programmes, with special tools invented to address this weakness, the problem still persists. The perceived **difficulty to exploit scientific results in order to gain technological and economic benefits is still addressed within framework programmes**.

Nevertheless, this unified industrial policy aimed at attracting researchers was shaped with the important involvement of industrial ICT giants (Siemens, CGE, Philips, ICL, Bull, Olivetti, Nixdorf, STET, Plessey, Thomson, AEG, GEC). This setting allowed the creation of the first joint programme for R&D in information technology with the aim to develop European standards and to set Europe free from technological dependency. The programme's strategic goal was to stimulate transnational cooperation in Europe of R&D and to assure competitiveness. The first major European programme in IT technology, ESPRIT, was created in 1983 with the aim to strengthen the European information technology industry through cross-borders cooperative research and development projects. Simultaneously the First Framework Programme started in 1984, with a view to putting a little order into an increasing profusion of activities by placing them, as the name suggests, in a single 'framework'[37]. The First Framework Programme was an amalgamation of existing initiatives throughout the Commission in an attempt to develop a coherent research and development strategy.[38]

A considerable part was allocated to what was called new technologies including IT, biotechnology and telecommunications (18% of the budget). It was only with the Second Framework Programme that a major shift occurred in favour of IT (42% of the total budget) and particularly the ESPRIT II programme (30% of the total budget). The 'Big Twelve' major IT companies in Europe heavily dominated this programme. The focus of the FPs therefore moved strongly to IT as part of an OECD-wide push to increase IT research. This followed the spectacular successes of Japanese industry in the late 1970s in consumer electronics and telecommunications.[39] Those initiatives played a paramount role in facilitating the birth of the modern ICT-industry in Europe.

Finally the research policy itself was directly formulated for the first time in the Single European Act of 1987. From a political and institutional point of view, this was a fundamental development guiding the future of research programmes.

The years between the 4th and 5th FPs (1997/1998) were marked by the overall political objectives of the Community. Two major political developments of those years were the finalisation of the Amsterdam Treaty[40] and Agenda 2000,[41] the Commission's proposals for the future institutional and financial development of the Community. Both confirmed the need to attack major issues such as employment, competitiveness and sustainability by further developing the Community as a society founded on knowledge, and to build a Europe which is closer to its citizens.

The Amsterdam Treaty signalled a true maturity in research policy by removing the requirement in the co-decision process of unanimous voting in Council, thus bringing it in line with other policy areas such as the Single Market policy. This show of confidence in the European *acquis* should bring a more balanced debate and speed decision-making in the negotiation of future framework programmes. [42]

Since this milestone, European research policies and implementation of European research programmes are clearly defined in the Amsterdam Treaty. The Treaty includes a whole chapter

[37] The Seventh Framework Programme in the history of European research; Michel André; RTD info Special June 2007.

[38] Patries Boekholt, The European Community and Innovation Policy: Reorienting Towards Diffusion, Birmingham, 1994.

[39] Erik Arnold and Ken Guy, Parallel Convergence: National Strategies in IT, London: Frances Pinter, 1986.

[40] Official site http://eur-lex.europa.eu/en/treaties/dat/11997D/htm/11997D.html

[41] Official site http://ec.europa.eu/agenda2000/index_en.htm

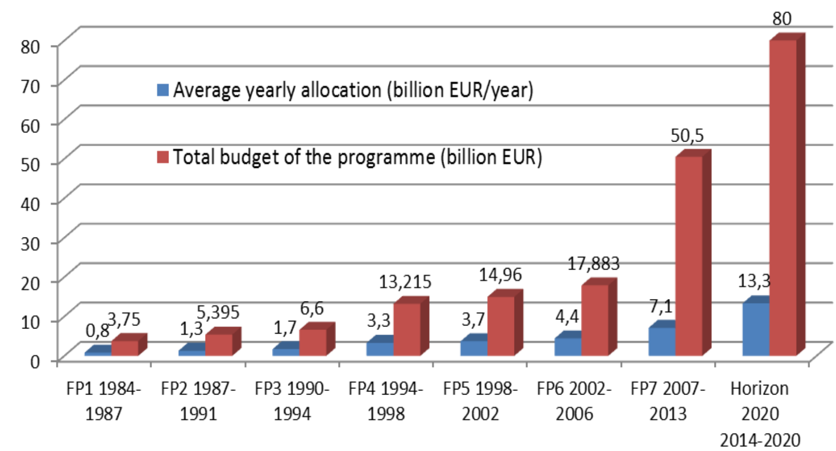
[42] Research and technological Activities of the European Union – 1998 Annual report, European Commission 1998, Brussels.

on research and technological development (RTD) as an essential element in the functioning of industrialised countries. At this particular moment an important element for the future European policies in globalizing world was confirmed: the need for competitiveness of companies and the employment they can provide. Policymakers assumed that to a great extent this may be assured by RTD; RTD was also indicated as essential for the support of other policies such as consumer protection and the protection of the environment. In short: the individual and collective wellbeing of citizens is thought to depend on the quality and relevance of RTD.

3.1.2 The framework programmes in the past

The framework programmes' scope have tended to widen over time, so that they

now cover a very wide range of themes and the repertoire of instruments has expanded from the early focus on collaborative research to areas such as health. One strand in the programmes has been strongly driven by the desire to achieve social and economic impacts. The early efforts in IT and industrial technology exemplify this strand, which is sometimes informally described as 'the Commission's industry policy'. Another strand has been more directed at research.



Source: Oxford Research AS, based on data from EC web pages.

Figure 4: R&D funding in European framework programmes

The evolution of framework programmes was three dimensional. First was a continuous increase of the budget, from several hundred million euros up to EUR 7 billion per annum in the Seventh Framework Programme and more than 13 billion in Horizon 2020. Second there was an extension of the Union's activities into new scientific and technological fields. Third, the diversification of mechanisms, types of financial support and intervention methods with the regular introduction of new formulas resulted in a portfolio that covered both projects and transnational networks for collaboration in research, individual grants, specific measures for small and medium-sized enterprises (SMEs), support schemes for cooperation and coordination at various levels as well as studies and conferences.

In more than 20 years of history of the FPs a number of shifts and trends can be observed on various dimensions:[43]

- Thematically: **While the first FPs were very much focused on energy and IT, the framework programmes became more diverse when 'horizontal' themes were introduced**. The core of the FPs remained technology focused. The 'distance-to-market' varies from programme to programme. In the early FPs the management of programmes and sub-themes was quite independent and hardly coordinated, each programme area had its own research culture and character. The ICT programmes managed in a separate DG (DG XIII, later called DG INFSO) were generally more focused on reaching a socio-economic impact than the programmes of DG Research.
- The size of the budget (see chart above).
- The support instruments used: While the early framework programmes were mostly based on collaborative research projects, in the course of the FPs' development other instruments gained in weight such as Marie Curie Fellowships, Research Infrastructures, Networks of Excellence, Technology Platforms, the European Research Council, etc. The introduction of the Integrated Projects was still collaborative research but on a larger scale and with more self-organisation of the consortia.
- The set of objectives addressed: In addition to an objective that focused on 'good science' there have always been secondary motivations involved in the selection of projects and themes. These were mostly covered under the broad term 'European Added Value'. In the early FPs these were typically cohesion, scale, financial benefits, complementarity and contribution to unification.[44] The

[43] Impacts of the framework programme in Sweden, by Erik Arnold et all., Technopolis Group, ISBN 978-91-85959-32-7, Vinnova 2008.

[44] Yellow Window, Technofi, Wise Guys, Identifying the constituent elements of the European Added Value (EAV) of the EU RTD Programmes: conceptual analysis based on practical experience, Antwerp, 2000.

Fifth Framework Programme explicitly aimed at creating 'socio-economic impact' (which was to be addressed in all programmes as well as separately). In practice it proved difficult for both proposers and evaluators to describe and assess this. The explicitly stated socio-economic aim disappeared again in **FP6 and was replaced by the overarching goal of 'contribution to the European Research Area'** (ERA), which was hardly operationalised at the start of FP6. Cohesion became less of an issue. However involving partners from the new Member States was considered a positive. FP6 established a focus on research excellence, which had not been very explicit in the first framework programmes, and increased the scale of projects. As the ERA philosophy was very much about creating excellence, improving coordination and reducing European fragmentation, these became more important drivers. They were implemented through the new instruments and particularly the Integrated Projects, which were foreseen to be large in scale in order to have a real impact, and the Networks of Excellence, which would support co-ordination between research organisations. In FP7 the 'additional' objectives were less visible. **Achieving the Lisbon objectives became a goal in itself and European competitiveness was more explicitly the ultimate aim**. Criteria for project selection were reduced to quality, implementation and potential impact. The latter was defined at the sub-programme level.

The thematic focus has shifted during the course of the framework programmes, starting with FP3. Nuclear energy research efforts, a heritage of early policies, were gradually reduced. Whereas ICT was still the largest component in FP6, its dominance is far reduced compared to FP3 and has decreased gradually. Energy, life sciences and environmental research remain major subjects in every FP, and also in Horizon 2020. The 'other' category comprising horizontal themes has increased in importance from FP5 onwards, especially NMP's priority in FP6 and FP7 shall be noted in this regard. It appears as if in FP6 old themes have disappeared (non-nuclear energy, transport) and new themes have come up (aerospace). However, this is partly because themes have been combined (sustainable energy and sustainable transport became part of the Environment and sustainable development in FP7, and in Horizon 2020 is part of the Secure, clean and efficient energy and Smart, green and integrated transport challenge), or disentangled out of former programmes (e.g. aerospace, part of the FP5 Growth Programme, was itself the successor to BRITE/EURAM).

3.1.3 From Lisbon Agenda to Europe 2020 strategy

The vision of a well-functioning European innovation system and commercialisation opportunities is tightly intertwined with the whole objective of efficiently transforming the EU economy from one based on a resources to one based on knowledge. This transformation was furthermore an objective at the heart of the Lisbon Agenda and also the focus of the European Research Area. A well-functioning innovation and research commercialisation concept would represent a unique chance to build upon the EU's research strengths. It is also an opportunity to gear up and link research to market by means of an innovation policy to a much higher degree than is currently realised.

The Lisbon strategy was criticized as weak and insufficient to achieve its objectives for two reasons. The first one is the top-down and dirigiste nature of the project, which does not result from a thorough consultation of all stakeholders (as was successfully done at the beginning of the 1980s by Davignon[45] to start a strategic collaboration in industrial research in Europe). Its agenda did not result from the kinds of involvement that could have led to consensus and commitments. This has created a situation in which none of the EU Member States and none of the industrial and academic communities has really adopted this strategy and feels to be its owner and defender, thus leaving both the initiative and the responsibility to the European Commission. The second reason is that the Lisbon strategy does not provide for sanctions if any of the parties involved do not comply with the plans and schedules proposed by the Council. However, no systems to inflict sanctions could be adopted since, according to the Maastricht Treaty,[46] education and national research investments fall under the exclusive competence of the EU Member States (subsidiarity principle). 'If not even the Growth and Stability Pact, which has been provided by the Treaty with control and sanctioning tools, manages to control the particular interests of the Member States, we cannot expect that the blunt knife of the Lisbon strategy is sufficient to solve Europe's competitiveness crisis.'[47]

Still, research has been a centrepiece of the Lisbon strategy since its launch in 2000.

Almost 10 years after the Lisbon Agenda, its Community research policy underpins the competitiveness of European industry and supports the development of other Community policies, making it a crucial policy domain for finding adequate responses to the Grand Challenges. The initial years of Seventh Framework Programme (FP7) were successful and continue to make progress towards the European Research Area. Overall, Community research policy has attained its initial objectives.

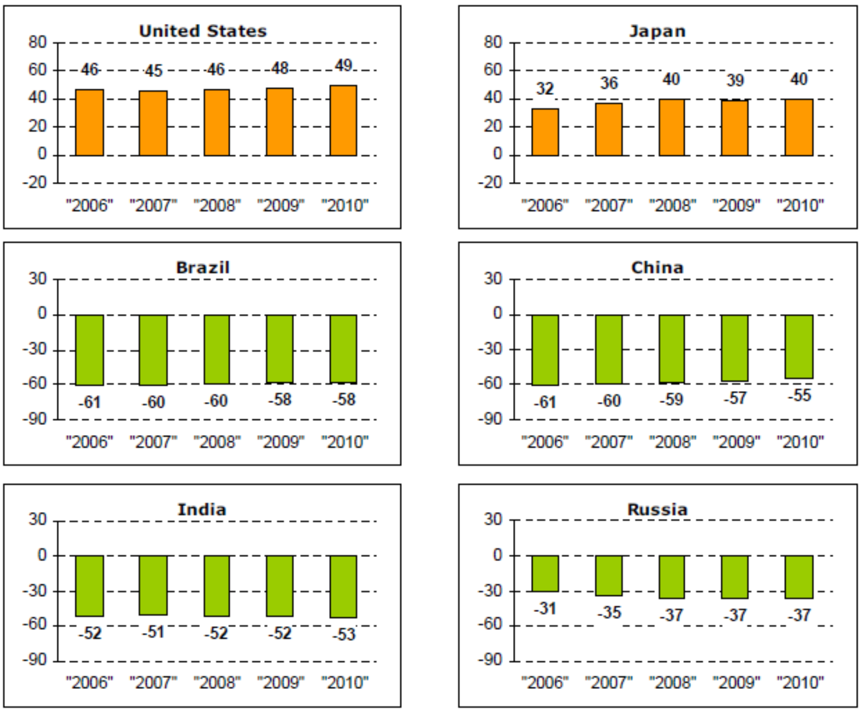
[45] At that time Member of the Commission of the European Communities with special responsibility for the Internal Market and Industrial Affairs, the Customs Union, the Information Market and Innovation, Energy, the Euratom Supply Agency and International Nuclear Relations (1977–1981).

[46] http://europa.eu/legislation_summaries/economic_and_monetary_affairs/institutional_and_economic_framework/treaties_maastricht_en.htm

[47] Attilio Stajano Research, Quality, Competitiveness European Union Technology Policy for the Information Society, ISBN 0-387-28741-8. Springer, 2006.

The principal aims of Community research policy continue to strive for greater research excellence and enhanced socio-economic relevance by increasing the openness and attractiveness of the ERA to realise the fifth freedom (freedom of circulation of knowledge). This is done by deepening international science and technology cooperation and by forging closer relationships with neighbouring countries. Building strategic relationships with the Member States continues to be one of the principal tools for progressing towards these objectives.

Figure 5: EU 27 innovation performance compared to main competitors



Performance is measured as 100*(X/EU)-1) where X refers to the value for the indicator for the country X and EU to the value for the indicator for the EU27. The values in the graphs should be interpreted as the relative performance compared to that of the EU27. E.g. the US in "2010" is performing 49% better than the EU27 and China is "2010" is performing 55% worse than the EU27.

Source: Innovation Union Scoreboard 2010

While the EU has made some headway in its bid to make itself more innovative and boost its economy it is still lagging far behind the US and Japan.

Investment by businesses in research and development in the Union has stagnated while EU companies' expenditure on training and new equipment — seen as an important contributor to growth — is declining.[48] Statistics on R&D investments for 2008-2009[49] reveal a persistent gap between the EU and the USA, with the EU's R&D intensity stagnating at 1.84% of Gross Domestic Product, well behind the 2.61% level in the USA.[50] This gap is particularly important in terms of the financial crisis. In more details the innovation performance is analysed by Innovation Union Scoreboard. On a long term perspective the EU's position in a global competitive race is worsening. Distance to US and Japan is growing over recent years and new powers – **China and to some extent Brazil — are systematically diminishing the gap.**

A good part of the performance gap in favour of the US can be explained by higher scores in license and patent revenues from abroad, public-private co-publications, tertiary education and business R&D expenditure. Trends show that the US performance is improving faster notably as regards new doctorate degrees, license and patent revenues and international co-publications. However, the EU outperforms the US in indicators such as public R&D expenditure and knowledge-intensive services exports. Its performance is growing faster in 6 indicators considered by this comparative study, including public R&D expenditures and PCT[51] patent applications for innovations that address societal challenges.[52]

3.1.4 Europe 2020 Strategy

To tackle these negative trends a new political initiative was created: the Europe 2020 Strategy.

As a successor of the Lisbon Agenda, the Europe 2020 Strategy aims to address the major structural challenges facing Europe today, including climate change, globalisation, ageing population and the economic downturn. The areas of focus of the strategy strongly enforce the promises for high research and development-oriented spending in the future. This is also confirmed by the structure of the strategy which introduces seven so-called 'flagship initiatives', underlying the concept that support for research and technical development (RTD) is a key issue for Europe's future position in the global economy.

The reorientation of the framework programmes towards the Grand Challenges was first indicated as the Europe 2020 Strategy and the Lund Declaration somehow impose this kind of approach. Today re-shaping of research activities in the European framework programmes in order to approach solving the Grand Challenges with an **integrated response** has already become a

[48] http://euobserver.com/9/27458

[49] See http://ec.europa.eu/research/era/pdf/key-figures-report2008-2009_en.pdf

[50] Annual Report on research and technological development activities of the European Union in 2008, European Commission, Brussels, 2009.

[51] Patent Cooperation Treaty

[52] Innovation Union Scoreboard 2010; http://www.proinno-europe.eu/inno-metrics/page/innovation-union-scoreboard-2010

fact. This includes also more move towards joint programming in order to foster innovation.

In October 2010, the EC issued a new policy flagship initiative named ***Innovation Union***[53] to address these issues and to step up support in favour of a more open innovation system for the benefit of the EU. In June 2010 Commissioner Máire Geoghegan-Quinn announced nearly EUR 6.4 billion of European Commission investment in research and innovation. The package covers a vast range of scientific disciplines, public policy areas and commercial sectors. It is also a long-term investment in a smarter, sustainable and more inclusive Europe.

The EU's strategy for sustainable growth and employment comes in the midst of the worst economic crisis in decades. It puts innovation and green growth at the heart of its blueprint for competitiveness, but will have to include tighter monitoring and evaluation systems if it is to succeed where the Lisbon Agenda failed. FP7 current shaping tries to address this challenge and more changes will appear in the nearest future.

Shaping current policy

The framework programmes (FPs) were created to support research in different dimensions long before Europe 2020 Strategy and the Lisbon Agenda. Since their launch in 1984, the framework programmes have played a lead role in multidisciplinary research and cooperative activities in Europe and beyond.

As presented above, each of the FPs implemented so far was structured differently, as the policies changed over the years and evaluations delivered suggestions for improving future FPs. In the following sections we present an overview of the two most recent framework programmes, concentrating especially on the outcomes of the FP6 evaluations and impact assessments, as well as the current shape of FP7.

3.1.5 FP6

FP6 took a considerable step forward towards coordination of EU and Member States' RTD policies. Initiatives like the ERA-NETs and European Technology Platforms (ETPs) have helped stakeholders identify and explain their needs jointly, easing the process of developing mutually supportive policies. Concern was raised about a downward trend of industrial (including SMEs) participation under FP6. [54]

Evaluation of FP6 revealed that activities undertaken, especially those of its **core thematic priorities that constituted 65% of total expenditures, have generated European Added Value (EAV), contributed generally towards increased industrial competitiveness,**

[53] Europe 2020 Flagship Initiative Innovation Union, COM(2010) 546 final.

[54] Evaluation of the 6th Framework programme (…) 2002-2006 - Report of the Expert Group, Brussels 2009.

generated network externalities, and strengthened the knowledge infrastructure in Europe.

Up to and including FP4, European Added Value in the form of networking, cohesion, scale benefits and so on was largely seen as sufficient justification for the FPs. In FP5, the focus shifted towards socio-economic benefits.

FP6 was designed at the time when the Commission launched the **European Research Area (ERA) policy, aiming to concentrate research resources and create a system whose most excellent parts could compete readily with those of the USA and Japan**. This led to an increased concern with research (instead of the earlier focus on industrial policy and impact). Policymakers agreed that European research should be excellent and built at an increased scale. **FP6 therefore included new, larger instruments**. The previous industrial strand continued but was less of a focus and – especially outside ICT – involved less effort. FP6 also marked the creation of Technology Platforms and ERA-NETs, in which the Commission encouraged groups within the Union to self-organise and develop cross-border groupings that would drive R&D and innovation policies for their sectors or technologies.[55]

The design of the Seventh Framework Programme (FP7) was strongly based on the results of evaluation exercises undertaken while FP6 was still on the run. Major steps towards FP7 were made in 2005 with the presentation by the Commission of its proposals for the entire legal framework, including the framework programmes themselves (EC and Euratom) together with an in depth ex ante impact assessment in April, the specific programmes in September and the rules for participation and dissemination of results in December.

3.1.6 ERA

The idea of a European Research Area (first proposed in the 1970s[56]) has grown together with FP6 out of the understanding that research in Europe suffers from three weaknesses: first, insufficient funding; second, the lack of an environment that stimulates research and exploits results; and third, the fragmented nature of activities and resources. It was launched to develop strengths and address the weaknesses of European research, especially key factors such as scope and scale of projects. Part of this work is improving coordination activities at the European level. The ERA effort furthermore includes mapping of excellence as a means to strengthen European quality. The creation of a European Research Area combines three interrelated and complementary concepts:

- Creation of an 'internal market' for research: an area of free

[55] Impacts of the framework programme in Sweden, by Erik Arnold et all., Technopolis Group, ISBN 978-91-85959-32-7, Vinnova 2008.

[56] by Commissioner Ralf Dahrendorf, then forgotten.

movement of knowledge, researchers and technology, with the aim of increasing cooperation, stimulating competition and achieving a better allocation of resources.

- Restructuring the European research fabric by improved coordination of national research activities and policies, which account for most of the research carried out and financed in Europe.
- Development of a European research policy which not only addresses the funding of research activities, but also takes account of all relevant aspects of other EU and national policies.

All three ERA concepts are directly linked with the idea of creating a strengthened European innovation system to enable research commercialisation.

The ERA concept in fact largely influenced national and European framework programmes. Dan Andrée[57] introduced a concept of 'pre-ERA era' and 'ERA-era':

During the 'pre-ERA era', i.e. FP1-FP5 (1984-2020) there was in principle little interaction between the FP and national programmes in the sense that programme owners (Research Councils, Government Agencies, etc.) were not engaged. The FP was something additional to national programmes. (…) This does not mean that the FP did not have an impact at national level; on the contrary it has played a major role depending on the funding structure in different Member States. In some thematic areas, the FP has accounted for a large proportion of national research (e.g. health) but less in other areas (e.g. ICT). In some of the smaller Member States, the share of the FP has been much higher than the average of 5%.

3.1.7 FP7

By adopting the Europe 2020 Strategy, Europe's political leaders have put **research and innovation at the top of the European political agenda**, making it the cornerstone of investment in sustainable growth and jobs. The Seventh Framework Programme is the largest single research programme in the world, with a budget of more than EUR 50,5 billion, for 2007-2013. The broad objectives of FP7 have been grouped into four categories: Cooperation, Ideas, People and Capacities:

- Cooperation to make the EU the world leader in the fields of science and technology by promoting wider cooperation between research teams, both within the EU and with the rest of the world, including through broad-based, long-term public-private partnerships.
- Ideas to allow a major new initiative, the creation of a scientific autonomous European Research Council, to support investigator-driven basic research at the frontiers of knowledge, thus promoting

[57] Dan Andrée, Priority-setting in the European Research Framework Programmes, Vinnova Analysis VA 2009:17 ISBN: 978-91-85959-69-3.

researchers whose excellence, creativity and intellectual curiosity will lead to major new discoveries.

- People to develop the quantity and quality of human resources in research and development.
- Capacities to develop the means available for research and innovation in order to give science a better place within society and to facilitate the coherent development of international cooperation.

The underlying objective is **to move towards a knowledge-based and more environmentally friendly industry through an integrated approach combining materials science, nanotechnology, production technologies, information technologies, biotechnologies and so forth (enabling technologies)**. This is a significant shift from the times of earlier framework programmes (cohesion, scale, financial benefits, complementarity and contribution to unification) towards priorities addressing not cohesion and unification, but rather highly advanced research at the frontiers of science, with its particular needs for world class researchers and their cooperation.

Still, FP7 presents strong elements of **continuity with its predecessor**, mainly as regards the themes which are covered in the Cooperation programme. The themes identified for this programme correspond to major fields in the progress of knowledge and technology, where research must be supported and strengthened to address European social, economic, environmental and industrial challenges. Still, the overarching aim is to contribute to sustainable development. In the case of particular subjects of industrial relevance, the topics have been identified relying on the work of different 'European Technology Platforms' (among other sources).

There are significant differences in the structure of the currently run framework programme compared to its predecessors. The new elements in FP7 include the following:

- Emphasis on research themes rather than on 'instruments' — a great difference comparing to FP6;
- Significant simplification of its operation —prompted by most of the evaluations of FP6, simplification is a 'must do' factor in order to succeed at attracting more industry in general and SMEs in particular into European projects;
- Focus on developing research that meets the needs of European industry, through the work of Technology Platforms and the new Joint Technology Initiatives;
- Establishment of a European Research Council (ERC), funding the best of European science. Integration of international cooperation in all four programmes;
- Introduction of new instruments including:

- The development of Regions of Knowledge,[58]
- A Risk-Sharing Finance Facility (RSFF)[59] aimed at fostering private investment in research.

Into the future – Horizon 2020

This section elaborates more on Horizon 2020 with comparisons of possible policy options.

Horizon 2020 is the first approach to orient European research towards the concept of addressing the Grand Societal Challenges, and not thematic priorities. In effect we will be able to distinguish now the 'pre-Horizon 2020 era' and 'Horizon 2020 era'. The priorities of European framework programmes were shaped along defined grand challenges indicating the main areas of intervention. The stakeholders' reaction to the split of Grand Challenges proposed by Commission is two-fold. First of all shaping the **Grand Challenges officially is regarded as a very good approach and structuring research agendas along these lines is seen in general as a positive change**. The comments from interviews within this study as well as discussions during the Innovation Convention (December 2011) show that the final proposed categories could have been discussed more. Especially controversial are formulations of the last challenge where three substantially different areas are connected, namely: security, openness and innovation. Openness and innovation are regarded as broader issues, and do not seem to fit with security. Allocating funds into this challenge may in the future cause many misunderstandings.

As depicted in the complex figure below, the structural changes of this future framework programme are striking. Most of all the two enabling technologies, which had their own priorities in previous Framework Programme 7, will disappear. Both NMP and ICT priorities are cancelled from the thematic structure of the Cooperation programme under FP7. In fact with the new six challenges split we have been able to track all remaining priorities existing in FP7 to one of the Grand Challenges. ICT and NMP will become cross-cutting research issues addressing societal challenges, accompanied also with 'Space' (also included on the list of enabling technologies[60]). In the future all proposals delivered within those fields will have to be incorporated into the remaining Grand Challenges.

Another important change is the creation of a separate pillar addressing 'Excellence in Science' – designed to meet the needs of the scientific community, develop talent within Europe and attract leading

[58] The 'Regions of knowledge' initiative aims to strengthen the research potential of European regions, in particular by encouraging and supporting the development, across Europe, of regional 'research-driven clusters', associating universities, research centres, enterprises and regional authorities.

[59] Facility consisting in the financial collaboration between the European Commission and the European Investment Bank (EIB). Allows the RSFF to produce additional loans for R&D projects.

[60] although not Key Enabling technologies.

researchers to Europe. This pillar is a clear continuation of all successful actions undertaken previously within ERA including especially the Marie Curie Actions, as well as the European Research Council activities in the area of basic research.

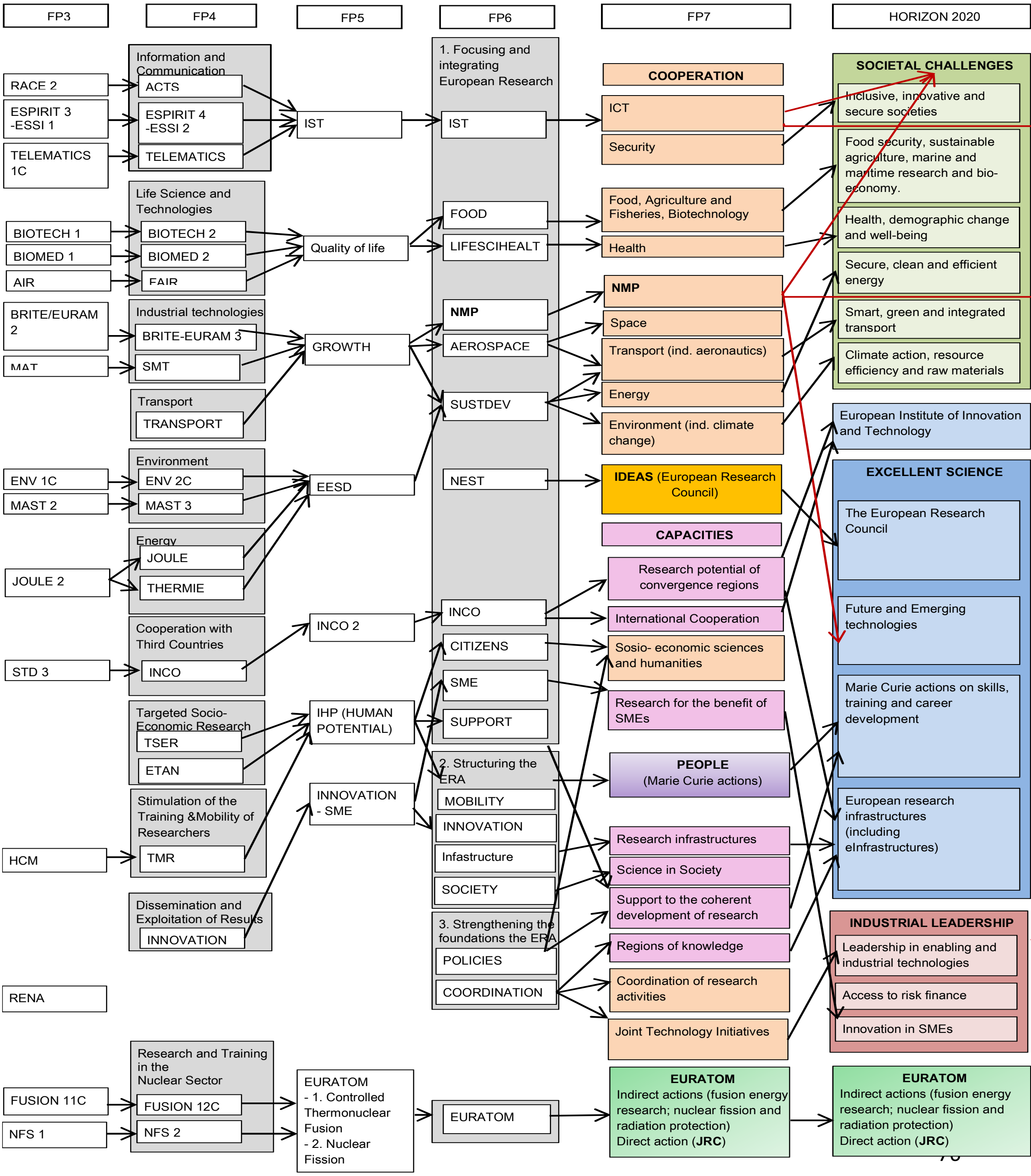
Finally the pillar of 'Industrial Leadership' was created as a continuation of other successful European programmes – the innovation-oriented part of the Competitiveness and Innovation Framework Programme (CIP) for support of entrepreneurs and transformative companies focusing on research and inventiveness to achieve industrial leadership in key enabling technologies.

These **changes are intended to address important market failures such as private sector underinvestment in R&D and insufficient financing for the growth of innovative SMEs and early stage eco-innovative companies in Europe**.

To summarize, **Horizon 2020 is in fact integrating the most successful parts of the past FPs, the innovation-related part of the CIP, and the European Institute of Innovation and Technology, put together into a single framework** and much different than previous historical approaches.

Source: Dan Andrée, Priority-setting in the European Research Framework Programmes, Vinnova Analysis VA 2009;
further developed to Horizon 2020 by Oxford Research AS.

Figure 6: Transformation of framework programmes structure



Past and current role of the FPs vis-à-vis grand challenges

In this section we describe and analyse the role of the FPs in solving the Grand Societal Challenges, with an eye to their strengths and weaknesses.

The analyses below are based on the data collected through desk research and semi-structured interviews. It has to be mentioned that the information provided by the interviewees expressed their personal opinions, based on their knowledge and experience with the FPs and national R&D programmes and does not express in any way the official position of their respective institutions regarding the issues discussed.

The FPs in general and the NMP in particular have played and continue to play an important role in driving excellent R&D in Europe, but the FPs are hardly a perfect tool providing the ultimate solutions to solving the Grand Challenges. The FPs are a central tool for R&D financing in Europe, but they have limitations in terms of time, fragmentation, impact, exploitation of results – issues that are addressed below. **The ambitions connected to them in terms of solving the Grand Challenges should be realistic and clearly communicated**.

3.1.8 The systems issue

The main question of what role the FPs and NMP should play in solving the Grand Challenges is that **the framework on which the FPs operate is either unclear or problematic, or both**. The conditions for the framework programmes have evolved for at least three decades, but the eminence, pervasiveness and complexity of the Grand Challenges that are focused on today require a revision of the framework conditions themselves. This process has been largely undertaken while planning Horizon 2020.

Many of the interviewees confirmed **the need for a common EU strategy for addressing the Grand Challenges**. Experts underlined also the need for effective collaboration between the EU and Member States in the formation of this strategy. Some interviewees express hope and positive expectations in connection to Horizon 2020 and the introduction of Joint Programming and Public Private Partnerships (PPPs), and believe that these are the right steps in this direction. Surprisingly Europe 2020 strategy is hardly named or referred to, or thought to play a role in creating a joint and committed plan to address the Grand Challenges. Horizon 2020 seems to be closer and more understandable to stakeholders than the strategy behind it.

As described in Chapter 3. **many of the bottlenecks lie not so much on the R&D level, where the FPs operate and have their mandate, but on the political, legal or economic levels**. Many of the interviewees pointed that there are excellent and promising results coming out of the FPs, but agreed that the bottlenecks usually lie at the political level, listing a lack of legal regulations, lack of political will to make committed decisions, lack of necessary mechanisms to regulate or influence the market. All these factors make it extremely hard and inefficient, if not impossible, to further exploit the results of research.

This is also in part why the research results end up either on the shelves, in the worst case, or are commercialised outside Europe, in the best case. This again proves the need for a committed strategy that would set up the conditions for how the EU and Members States shall address the Grand Challenges jointly. Political, legal and market mechanisms can assure that innovators' creative solutions are expediently and effectively exploited. This also implies **a clear and binding connection between Europe 2020 and Horizon 2020**, as many of the bottlenecks that the Members States have committed themselves to remove according to the Europe 2020 strategy are directly relevant for achieving the objectives of Horizon 2020.

3.1.9 The time issue

A strong finding from the interviews is that **the role of FPs in solving Grand Challenges depends on the lifetime of the programme, not projects**. According to the interviewees, the changes required to meet the Grand Challenges, especially changes in energy consumption behaviours in industry, need a longer perspective than the time range of average projects, which are usually 3-4 years. The complexity and interconnectedness of the Grand Challenges require a longer time span and continuation of logic throughout the entire programme and its mechanisms.

An example is earth science research that requires long spans of observations — much longer than those given in FP projects — to measure climate change and its impacts on earth systems. In such studies a duration of decades is need to observe results and act.

3.1.10 The focus issue

There is no doubt among our interviewees that the FPs already play a central role in financing, coordinating and driving R&D into delivering solutions for addressing the Grand Challenges. One of the main findings from interviews is that **the Commission needs to be very clear about the strategic priorities on one hand, and the mechanisms and tools created to implement these priorities on the other**.

According to the interviewees, many Member States follow (to greater or lesser extent) the priorities set up by the Commission in its FPs. However these priorities and topics are perceived as being too fragmented, too segmented, all-encompassing or too general. Said one expert, *'The FPs have a tendency to cover a wide area of activities and have difficulties* *concentrating on strategic areas.'* Since the FPs are meant to be strategic by design, the Commission needs to focus on a limited number of research issues in each of Grand Challenges. Researchers say **they would benefit from a greater focus on the strategic areas and a clear differentiation between the roles that different tools and mechanisms have created so far**: JTIs/JUs, JP and ERA-NETs, FETs (Future Emerging Technologies), PPPs (Public Private Partnerships under European Economic Recovery Plan), and the role that Lead Markets Initiatives are supposed to play.

Supporting information to this finding can be found in the evaluation of FP6 and interim evaluation of FP7. These evaluations highlight shortcomings of the FPs, and specify issues such as increasing added value and leverage, and avoiding duplication and fragmentation of the EU research and innovation funding. In line with our findings on strategic framework and the need for a clear differentiation between the different instruments and a clear focus on strategic areas, these evaluations point out that: *'EU research and innovation programmes have expanded the set of instruments leaving an impression of catering to too many objectives and spreading funding too thinly'.* [61] In addition, *'The Budget Review identified a way forward in this respect through the development of a Common Strategic Framework. This would cover all relevant EU research and innovation funding currently provided through FP7 and CIP and EU innovation initiatives such as the EIT on the basis of coherent goals and shared strategic objectives'*.[62]

Horizon 2020 is considered by the interviewees a positive step forward in terms of focusing on Grand Societal Challenges. Joint Programming is also thought to be a tool with strong potential for coordination of EU and national funding to avoid duplication and fragmentation, but also more generally because addressing the Grand Challenges requires a joint, coordinated effort between the EU and the Member States. It still remains to be seen how Horizon 2020 will work in practice and how the different mechanisms, tools and initiatives developed under FPs 6 and 7 and maintained in Horizon 2020 will contribute to channelling effectively and efficiently the financial and human R&D capital.

It is worth emphasizing that **the current EU R&D system is complicated, comprising a variety of activities. It is difficult to have an overview of the different initiatives, mechanisms and instruments that are created by the Commission throughout the FPs.** It is further difficult to have a clear picture on the part of each

[61] European Commission. 2011. Green Paper. From Challenges to Opportunities: Towards a Common Strategic Framework for EU Research and Innovation Funding.

[62] Ibidem.

and every one of them in the R&D system, including their role in addressing the Grand Challenges. During the interviews, it was obvious that our informants were unclear or did not know about the roles different mechanisms play in confronting the Grand Challenges, or the frameworks that they operate on — and even less about the potentials and synergies created by the different initiatives, tools and mechanisms.

Europe's R&D community requires a clear definition and clarification of the roles now divided among different instruments, tools and initiatives. These need to be communicated and updated on a single platform (currently the information is provided on different websites of the DGs and other agencies). Such a vital step will create focus and a clear overview on strategic priorities and the means to meet them.

3.1.11 The role of the different instruments

A natural process during the development and implementation of the FPs, in connection with different EU policies, has been the creation of a variety of instruments such as ERA-NETs (FP6), JTIs and JUs (FP7), Flagship Initiatives (Europe 2020, FP7), Joint Programming; PPPs are among the most important ones. In addition, advanced work has been done with preparing a common strategy for key enabling technologies in the EU.[63] Being based on active participation and strong commitment from the stakeholders, efficient governance and implementation structures,[64] it becomes obvious that all these instruments are important and engage effectively a variety of stakeholders both at the EU and national levels.

It is also obvious from the interviews that each and every instrument is 'living its own life', although they have overlapping economic and social aims. Another characteristic of these instruments is that they have as their main focus either competitiveness of the European industries (the ones where the industry is involved and is the driver: JTI/JUs, Factories of the Future, Green Cars) or excellence in research (the ones where the universities and research institutes are the stakeholder and also the drivers: European Research Council projects, to some extent the ERA-NETs and possibly the JPs). **What seems to be missing is a clear focus on the Grand Challenges and an expectation that research results and outputs will address the Grand Challenges**.

[63] European Commission. 2009. Communication. Preparing for our future: Developing a common strategy for key enabling technologies in the EU" COM(2009)512 and European Commission. 2011. High-Level Expert Group on Key Enabling Technologies. Final Report.

[64] European Commission. 2010. Interim Evaluation of the Seventh Framework Programme. Report of the Expert Group.

Rather than create more new instruments the Commission should instead consider making use of the existing successful instruments, mechanisms and initiatives, and redefine and direct them towards a concrete output that applies to the Grand Societal Challenges.

Strengths

Below follow the strengths of the FPs in terms of addressing the Grand Challenges, according to the findings from the interviews.

FPs connect the best people in Europe and make them work together

The FPs are **a powerful tool** to connect the best scientists in Europe, which creates a powerful foundation of human and knowledge potential.

Stronger focus on and involvement of the industry.

The FPs, especially in FP7, have managed **to open up and involve industry** at a higher level and more intensity than before. In line with the conclusions of the interim evaluation of FP7, many of the interviewees consider industry involvement in the FPs as a positive development, especially when it comes to developing demand-driven innovation and exploiting R&D results. In NMP this has been especially successful, and should be extended to the other priorities.

The Interim Evaluation of FP7 has documented that the **success of the ETPs, followed by the JTIs and the PPPs, depend on the active and committed involvement of stakeholders from the industries and their simple and efficient governance**.[65] This insight is supported by the interviews in this study as well.

A complementary insight came out of the interviews with informants from different industries (which actually leads into our discussion of 'weaknesses' in the current system). These industry partners had experienced projects where academic researchers in the projects cared solely about publications of the results and not so much about industrial applications or commercialisation. An explanation for this, according to the same informants, was that the governing practices of evaluating researchers in universities mainly looked to their publications in top-tier journals and the numbers of citations per article or per researcher. **A change in the means of evaluations and grading of research and science quality at universities is therefore needed, so as to include exploitation of research results, social and industrial applications, knowledge transfer and commercialisation of research**.

Weaknesses

Below follows a presentation of the weaknesses of the FPs in respect to addressing the Grand Societal Challenges, based on the

[65] European Commission. 2010. Interim Evaluation of the Seventh Framework Programme. Report of the Expert Group.

information coming out from the interviews.

The bureaucracy still needs to be reduced

Although there have been continuous efforts to cut the red tape in the administration of the FPs, bureaucracy is still a weak feature. The bureaucracy takes many resources both from the Commission and from the FP participants, in coordination, project management and monitoring. The application process is still complicated, requiring considerable paper work, which scares researchers from smaller research institutions and SMEs. **The participation process should be simplified.** The interim evaluation of FP7 recommends lowering of the administrative burdens, reducing time-to-contract and time-to-payment and considering trust-based approaches in the administration and management of the projects.[66]

Such **positive expectations are connected to the Horizon 2020**, where cutting red tape is a strong priority.

Exploitation of R&D results

A strong finding is that **exploitation of the R&D results coming out of the FPs does not happen in an effective and efficient way**. According to the interviewees, there is much unutilised R&D material lying in the FPs that is systematically filed up on the Commission's shelves. These data may have potential industrial and social applications, but are not sufficiently taken care of or exploited in practice.

Measures sought by our informants that could solve this problem are:

- Allocate dedicated resources for the exploitation of all R&D results with potential;
- Create a mechanism within the Commission or in collaboration with other institutions to follow up the most promising R&D results;
- Provide opportunities for those interested actors who are willing to exploit these results.

An important step in addressing the exploitation of research issue is training the young researchers in an entrepreneurial mind-set and gives them the necessary tools to exploit their research early in their careers. A useful tool that was mentioned in this respect was the Fab Lab concept developed at MIT, the USA that provides young researchers and engineers with machine tools to fabricate real products from their ideas. The Fab Lab proved in many cases to be the first step from an idea to an industrial-like fabrication of the future products (See Box).

Many of the interviewees feel that the responsibility is on the Commission **to create mechanisms and finance exploitation of the most promising results** that are now in limbo, or may end up on the shelf in the future. However the issue of

[66] Ibidem.

how and who is to make the assessment of the most promising technologies and other R&D results coming out of the FPs remains unclear after the analysis of interview data.

It has to be noted that there have been taken some initiatives to assist R&D projects in exploitation and commercialisation of project results already in FP7. An example is the service provided through 'ESIC – Exploitation Strategy Innovation Consultants'[67], where R&D projects funded by the NMP programme, can solicit support on matters connected to commercial exploitation, such as project risk analysis, exploitation strategy seminars, business plan development, patenting assistance and standardisation assistance. The service has received a positive feedback from the projects and was assessed to have a positive impact on commercialisation of their R&D results. Another example is the project Nano2market, also financed in FP7, focuses on commercialisation of results of EU R&D projects in the nanotechnology field, providing support in knowledge transfer, guidance on IPR agreements, among others.

67 http://ec.europa.eu/research/industrial_technologies/assessment-and-exploitation_en.html

Fab Labs

Fab lab or 'fabrication laboratory' is a technology platform for learning and innovation, *a place to play, to create, to learn, to invent, to mentor*[1].

The first fab lab was created as an educational component for the Center for Bits & Atoms (CBA) at the Massachusetts Institute of Technology with the **aim to stimulate creativity, innovation and entrepreneurship and was subsequently adopted by schools and communities as platforms for project-based, hands-on education.** Users learn by designing and creating objects of personal interest or importance. The concept proved to connect successfully the global community of learners, educators, technology developers and innovators. There are currently 32 fab labs worldwide.

The basic tools that form a fab lab include, but are not necessary are limited to: a laser cutter that makes 2D and 3D structures, a sign cutter that plots in copper to make antennas and flex circuits, a high-resolution milling machine that makes circuit boards and precision parts, a large wood router for building furniture and housing, and a suite of electronic components and programming tools for low-cost, high-speed microcontrollers for on-site rapid circuit prototyping. However these can vary depending on resource availability and stakeholders interests.

Neil Gershenfeld the founder and developed of the Fab Lab concept describes it in his book as 'Personal fabrication systems are small, inexpensive clusters of tools and software that function as complete job shops. Typically, they have easy-to-use controls that enable almost anyone, including people in remote African villages, to manufacture an amazing variety of things. A typical system includes a milling machine for making precision parts, a cutter for producing simple printed circuit boards, and software for programming cheap chips called microcontrollers.'[1]

For more examples on Fab Labs worldwide please consult:
http://fab.cba.mit.edu/about/labs/

However, considering the complex and sometimes sensitive political, legal and market nature of the different bottlenecks that are in the way of exploitation of R&D results, the mechanisms created by the Commission and the resources invested in this endeavour can prove to be insufficient as long the Member States are not committed to creating the necessary framework conditions and instruments for efficient, effective and timely exploitation of R&D results. Thus, **an all-level collaboration, strategic and operative, between the Commission and the Members States should be considered in this effort of facilitating and supporting all worthy R&D results**.

Exploitation of R&D results was also addressed in the interim evaluation of FP7 as an area that needs improvement. Our findings are in line with- and complement the conclusions drawn by the the expert group which emphasised the need for better communication of the objectives and relevance of the research activities to a wider audience and suggested an earlier involvement of the ultimate consumer of innovations in the R&D process.[68]

The lack of a value chain

A related finding coming out of the interviews is the lack or incomplete presence of a value chain in the R&D process as funded by the FPs, nor is this standard business practice promoted. It is still the case today that consortia are composed of groups of actors with separate interests and objectives in the project, who most often than not care little about transforming the results into marketable products. Among the experiences shared in the interviews were projects where researchers cared solely about their publications in high level journals, which undermined the IPs of the SMEs involved, or instances where the members of the consortia actually were interested in the R&D and detained the IP in order to hinder its further exploitation on the market.

Cooperation along the value chain should be a precondition in consortia that apply for EU funds. **The logics and potential for exploitation of the results should be taken into account in the early phase of establishing the consortium**. The consortium should **be able to prove real interest and commitment for further exploitation of the results produced in the project**.

Cooperation between EU and Member States

An in-depth comparison between the EU's research activities and those in the Members States and third countries, with respect to their role, strengths and weaknesses in addressing the Grand Challenges, is generally difficult to make due to the resource limitation of the study. Chapter 5. presents a brief analysis of a sample of Members States and third countries in terms of their research policies and instruments to remedy the Grand Challenges, based on existing monitoring data, policy briefs and official reports.

As shown in this study, a number of countries have developed programmes that support scientific and technological R&D in many or all of the societal challenges. However, as in the FPs, exploitation of R&D results and their commercialisation by industry and is insufficient and does not match the amount of funding and support invested by public authorities. This is also confirmed in the interviews, where comparisons between the EU and national research activities were made.

Based on the picture drawn by the interviewees, the potential and the

[68] European Commission. 2011. Green Paper. From Challenges to Opportunities: Towards a Common Strategic Framework for EU Research and Innovation Funding.

capacity for addressing the Grand Challenges lies not so much in the strengths or efficiency of individual countries' R&D programmes or instruments, but in the **effective cooperation between the priorities, programmes and instruments at the EU level with those at the national level**. Some interviewees explained that their institutions or businesses rely on two pillars: national funding and EU funding. They therefore have incentives to improve coordination between the two. **Joint Programming and ERA-NETs have been named as good instruments to achieve this**.

CHAPTER 4. MEMBER STATES' EXPERIENCE IN ADDRESSING GRAND CHALLENGES

Awareness of the existence of a number of interconnected problems of global character has constantly grown among the research communities to gradually spill over into the political and industrial communities. A series of top policy documents, among them The Lund Declaration (2009), Europe 2020 Strategy and most recently Horizon 2020, bring the fundamental importance of coping with the Grand Challenges onto high-level agendas all over Europe. In this chapter we will present and analyse existing evidence on how various EU Member States and third counties shape their research, innovation and technology policies and activities in order to approach the Grand Societal Challenges.

Defining Grand Challenges

Grand Challenges also referred to as Global Challenges or societal challenges, is a policy term that has been approached and defined in variable ways. A recent study from Fraunhofer ISI (2011) that has reviewed nine European national forward-looking studies conducted between 2007 and 2011 found that most of these synthesized and adopted different definitions from existing documents, while they tended to agree on the fundamental importance of RDI priority-setting based on the need to address Grand Challenges.[69]

The Grand Challenges that were found to be addressed by the national forward-looking studies were:

- securing energy supply and decarbonising energy production;
- counteracting climate change;
- preserving biodiversity;
- food safety and security;
- preserving ecosystem services/securing clean environment;
- adapting to climate change;
- securing water supply;
- combating chronic and infectious diseases;
- handling global conflicts;
- understanding and dealing with changes in social fabric, in particular
- demographic change but also diversity;
- ensuring well-being and quality of life;
- ensuring resource security.[70]

[69] Towards transformative innovation priorities: Synthesis of findings from forward-looking studies across Europe, Philine Warnke, Fraunhofer ISI, Karlsruhe, February 2011.

[70] Ibidem.

National strategies for science, technology and innovation

National plans and strategies serve to articulate priorities for research and innovation, and to set out policies and instruments. In terms of main trends that can be observed in the national strategies for science, technology and innovation, '**competitive advantage' is a central issue**. Strengthening business innovation to improve industrial competitiveness, in terms of raising productivity growth, jobs and living standards is a common goal of the OECD countries' national strategies or action plans for science, technology and innovation.[71] A part of this trend is that **competitive advantage is addressed in connection with Grand Challenges**. This however is not a trend characteristic for all the countries.

There are differences among the OECD countries in the priorities they choose as essential and what emphasis they put on them (See Table 7). It has been registered that countries such as Korea, Japan and the United States, that already score high on business R&D and innovation, invest considerable resources to strengthen the base for *future innovation*. Also these same countries prioritise competitive advantage for future growth areas such as green technologies and health, as well as helping to address Grand Challenges.

[71] OECD Science, Technology and industry Outlook 2010. P. 74.

Table 7: Revised or new national plans for science, technology and innovation policy in OECD countries and selected non-member economies, 2010

Country	National Plan	Period Covered	Main objectives
China	Medium- and Long-term Programme for Science and Technology Development	2006-20	Enhance China's S&T and innovation capabilities; use innovation as a tool for restructuring Chinese industry; shift growth modes from investment-driven to innovation-driven; **build a conservation-minded and environmentally friendly society**; and enhance independent innovation capabilities as a national priority. Raise R&D investment to 2.5% of GDP by 2020; rank in the world top five in patenting and international citations.
France	National Strategy for Research and Innovation	From 2009	Strengthen incentives for the private sector to invest in R&D (increase in the Research Tax Credit, CIR), develop synergies between key innovation actors and improve transfer from public research to innovation (competitiveness cluster policy), support SME competitiveness and growth through better funding. Three priorities over the next four years: **health, well being, food and biotechnologies; environment, emergency and eco-technologies; and information, communication and nanotechnologies**.
Germany	High-Tech Strategy 2020	2020	Following a review, the strategy now focuses on priorities which have been defined in **accordance with lead-market-oriented topic areas** in which the state has special responsibilities and which are of **special societal and global relevance: health, nutrition, climate protection, energy, mobility, security and communication**.

Hungary	S&T Innovation Policy Strategy	2007-13	Increase total R&D expenditure to 1.8% of GDP by 2013 with half the R&D performed by the business sector. **Strong focus on 'key technology areas'** (incl. **ICT, biotech, nanotech, renewable energy resources tech, environmental technologies**), commercialisation (translation into knowledge-based industries) and regional innovation systems.
India	Science and Technology for the XIth Five Year Plan and other policy documents	2007-12	Increase R&D spending to 2% of GDP with the business sector doubling its contribution; give top priority to primary education and higher education (increase spending by 6% of GDP by 2015) as well as vocational training; better link public research to business needs; strengthen IPR; promote international co-operation; foster research and innovation in agricultural sector (i.e. the **Second Green Revolution**) **to address climate change**.
Japan	New Growth Strategy	2009-20	**Lead the world in green innovation and life innovation**; increase the number of world-leading universities and research institutions and reform public research institutes; ensure full employment of S&T doctorate holders and provide young researchers with career prospects; foster innovation; encourage utilisation of intellectual property by SMEs; improve ICT use; increase public and private investment in R&D (4% of GDP); improve government services delivery.
Netherlands	Innovative, Competitive and Enterprising	2007-11	Strengthen the innovativeness of the Dutch business sector: stimulate innovation in SMEs and **promote environmental innovation in industry**; foster the development of strong internationally prominent clusters; **pursue social innovation (health, safety and security, water, energy)**; **support eco-efficient**

			innovation; strengthen workforce through education and research and strengthen higher education system.
Norway	White Paper on Climate for Research	2009-onwards	A stronger focus on impacts and results. The White Paper on research defines the nine goals and output areas. These output goals are meant to complement the long-term ambition that total R&D expenditure will reach 3% of GDP. The new goals imply **a new direction in research policy with a stronger emphasis on global challenges, welfare issues in research**, and on impacts and results. One goal is to introduce a systematic approach to indicators, evaluations and other types of assessments of research.
	White Paper on 'An Innovative and Sustainable Norway'		Increase innovation by advancing a creative society with a sound framework and a favourable climate for innovation; creative human beings who develop their resources and competences, while grasping the possibility to apply them; and creative undertakings that develop profitable innovations. Improve the knowledge base and establish strategy councils in specific areas (for SMEs and **environmental technology** further to those for tourism and the maritime industry).
Poland	Strategy for increasing the innovativeness of the Polish Economy	2007-13	Develop human resources to build the knowledge-based economy; link public R&D activities to the needs of the enterprise sector; improve IPRs; mobilise private capital to create and develop innovative companies; build the infrastructure for innovation.

	National Foresight Programme – Poland 2020	2020	Four development scenarios for Poland to 2020. Based on a special report, Poland 2030. Development Challenges that outlines potential routes for Poland's development during the next 20 years and will serve as the basis for the Long-term Strategy of Developing Poland.
United States	A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality	From 2009	The US Innovation Strategy is organised around three pillars: invest in the building blocks of American innovation, including R&D and human, physical and technological capital; promote competitive markets that spur productive entrepreneurship; and catalyse breakthroughs for **national priorities such as developing alternative energy sources** and **improving health outcomes**.
	American Recovery and Reinvestment Act (ARR)	2009-13	Out of the USD 787 billion allocated under the AAR, USD 100 billion will be used to support investment in innovative and transformative programmes. In this context, four areas are targeted: modernisation of transport, including **advanced vehicle technology and high-speed rail; renewable energies (wind and solar); broadband, Smart Grid, and health IT; and ground-breaking medical research**.

	Strategy for American Innovation	Updated 2011	Invest in the Building Blocks of American Innovation: Restore American leadership in fundamental research, which will lay the foundation for **new discoveries and new technologies that will improve our lives and create the industries of the future**. Educate the next generation with 21st century knowledge and skills while creating a world-class workforce. Catalyse Breakthroughs for National Priorities: **unleash a clean energy revolution; support advanced vehicle technologies; drive innovations in health care technology; harness science and technology to address the "grand challenges" of the 21st century**.
Source: Responses to the STI Outlook 2010 Policy Questionnaire; OECD (2008), OECD Science, Technology and Industry Outlook, OECD, Paris; European Commission, ProInno Europe country reports and national sources. Adapted and completed by Oxford Research			

From the highlights in Table above there can be clearly observed **a continuous shift towards priorities attending the Grand Challenges across the OECD and third countries**. Those issues which remain high on the agenda of the national STI (Science, Technology and Innovation) strategies are **environment and energy, new and emerging technologies, as well as food security**. In addition, issues such as health sciences, sustainable high-tech transport, aging and urbanisation rank high in national STI strategies.

A prominent example is Germany, where successive governments have chosen to focus on health, nutrition, climate protection, energy, mobility, security and communication. Lead-market concepts were put at the basis of this work, while the focus was put on those areas in which Germany has strategic potential to develop lead-markets and contribute to solving the Grand Challenges.[72]

France is another front-runner in this respect, prioritizing health, wellbeing, food and biotechnologies; environment, emergency and eco-technologies; and information, communication and nanotechnologies in their National Strategy for Research and Innovation. In the Netherlands we

[72] OECD Science, Technology and Industry Outlook 2010. P. 74

find high on the agenda promotion of industrial-environmental innovation and social innovation. Similarly, in Norway we find a strategic focus on environmental technology, global challenges and welfare issues.

The validation workshop for this report brought possibility to compare several countries' approaches towards structuring their research efforts.

National programme representatives discussed current trends in shaping countries intervention around grand challenges.

Main findings of this exercise can be summarised as follows:

- Grand challenges are gradually influencing existing and new coming programmes
- Key enabling technologies are crosscutting all defined challenges. There is a trend to address innovation support with inter-disciplinary projects.
- National programmes will continue and encourage measures aiming at international cooperation.
- Closer coordination and co-funding of projects with other countries and at EU level is valuable.
- Basic/blue sky research will be continued, and is seen as extremely important development factor
- The 'challenge-oriented' approach is more corresponding to the close to market, direct innovation support measures.
- Human resources are becoming more and more important in the context of KETs ability to be used in industries of the future; education is becoming important factor of national programmes.
- Cluster-oriented approaches appear to be very effective in countries which already implement such measures (see examples in this study for Germany, Sweden and Finland).
- Research infrastructure is important factor for capacity building

The conducted presentations and subsequent discussions enabled preparation of a comparative table demonstrating overview of approaches to this regard.

Table 8: Overview of selected national programmes' management issues

Country	Challenge-driven support structure	Structure of priorities /challenges	Cross-cutting issues	Instruments	Specific issues
Norway	Yes, but limited in scope	• Energy • Climate • Industrial innovation	• International collaboration important • Strengthening research quality • Develop knowledge for solving global challenges • Value creation for industry important	• New research centres • Programs: Basic Science / Innovation • Infrastructure • Test/pilot projects • International collaboration	• Innovation through clustering the country's leading companies, research institutes and universities • structured effort to strengthen country's competitive advantage areas
Sweden	Yes	• Future Health and Health Care • Sustainable and Attractive Cities • Information Society 3.0 • Competitive Industries	• Cross-functional and cross-sectoral approach	• long-term investment in strong research and innovation milieus • projects to increase commercialisation of research results • conferences and seminars	• Demands in focus …not technology • Involve end-users / problem owners early in the process – "open innovation" •

Israel	No, but some priorities corresponding	• support industrial R&D • encourage entrepreneurs in high-tech start-up companies • leverage Israel's highly capable scientific and technological labour force • facilitate the academic industrial interface • to stimulate cooperation in state of the art R&D	• Programmes are supported along the R&D chain with the split to : • Excellence (for basic research) • Market driven project (for industrial R&D)	• The R&D Fund • Technological Incubators • Pre-seed Fund TNUFA • Seed Fund - the HEZNEK • The MAGNET Program for Generic pre-competitive technologies • NOFAR Program, to bridge the gap between basic and applied research • International programmes as separate line	• Special areas of focus : • Alternative Fuel • Cyber • Space

Spain	No; New plan under preparation in 2012	Currently national plan is based on 'instrumental lines' and a few "strategic actions". Less priority paid to thematic priorities.	In the future programme: • Strong alignment with H2020 to maximize synergies • Attention to socio-economic challenges	Balance between bottom-up and top-down actions.	• Priorities covered from basic research to innovation • Strong international and regional cooperation
Germany	Yes	• Climate &Energy • Health & Nutrition • Mobility, including electromobility • Security • Communication	• Risk assessment, • Standardisation, • Regulation	• Patent policy • New campus models • Leading-Edge Cluster Competition • Innovation Alliance (bringing together industry, science and research policy) based on mandatory cluster approach	• Industrial and societal needs are investigated and compared before publication of calls • Significant financial contribution by industry during lifetime of projects • Industrial commitment to implement project results and for further investments (leverage effect)
Source: Final validation workshop for this study - presentations by national innovation agencies representatives; table prepared by Oxford Research.					

Based on the research conducted it must be stated that grand challenges impacted research programmes in Member States very recently. It appears that in Europe this process was mostly triggered by EU-wide discussions in the context of Horizon 2020 preparation over last three years.

It is impossible to assess what are the results of new shaped programmes. Such evaluation will be possible in the future, when challenge-focused projects will bring its first quantifiable results. Agencies' experience in preparation of these new programmes can nevertheless be revealed.

Interesting findings regarding the process of implementation of new-shaped programme are described in box below, bringing experience of Swedish Vinnova managers.

From technology-driven to challenge-driven approach – the Vinnova experience

An approach similar to European Commission's currently developed ideas, shaping Horizon 2020 was tested in 'real life' by Swedish Governmental Agency for Innovation Systems- Vinnova. The agency's recent programmes were re-shaped **from technology-driven approach to challenge-driven split along 2011** calls. First and the most important point of this radical change of approach was the shift in the way of thinking. The main issue here was to induct new thinking about **challenges as business opportunities**. This changed approach resulted in **more cross-sectoral projects**, not being that much technology-oriented and therefore demanding user-driven innovation (opposite to researcher-driven innovation). The additional requirement was also to create new collaborations between industry sectors, research fields and their respective actors. In this way totally new projects were proposed in 2011 calls.

The planning process of the entire new programme undertaken through the wide consultation process fed finally on VINNOVA's mission statement and selected fields being highly relevant for Swedish industry and society, listing four main challenges:

- Sustainable and Attractive Cities
- Information Society 3.0
- Future Health and Health Care
- Competitive Industries

The important issue in defining the new programme approach was to be explicit what is meant with a 'challenge', also the evaluation of proposals was more complicated, as more diversified competence was required among the evaluators.

The Vinnova approach was built upon key attributes of challenge-driven innovation where the most clear were:

- **'Open innovation'**- involving end-users / problem owners early in the process
- **Cross-functional and cross-sectoral approach** with broad criteria, sharpen underway programme preparation

The first call organized with this new approach brought the **largest number of applications in a single call** in the agency's history. The concept in general appears to be well received and mainly understood both in industry and research community. Still a number of classical technology-oriented project proposals was received. Evaluators also noticed applications trying to adapt 'old' technology driven project to the new programme concept. The problematic element for applicants was that **the new programme was largely investment-oriented, instead of the typical way of financing research projects**.

Other problematic elements faced were connected with application consortia. It was seen as more **complicated for the applicant to form a consortium with the multi- sectorial competence needed**, and therefore supporting actions have to be implemented from the agency side (including matchmaking events, separate for each of the challenges) in order to support this new approach. It also appeared that some applicants focused too much on the consortium formulation and presented a too sketchy description of the approach.

The new concept also attracted many new actors, sometimes with limited experience in similar programmes and narrow, very local view. This also created a need for adjusting program's legal framework to some new situations.

On the side of programme preparation also several new issues appeared, including the need for a country wide - information tour organized to introduce the new approach. On the proposals evaluation side -the evaluation criteria for the programme were perceived as being more difficult to formulate, due to the context complexity. It must be underlined that the new concept is still under development and the adjustments are foreseen in the future.

Source: developed based on the presentation 'VINNOVA and Challenge Driven Innovation' by Ulf Holmgren, Vinnova Chief Strategy Officer - Industrial Technologies, 2012.

When it comes to countries outside the EU, the United States and Japan are the front-runners, making the Grand Challenges, along with industrial competitiveness, a strategic focus in their STI policies. In the United States we find 'clean energy revolutions', health, new and advanced technologies for improved life conditions and industrial competitiveness (KETs) as national priorities. In the Strategy for American Innovation, which was updated in the beginning of 2011, science and technology are actively and strategically to be mobilized for addressing the Grand Challenges of the 21st Century.

Similarly, while Japan establishes in their New Growth Strategy for 2009-2020 the ambition to 'lead the world in green innovation and life innovation', China aims in this period to 'build a conservation-minded and environmentally friendly society'.

For some OECD and third countries, usually the emerging economies and those who lag in innovation performance, Grand Challenges-related priorities are not easily found in their plans for STI policies. One natural explanation for this is that these countries need to focus on building or consolidating their STI systems, in terms of linking public research and industry, encouraging industry R&D and improving the quality of higher education and research.

It is important to note that many of the identified plans and strategies for STI policies are running out in 2010-2011 (e.g. Spain- presented in Table 8 above), which means that many of these will undergo further development and updates, where new Grand Challenges-related priorities shall eventually be taken on. **According to the existing analyses the trend is strong and will continue to put an increased focus on Grand Challenges**.

Grand Challenges – related debate, policy attention and instruments on the national level

National action plans and strategies in STI are a result of complex and interrelated processes which have been preceded, accompanied and followed by active debates and policy discussions at the national level. In the following we present a summary of four Policy Briefs addressing national STI policies and their focus on the Grand Challenges. The information in the Policy Briefs was collected from the network of INNO-Policy TrendChart correspondents. Besides the EU, third countries were also included in the briefs.

4.1.1 In terms of debate and policy attention

At the moment there can be distinguished two groups of countries.[73] One group reported an active, public and high-level debate on climate change and a resource efficient economy in connection with innovation. The specific themes debated vary from broader topics, such as sustainable development, climate change, global warming and energy efficiency to more specific and in some cases more applied topics, such as clean or environmental technologies, natural resources, sustainable energies, energy security, waste recycling, energy saving, renewable resources, sustainable building and many more.

[73] Karakasidou, A., Cunningham P., 2010. Innovation, climate change and a more resource efficient economy. Policy Brief N. 4.

Case Study - German experience in dealing with Grand Societal Challenges and successful PPPs /clusters -Innovation Alliance Lithium Ion Battery LIB 2015

The efficient storage of electrical energy is essential for climate-friendly energy use. The lithium ion battery is considered to be a key source of sustainable energy storage in the development of hybrid and electric vehicles and wind power, among other applications. The Innovation Alliance 'Lithium Ion Battery LIB 2015' was founded in November 2007 in Germany. **The Alliance consists of about 60 partners coming from industry, academia and governmental organizations**. The general aim of LIB 2015 is to support research and development of efficient lithium ion batteries along the entire value chain. The goal is to develop a new generation of lithium ion batteries that will provide efficient energy storage for industry and household use.

Specific objectives of LIB 2015:

- development of large, high-capacity lithium ion batteries;
- electromobility: hybrid battery; battery for electric vehicles;
- steady state: storage of regenerative energy.

Topics addressed by LIB 2015:

- materials and components;
- process technologies for production of battery cells;
- integration of battery cells into a battery system;
- batteries for specific applications.

To achieve these objectives, LIB 2015 is based on: 12 industrial collaborations, 3 academic collaborations, 3 young scientist groups, 1 cross-cutting project, BMBF funding: EUR 60 million, industrial investment: EUR 360 million, DFG Research Initiative: EUR 4 million.

One of the central projects within LIB 2015, HE-Lion, concerns development of new generations of high energy batteries for use in plug-in hybrid automobiles and the electric-powered vehicles of the future. The funding is based on equal proportions of money coming from BMBF (EUR 21 million) and the industrial partners involved. The companies involved are from the chemical industry, battery industry, automotive and energy sectors. The consortium consists of 18 science and industrial partners, under the guidance of BASF Future Business GmbH. **Its goals are to develop and commercialize efficient, safe and affordable ion batteries with higher**

capacity for future propulsion systems such as plug-in hybrid automobiles by 2015. The ambition is to develop batteries with 2 to 5 times more energy density compared with older generation of batteries.

The consortium is cross-disciplinary and covers the entire value chain in battery development and production, extending from materials research to system integration. Most importantly it puts together a constellation of actors that provides for a powerful competitive advantage in development and commercialisation of the next generation of lithium ion batteries. BASF, Freudenberg Vliesstoffe and SGL Carbon are responsible for material manufacture. Prototype development and cell technology are provided by Fraunhofer Institute Itzehoe and the companies Gaia, Leclanché and Bosch. Implementation in the vehicle is being undertaken by Volkswagen. The EnBW energy company will develop models for integrating the high-energy batteries into a new power supply concept for load balancing. In fundamental research, cooperative projects are ongoing with the universities of Berlin, Bonn, Clausthal, Darmstadt, Giessen, Hannover, Münster, the Paul-Scherrer Institute in Switzerland and the Leibniz Institute of Dresden.

LIB 2015 is managed as a cluster organization. The cluster management consists of the executive, Prof. Martin Winter, and the Cluster Management Team. Annual cluster workshops and meetings are organized with interactive sessions on cross-cutting projects and working groups on issues such as road-mapping, recycling, materials, systems and standardisation.

Sources:
Innovation Alliance LIB 2015 webpage http://www.lib2015.de/
BASF http://basf.com/group/pressrelease/P-09-158
Dr. Herbert Zeisel, Federal Ministry of Education and Research. Presentation on 'National Funding Strategies to Address the Grand Societal Challenges'.

The countries included in this group were Austria, Denmark, France, Germany, Ireland, Italy, the Netherlands, UK, Romania, Iceland, Japan, Norway and Belgium. The debate in most of these countries has materialized in policy documents, with clearly formulated Grand Challenges-related priorities, as partly shown in Table 7.

The second group of countries, where the debate was not so long-standing and pervasive included Finland, Luxembourg, Portugal, Spain, Bulgaria, Poland, Canada, India, Liechtenstein, Switzerland and the United States. Despite a weak public debate and stakeholder involvement, some of these countries strongly prioritize Grand Challenges in their STI policies, for example, the United States. This could mean that the Grand Challenges priorities are top-down concerns, and require direction in order to be anchored in the national industries, the research and innovation communities and the wide public.

4.1.2 In terms of policy instruments

The majority of the countries have allocated budgets and established programmes addressing Grand Challenges. However these programmes vary in terms of the focus they put on research, innovation and technologies.[74] An important finding is that whilst a number of countries have developed programmes that support scientific and technological R&D in many or all of the societal challenges, far fewer countries have developed programmes of innovation support. This is, according to INNO-Policy correspondents, a weakness in the sense that **the efforts in research and technology may not be matched by the support needed for the uptake and development by industry**.[75]

Among the variety of schemes that are used by the countries, they found:

- research programmes aiming to produce research on efficient energy use and storage, renewable energies and intelligent energy systems;
- research programmes with broader, more generic purposes such as to assess the risks and impacts associated with climate change;
- innovation programmes looking to commercialise relevant technologies;
- special seed and VC Funds that provide equity to relevant innovative start-ups;
- more applied industry-oriented projects, for example supporting energy efficient production or supporting the construction industry to develop energy efficient buildings (households and businesses);
- large scale national infrastructure projects.

4.1.3 In terms of structural changes

The countries reported very few structural and institutional changes produced as a result of STI policies. The changes that were reported involved **mostly administrative changes in the upper levels of the state bodies, such as development of new coordination mechanisms, establishment of new advisory bodies and institutions**.

Some of examples on recent structural changes are presented below:

- Shifts in policy focus as a result of political challenges: In Belgium a new governance structure, created as a result of elections in 2009,

[74] Ibidem.

[75] Karakasidou, A., Cunningham P., 2010. Innovation and Societal Challenges. Thematic Report N. 1.

restructured the ministries to put more emphasis on sustainable development; in Greece a new Ministry of Environment and Energy has been formed that is to develop initiatives on environmental issues.

- Set up of new dedicated institutions: the creation of the ministry of Climate and Energy (2007) in Denmark; the establishment of a national strategy committee for climate change–related RDI and a committee to develop a national innovation strategy in the healthcare sector in Norway (2009); appointment of an Assistant to the President for Energy and Climate Change in the United States (2009).
- Shifts in ministerial responsibilities: in France, the Ministry for Ecology, Energy, Sustainable Development and the Sea was to present in 2008 a strategic action for addressing Grand Challenges; in Spain, the creation of the State Secretariat for Climate Change within the Ministry of environment.

4.1.4 In terms of healthcare, quality of life and aging

The analysts found it difficult to distinguish evidence between the focus on medical issues in general and the more specific focus on narrow healthcare issues related to aging population, modern lifestyle diseases, pandemics and zoonoses, increased longevity, etc.[76] The general finding is that *there is* evidence of an existing debate and prioritisation of healthcare, quality of life and aging population from several countries. However the authors find that **the countries place a different emphasis on the role of innovation and industry in addressing these respective challenges**. The authors could also observe in some of the countries (Austria, Switzerland, Denmark, Portugal, Norway and Finland) that healthcare, quality of life and aging are prioritized to a lesser extent compared with climate change and a resource efficient economy, but to a larger extent than security issues. They conclude that the trend is positive and that these issues have become increasingly a part of the national priorities.

4.1.5 In terms of innovative and secure societies

The authors have found only a limited number of countries that use the 'broad issue' of security in the context of their research and innovation policies.[77] The public debate on broad security issues in terms of Grand Challenges is minimal. However the countries where a debate was reported included France, Germany, Netherlands, UK, Spain, Estonia, China, India, Israel, Japan and Norway. The authors reported no

[76] Karakasidou, A., Cunningham, P. 2010 Innovation and healthcare/quality of life and ageing. Policy Brief N. 5.

[77] Karakasidou, A., Cunningham, P. 2010 Innovation and Security. Policy Brief N. 6.

evidence of a trend in increasing or decreasing attention to the security issues in the national STI policies. In the same manner few countries reported the existence of earmarked budgets or programmes supporting security as an objective of innovation policy.

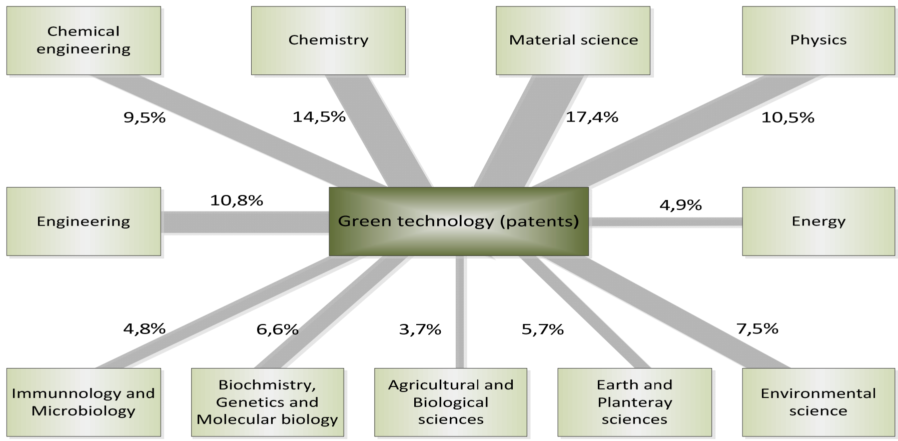
4.1.6 What green technologies can say about STI addressing Grand Challenges

Innovation in green technologies has been at the core of many national action plans and strategies for STI in the context of addressing Grand Challenges. Statistics show that public spending in environment and energy related R&D has been constantly increasing in the OECD countries since the beginning of '90, with an increase in funding for renewable energy materials and technologies, mounting to 10% of the total funding in this field, by 2009 (See Figure 8). Existence of patenting and citations statistics provides strong evidence on governments' spending, the actual results of these spending decisions and how this relates to the trends in research and the growing urgency of addressing Grand Challenges.

A number of studies mapping the scientific fields that influence innovation in green technologies, using expenditure measurement and green patenting statistics, have been able to show that **some scientific areas such as chemistry and materials sciences are more important for green technologies than research on environment and energy**. They found for example that sciences that account for most patens in green technologies are materials sciences (17,4%), chemistry (14,5%), physics (10,5%) and engineering (10,8%) (See figure 7). The United States, Japan and Germany have been found to have most links to the green patents.[78]

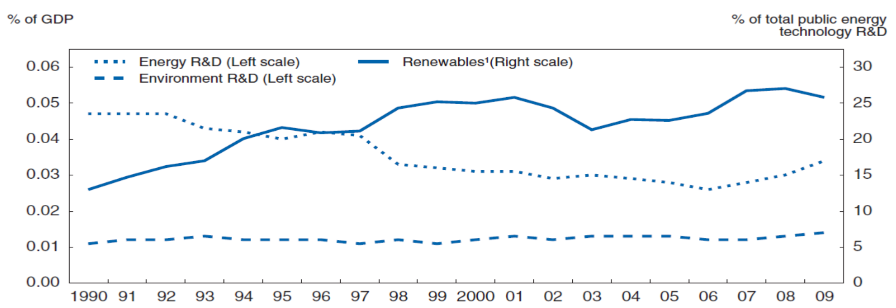
[78] OECD. 2011. Fostering Innovation for Green Growth.

Figure 7: The innovation – science link in 'green technologies' 2000-2007



Source: OECD (2010), Measuring Innovation – A New Perspective, based on Scopus Custom Data, Elsevier, July 2009; OECD, Patent Database, January 2010; and EPO, Worldwide Patent Statistical Database, September 2009.; percentages indicate patent – science link via citations 100= all citations

Figure 8: Public spending in energy- and environment-related R&D-OECD average



Source: Energy and environment R&D as a % of GDP based on OECD (2011), Research and Development Statistics Database and Renewables as % of total Energy R&D from IEA (2011), RD&D Budget Database, covering the 28 IEA member countries.

OECD findings are supported by similar mappings in other fields, which all show that **scientific progress depends on research efforts across a wide range of fields**. The same mappings have shown that government spending on energy R&D and environmental R&D

have not kept pace with the growing urgency of climate challenge.[79]

Based on these mappings, OECD analysts have concluded that the low levels of energy and environmental R&D spending do not necessarily imply that more investments is needed in this field. It is rather the case that innovation in energy and other green areas depends on a wide range of and multidisciplinary research. They find that promoting green innovation requires a broad portfolio of investments and not just focused or targeted R&D on energy or environmental issues.

[79] Ibidem.

CHAPTER 5. LINKS AND RELEVANCE OF NMP ACTIVITIES AND TOPICS TO GRAND CHALLENGES

Contribution of NMP to solve Grand Challenges

This chapter addresses the contributions of respective technologies and research undertaken by EU research programmes towards addressing the Grand Challenges.

It must be stated at the beginning that our interview respondents indicated that the NMP theme under FP7 is already very relevant for addressing all challenges. Respondents indicated that energy and environmental issues are and will be crucial areas where the allocation of project resources is the most significant.

5.1.1 Analysis of projects based on project abstract descriptions

The conducted analysis of FP7 projects based on their abstract descriptions (as provided by applicants) creates many challenges.

First of all, project content in many cases crosscuts many, sometimes most, of the defined challenges. The reasons for this have different roots. First, many projects develop entire categories of materials, technologies or processes that may be used in several industries and applied in dozens of applications. Some projects dedicated only to cooperation activities bring together groups of scientists from research institutes dealing with many crosscutting disciplines. Finally a large group of projects by definition address crosscutting issues for the NMP theme, for example projects dedicated to metrology, awareness building, standardisation or organisation of industrial processes. Some of the projects are simply dedicated to organisation of multi-subject conferences.

While analysing the database of project abstracts, we had to make decisions for each one of them in order to align the entire sample with the Grand Challenges. Also the split of challenges had to be adjusted to perform this exercise. The following categories were used:

- health,
- wellbeing,
- food,
- energy,
- transport,
- climate,
- materials,
- security,
- crosscutting (including standardisation, metrology, processes, control machinery sensors, communication, media and conferences).

A total of 518 FP7 projects were analysed. Each project abstract was assessed and could receive one point in each of the categories listed above; multiple scoring was therefore possible.

For example: Projects dealing with 'advanced eco-design and manufacturing processes for batteries and electrical components' received points as being relevant for three categories listed above: energy, transport and materials.

The category 'materials' contains projects related to raw materials as well as those programs developing materials in general. 'Materials' therefore is very crosscutting for the entire NMP theme.

Another decision of this analysis regards most of the projects dealing with textiles for domestic use. In most cases they have been included in 'wellbeing'. A separate group of projects dealing with development of textiles for security-related applications (extreme environment textiles) were counted in the category of 'security'.

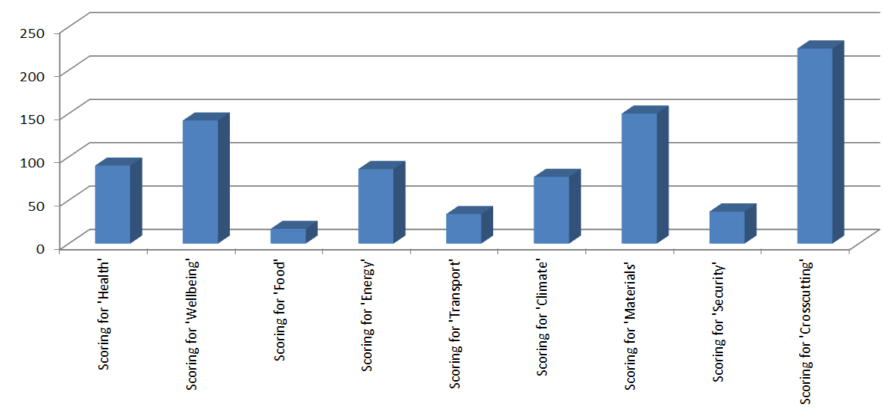
Projects dealing with materials with possible ICT application were also scored in the 'security' category.

Table 9: Analysis of FP7 NMP project relevance for Grand Challenges based on project abstract

	Health	Well-being	Food	Energy	Trans-port	Climate	Materials	Security	Cross-cutting
CP	1	14		18	4	9	8		15
CP-FP	47	51	9	30	14	31	64	19	87
CP-FP-SICA		3	2			1			
CP-IP	27	38	4	29	10	28	43	10	35
CP-TP	12	31		7	6	5	21	8	24
CSA-CA	1	4	1	2		3	10		33
CSA-ERA-Plus							1		2
CSA-SA	2	1	1				3		29
Total score	90	142	17	86	34	77	150	37	225
Source: Oxford Research AS based on Commission database of FP 7 projects in NMP theme.									

CP: Collaborative project (generic)
CP-FP: Small or medium-scale focused research project
CP-FP-SICA: Small or medium-scale focused research project for specific cooperation actions dedicated to international cooperation partner countries (SICA)
CP-IP: Large-scale integrating project
CP-TP: Collaborative Project targeted to a special group (such as SMEs)
CSA-CA: Coordinating action
CSA-ERA-Plus: ERANETplus
CSA-SA: Supporting action

Figure 9: NMP FP7 project relevance for Grand Societal Challenges — overview.



Source: Oxford Research AS based on Commission database of FP 7 projects in NMP theme.

As can be seen, **many of the projects have a crosscutting character, while most of them address detailed subjects**. A considerable number of projects dealt with different materials, again addressing multiple challenges when finally applied as products. Projects dedicated directly to scarcity of raw materials are in fact not numerous in this category. Instead projects were mostly dedicated to the creation, understanding and application of new advanced materials created on micro and nano scales.

After the most numerous categories of materials and crosscutting, the scoring of

projects that addressed health, wellbeing, energy and climate reflected their relative ranking on the research agenda. The smallest number of projects that addressed 3 of the challenges were those connected to security, transport and finally, with the lowest score, food.

5.1.2 Grand Challenges word co-occurrence in project abstracts

Another analysis that demonstrates the intensity and relevance of NMP FP7 research projects to address the Grand Challenges is based on the co-occurrence of words used in the projects' abstracts.

We conducted this analysis for both NMP FP6 and FP7 projects to give a comparative view on the Grand Challenges' themes between the two programmes over years.

The analysis is based on Wordle,[80] a tool for generating 'word clouds'. The cloud gives greater prominence to words that appear more frequently.

For this analysis we have used all text of project abstracts (a total of 134 pages of text for FP7 and 148 pages of text for FP6). Then we analysed the co-occurrence of all key words in the definition of Horizon 2020's Grand Societal Challenges. Results of this approach are displayed in form of clouds presented in figures 10 and 11.

[80] http://www.wordle.net/

Figure 10: Result of FP6 analysis of project abstracts' word co-occurrence

Figure 11: Result of FP7 analysis of project abstracts' word co-occurrence

Results of this 'clouding' exercise bring some interesting observations:

- **Materials are of highest importance** in both FP6 and FP7 NMP projects.
- **Energy became a much more important** key word in NMP FP7 than in FP6;
- Projects related to **bio-science, transport and health lost a bit of importance** in FP7.
- Some other words received more attention in FP7, especially 'efficient' and 'water'.
- 'Food' and 'raw' (materials) were not used to a large extent in either NMP programme editions, nor were words such as 'green', 'clean', 'smart' and, quite surprisingly, 'security', despite their frequent occurrence in the Grand Challenges descriptions.

5.1.3 Sustainable Development Strategy Database

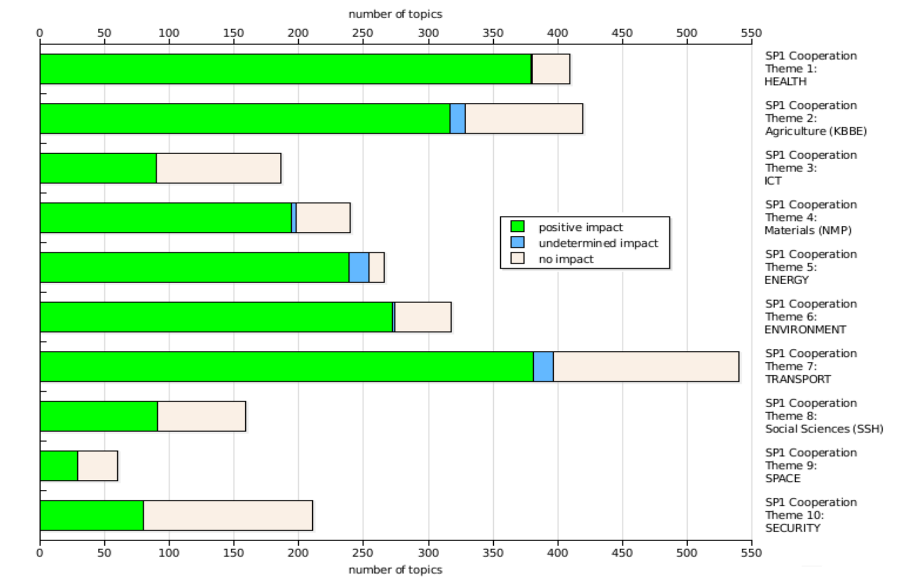
In order to obtain a more quantitative view European Commission Directorate General Environment conducts a comparative analysis of the work programmes relevance to European Union Sustainable Development Strategy[81] based on data from other DGs. The 'FP7 View' data-base built with this data allows one to interactively analyse the information of the monitoring system according to the structure of the 7th EU Framework Programme.

Once a year, several Directorates responsible for issuing calls for proposals are asked to perform a check of the calls and projects in order to identify their relevance. This brings of course a very subjective picture of the European Commission calls' relevance, but enables us to produce basic statistical information about the calls from NMP priority in FP7, with a split very similar to the final split of Grand Challenges relevant for this study. The missing challenge not listed along in this statistic is 'security'.

The comparative analysis towards other Cooperation Programme themes is not very reliable, as data is provided by different Directorates and therefore the understanding of which project has a positive impact or not is very much subjective. A fast overview shows **NMP priority (surprisingly) not in the top of the list**; still other data sources enabling such comparison do not exist. It is also possible that the enabling nature of NMP priority is not fully reflected in this database as the topics and projects of NMP calls are of a cross-cutting nature and therefore in many cases it is simply difficult to clearly distinguish which of EU SDS challenges and objectives are covered.

[81] http://ec.europa.eu/environment/eussd/

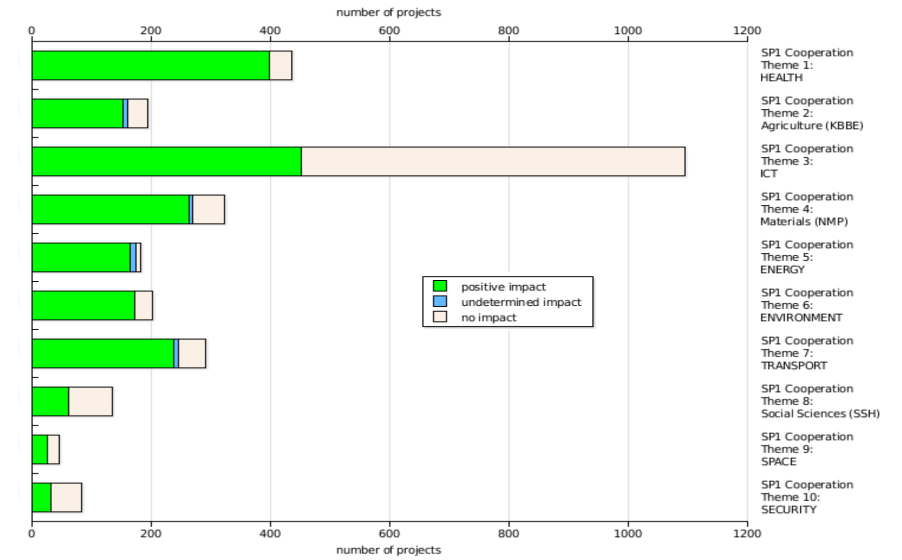
Figure 12: Cooperation Programme contribution to EU SDS objectives per theme — number of topics



Source: European Commission https://www.fp7-4-sd.eu

Much better relative performance of NMP is recorded on the level of projects addressing the challenges. While compared to other themes NMP is on 3rd position after ICT and Transport.

Figure 13: Cooperation Programme contribution to EU SDS objectives per theme — number of projects



Source: European Commission https://www.fp7-4-sd.eu

The more valid overview of NMP relevance to Grand Challenges can be obtained by analysis of data inside the NMP theme in 'FP7 View'. The data-base brings information regarding the relevance of NMP activities to each of the objectives (Grand Challenges) with a split to topics defined in EU SDS as well with the number of projects claimed to positively address those topics.

It must be noted that due to its enabling nature NMP projects contribute to more than one topic defined for EU SDS. This fact is not reflected in the statistics presented above and therefore the joint influence and relevance for addressing Grand Challenges shall not be underestimated.

Table 10: Number of topics and projects financed from NMP priority affecting EU Sustainable Development Strategy key challenges

Key challenges — split by EU SDS	NMP topics with positive impact	NMP topics with undetermined impact	NMP Projects with positive impact	Projects with undetermined impact
Climate Change and clean energy	74		65	
Sustainable Transport	14		12	
Sustainable consumption and production	127	1	149	
Conservation and management of natural resources	118	2	157	
Public Health	67	2	92	5
Social inclusion, demography and migration	2		4	
Global poverty & sustainable development challenges	15		28	
Total (with regard to all selected SDS challenges)	194	4	264	5
Source: European Commission https://www.fp7-4-sd.eu				

Full information regarding the NMP priority relevance regarding the Grand Challenges is presented in the table below, listing especially the number of projects responding to each of operational objectives of the strategy. The biggest number of projects definitely reflects two similar objectives:

- conservation and management of natural resources, and
- sustainable consumption and production,

clearly indicating that **NMP priority is very much oriented towards the environmental challenges**. This is a little bit contradictory to the qualitative information from interviews — energy-related challenges are not that significantly reflected in the implemented projects. The same split is also confirmed with a look at total projects' value, where the two environmental objectives reached EUR 1,8 billion and the energy issues accumulate only to EUR 0,45 billion allocation.

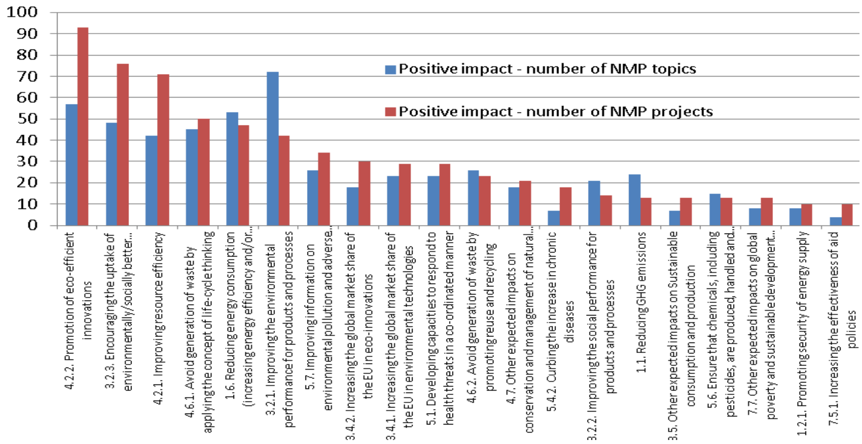
Table 11: Number of topics and projects financed from NMP priority affecting EU Sustainable Development Strategy operational objectives.

Key challenge	Operational objective	Positive impact – number of topics	Positive impact – number of projects
Energy			
	1.1. Reducing GHG emissions	24	13
	1.2.1. Promoting security of energy supply	8	10
	1.2.2. Promoting competitiveness of energy	6	4
	1.2.3. Promoting environmental sustainability of energy	14	8
	1.3. Enhancing adaptation and mitigation of Climate Change	4	1
	1.4. Raising the share of renewables	11	8
	1.5. Raising the share of biofuels	2	2
	1.6. Reducing energy consumption (increasing energy efficiency and/or decreasing energy demand)	53	47
	1.7. Other expected impacts on Climate Change and clean energy	3	6
	Total	74	65
Sustainable Transport			
	2.1. Decoupling economic growth and demand for transport	1	
	2.2.1. Achieving sustainable levels of transport energy use	6	
	2.2.2. Reducing transport greenhouse gas emissions	7	1
	2.3. Reducing pollutant emissions	7	7
	2.4. Achieving environment friendly transport modes	6	
	2.5. Reducing transport noise	1	
	2.6.1. Modernising the EU framework for public passenger transport	1	
	2.6.2. Encouraging better efficiency of public passenger transport	2	
	2.6.3. Encouraging better performance of public passenger transport	1	
	2.7. Reducing CO_2 emissions from new car fleets	1	
	2.8. Reducing road transport deaths (or accidents)	2	3

	2.9. Other expected impacts on Sustainable Transport	7	5
	Total	14	12
Sustainable consumption and production			
	3.1.1. Addressing social and economic development within the carrying capacity of ecosystems	2	1
	3.1.2. Decoupling economic growth from environmental degradation	7	
	3.2.1. Improving the environmental performance for products and processes	72	42
	3.2.2. Improving the social performance for products and processes	21	14
	3.2.3. Encouraging the uptake of environmentally/socially better performing products and processes by businesses and consumers	48	76
	3.3. Raising the level of Green Public Procurement (GPP)	1	6
	3.4.1. Increasing the global market share of the EU in environmental technologies	23	29
	3.4.2. Increasing the global market share of the EU in eco-innovations	18	30
	3.5. Other expected impacts on Sustainable consumption and production	7	13
	Total	127	149
Conservation and management of natural resources			
	4.1.1. Reduce the overall use of non renewable natural resources	26	7
	4.1.2. Reduce environmental impacts of raw materials use	15	8
	4.2.1. Improving resource efficiency	42	71
	4.2.2. Promotion of eco-efficient innovations	57	93
	4.3. Improving management and avoiding overexploitation of renewable natural resources	5	0
	4.4. Halting the loss of biodiversity	1	0
	4.5. Contributing effectively to achieving the four United Nations global objectives on forests	1	0
	4.6.1. Avoid generation of waste by applying the concept of life-cycle thinking	45	50
	4.6.2. Avoid generation of waste by promoting reuse and recycling	26	23
	4.7. Other expected impacts on conservation and management of natural resources	18	21
	Total	118	157

Public Health			
	5.1. Developing capacities to respond to health threats in a coordinated manner	23	29
	5.2. Improving food and feed legislation (incl. labelling)	5	5
	5.3. Promoting high animal health and welfare standards	3	4
	5.4.1. Curbing the increase in lifestyle-related diseases	3	8
	5.4.2. Curbing the increase in chronic diseases	7	18
	5.5.1. Reducing health inequalities by addressing the wider determinants of health and appropriate health promotion and disease prevention strategies	1	1
	5.5.2. Promoting better international cooperation for reducing health inequalities	0	0
	5.6. Ensure that chemicals, including pesticides, are produced, handled and used in ways that do not pose significant threats to human health and the environment	15	13
	5.7. Improving information on environmental pollution and adverse health impacts	26	34
	5.8.1. Improving mental health	1	5
	5.9. Other expected impacts on public health	37	0
	Total	67	59
Social inclusion, demography and migration			
	6.7.1. Promoting increased employment of young people	2	4
	Total	2	4
Global poverty & sustainable development challenges			
	7.1. Contributing to achieve the Millennium Development Goals	1	
	7.2.1. Improving international environmental governance (IEG)	4	7
	7.5.1. Increasing the effectiveness of aid policies	4	10
	7.5.2. Increasing the coherence of aid policies	2	1
	7.7. Other expected impacts on global poverty and sustainable development challenges	8	13
	Total	15	28
Source: European Commission https://www.fp7-4-sd.eu			

Figure 14: Number of most popular topics and projects addressing operational objectives of EU SDS



Source: European Commission https://www.fp7-4-sd.eu Data range: from top scoring to up-and-including 10 projects per operational objective. See table above for full objectives names.

Current focus of calls within NMP, Transport Research, Environment and Health Research and KBBE under FP7[82]

It can be clearly observed that **the work programmes in different themes have already been largely affected by the grand challenges policy discussion in the context of Horizon 2020**. A view at work programmes before 2009 reveal that the wording 'societal challenges' simply did not appear in chapters describing objectives and focus of the programmes. Also their structure and detailed calls were planned without the split characteristic for the recent programmes which are very much 'challenges focused'.

This chapter is presenting the recent focus of the work programmes, comparing it to the historical focus of 2006.

NMP in 2012

Broadly speaking, calls of the NMP priority in 2012 and 2013 will continue to span the spectrum from enabling research to applications and demonstration activities. **Sustainability and societal challenges have always been implicit in NMP strategies, but are receiving increased attention and direct focus**.

A key feature of the 2012 Work Programme (WP) is its participation for the third year in actions within the European recovery package. Starting with the WP 2010, the NMP theme supports the European Economic Recovery Plan through three public-private partnerships (PPPs): 'factories of the future', 'energy efficient buildings' and 'green cars'.

With regard to specific challenges, the following issues are addressed: [83]

- Energy and energy efficiency: These activities are in tune with the Strategic Energy Technology (SET) Plan. They include topics in support of the 'European energy-efficient buildings' in the PPP initiative, outlined below.
- Environmental issues and sustainable development: These topics complement activities of the environment and the food, agriculture and fisheries, and biotechnology (FAFB) themes.
- Raw Materials: In support of the Commission's Raw Materials Initiative, research is supported on the extraction and processing of raw materials, reduction of waste and recycling.
- Health and safety: This covers research based on nanomedicine and materials for health, under the health theme. It also includes research necessary to ensure the safe use of

[82] Following FP7 orientation papers, by Ms. Ines Marinkovic, http://www.wbc-inco.net/object/news/117770.html

[83] Orientation paper - Proposed priorities for 2012, European Commission2011

nanotechnologies, building on an extensive body of previous work under the NMP theme.

- Factories of the future: The objective of this PPP initiative is to help EU manufacturers across sectors, in particular SMEs, adapt to global competitive pressures by increasing the technological base of EU manufacturing through the development and integration of the enabling technologies of the future, such as engineering technologies for adaptable machines and industrial processes, ICT, and advanced materials. Demonstration-targeted activities include high-performance manufacturing technologies (covering efficiency, robustness and accuracy), and technologies for casting, material removing and forming processes.

- European energy-efficient buildings: This PPP initiative promotes green technologies and aims at the development of energy-efficient systems and materials in new and renovated buildings with a view to reducing radically their energy consumption and CO_2 emissions. These activities are in tune with the Strategic Energy Technology (SET) plan.

- Green cars: This PPP supports research on a broad range of technologies and smart energy infrastructures, essential to achieve a breakthrough in the use of renewable and non-polluting energy sources, safety and traffic fluidity.

NMP Work Programme 2004 main objectives:

(main points of focus in bold):

The primary objective of this thematic area is to promote real **industrial breakthroughs**, based on scientific **z** technological excellence. (…)

The **transformation of industry** towards high-added value organisations (…). Particular attention will be given to the **strong presence and interaction of innovative enterprises**, universities and research organisations in research actions. **Research projects** are required that give research organisations and industry access to new technologies, therefore stimulating implementation of new approaches in most industrial sectors, **in particular SME intensive sectors**. A key issue will be to integrate **competitiveness, innovation and sustainability** into consistent RTD activities. This is why it is extremely important and relevant that industry itself is well represented and integrated in the proposed research projects. The integration of **education and skills development** with research activities will play an important role in increasing European knowledge, in particular in nanosciences and their associated new technologies, opening up opportunities for numerous industrial applications. In addition, it is expected that breakthrough research activities should help to foster dialogue with society and generate **enthusiasm for science**.

NMP Work Programme 2009 main objectives:

The principle objectives of this Theme are to **improve the competitiveness** of European industry and to generate knowledge to ensure its transformation from a **resource-intensive to a knowledge-intensive** base, by creating step changes through research and implementing decisive knowledge for new applications at the crossroads between different technologies and disciplines. This will benefit 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**. These activities are concerned with enabling technologies which impact all industrial sectors and many other FP7 Themes.

As clearly seen form the information presented above, the formulation of objectives for NMP work programmes has been **largely affected by the overwhelming discussion on grand challenges**. Also other themes have changed their focus over the years.

Transport (including aeronautics)

A new approach has been adopted for Work Programme 2012, reflecting the new political context and the priority given to the Innovation Union. This new approach focuses on major socio-economic challenges and responding to societal concerns. Emphasis is on eco-innovation, safe and seamless mobility, and competitiveness through innovation.

Environment (including climate change)

The novelty of the 2012 Environment (including climate change) work programme is the challenge-driven approach that is implemented through fewer but broader topics using a two-stage submission and evaluation procedure. In support of the objectives of the Innovation Union Flagship Initiative, efforts are made to boost industry and SME participation by introducing specific SME-targeted and SME-friendly topics. Furthermore, a shift towards larger scale projects has been introduced with the possibility to support several projects per topic.

ICT

The work programme 2011 for this theme underlines:

The ICT sector has been identified as a potential major player in the fight against climate change – in particular its role in improving energy efficiency.

'Societal challenges (...) will also govern policies and drive economic and societal development for the decades to come. ICT R&D plays a major role in providing responses to such challenges.

In historical work programme editions the focus was put much more into competitiveness and European leadership ICT.

> ***ICT Work Programme 2007-8 main objectives:***
>
> **Improving the competitiveness** of European industry and enabling Europe to master and shape future developments in ICT so that the demands of its society and economy are met. ICT is at the very core of the knowledge-based society. Activities will **strengthen Europe's scientific and technology base and ensure its global leadership in ICT**, help drive and stimulate product, service and process innovation and creativity through ICT use and ensure that ICT progress is rapidly transformed into benefits for Europe's citizens, businesses, industry and governments. These activities will also help reduce the digital divide and social exclusion.

Health

The theme of Health is aligned with the fundamental objectives of EU research policies: improving the health of European citizens and increasing competitiveness of European health-related industries and services, as well as addressing the socio-economic dimension of health care and global health issues. With a view to achieve the EU 2020 objective of smart, sustainable and inclusive growth, the Commission launched the European Innovation Partnership on active and healthy ageing. It aims by 2020 to enable citizens to live longer independently in good health by increasing the average number of healthy life years by 2. Achieving this target will improve the sustainability and efficiency of our social and healthcare systems, and create an EU and global market for innovative products and services with new opportunities for EU business.

The ‘health’ theme in Cooperation Programme is currently shaped around 3 main areas:

- Biotechnology, generic tools and technologies for human health;
- Translating research for human health;
- Optimising the delivery of healthcare to citizens.

The approach also changed here between the FP6 and FP7. Grand challenges are already more reflected in current calls. FP7 calls are characterised by broader scope, less focus on genomics and more emphasis on translational research.

The health policy driven research was strongly reinforced with new issues very much in line with challenge definition and understanding including especially such area as emerging epidemics, obesity, chronic diseases, biomedical technology & engineering. In all these fields enabling technologies play enormous role.

Food, Agriculture and Fisheries and Biotechnologies

This work programme promotes world leadership in European Knowledge Based Bio-Economy (KBBE) research and aims at technological breakthroughs that support the competitiveness of the European bio-economy industry. Compared to previous years, this work programme puts substantially more emphasis on the foundation that research provides to innovation. It does so primarily by advancing the participation of SMEs as active stakeholders in the research with a view to apply and exploit the results in their innovation projects.

It must be stated that **KBBE ability to tackle grand challenges was visible throughout the pervious planning documents of European Commission.** For example in 2008 the programme was already operating with the following major trends:

- changing patterns in world trade
- coping with climate change
- feeding the increasing world population
- increasing environmental considerations
- shifts in energy supply

The topics in WP 2012 support the development of a sustainable European KBBE and contribute to the Europe 2020 strategy and the Innovation Union, in particular by:

- moving towards the completion of the European Research Area in the bio-based economy sectors;
- linking the existing and new initiatives in the bio-based economy field such as joint programming, Lead Market, Innovation Partnership into a coherent policy framework;
- stimulating innovation including promotion of knowledge transfer;
- contributing to the EU policies e.g. Common Agricultural Policy (CAP); reform of the Common Fisheries Policy (CFP); Integrated Maritime Policy (IMP); Community Animal Health Policy (CAHP); Key Enabling Technologies (KETs), regulatory frameworks to protect the environment, health and safety; regulatory frameworks related to resource efficiency and waste;
- supporting international initiatives such as the Millennium Development Goals and Global Research Alliance on Agricultural Greenhouse Gases.

Energy

Annual work programme 2012 for Energy theme was adjusted to best fit most of the ideas planned for implementation under Horizon 2020 in the future.

It must be underlined that the programme itself did not change much in terms of structure and the main objective since 2007, already including the 'challenge' factor in the main objective formulation.

Overall objective for FP7 Energy theme:

Adapting the current energy system into a more sustainable one, less dependent on imported fuels and based on a diverse mix of energy sources, in particular **renewables, energy carriers and non polluting sources**; enhancing energy efficiency, including by rationalising use and storage of energy; **addressing the pressing challenges of security of supply and climate change**, whilst increasing the competitiveness of Europe's industries.

Adopting a challenge driven approach, a new area on 'Smart Cities and Communities' has been created within Activity 8 ('Energy Efficiency and Savings'). Topics under this area address the challenge of smart cities and communities in a holistic way that cuts across many technology areas.

All important areas indicated in Horizon 2020 Impact Assessment are also reflected in current and previous work programmes for the Energy theme, including:

- hydrogen and fuel cells,
- renewable electricity generation,
- renewable fuel production,
- renewables for heating and cooling,
- CO_2 capture and storage technologies for zero emission power generation,
- clean coal technologies,
- smart energy networks,
- energy efficiency and savings,
- knowledge for energy policy making,
- horizontal programme actions.

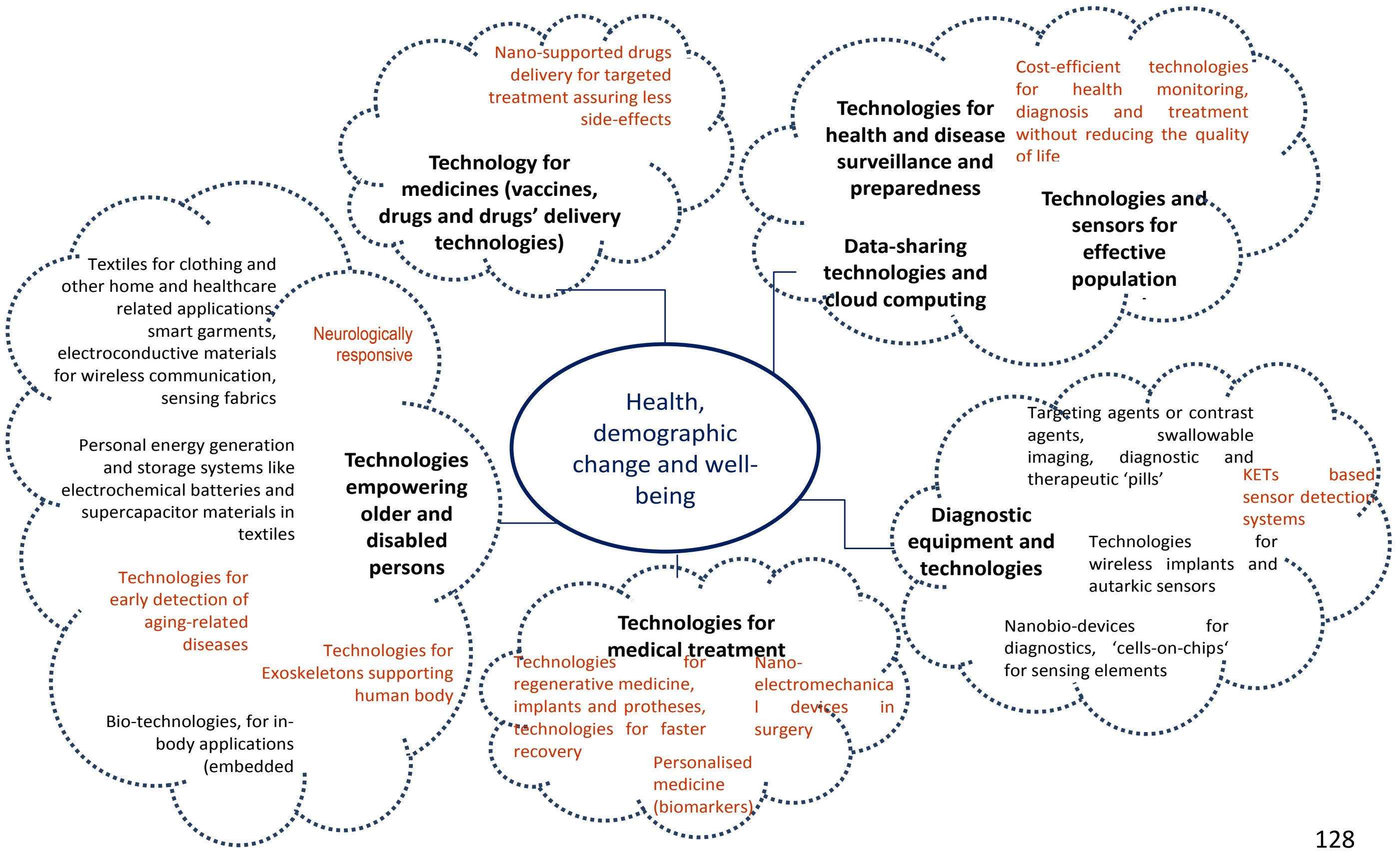
Future relevance

This chapter looks at the issue of the contributions of respective technologies and research undertaken under NMP programmes towards the Grand Challenges in the near future.

The desk research covering many industrial roadmaps and strategic documents, as well as new documentation regarding Horizon 2020, enabled us to produce an indicative split of the most desired technologies to be addressed through projects financed within the field of industrial technologies under Horizon 2020. The graphs presented have been produced mostly as a result of desk research, and supplemented with outcomes of the project workshops.

The main fields of industrial technologies' interest, also highlighted in Horizon's 2020 planning documents, are marked with **bold black font,** with additional applications given for orientation and shown with regular black font. The outcome of discussions undertaken during workshops organized during preparation of this study, reflecting technologies that are intended to importantly affect the future, are marked with red font in all graphs below.

Figure 15: Future key supported fields in the area of 'Health, demographic change and well-being'



Additionally the first hypothesis workshop conducted within this study delivered a longer list of interesting promising areas where enabling technologies are able to deliver solutions in the near future. These areas shall be considered as key points of focus indicated by experts engaged in the project in the years to come, regarding possible financing of projects within Horizon 2020 intervention. Within the area of health, demographic change and well-being the list of promising areas discussed by experts during group sessions included:

- massive data treatment, assistive monitoring, smart networks;
- deployment of KETs: Internet of things, GPS combined sensors analysers, wireless-enabled systems;
- development of standards for elderly services at EU level, including standards for elderly equipment;
- smart, locally active treatment technologies;
- one drop blood desktop labs, analysis technologies;
- miniaturization of health sensors and support equipment through usage of plastic electricity, MEMS, MOEMS and micron-scale devices, plastic photovoltaics;
- creation of industry able to respond to productivity drop in the years to come including robotics for house and industry applications;
- decrease the cost of sensors and health support equipment through massive volume production and internet information capture and distribution;
- decrease the cost of healthcare through introduction of ICT services and management;
- technologies for reducing human functional degradation;
- signal processing of neurons, brain cells to negate degenerative mental diseases;
- non visual or audio communications technology for the ageing population;
- in-situ regenerative biocompatible materials;
- smart implants powered by "sugar" (fuel cells using sugar from the blood);
- research within human brain;
- mobility enhancement through brain-wave activated micro-nano components;
- push development of technologies towards more flexibility and lower cost, specific for this market;
- smart medical devices: nanoparticle-based treatment for cancer and other illnesses;
- non-charging batteries with infinite life (non-radiological);
- push-technologies of multi-spectral detection.

Additionally to the results of project workshops, a long list of possible technologies discussed in various industrial roadmaps and strategies was identified. For this particular challenge, the secondary sources list following technologies:

Health and mobility:

- Embedded Systems for comprehensive sensor based detection of the environment and optimal filtering and presentation of the situation.
- Assistive systems compensating degradation of visual and hearing capabilities or personal immobility.
- On-person and on-board healthcare management systems, including biosensors to monitor the state of the driver and provide reminders and warnings and even take automatic action.

Micro- and nanoelectronic systems for medical applications:

- Real-time tests.
- Micro-Fluidic-Systems (MFS) for diseases early diagnosis.
- Improvement of current and future imaging systems.
- Design of new contrasts agents.
- Imaging techniques with advanced optical and luminescence imaging and spectroscopy, nuclear imaging with radioactive tracers, magnetic resonance imaging and spectroscopy, ultrasound, and X-ray imaging.
- The swallowable imaging, diagnostic and therapeutic 'pill', new endoscopic instruments.
- Implantable devices.
- Miniaturisation for lower invasiveness, combined with surface functionalisation and the 'biologicalisation' of instruments.
- Wireless implants and autarktic sensors (smart power management).
- Point of care systems and breath analysis (chemical and biological sensing).
- Active delivery systems, releasing drugs, vitamins or nutrients into the body when certain conditions appear.

Flexible printed systems

- The “lab on a chip”, an integrated microprocessor capable of data analysis for early detection and diagnosis of illnesses or diseases, combined with the smart delivery system.
- Smart clothes (fitted with nanosensors to record parameters such as blood pressure, pulse and body temperature, communicated instantly to the doctor) and home monitoring.
- Photosensors for fluorescence (vision systems).
- Smart energy management: storage techniques include ink batteries, micro batteries, supercapacitors, and micro fuel cells.

Diagnosis and treatment

- Energy conversion systems: SiC (wide bandgap semiconductor material), advanced materials for interconnections and bonding techniques, thick layer deposition processes and encapsulation techniques.

- Smart miniaturized devices: Biochemical sensors or, in short, biosensors, that detect specific molecular markers in minute amounts of body fluids or body tissue.
- Smart robotics (biorobotics) or bio-mechatronic devices to assist minimal invasive surgery.
- Biosensing and bioanalysis are experiencing a paradigm shift in which complete biological assays are integrated into a single device, such as a disposable cartridge with an embedded 'lab on a chip'.

Energy-efficient buildings

- Sensors, actuators and control and communication systems to give new capacities to buildings and at district level to manage and maintain community energy-related services, such as outdoor smart lighting solutions, renewable energy systems at district level, micro-grid management, etc.
- New concepts, technologies, design tools for the large-scale development of affordable new buildings with very low energy consumption, able to meet their own energy demand through renewable energy source (smart systems)
- Developing new technologies for embedded renewable energy sources, cladding and ventilation technologies, sensors and pervasive computing systems to develop the concept of the "intelligent building" to improve building energy performance.
- Net CO_2-free and energy-producing new buildings, able to produce the energy they consume without CO_2 emission.
- Development of new visualization, virtual reality and communication tools, based on advanced ICT systems and using shared integrated data models.
- Adoption of radically-advanced construction concepts such as integrated and intelligent agent systems, programmable nano-materials and nano-constructors, bio-mimetic materials, structures and facility systems.
- Products and technologies such as solar cells and active phase-changing materials for saving energy. New nanoporous insulating materials for enhanced insulation. Efficient lighting technologies.
- Radiant barriers in ceilings and walls to reduce heat loss by reflecting or absorbing infrared radiation.
- Electrochromic "smart" windows.
- White organic light emitting diodes (OLEDs) to replace current fluorescent light tubes.
- Photovoltaic (PV) solar energy panels incorporation into various surfaces of the house.

Construction materials:

- Introduction of nano- and bio-technologies to develop new advanced multifunctional materials and to re-engineer the corresponding components and construction processes.
- Introduction of new services offered by satellites for positioning construction equipment, and for monitoring works and their impact.
- Development and improvement of manufacturing technologies focused on the reduction of embodied energy and resource consumption in construction materials and components.
- New manufacturing processes of construction materials with high performance and with a reduced environmental impact, through reduced energy, reduced raw material demand and use of large quantities of residual products and waste.
- Improvement and development of durable materials with prolonged and predictable service life under aggressive conditions, including self-assessment and innovative and non-intrusive in-situ inspection techniques.
- Innovative materials and technologies for the recycling/reuse of construction waste and incorporation of other waste streams into building materials.
- Control methods to address corrosion: protective coatings, corrosion resistant metals and alloys, corrosion inhibitors, polymers, anodic and catholic protection, corrosion control services.
- Development of construction components and processes with the objective of optimising the deconstruction processes.
- Integrated life-cycle process for flexible buildings and infrastructures:
    - new logistics management systems;
    - development of methods for service-life prediction of products, service life design and service life management of buildings;
    - New logistic concepts and manufacturing technologies for full use of construction and demolition waste;
    - Introduction of ICTs at all levels of the construction process and of the life-cycle of structures;
    - Knowledge-based control of properties of building materials (such as porosity, microstructure and behaviour at a nano scale) to allow total architectural freedom in structural design and in the design of surface appearance;
    - New and innovative building materials and production technologies compatible with the application of ICT technologies within the building.

ICT and automation in construction industry:

- Materials with new functionalities and improved properties and comfort (resistance against an aggressive environment, that are hygienic and easy to clean, with moisture control, thermal, electro-magnetic and acoustic isolation, heat storage and climatic functionality, creating a "warm feeling" and aesthetic appearance);
- Exploration of the potential for application of biological technology in the production of building materials.
- Active, multi-functional materials, which improve the indoor climate and energy consumption of buildings by means of nano, sensor and information technology.
- New materials based on bio-technologies, for example embedded bioelectronics, active surface properties, or natural process technologies.

Textiles

- Low water or water-free textile dyeing, printing and finishing techniques.
- Integrated and intensified processes for fast multistep treatments and maximum use of input resources.
- Technologies for clothing production directly in an 3D environment with 3D production equipment.
- Replacement of chemical processing by biotechnological processing through use of enzymes or other bio-organisms instead of chemicals.
- Small-scale low-cost textile processing waste water treatment units.
- Fault-free manufacturing systems for reduced production waste.
- Smart garments able to:
  - adapt their insulation function according to temperature changes,
  - detect vital signals of the wearer's body and react to them (through integrated sensors and actuators), change colour or emit light upon defined stimuli, detect and signal significant changes in the wearer's environment (absence of oxygen, presence of toxic gases or chemicals, radiation, strong electromagnetic fields etc., generate or accumulate electric energy to power medical and other electronic devices).
  - Speed up recovery after medical treatment (innovative wound dressings; light, breathable orthoses/ protheses)
  - Enhance quality of life of chronically ill people (functional clothing for people suffering from neurodermitis or psoriasis, anti-dust mite bedding for asthmatics etc.),
  - Facilitate and secure the life of the elderly (adaptive

compressing stockings, functional diapers, customised clothing for easy use and functionalities adapted to special needs).

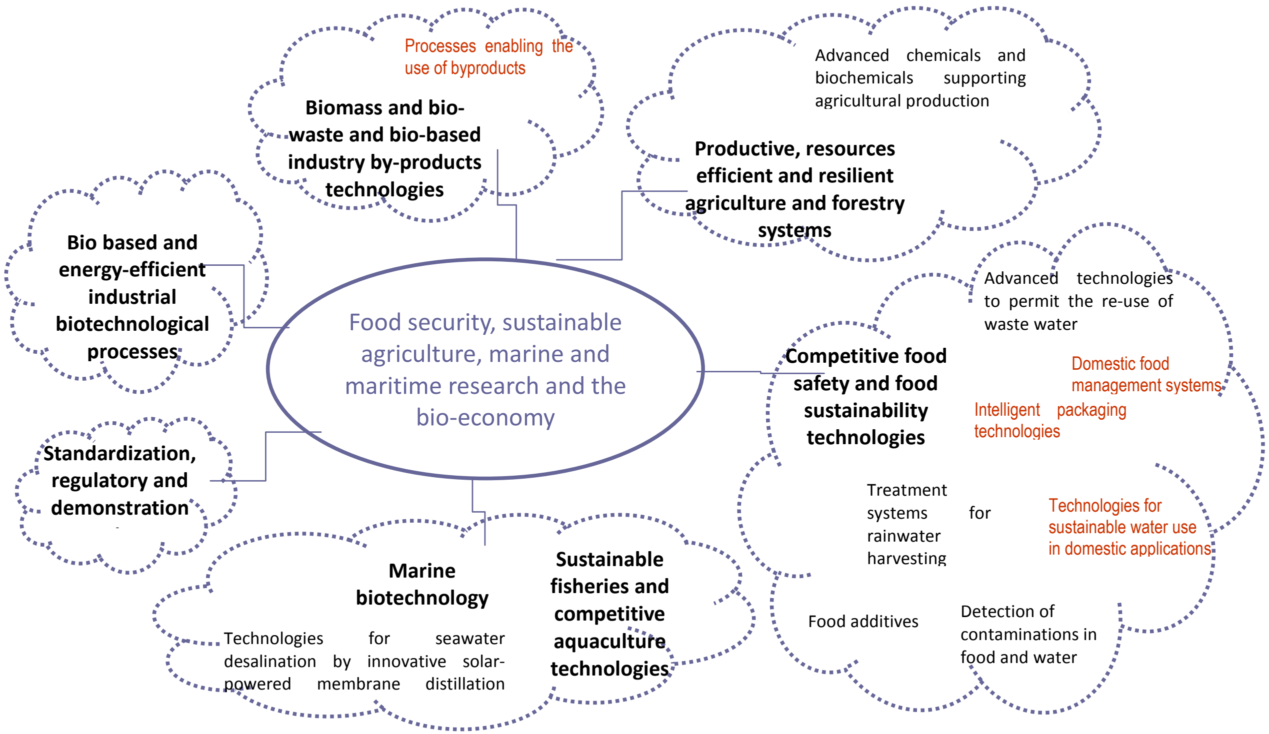
- Textile-compatible energy storage systems like electrochemical batteries and supercapacitor materials as well as energy harvesting are critical. Flexible or fibre-based photovoltaic cells and piezo-electric materials.

Other

- Engineering energy-aware software to improve power-efficiency of software systems and services.
- New materials for electronics: materials for superconductors, polymeric conductors and semiconductors, dielectrics, capacitors, photo resists, laser materials, luminescent materials for displays as well as new adhesives, solders and packaging materials.
- Development of new materials in the field of optical data transfer: non-linear optics materials, responsive optical materials for molecular switches, refractive materials and fibre optics materials for optical cables
- Conforming materials for electronic paper (alternative to conventional books, newspapers and magazines) and their effective incorporation into functional systems.

The above overview of technologies and areas promising in the future indicates a very **important interrelation between ICT and NMP technologies to address future challenges in the health sector. These two KETs will play enormous role in all applications addressing the future needs for efficient diagnostics, treatment and monitoring of population**.

Figure 16: Future key supported fields in the area of 'Food security, sustainable agriculture, marine and maritime research and the bio-economy



Regarding the area of food security and sustainable agriculture, experts indicated a range of promising technologies/areas where KETs may play a role, especially within:

- development of byproducts technologies to avoid agricultural waste;
- better packaging technologies, intelligent packaging — fresheners indicator instead of 'best before' date;
- improved technologies for desalination and treatment of water, nano-filtration technologies;
- water management systems (different quality for different purpose, reuse, desalination, consumption);
- use of natural antioxidants, fortified food;
- water purification through non-chemical mechanical means, hydrodynamic cavitation;
- high yield food crops capable of growing in drought conditions, root technology;
- bio-generation of wider range of products;
- marine farming and extraction of marine food products;
- fertility research using NMP multidisciplinary technologies.

Additionally to the results of project workshops, a long list of possible technologies discussed in various industrial roadmaps and strategies was identified. For this particular challenge, the secondary sources list following technologies:

Productivity:

- Technologies to identify the sources of crop and tree improvements, namely the genes that contribute to the improved productivity and quality of modern crop varieties and the genes that enhance tolerance to stresses, or to a better utilisation of inputs.
- The development of viable processes and strategies for converting and adding value to food industry by-products, into compounds suitable for agro-, biotechnology-, or food industry applications using the biorefinery concept, will be important for increasing sustainability.
- Value-added material in the chemical sector supporting agricultural production.

Sustainability/ Reducing food wastes:

- Industrial Ecology Approach: to restructure production systems into clusters of industrial firms with output-input connections as stocks and flow of materials, energy and information, according to the principles of ecosystems.

Solutions to better preserve food

- Process improvements involving, e.g. reductions in losses, delivery on demand to avoid over-supply (just-in-time), the efficient integration of new technological developments (in, e.g., production, analytical methods, logistics, or communication).

Water distribution/treatment:

- Advanced metering technologies (district metering) to promote efficient water use.
- On-line leak detection, automated meter reading through fixed networks.
- Tools to understand, predict and manage demand.
- Alternative water resources (identification of potential sources, reduction of the environmental impact of desalination plants, development of other advanced technologies to permit the re-use of waste water, treatment systems for rainwater harvesting).
- (Microbiological) risk assessment and management tools "from resource to tap" for assuring drinking water quality.
- Sensors and monitoring systems to detect low levels of chemicals and microbiological contamination in river water or distribution systems.
- Improved processes for removal of microbial pollution (including virus) and emerging contaminants.
- Desalination technologies: membrane based desalination: an integrated approach, seawater desalination by innovative solar-powered membrane distillation system.
- Integrated long-term monitoring of materials and components for new and existing infrastructures based on innovative, cost-efficient wireless sensors using bio or nanotechnologies.
- Development of integrated life-cycle assessment systems combining cost-efficient and easy-to-maintain sensors, monitoring and performance prediction systems, and covering all stages of construction control, asset management, and optimisation of maintenance.
- Risk-based inspection regimes for low impact on demand and costs.
- New testing methods for early detection of damages.
- New non-destructive, automated, inspection/testing techniques to control, identify, localise and monitor structures and infrastructures, even those that are buried, with minimal impact on traffic and supply.

Protecting water:

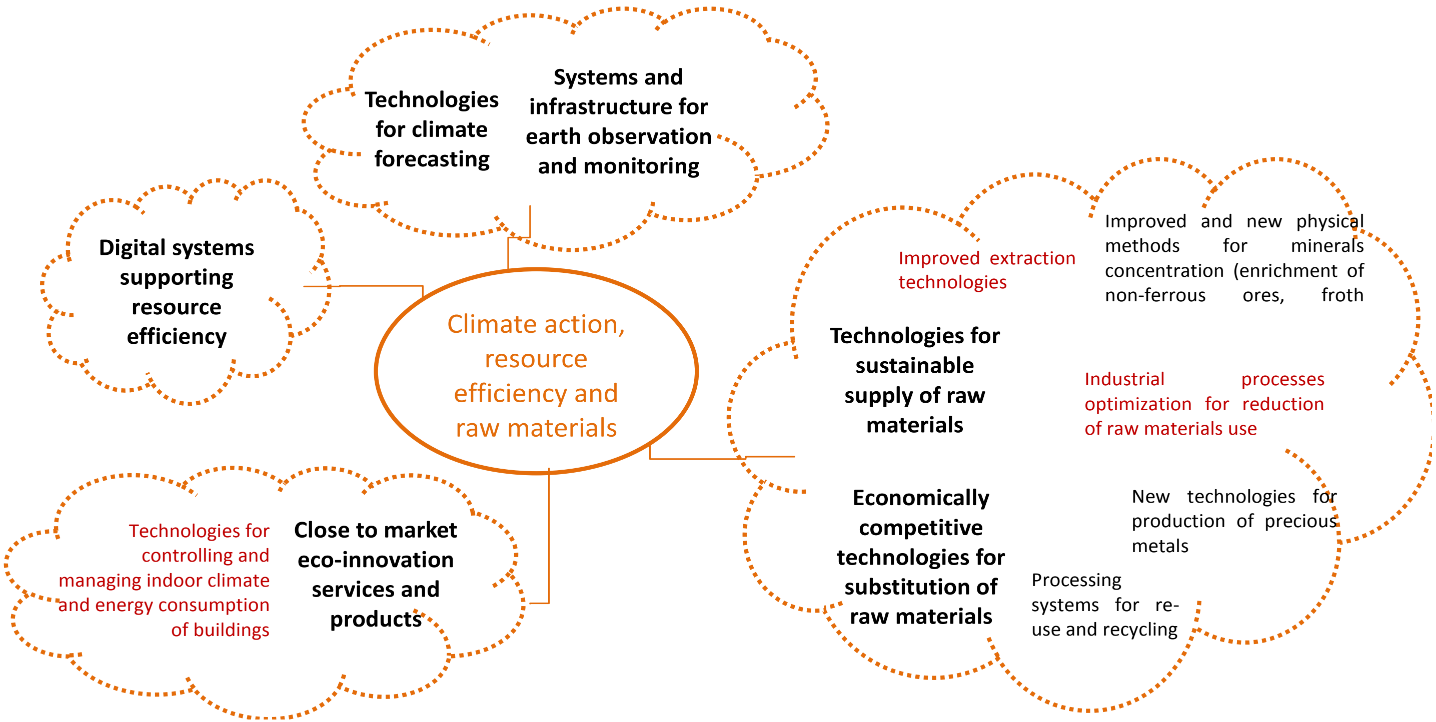
- Monitoring systems adapted to coastal carbonates to assess recharge, abstraction, implement protection and management practices as well as contingency plans.
- Salt water intrusion mitigation technologies in karstified carbonates.
- Improved agriculture irrigation technologies.
- Methods to monitor and remove point source and diffuse chemical and biological pollutants, including emerging/priority contaminants.
- Water and wastewater treatment systems having

reduced energy and chemical usage.

- Methods and tools to determine environmentally sustainable river flows.
- Decision support systems for the implementation of the sustainable management of bio-solids in urban areas.
- Processes to produce energy and usable products from bio-solids and other residuals.

With regards to food-related challenges it seems that **biotechnology will play its important role in the future towards assuring environmental sustainability of our agriculture and stable food supply to future generations**. The NMP field will be directly engaged in delivery of solutions for filtration, treatment, packaging and conservation of food. Still an **important effort is to be made regarding the standardisation and regulatory issues in this area**.

Figure 17: Future key supported fields in the area of 'Climate action, resource efficiency and raw materials'



In the area of climate action, resource efficiency and raw materials, experts identified a number of technologies which may play important roles in the future, indicating possible areas of industrial technologies intervention:

- CO_2 and CH_4 consuming plants / technologies for production of carbon-based products (e.g. plastics);
- technologies for safe, large scale CH4 deep sea storage;
- CO_2 recycling and recovery, transformation to another energy sector, use of wind and solar energy;
- technologies for reduction of greenhouse gas (GHG) emissions by introduction of novel catalysts, solid oxide fuel cells;
- CO_2 conversion technologies (graphite plus oxygen) to be used in HEV batteries and solar panels;
- CO_2 absorption by anaerobic digestion;
- technologies for bioplastics using methane from biomass;
- cloud computing for environment monitoring;
- smart production systems and energy saving through smart systems (houses offices);
- technologies for sorting water for food and consumption use, separating water for productivity cycles;
- technologies for water treatment using photonic and nano-filter technologies;
- development of technologies for cross European water distribution systems — balancing surplus and deficit;
- new advanced materials in construction industry;
- implementation of existing/new solid waste (management) technologies;
- waste heat recovery technologies;
- value-added materials as substitutes for rare materials;
- smart mining, surgery underground mining technologies (saving also fuel, water and land);
- exploitation technologies for marine raw materials, deep sea mining technologies and regulation;
- robotics — remote-controlled harvesting (with energy source via ion exchange in sea water);
- new improved recycling technologies for materials;
- European-controlled value chains, closed cycles for all types of raw materials, minimum waste of material;
- technologies for bio-engineering of bacteria plus catalytic activation, advanced micro-engineered units for raw material production.

Additionally to the results of project workshops, a long list of possible technologies discussed in various industrial roadmaps and strategies was identified. For this particular challenge, the secondary sources list following technologies:

CCS technology:

- Innovative combustion technologies (H2-burners, oxy-fuel combustion, flameless and catalytic combustion, fluidised beds and heterogenic reaction systems).
- Thermodynamic processes and their combinations with chemical engineering to form innovative concepts, such as chemical looping technology, new separation technologies and new machinery for energy conversion.
- Computer-aided modelling: The only way to establish a basic knowledge of large-scale processes and chemical/physical mechanisms available is through experimental research, combined with computational fluid dynamics (CFD) modelling.
- Highly allied steels metallurgy, coatings and alternative materials (ceramics, composite materials etc) which can withstand high temperatures, high pressures and corrosion from flue gases. This is also essential for CO_2 transportation infrastructures.
- Turbomachinery: A key area is the integration of new materials, combustion technologies, new cooling concepts and new aerodynamic designs for turbomachinery. This includes large-scale development and testing, before these concepts can be applied. The development and improvement of CO_2 compression on a large-scale is also important.
- Innovative separation technologies based on new membranes, sorbents or solvents can lead to very significant reductions in CO_2 capture cost. CO_2 separation is the first application, but innovative methods for separating O_2 from air may also have a very important impact on pre-combustion and oxyfuel combustion technologies.
- Geological reservoir modelling: Advanced modelling and simulation tools are needed to assess the behaviour, security and long-term integrity of CO_2 stored underground and its interactions with its surroundings.
- Storage monitoring: Monitoring based on the transmission of different physical and chemical signals makes it possible to control the behaviour of the storage system at different stages of operation. This requires innovative tools in the area of physical emitters and sensors, as well as signal analysis methods.
- Storage standards: As with a number of other natural resources (e.g. petroleum, minerals etc), standards are required for the assessment of storage capacity (reserves) and performance (amount, permanence etc).
- To address the flaring or venting of gas, catalysis is a key technology enabling gas to liquid conversion to synfuels and other chemical basic products, thereby providing efficient solutions to harness this “excess” gas. "

Environment monitoring and control:

- Satellite-based and Earth-based observation systems.
- For forecasting extremes: seasonal forecasting, drought forecasting and monitoring, combined forecasting of water resources and water demands, forecasting using uncertainty estimation and data assimilation of traditional & new measuring techniques.
- Satellite-based instruments are used as data-collection systems (DCS), from sensors located at sea, on remote unattended areas or even from transmitters carried by persons and animals.
- Remote sensing (satellite, doppler radar, wireless sensor).
- Global monitoring for environment and sustainability: data provision to monitor the environment.
- Mitigation of natural and man-made hazards should be reached by the development of integrated assessment, management and prevention methods, new materials and technologies.
- SAR[84] and optical instruments (e.g imagers, spectrometeres, LIDARs) with a view to increase accuracy and enlarge field of view, enhance all weather observation capacities and improve revisit time.
- For long term planning/management of extremes: Quantifying combined hydro-meteorological uncertainty in climate change impact assessment, climate proofing and adaptation.
- Optimisation of water uses and saving and the management of multiple water users.
- Integrated modelling across surface water and groundwater, coastal and fluvial systems, hydrological and meteorology, water and sediment transport.
- New construction materials and concepts to maintain or enhance soil functions (permeable cover materials, non soil-compaction construction methods, etc); soil stabilisation using bio-technology (cementation).
- Advanced materials for resistance to extreme weather conditions.
- Recognition and prevention using learning systems (pervasive computing, data mining, neural network applications able to process and analyse data).
- Linking servers through robust and reliable transmission channels to multiple kinds of terminals (such as,

positioning-enabled terminals

receiving warnings based on direct satellite signals and other systems, short range sensors and transmitters connected to a

[84] Synthetic Aperture Radar

remote server storing and packing the data for later use).

Raw materials Exploration and extraction:

- Energy-optimised fragmentation and extraction: optimal fragmentation and controlled blasting for different sectors.
- Future fragmentation & excavation methods (e.g. mechanical cutting, high-pressure water, microwaves etc.).
- Alternative hauling- and transportation methods.
- New and more efficient power supply for production equipment.
- Towards fully automated extraction: computer- based optimisation & simulation models and on-line control methods for extraction, crushing and screening.
- Development of wear parts and prognostics for predictive maintenance.
- Improvement of robotics for underground and surface operations.
- Development of monitoring-, control-, positioning- and communication systems;
- Further development of mine modelling.
- New exploration technologies: Pan-EU predictive resource assessment, 4-D mineral belt models, Pan-EU data management and visualisation systems for mineral endowment,

New exploration tools.

- Technologies to detect and map new mineral occurrences with non-destructive exploration, sampling and sensing techniques.
- Technologies and equipment in the oil and gas sector to explore for HP/HT (High Pressure/High Temperature) reservoirs and deep/ultra-deep water fields.
- Robotics for exploration: automated undersea inspection, mining and mineral extraction under hazardous conditions. Robots for inspection in environments inaccessible to humans, underwater robot.
- Geological data management and systems for mineral endowment analyses: Pan-EU assessment and land use planning on mineral resources in the context of integrated natural resources management.
- Develop computer systems which will use the data and information bases to model and visualise the key spatial, geological, geophysical, geochemical and financial parameters of mineral occurrences on common EU platforms.
- Use the GIS[85] models interactively to measure the likely environmental and societal impacts of mineral extraction.

[85] Geographic information system

- Projects on advanced underground technologies for intelligent mining.
- Advanced materials and bio- and nanotechnologies: finding substitutes to existing products (such as rare earths and platinum group metals) and higher added-value materials.
- Sustainable and competitive extraction systems towards zero impact: Development of drilling and blasting techniques for minimising of noise, dust, emissions and vibrations.
- More efficient in-situ extraction and near-face beneficiation.
- In-situ (solution) mining of metal ores for energy saving and less excavation.
- Optimisation of the aggregate production chain: drilling/blasting – loading/haulage – crushing/screening for improvement of production and energy efficiency of operations.
- Crushed rock aggregate replacing natural sand and gravel for protection of ground water resources and better land use.
- New restoration methods for surface mining sites – use of stripped soil, waste and fines;
- New strategies and technologies for transformation: use of new machinery in the quarry business;
- Chemical treatment of stone - development of optimal chemical, physical and high temperature processes for the industrial minerals treatment with respect to physiochemical properties of the raw and secondary materials.
- Process simulation & optimisation modelling – improve process efficiency, reduce risk of scale-up to commercial scale and improve product recovery.
- New technological processes for treatment of polymetallic materials and slags with recovery of usable metals.
- New technologies for recovery of accompanying metals for better utilisation of natural resources.
- Direct treatment systems; in-situ mining, Improved "green" hydrometallurgy, Processes for metal recovery.
- Holistic processing strategies: from extraction to product to minimise waste and maximise efficiency, optimisation for end product use.
- Sub-sea mining using derived equipment from oil & gas deep water production technology.
- Optimisation of metallurgical processes to improve efficiency and reduce waste.
- Development of ion-exchange and membrane techniques in non-ferrous metals hydrometallurgy.
- Development of chemical analyses methods for lowering costs of quality controls in metallurgical processes and for continuous control of the processes.

- New processing technologies for physical separation of minerals – improved physical methods for minerals concentration (enrichment of non-ferrous ores, froth flotation, new techniques for fine & ultra-fine particles).
- New technologies for production of precious metals.
- Development of chloride metallurgy.
- The development and validation of new industrial models and strategies covering all aspects of product and process life-cycle.
- Improved energy utilisation in electrometallurgy processing.

Recycling / use of secondary raw materials / substitution:

- Internal processing systems for re-use and recycle: New solutions in combustion engineering and heat recovery.
- Feed stock recycling (plastics, waste wood, chemicals, CRT/LCD glass). Use of recyclables as fluxes, reductants or process chemicals.
- Improved methods for heat recovery and re-use;
- Stabilisation of hazardous substances in waste materials.
- Improved method for water recovery, re-use and recycle.
- Reduce the consumption of critical resources and consumables in whole chain production.
- Methods to improve disposal of solids waste.
- New technologies for lead production with generation of ecological waste slags.
- Environmental footprint reduction using new processing systems, techniques (life cycle assessment), monitoring methods and materials.
- New processes for treatment of low quality scraps and waste.
- Clean technologies for raw materials treatment and product production, reducing environmental footprint or process emissions.
- New methods for separation of arsenic and other toxic elements from production lines of non-ferrous metals smelters.
- Protecting ground and surface water quality. Treatment of acid mine drainage, recovery of contained metals, etc.
- Improved methods for disposal and use of minerals tailings.
- Innovative use of alternative energy sources for processing of raw materials and metals recovery.
- New chemical/biochemical processes for recovery or sequestering of pollutants from contaminated land.
- Bioprocessing and microbial functions – improving performance and understanding.
- Industrial network on waste prevention and recycling aiming at turning wastes into products: recycling data source (collectors, recyclers, energy, metallurgy, mineral, mines, equipment).

- Mining and quarrying environmental and waste GIS database development.
- Prevention of waste by innovative processing: Combined technologies for processing of waste and scrap.
- New technological processes (hydro, bio, pyrobeneficiation) for treatment of complex waste (incl. dust, tailings, residues).
- Feedstock recycling: waste to chemicals technologies.

Lighting:

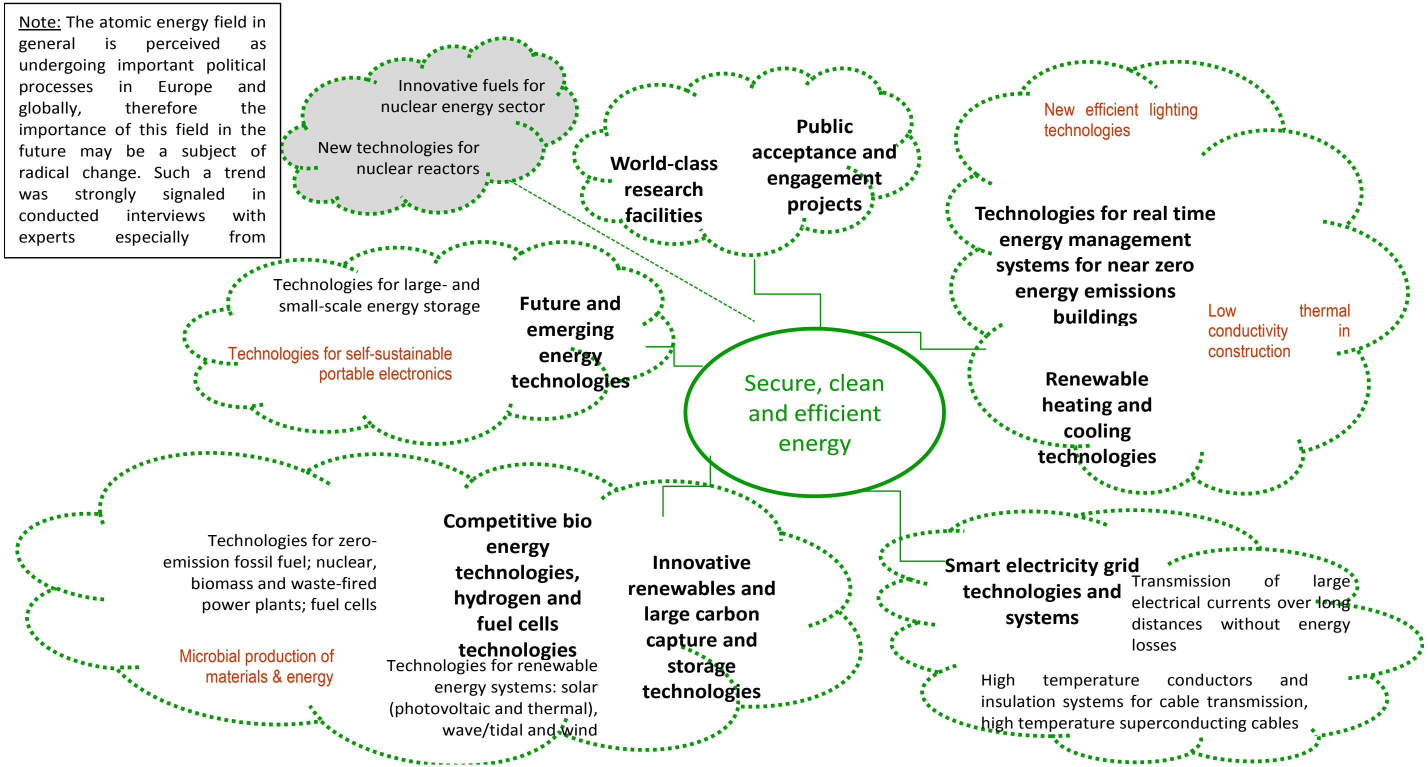
- Technologies for energy-efficient solid-state lighting based on electroluminescence by inorganic (LED) and organic (OLED) semiconductors.

This overview of technologies indicates that our **industries of today require analysis and reformulation of their production cycles**. This approach aims to introduce usage of GHG-related technologies, which are already available to us, but difficult to implement, due mostly to market and system causes.

As mentioned in Chapter 5.3.6 **there are a lot of cross-cutting science fields contributing to the promise of green technologies**. These cross-cutting technologies are important for other challenges, contributing to the general environmental imprint of humanity.

An additional, underlying and very important factor for the future development of enabling technologies is **the provision of raw materials**. This area of research, both extraction as well as the reuse/recycling of materials, will play an important role in shaping EU research policy in coming years.

Figure 18: Future key supported fields in the area of 'Secure clean and efficient energy"



A list of promising areas within the theme of 'secure, clean and efficient energy' emphasized by experts during our workshops covered:

- technologies for smart grids;
- increase of green energy production;
- materials technologies for more efficient batteries;
- support for nuclear energy production;
- reduction of energy consumption by miniaturization, smart embedded systems and use of new materials;
- improvement in solar power efficiency;
- use of PCM (phase change materials) for cool energy (heat) refrigeration;
- energy saving new insulating materials;
- empowering users (e.g. energy production from walking);
- technologies creating energy through methanisation (use of food waste);
- large energy storage technologies for smart coupled grids;
- development of algae-obtained biofuels;
- use of waves energy technologies;
- energy recovery from waste, thermoelectricity.

Additionally to the results of project workshops, a long list of possible technologies discussed in various industrial roadmaps and strategies was identified. For this particular challenge, the secondary sources list following technologies:

Fossil and non-fossil energy sources:

- Enhanced oil recovery techniques.
- Advanced materials allowing for exploration and extraction in a harsh environment (especially to address corrosion). New sophisticated multifunctional, multielement coatings.
- Materials for the generation of electricity, heat and clean fuels (e.g. hydrogen, bio-fuels, etc.). These will include high temperature materials, coatings and functional materials for zero-emission fossil fuel, nuclear, biomass and waste-fired power plant, including fuel cells, as well as materials for other renewable energy technologies including solar (PV & thermal), wave/tidal and wind.
- New materials with conducting and superconducting properties for the transmission of large electrical currents over long distances without energy losses. This should include materials for electricity, gas and hydrogen distribution, pipelines for captured CO_2. New ceramic materials will play an important role in this area.
- Materials and methods for energy storage: H2 storage,

advanced battery technologies and other methods for energy storage.

- Materials design and selection for rejuvenation and recyclability, thus maximizing sustainability and providing new approaches to design of engineering systems and 'eco' buildings.
- Materials for energy conservation and efficiency in use. This will include materials for construction e.g. glass, insulating materials, ceramics, coatings, etc. It will also include development of lightweight materials for automotive and aerospace sectors in order to reduce fuel consumption and emissions.
- New catalysts to increase the conversion efficiencies of fuel cells and biodiesel and to synthesize biodegradable lubricants.
- New high temperature resistant materials for nuclear reactors, energy micro-generation units for energy scavenging and conversion materials for waste energy.
- New materials with useful conducting and superconducting properties will have a significant impact on society in practical systems for the transmission of large electrical currents over long distances without energy losses.
- Nanoelectronics: energy management systems needed to utilise new and diversified energy sources.
- Power conversion systems: industry-compliant wide band gap semiconductor materials, design of new architectures of power converters and innovative solutions for packaging and thermal management on system level.

Reducing fossil fuel consumption:

- "Green" specialty chemicals. The base or platform chemicals isolated or produced in bio-refineries from wood, pulping liquors and different types of forest residues can be upgraded to specialty chemicals.
- Electricity distribution:
- Micro-grid technologies: advanced manufacturing systems, nanotechnologies, micro- and nanoelectronics, biotechnology, photonics and advanced materials.
- Smart distribution infrastructures, smart operation, energy flows and customer adaptation: Power flow assessment, voltage control and protection technologies.
- ICT solutions for effective customer response programs.
- Smartgrids assets and asset management (transmission and distribution) technologies
- Development of more intelligent devices to control power flows and avoid network congestion.
- Models and methods suitable for addressing the interoperability of the European grid, including simulation tools, forecasting

tools for load and RES power manufacturing, testing etc.

- Wide area monitoring and modern visualisation techniques.
- Energy management solutions: energy efficient OS, low-power compilers, design of energy constrained architectures, power modelling and estimation, management of energy sources, distributed energy management (wireless connectivity), user-centric power management.
- System level techniques to save energy such as clock gating, circuit design for ultra-low power consumption as well as self-configuring energy management systems.

Non-fossil energy sources:

- Power plants utilizing renewable fuel (waste/biomass plants, wind turbines, fuel cells and solar plants) require advanced materials with specific requirements for corrosion resistance (aqueous & high temperature), light weight technologies (composites, plastics) and environmental coatings.
- Textiles: flexible reservoirs, containers or bags used for transportation of gases, liquids and bulk goods by road, rail, water or air. For energy generation, transportation and storage, textiles find innovative uses. These include: storage and piping systems for water, liquid fuels and gases made of textiles and fibre composites, anchoring or flotation elements for off-shore platforms, high-resistance aramid based rotor blades for gas and wind turbines, flexible solar cells and inflatable solar panels.

Nuclear energy:

- Improved materials used for plasma surrounding components.
- A new generation of more sustainable reactor technologies – so-called Generation IV fast neutron reactors with closed fuel cycles.
- Innovative heat exchangers and power conversion systems,
- Advanced instrumentation, in-service inspection systems,
- Innovative fuels (incl. minor actinide-bearing) and core performance.
- For waste minimisation and resource optimisation: advanced fuel cycles.
- Partitioning and transmutation: partitioning technologies and fast neutron systems.

PV energy:

- PV cells require advanced materials (organic product), microelectronics (smart meter for utility energy consumption), nanotechnologies (SI Nanowire) and photonics (PV modules).
- Laser processing for high-volume, low-cost manufacturing of thin-film panels.
- High-speed robotic systems used in conjunction with high-performance vision systems.

- New cheaper, more flexible, highly durable encapsulation materials with improved optical properties, new materials and techniques for connections between cells to improve the automated assembly of very thin wafers.
- Reliable, cost-effective production equipment for all existing thin-film technologies; low cost packaging solutions both for rigid and flexible modules; low cost transparent conductive oxides;
- Advanced module testing and improved module performance assessment.
- Handling of scrap modules, including re-use of materials; developing replacements for scarce substances such as indium.
- Materials and production technologies for concentrator solar cells with very high efficiencies,
- Reliable and low-cost optical systems; low-cost, fully-automated module assembly; optimised tracking.
- Renewable heating and cooling:
  - Thermoelectric devices are solid-state systems that can convert heat into electricity, providing cooling and precise temperature control.
  - Micro-CHP (Combined Heat and Power) Systems for independence from commercial power plants, by generating energy from any source, including potentially a hydrogen fuel cell.
  - District heating and cooling systems.
  - Hybrid systems: bring together different sources, to move beyond the limitations of individual technologies.
- New ICT such as real-time smart metering devices and plug-and-play intelligent substations for individual customers, to regulate energy inputs and outputs in order to optimise the interaction between sources of energy supply and the various temperature demands of customers.

Wind energy:

- Better high-voltage electronics in order to increase efficiency and reduce costs.
- Enhanced power converters to maximise system efficiency, make it easier to control and improve the power quality.
- Light-weight, low-speed and low-maintenance generators, including high-temperature super conductors.
- New materials, including recycling possibilities.
- Optimisation of the electricity output and capacity factor, both for the individual wind turbine and the wind farm.
- Development of control algorithms to ensure the aeroelastic stability of the wind turbine.
- Development of new control sensors, in order to forecast the flow in the rotor plane and the

integration of this forecast into control strategies.

- Development of integrated control and maintenance strategies incorporating condition monitoring systems
- Development of innovative wind turbines and sub-system concepts, for example, advanced rotor designs for the next generation of wind turbines, and integrated design methods.
- New and improved materials and manufacturing technologies are required for welding, casting and concreting. These must be coupled with more efficient manufacturing processes and procedures, making use of automation and robotics.
- Better infield cabling design, improved cabling technologies and installation processes. In the longer term, pre-installation of the cable on the sub-structures, combined with connector technologies (wet or dry) to speed up the installation process and reduce costs, diminishing the need for offshore terminals and access to the structure during installation.
- Turbines: turbine design and simulation, understanding the external climate, wake effects and opportunities to increase reliability and reduce costs.

Biofuels:

- Genetically-modified trees for superior performances: increased crop productivity and "precision raw materials".
- Improved industrial biotech processes that facilitate the conversion from biomass into fuel.

Renewable Heating and Cooling systems:

- Components for enhanced thermal storages, improvements on thermally and electrically driven heat pumps and heat sinks-must be optimised both at the level of single components, and enhanced as tools for building integrated systems.
- For hybrid systems, integrated and adapted control system, a specific hydraulic scheme and optimised auxiliary components (e.g. heat rejection and water treatment units, pumps, fans).
- Heat Pumps: Next-generation heat pump technologies (electrically-driven heat pumps using alternative refrigerants, improved sorption heat pump technologies) as well as intelligent system integration of heat pump technologies.
- For thermal energy storage, new approaches, like thermochemical storage concepts, need to be explored.
- To address the high energy costs of wooden pulp production: new biotechnologies and dry processes to replace today's energy intensive processes in mechanical pulping, mechanical fibre treatments and drying.
- To ensure supply: plant breeding (resource efficiency

with regard to efficient cultivation systems for energy crops (minimal input / maximal output).

- Algae: Efficient cultivation reactors, low-cost harvesting technologies are still in their infancy, with floating, filtration, flocculation and energy-efficient centrifugation.
- Algae-to-biofuels conversion technologies.
- Biomass and biofuel quality and monitoring system.
- New tools for biomass conversion into biofuels: synthetic biology and catalytic/chemical conversion.
- Industrial Biotechnology can improve existing fermentation or enzymatic processes, as well as provide new processes from diversified, cheaper sources of renewable raw materials.

Interoperability of smart-grids.

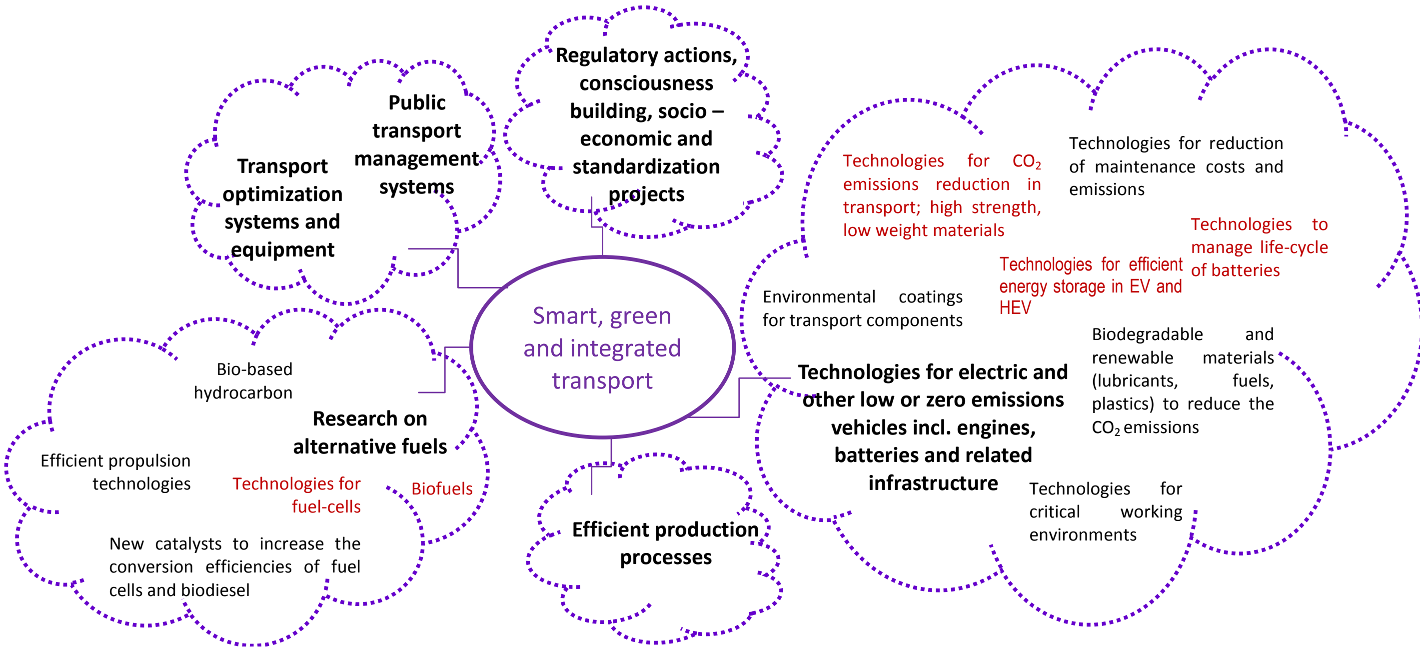
- Control methodologies for Smart grid resiliency.
- Smart grid catalysts and crosscutting issues: electronic meters and Automated Meter Management systems (AMM), characterised by providing two way communications, represent the enabling advanced technologies to enable customer choice in the energy field of the future.
- Decentralized energy management technologies e.g. provision of system services through clustering of dispersed and renewable generation, storage and demand side management with off-line planning and on-line dispatch of power exchange with the neighbouring systems.
- Metering services – e.g. automated billing "from meter to cash", energy cost optimization, home automation.
- Advanced materials for overhead transmission: high-temperature conductors suitable for use on both transmission and distribution circuits to increase their thermal ratings, improved insulation systems.
- Advanced materials for underground/submarine transmission: high temperature conductors and insulation systems for cable transmission, high temperature superconducting cables and Gas Insulated Lines.
- Advanced ICT: beyond current Wide Areas Measurement and Phasor Measurement systems.

The energy challenge is definitely in a very close relation with climate issues described above. In the overview of technologies with the most promising potential to influence the future it must be stressed that **grid-related technologies and large energy storage capacity are critically important to the way we manage and use our energy resources**.

Another clear message is that **technologies for alternative**

smart energy sources need to be continuously developed and the efficiency of the existing technologies improved in order to ensure a market-driven diversion from fossil fuels towards more green technologies. Such an approach will potentially cause a radical change in consumers' behaviours, making fossil fuel less attractive for economic reasons.

Figure 19: Future key supported fields in the area of 'Smart, green and integrated transport'



'Smart, green and integrated transport' is definitely an area intersecting with the energy and environment fields, therefore many promising areas listed in these two fields will influence future transport developments. Additional promising areas indicated by the experts are:

- technologies for more efficient public transport and individual systems;
- a need for regulatory framework for CO_2 storage;
- international cooperation regarding decarbonisation of transport;
- smart car systems (including CO_2 capture technologies);
- efficient hydrogen technologies for transport;
- technologies and information systems enabling change in mobility from individual to public transport;
- efficient energy storage technologies for transport;
- efficient green car (EV and HEV) technologies;
- technologies and materials for vehicle safety.

Additionally to the results of project workshops, a long list of possible technologies discussed in various industrial roadmaps and strategies was identified. For this particular challenge, the secondary sources list following technologies:

Road transport:

- Advanced materials and nanotechnologies: high strength-low weight materials to reduce weight and friction, and therefore fuel consumption and CO_2 emissions; materials reducing maintenance.
- Light materials and tailored nanostructured coatings, with high mechanical strength, wear and corrosion resistance, flame retardant properties and high capacity of energy absorption properties that allow emission reduction.
- Near net shape materials production and on line production and coating processes. Multimaterials (hybrid) systems for automotive applications.
- Functionally graded materials and self-lubricant coatings for critical working environments (engines, sensors, mechanical components, bifuels and trifuels engines, energy or fuel storage).
- High temperature materials (thermal barrier coatings, nanocoatings, ceramic thin film coatings) for engine components, turbines resistant to corrosion, wear, creep, temperatures.
- Catalytic and photocatalytic materials and nanostructured coatings for different applications (new combustion systems, alternative fuels, micro-combustion, environmental treatment, self cleaning).
- Materials for embedded sensors, to improve data acquisition, on line monitoring and new

designs. Anti-icing coatings for aeronautic applications.

- Environmentally friendly coatings for transport components (free of Cd, Cr, and Pb…)
- Advanced materials that allow noise (absorption and isolation), vibration damping, impact, formable, corrosion and wear resistant.
- Materials design taking into account lifecycle of material fabrication processes and assembly, their recyclability and cost.
- Biodegradable and renewable materials (lubricants, fuels, plastics) to reduce the CO2 emissions.
- Electric vehicle: nanotechnologies, advanced manufacturing systems, advanced materials, photonics, biotechnologies, microelectronics, energy storage and battery systems (e.g. Li-Ion battery for a storage system for electrical cars)
- Drive Train Technologies
- System Integration; micro- and nanoelectronics: communications and cooperative systems, energy management, automated systems, matching vehicles to tasks.
- Advanced materials and nanotechnologies: advanced road surface and bridge materials
- For logistical and mobility services: integrated information services / understanding users mobility behaviour / integrated and optimized logistics services / services at transport interfaces / sustainable mobility services / grid-integration and reliability.
- ICT for transport: Intelligent Transport Systems for a more effective and efficient use of road infrastructure.
- High voltage and power: To implement ultrafast multi-point injection systems, piezo-electric injectors.
- For hybrid cars, high-power electronic systems will be needed to optimise overall efficiency, adjusting the relative torque produced by the electric motor and combustion engine, and recovering energy during braking.

Maritime transport:

- ICT and robotics: Intelligent automation and navigation systems, information management
- Ship/shore interface design.
- High performance materials- lighter and stronger engineering materials such as advanced composites, alloys and sandwich structures; corrosion-resistant materials, coating systems.
- LNG will play an important role as an alternative fuel, in the medium term for gas fuelled combustion motors
- Energy recovery systems; renewable energy systems: kites, solar panels.
- Propulsion technologies: Advanced design techniques and

materials applied to existing technology and a range of new propulsion technologies

- New permanent magnet and super-conducting technology will enable very efficient generators and new rim driven motors for propulsors and thrusters.
- Automation and communication technologies for optimum routing
- Transport Embedded Equipment Health monitoring for improved and optimal maintenance scheduling.
- Effective fuel consumption technologies
- Process automation, computer technology, sensors, smart components and communication for the efficient operation of a ship with a reduced crew.

Rail transport:

- Advanced materials and nanotechnologies: light-weight, noise-reducing materials for the rolling stock and infrastructure (low thermal expansion polymer matrix nanocomposites, super hard nanocrystalline metals, alloys and intermetallics)
- Coatings and surface treatment.
- Rail traction and energy supply; energy regeneration braking systems;
- Design of vehicle constituents using recycling materials and research on their operational effects.
- Weight reduction methods to reduce deadweight per passenger.
- Streamlining the infrastructure for more efficient land use such as removing bottlenecks, building high speed flyovers and reducing the number of level crossings.
- Improve standards for noise, emissions and diesel engines.
- Train control systems
- To reduce costs: Virtual testing can help reduce the cost of approval of new vehicles and infrastructure.
- Innovative low labour technologies such as remote monitoring of the integrity of bridges and tunnels; track-train interaction models to aid predictive maintenance; degradation modelling of infrastructure to support predictive maintenance.
- Innovative predictive maintenance methodologies for fleet management will also be developed using automated remote workshop technologies.
- Improved route planning and optimised timetable.
- Vehicle propulsion systems and power train technologies.
- Virtual product development technologies will provide increased modularity, reducing R & D and maintenance costs.

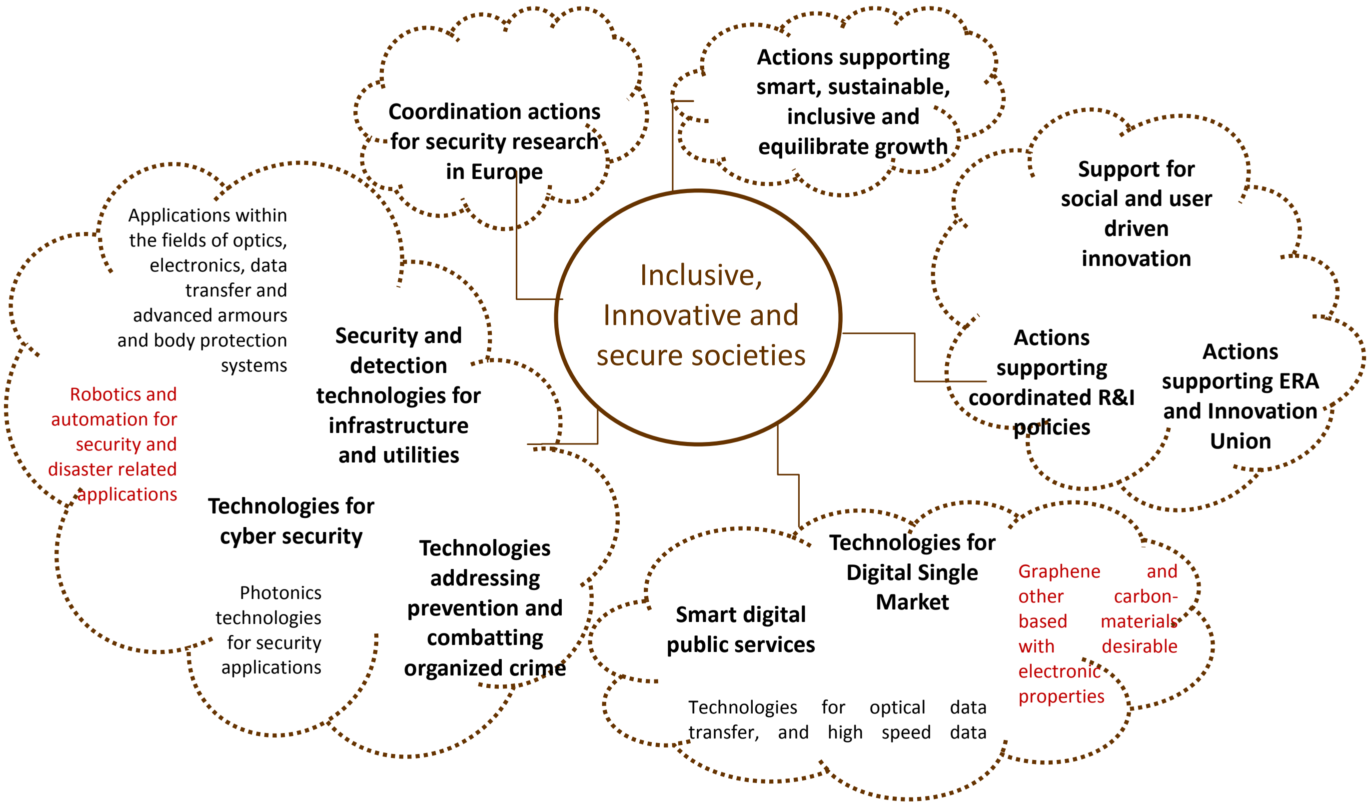
Air transport:

- High strength-low weight materials and nanotechnology: weight and friction reduction (low thermal expansion polymer matrix nanocomposites, superhard nanocrystalline metals, alloys and intermetallics); paintless materials.

- Advanced design for aerodynamic improvements.
- Airports that minimise their environmental impact through solar power, energy-efficient construction and operation, and the minimisation of resource use through water, chemicals etc.
- Fuel efficient engines and systems
- Air Traffic Management.
- Technologies in Aircraft Avionics, Systems & Equipment,
- Filght mechanics - performance,
- Integrated Design & Validation (methods & tools).

Smart, green and integrated transport can only be achieved through a complex approach. The above overview leads to the conclusion that **breakthrough technologies and regulation must still be fostered and introduced to the market** in order to assure that such complex ideas as EV/HEV will reasonably influence the transport sector's environmental impact.

Figure 20: Future key supported fields in the area of 'Inclusive, Innovative and secure societies'



The area of security shall be noted in regards to its influence also on the openness of societies. The security theme was not directly discussed during workshops organized within this study. Still secondary sources analysed indicate other experts views, listing a number of key important areas that will have a reasonable impact in the future, including:

- materials and systems for advanced armours and weapons;
- technologies for optics, electronics, data transfer for security-related applications; optical data transfer technologies; high speed data processing technologies;
- technologies, systems and materials for satellites;
- detection technologies, sensors, etc.;
- quantum computing and quantum cryptography;
- applications for genetic algorithms in battlefield operations to allow machines to learn and solve problems on-site;
- multi-layered network dynamics – understanding social, physical, and telecommunications networks;
- technologies, initiatives and systems assuring cyberspace security;
- technologies for biometric data collection and analysis.

Additionally to the above summary of key technologies, a long list of possible technologies discussed in various industrial roadmaps and strategies was identified. For this particular challenge, the secondary sources list following technologies:

Technologies for security threats:

- ICT (with a particular focus on satellite communications), photonics, micro- and nanoelectronics, robotics for security applications.
- Video surveillance and border biometrics.
- Technologies for detection of dangerous and prohibited goods: affordable single photon imaging,
- Specific wavelength detectors for detection of pollution.
- Secure personal devices, including smart cards: obstruction technologies, authentication technologies (biometry).
- Personal emergency and home security systems: sensor integration for monitoring,
- Secure and reactive packaging.
- Detection, authentication and surveillance technologies: faster fingerprint ID, matric detection imaging systems, multi-spectral integrated IR+ visible imaging,
- For vital infrastructure security: smart and communicative high resolution cameras, tracing technologies.

- For emergency and security: indoor localisation, seeing through the wall radars etc.
- Anti-jamming, anti-spoofing, anti-piracy technologies
- New upper stage propulsion (incl. tanks)
- Light weight structures
- Security in air transport including:
  - Terrain and obstacle database processing;
  - Tracking of aircraft without transponder signal;
  - Automatic tracking and alerting of flight path deviation;
  - Satellite positioning and guidance system;
  - Data fusion and signal processing for pattern recognition;
  - Tracking of aircraft without transponder signal;
  - Security and proof of asynchronous system and software;
  - System simulation and validation;
  - Decision support using artificial intelligence;
  - Required target performance oriented system architecture;
  - Anti-missile systems fitted onto aircrafts;
  - Biometric checks to establish passengers identities (using robotics for automated checks).

Disaster relief:

- Satellite systems used for search and rescue purposes.
- Monitoring and early warning systems with low cost, portable test kits for rapid and reliable determination of toxins, pathogens (including genomic and proteomic) and key contaminants.
- Textiles for erosion and landslide protection systems.

Security:

- Technologies for information security for intrusion tolerance, low-cost security, denial of service, authenticity, integrity and confidentiality.
- Technologies increasing the high-frequency capabilities of semiconductor processes to enable more computing power and/or the running of systems at higher frequencies for better precision.
- Technologies for high-efficiency frequencies; antennae architectures; compact antenna systems and power amplifiers.

Sensors and actuators:

- Technologies for sensors and actuators higher performance and sensitivity
- Sensors networks, MEMS technology integration, RFID (radio frequency identification) and biomedical sensors, voting actuators, autonomous sensors, energy harvesting technologies.

- Interoperability of sensor and actuator networks up to the exchange of data with applications for mobile, home or back-end services (standardisation).
- Self-organisation/autonomy: Position awareness, time awareness, discovery protocols, plan formulation, sensors fusion, 'ways-and-means' modelling, neutral networks, expert systems or production systems.
- Internet cyber security:
- New ways for system-wide security monitoring and analysis at all levels from networking up to services, by deploying innovative methodologies such as proactive protection, detection, analysis, and automatic mitigation.
- Use of cloud technology to facilitate collaboration among network operators, service providers and governments on security issues such as pro-active defence against massive attacks using cloud federation.
- Devise security mechanisms and controls for the Internet of Content (e.g. managed data distribution services), Internet of Things and the underlying network infrastructure (e.g. mobilenetworks).
- Security by Design:
    - Security test environments, defining widely accepted assurance levels and common guidelines supporting product integrity protection;
    - Dynamic and context-aware adaptation of security mechanisms ("just-in time security");

Satellite technologies for telecommunications and observation:

- Satellites require advanced materials (harsh environment skin), microelectronics (rad hard, RF), nanotechnologies (sensors and radars) and photonics (PV modules).
- KETs for earth observation: Moving Target Indicator (MTI) technologies (satellite, Long Endurance UAV[86], and surface), Technologies for new cryptographic systems (including ground segment).
- Launch system optimisation for satellites (incl. ground operations, mainly for quick launch capability).
- Rapid on-orbit operation and quick launch capability (satellite launch on-demand, replacement of failed satellite).
- Quick deployment capability of satellites - Small satellite technologies: Low cost, short life time, storable building blocks/elements, Adequate mission control Centre and dissemination data, Rapid integration and tests.

[86] Unpiloted Aerial Vehicle

Technologies for the space sector:

- Advanced Electrical & Electronics Engineering (EEE) components: high speed proc. technologies.
- Advanced software technologies for satellites.
- High performance data processing for satellites.
- Developing techniques and system designs that improve radio transmission efficiency and spectrum utilisation.
- Technologies for delivering full, seamless integration of satellite services with global (terrestrial) telecommunications infrastructures.
- Dual use: Developing ground and space technologies to allow satellite systems to play a role in future security oriented applications (civil security or military) and allow for the development of dual use of satellite capacity.
- TCP/IP QoS-oriented architectures and protocols for satellite and space networks for secure communications.
- Security for multicast and broadcast services over satellites

CHAPTER 6. POLICY OPTIONS AND THEIR OBJECTIVES

The following chapter elaborates on policy options as defined in Terms of Reference for this study.

Business as usual (FP 7 reloaded)

In this scenario, **the main existing EU sources of funding for research and innovation – the FP, the innovation-related part of the CIP, and the EIT – are simply carried forward into the next Multi-annual Financial Framework as separate instruments, with separate objectives, and in their current formats**. The next Multi-annual Financial Framework therefore includes a 'Framework Programme of the European Community for Research, Technological Development and Demonstration Activities' composed of five specific programmes ('Cooperation' ,'Ideas', 'People', 'Capacities' and 'Non-nuclear actions of the Joint Research Centre'), a 'Framework Programme of the European Atomic Energy Community (Euratom) for Nuclear Research and Training Activities' consisting of two specific programmes (one on fusion energy research, and nuclear fission and radiation protection, and one on the activities of the Joint Research Centre in the field of nuclear energy), a CIP including innovation-related actions, and the EIT.[87]

This policy option was actually not taken into consideration while planning future EU research policies. The continuation of FP 7 in the future apparently was considered as not constituting the right response to current European economical problems and the Grand Challenges of our times.

FP8, business as usual

The possible characteristics of outcomes for such scenario:

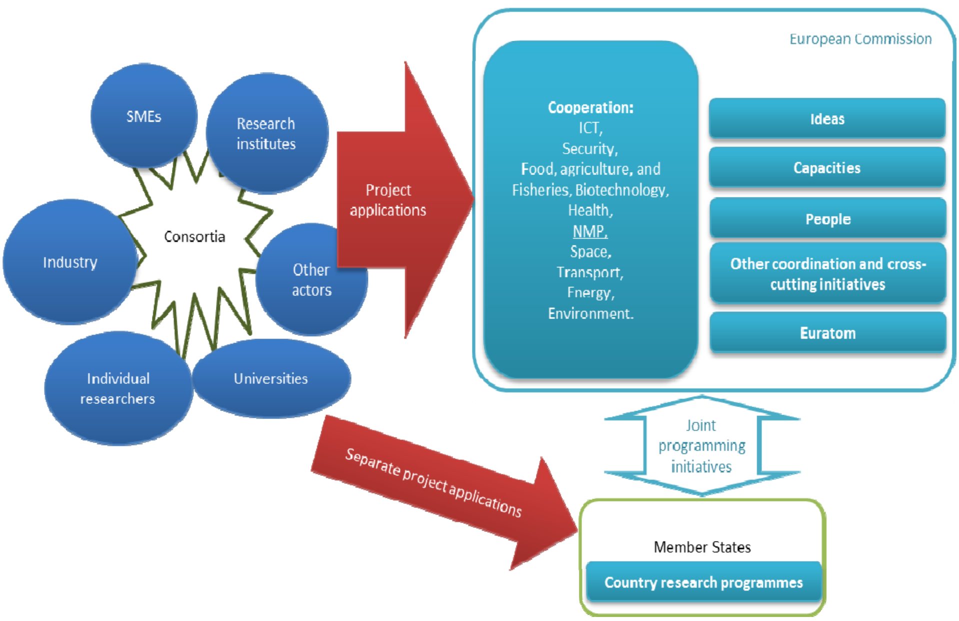
- Europe will continuously build its research capacity.
- Part of the knowledge created will be used on the market but production processes will continue to migrate outside Europe.
- Not necessarily first-class knowledge will be created under financed projects but knowledge transfer will be assured through collaborative international projects financed from the common budget.
- The societal challenges will not be directly handled in such case, bringing still positive

[87] This and following (Horizon 2020) policy option description is taken from: Commission staff working paper; Impact assessment Accompanying the Communication from the Commission 'Horizon 2020 - The Framework Programme for Research and Innovation'; Brussels, 30.11.2011, SEC(2011) 1427 final.

contributions, but not tackling them directly.

- Key universities and research centres and the most innovative companies will be attracted, with not so many newcomers.
- Time-to-market indicators will not change.
- European competitiveness will not catch-up largely with the developing markets.
- Monitoring and evaluation of results and impacts mainly administrative.
- Duplication of research will continue.
- Leading national programmes will adjust /coordinate research efforts along the European agenda, trying to be proactive in the areas of key importance/competitive advantage for Member States, rest of countries will adjust to fit into FP.
- Lack of strategy and lack of coordination with other bodies involved on education and training.
- Lack of large investments into infrastructure bringing production back to Europe.
- Education and training content of projects does not influence job market.
- Opportunities for young researchers created.

Figure 21: Framework Programme 7 – policy option 'business as usual'



Source: Oxford Research AS

Gradual evolution -

In this scenario**, the FP, the innovation-related part of the CIP, and the EIT are put together into a single framework: Horizon 2020, the Framework Programme for Research and Innovation**. The current separation between research and innovation is fully overcome; seamless support is provided from research to innovation, from idea to market. Horizon 2020 sets out three strategic policy objectives for all research and innovation actions closely linked to the Europe 2020 agenda and the flagships on Innovation Union, Digital Agenda, Industrial Policy, Resource-efficient Europe, Agenda for New Skills for New Jobs and Youth on the Move: raising and spreading the levels of excellence in the research base; tackling major societal challenges; and maximising competitiveness impacts of research and innovation. The selection of actions and instruments is driven by policy objectives and not by instruments. To address its aims, Horizon 2020 is structured around three complementary and interlinked priorities —1) Excellent Science, 2) Industrial Leadership 3) Societal Challenges – and two additional parts supporting those priorities: JRC non-nuclear direct actions and EIT.

Horizon 2020 provides the context for a major simplification and standardisation of implementing modalities. The simplification concerns both funding schemes and administrative rules for participation and dissemination of results. The new single set of simplified rules applies across the three blocks of Horizon 2020, while allowing for flexibility in justified cases. The Horizon 2020 option also includes an expanded use of externalisation of the implementation of research and innovation actions and a greater reliance on innovative financial instruments.[88]

In this context of new implementation rules and reshaped priorities settings Horizon 2020 is quite revolutionary indeed.

It might be argued that Horizon 2020 in fact corresponds to gradual evolution. It’s a comparative issue. The biggest reason for defining the Horizon 2020 approach as a continuation is that **it will in fact maintain continuity as regards the elements of the current programmes which are considered to be the most successful**, notably the European Research Council and Marie Curie actions, along with recurring messages on keeping collaborative research (centred on themes/challenges) as the core element of the future funding programme. Again more focus will be put to innovation, simplification, innovative SME participation — these words reappear in EC’s vocabulary each time when a bit ‘refreshed’ FP is planned (especially visible under preparation of FP6 and FP7), therefore it clearly brings the reader to see continuation between the programmes. Horizon 2020

[88] Ibidem.

though is not a fully revolutionary approach as seen from participants' perspective, but clearly a largely reshaped continuation.

Reshaped continuation – Horizon 2020

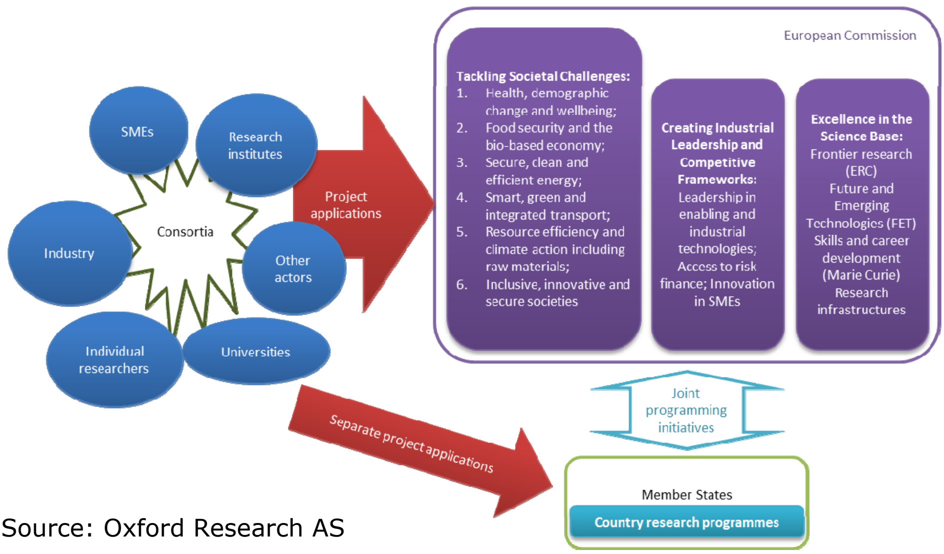
The possible characteristics of outcomes for such scenario:

- Europe will continuously build its research capacity, slightly reinforcing its market orientation of the research.
- Capacity building, knowledge creation and knowledge transfer maintained.
- Some of the European-made innovation will be kept for production processes in Europe, still leakage of know-how will be visible towards less labour-expensive countries with existing research facilities in the future.
- First class knowledge has a chance to be created in the areas defined by the set of Grand Societal Challenges, as the calls and money stream will address most important bottlenecks identified.
- Societal Grand Challenges will be tackled directly, some innovative breakthroughs may appear which will reshape the list of Societal Grand Challenges in the future.
- Key universities and research centres and the most innovative companies will be attracted, with not so many newcomers.
- Competitive innovative clusters will be strongly supported with research investments.
- Time-to-market indicators will improve, nevertheless Europe will not necessarily reduce the gap appearing to new innovation powers and US.
- In general European industry will become more competitive, but the main economic and organisational bottlenecks for market implementation of European research will still not be fully targeted.
- Monitoring and evaluation of results on a project level and impacts on a programme level will be possible regarding environmental and economic indicators, if baseline and target indicators will be defined for each Grand Challenge while planning Horizon 2020.
- Monitoring and evaluation of EC financed projects will be supporting demonstration and close-to-market results exploitation.
- Measurable and technological goals would be at the core of the management.
- Benchmark indicators captured and used for project monitoring.
- Policy-definition based on analysis of scientific, technological and industrial trends through collaboration with academia-industry-public institutions is maintained.
- Pro-active regulatory actions from the EU to promote smart and sustainable technologies implemented.
- Duplication of research will continue, but some progress will be made towards integration of policy planning;

joint programming gets stronger engaging leading MS and the Commission, reflecting the need for stronger and more unified European research support.

- National programmes will participate in joint programming with more resources in order to create momentum and opportunities of scale, also with intention to support more effectively country competitive research teams.
- Education and training will still not be fully coordinated with the research programmes and market needs; industry dealing with KETS will suffer from scarcity of high profile educated personnel.
- Migration of researchers will start in large scale, attracted by growing opportunities outside Europe, a factor also enforced by general economic situation in Europe.
- Lack of large new investments in infrastructure supporting PPP initiatives in KETs bringing production back to Europe will hinder further Europe development.
- Education and training related to KET is not providing enough qualified workforce able to establish competitive advantage in a world scale.
- Opportunities for young researchers are created.

Figure 22: Horizon 2020 - policy option 'gradual evolution'



Source: Oxford Research AS

Radical reorientation

This particular policy option differs from the two cases described above, especially with the way money is distributed to current actors. The word 'radical' in this context means 'revolutionary', or **'totally different than previous attempts'**. In these terms one may think of many scenarios, all probably not fully describable as possible for implementation without many 'ifs' and political discussions, or simply hard to imagine with the current state of affairs in Europe.

For the purpose of this exercise we considered a policy option which feeds on the previous and current efforts, trends and tendencies in European general policy measures, namely:

A European research policy based on strong support given directly to innovative regional clusters.

Elements of such an approach for R&D financing has been previously discussed at the EU-level, to mention CIP activities addressing clusters and various clustering efforts put in the different FPs, but also policy discussions on 'Smart Specialisation strategy'[89], according to which: 'each region should identify its best assets and R&I potential in order to concentrate its efforts and resources on a limited number of priorities where it can really develop excellence and compete in the global economy'[90].

It is also planned in the context of a future research programme — Horizon 2020, where the role of innovative clusters appeared[91] and is slated to be visibly strengthened within the 'Regions of Knowledge'[92] initiative and better coordinated with Structural Funds. These former are allocating most of the resources into less developed European regions, with the aim to reduce regional disparities in terms of income, wealth and opportunities. Particular efforts of EU regional policy are being made in central and east EU countries and regions with special needs.[93]

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89 Foray, D., David, P.A., Hall, B., 2009. Smart Specialisation – The Concept. Knowledge Economists Policy Brief N. 9. June 2009

90 http://europa.eu/rapid/pressReleasesAction.do?reference=IP/11/776&type=HTML

91 For example, during Horizon 2020 thematic workshops http://ec.europa.eu/research/horizon2020/index_en.cfm?pg=workshops&workshop=innovation_and_horizon_2020

92 The 'Regions of Knowledge' initiative aims to strengthen the research potential of European regions, in particular by encouraging and supporting the development, across Europe, of regional 'research-driven clusters', associating universities, research centres, enterprises and regional authorities. http://cordis.europa.eu/fp7/capacities/regions-knowledge_en.html

93 Depending on the what is being funded, and in which country or region, the money comes from different funds:

- The European Regional Development Fund (ERDF) – general infrastructure, innovation, and investments- being most important in the context of building research infrastructure in line with Horizon 2020.
- The European Social Fund (ESF) – vocational training projects, other kinds of employment assistance, and job-creation programmes- highly relevant for the discussion on KETs need for well-educated labour in all EU countries.
- The Cohesion Fund – environmental and transport infrastructure projects and the development of renewable energy. This funding is for 15 countries whose living standards are less than 90% of the EU average (12 newest EU members plus Portugal, Greece and Spain).

While Horizon 2020 is focused on addressing Grand Societal Challenges and supporting competitiveness an all-EU level, 'Structural Funds' are targeted at the national level and at European regions, and are more concerned with capacity building and (in connection to EU research support) development of Research Infrastructures. Horizon 2020 and Structural Funds are therefore different programmes designed to develop synergies and jointly contribute to the shared objectives of Europe 2020, the Digital Agenda for Europe (DAE) and Innovation Union (IU). These schemes could be effectively combined with the Smart Specialisation concept, where funding of Research and innovation would be channelled towards the priority fields in which the different European regions choose to specialise.

Already in Horizon 2020 the Commission will test the tandem elements of integrating closely its research programme with the regional/structural funds.

After 2013, Structural Funds will have an increased emphasis on innovation and smart growth specialisation in order to address the divide between countries and regions. This will be achieved by developing world-class research infrastructures, establishing networks of research facilities, and developing regional partner facilities.

Under the current proposals, Horizon 2020 will award 'seals of excellence' to universities and research centres once they have demonstrated a level of proficiency up to the highest EU standards[94]. Such regions, will be encouraged to use structural funds to bring their research infrastructure up to scratch to win such seals, which will enable them to attract more funds from Horizon and private investors. However, there has been already some resistance appearing towards such an approach, since the new Member States actors believe it could reduce their ability to use the structural funds for other infrastructure projects, and also limit their access to Horizon 2020. Judging from these initial reactions to a reorientation of Structural Funds and a clustering of regions according to smart specialisation priorities, we may anticipate that **cluster oriented approach would be sensitive in terms of changing perspectives for many established groups and standard approaches**.

The radical change that is considered in this chapter is based on a bottom-up approach and implied to restructure the organisation, priority setting, monitoring and funding of the research from the EU R&D funds. **Strong innovation-driven clusters, based on academic excellence, collaborating with industrial complexes and locally active SMEs would be the key actors competing for the funds.** The Commission would be the one setting the strategic priorities and dividing the funds into a number of 'money pots', according to the Grand Challenges, as it is the case for the Horizon 2020 option proposed currently. Further distribution of resources is a key for

[94] 'EU unveils giant research funding programme'; Euractiv; www.euractiv.com

considering the revolutionary dimension of this option. Currently the development of clusters in Europe is hampered by the inability to stream all funds available through cluster organisations. This is due to several factors:

- Clusters' organisations are not organized with a common legal pattern, therefore many of them will not be eligible to apply for any projects at current stage of development.
- Since highly innovative clusters are now concentrated in Western Europe, their participation will lead to exclusion of new Member States.

Regarding the management side of undertaking, in most cases clusters' organisations are not prepared or experienced enough to implement complex projects with large budgets. **Still this option proposes to stream the biggest part of the available resources for R&D financing through cluster organisations, which would be responsible for coordination and management of large projects utilising the processes and concepts of a value chain, the coordination of infrastructure-related efforts, as well as training and education assuring the required workforce for the cluster members.**

This solution also proposes **to maintain those mechanisms supporting European research that prove their high efficiency in addressing the Grand Challenges and strengthening competitive advantage on the market, and also those supporting basic and blue-sky research.** In fact the structure proposed in Horizon 2020 is to be maintained regarding most of the tools split.

Cluster organisations gain the role of important priority setters through the possibility of applying for large scale programmes and later on through coordination and management of these large programmes, connecting all the available measures and tools.

Interviews conducted within this study support this policy option with many statements: '*Since we have put so much effort into building regional clusters – let's give them the power to drive innovation in Europe towards addressing Grand Challenges.*' '*Only inside locally managed clusters we have really expertise on what is needed to assure collaboration between academia and industry, this also includes SME support, infrastructure, mobility, etc*.' '*Let's give the clusters a chance*.'[95]

The role of the Commission will be decision making, priority-setting, facilitation, support, monitoring and follow-up:

- To set-up the strategic priorities.
- To divide the money in the pots for Grand Challenges.
- To decide what conditions the clusters organisations should fulfil in order to run for projects, including possible certification process for the cluster organisations.
- Assess programme applications of the clusters indicating what

[95] Quotes from different interviews conducted within the study.

and how they are going to spend the money to address the challenges.

- Monitor and evaluate.

The role of the clusters:

- Operationalize the strategic priorities following cluster profile.
- Decide which promising technologies, products etc. to invest the money in the future.
- Programme application preparations and coordination.
- Programme management within the cluster in cases when the Commission grants the resources.
- Distribute the money between a group of interrelated R&D, infrastructure and educational projects.
- Manage and report on the programme and all its sub-projects.
- Report to the Commission on progress and results.

EC will therefore have the possibility to indicate the thematic priorities based on the Grand Challenges, while also defining the allocations behind each of these crucial areas. The final decision of the Commission will be to select these clusters, seeking to establish world excellence in a particular field. In this way the Commission will retain all decision making, but the number of applicants will be lower, as propositions from clusters are to be much larger and will integrate many types of projects financed separately in the same setup. The projects are also to integrate educational programmes of the Commission as well as (where available) investments into infrastructure from structural funds.

Innovative clusters will compete for these very large grants based on their proven excellence in research and the market success of their products within the area they apply for. In this way the competitive advantage of European clusters might be raised to new levels.

In 2009 the "Knowledge for Growth" expert group advising the DG Research commissioner addressed the issue of specialisation in R&D and innovation, and introduced the concept of Smart Specialisation.

Smart Specialisation was to assure creation of a better alternative to a policy that spreads that investment thinly across several frontier technology research fields — some in biotechnology, some in information technology, some in the several branches of nanotechnology —and as a consequence did not make much of an impact in any one area. The more promising proposed strategy encouraged investment in programs to complement the country’s and region’s other productive assets to create future domestic capability and interregional comparative advantage.

In the option proposed here for innovative regional clusters, the competition existing now (in FP7) in the form of consortiums applying for European funds through many relatively small calls for proposals will shift towards competition of strong cluster initiatives that will cover very complex projects.

Such clusters will be able to present innovative but also very complex projects that are integrated inside the triple-helix[96] chains, including such actions as:

- Creation of infrastructure (clear space labs, indicated as a missing point of FPs in the past);
- PPP initiatives;
- Close-to-market demonstration projects;
- Access to financial support for innovative SMEs that are members of such clusters (already underlined largely in Horizon 2020 planning);
- Large education programmes integrating local universities into the value chain – enabling 'production' of qualified workforce for the purpose of the local cluster operating in KETs.

Capacity building and knowledge transfer will be ensured through financing of cross-border clusters, and the inherent dissemination and collaborative projects that run between competitive clusters themselves.

Responsibility for monitoring and evaluation will still remain fully at the Commission level.

Is this option feasible? Europe was testing a similar approach within other policies where decision making was in fact decentralised to the level of regions (structural funds). In this proposition the cluster organisations will receive a powerful tool to shape its activities and create excellence on a global scale. Of course a lot has to be done to assure and certify that cluster organisations are able to manage such large undertakings.

[96] Concept of joint actions undertaken by research/academia, industry and government.

Table 12: Baseline factor analysis of proposed policy options

Policy option	Legal framework	Risk of conflict of interest[97]	Discrimination of actors	Management issues
Business as usual -FP 7 reloaded	The legal framework for FP implementation was set up along previous years and will not require any further intervention.	Regular established procedures apply.	FPs were designed in order to finance excellence in research. It is natural that research groups proposing less challenging projects are not financed.	Numerous evaluation of FPs identified their strong and weak points.
Gradual evolution- Horizon 2020	Horizon 2020 is undergoing Parliament and Council negotiations on EU budget 2014-20 (including overall budget for Horizon 2020). Most of the legal structures to be used will be based on adjusted legal framework from Framework Programmes experience. Additional regulations will	Both established consortia and new groups will be able to apply for projects with slightly changed and simplified rules. The risks of conflict of interest always exist inside consortia. Additional risks may appear especially with	Initial reactions addressing possible discrimination with regards to financing excellence centres appear already while discussing Horizon 2020. This is due to the concept of integrating Horizon 2020 more with structural funds and regional development measures. Some regions	Mid-term and final evaluation of NMP in FP7 shall bring more information for fine-tuning the theme of actions in the future especially in the context of Horizon 2020 and beyond.

[97] A conflict of interest (COI) occurs when an individual or organization is involved in multiple interests, one of which could possibly corrupt the motivation for an act in the other.

The presence of a conflict of interest is independent from the execution of impropriety. Therefore, a conflict of interest can be discovered and voluntarily defused before any corruption occurs. Source :Wikipedia.

	be needed in terms of planned pre-commercial public procurement measures[98,99].	introduction of pre-commercial procurement mechanisms. Additional risk management measures will have to be applied to this regard.	and research centres are expressing the fear of being excluded. This is especially cogent regarding new Member States.	
Radical reorientation-cluster approach	Since the option is proposing to make cluster organisations more responsible for application, the legal discussion will have to cover such aspects as cluster organizations' legal forms and eligibility for application, their accounting procedures and reporting. Since the mechanisms for application and contracting will remain the same from the side of the	High risks regarding possible conflict of interest may appear in implemented large programmes between cluster partners and inside cluster organisations managing projects within established programmes. Additional risk management procedures and rules will have to be established and applied.	Potential discrimination of actors is considered as one of the biggest negative factors in this policy option. Financing of innovative and well-organised clusters will be naturally discriminate against those less developed and with lower potential. Since the described policy option is proposed as revolutionary	Management of cluster organisations and their real potential will be challenged, if clusters are to become important actors under this policy option. Additional measures for strengthening of cluster organisation can be envisaged. Also international cooperation of clusters will largely affect programme results and

98 Communication from the Commission: Pre-commercial Procurement: Driving innovation to ensure sustainable high quality public services in Europe {SEC(2007) 1668}.

99 By developing forward looking procurement strategies that include R&D procurement to develop new solutions that address challenges, the public sector can have a significant impact on the mid- to long-term efficiency and effectiveness of public services as well as on the innovation performance and the competitiveness of European industry. Thus, by acting as technologically demanding first buyers of new R&D, public procurers can drive innovation from the demand side.

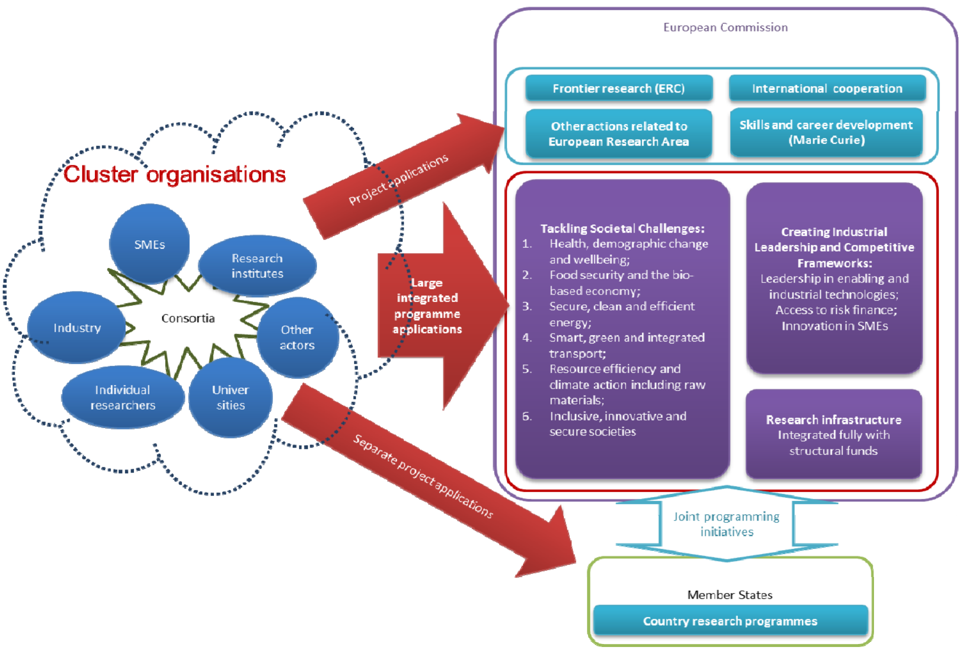
	European Commission, therefore no need exists for other actions to this regard. Additional intervention is also required regarding the pre-commercial public procurement rules.		and is to create discussion, this factor is considered to be one of the crucial elements for consideration.	shall be taken into consideration.
Source: Oxford Research AS				

The possible characteristics of outcomes for such scenario:

- Europe will continuously build its research capacity, but with specialisation defined at innovative clusters level (mostly in MS, but sometimes cross-border).
- Allocation of resources per country is a problematic issue; existing excellence centres are promoted, so countries without competitive clusters are left behind.
- Projects containing infrastructure construction in smaller countries are hardly possible due to scarcity of available resources — big actors promoted.
- Large investments in infrastructure possible at regional level.
- Knowledge created is directly used and targeted to develop innovative regions, very close to market.
- A lot of first-class knowledge (and some less valuable) is created under financed projects, many innovations may reach commercialisation stage due to direct engagement of industry at local level.
- Knowledge transfer can be assured through special project types requiring knowledge exchange between clusters operating in the same fields.
- The societal challenges will be directly handled through appropriate coordination of efforts from the Commission – being able to shape allocations addressing selected challenges and their technological bottlenecks.
- Key universities and research centres and the most innovative companies will be attracted directly at all levels through internal clusters' coordination mechanisms.
- Many newcomers will participate, as the cluster is much closer and much more open than established consortia.
- Time-to-market indicators have a potential to radically change.

- European competitiveness grows.
- Monitoring and evaluation of results and impacts done at the Commission level, with unified system of indicators established, enabling generalisation.
- Duplication of research will continue between clusters to some extent, but seen as necessary 'coopetition'.
- Coordination of main research directions still assured at the Commission level.
- Education systems very much adjusted to local industry needs, through integration of local universities with the industry (e.g. Norwegian examples existing today in oil drilling industry).
- Education and training content of projects implemented by clusters is directly influencing job market locally.
- Opportunities for young researchers created locally.

Figure 23: The 'Cluster' oriented approach - policy option 'radical reorientation'



The chart above depicts the general idea for the innovative regional clusters policy option. The overall layout of European support for R&D in the context of the Grand Challenges (elements to the right side) will mostly remain unchanged.

The novelty proposed is on the left side of the drawing. Here cluster organisations will be responsible for the application and implementation of large integrated programmes, achieved by all actors along the triple-helix concept on a regional level. The objective is to address Grand Challenges as well to manage competitiveness and infrastructure development.

The Commission in this option receives project applications and decides on large integrated programmes managed by clusters. Simultaneously the Commission deals with all other applications in all retained mechanisms (ERC, Marie-Curie, etc.). Member States still manage their programmes separately. Joint programming is retained and developed.

Simultaneously, as in previous policy options, all European actors including those in cluster-managed consortia will retain full liberty of application regarding such mechanisms as ERC funding, Marie-Curie actions, international cooperation or applications to the national programmes.

Policy options' objectives

Policy options discussed above might be also differentiated through comparing the objectives. Framework Programmes as we know them today were criticised for lack of measurable indicators (targets) able to demonstrate their impact in the objectives context. Terms of reference for this study underline the need for elaboration of measurable objectives for policy options. To respond to this need, objectives for the 'gradual evolution' option were presented following the current Horizon 2020 planning.

For 'radical reorientation' the basic starting point was the set-up of objectives defined for 'gradual evolution'. This policy option differs especially with the implementation structures, not with the general approach to grand challenges, other well working tools are not proposed to be changed, therefore most of the detailed objectives and indicators will remain the same. Possible advantages are to be sought especially in more efficient cooperation within knowledge triangle in clusters, leading to more successful market introduction of new products and processes, as well as better performance in patent related indicators.

Table 13: Policy options objectives

Policy option 'Business as usual' (BAU): **General objective:** to strengthen industrial competitiveness and meet the research needs of other Community policies and thereby in contributing towards the creation of a knowledge-based society, building on a European Research Area and complementing activities at a national and regional level	
First level objectives	Second level objectives
Cooperation programme: transition to a knowledge society, the relevant European research potential and the added value of EU Community level intervention grouped into 10 themes (including NMP).	• to establish, in the major fields of advancement of knowledge, • excellent research projects and networks able to attract researchers and investments from Europe and the entire world
Ideas programme: To support investigator-driven 'frontier research', within the framework of activities commonly understood as 'basic research', creating new opportunities for scientific and technological advance, instrumental in producing new knowledge leading to future applications and markets	• to reinforce excellence, dynamism and creativity in European research • to improve the attractiveness of Europe for the best researchers from both European and third countries, as well as for industrial research investment, by providing a Europe-wide competitive funding structure, in addition to and not replacing national funding, for 'frontier research' executed by individual teams

People programme: to make Europe more attractive for the best researchers	• Strengthening, quantitatively and qualitatively, the human potential in research and technology in Europe, by stimulating people to enter into the profession of researcher, • Encouraging European researchers to stay in Europe, Attracting to Europe researchers from the entire world, making Europe more attractive to the best researchers.

Policy option 'gradual evolution' (GE) – Horizon 2020

General objective: Contribute to the objectives of the Europe 2020 strategy and to the completion of the European Research Area.

Policy option 'radical reorientation'(RR) – cluster approach

General objective: To assure Europe's leading position in research and industry uptake of emerging technologies through development of knowledge intensive innovative clusters **(blue font used to distinguish content for this policy option).**

First level objectives	Objectives (for RR option)	Indicators for GE option	Comparative discussion of indicators for RR option
Strengthen Europe's science base by: • improving its performance in frontier research (no change compared to GE option) • stimulating future and emerging technologies (possible better performance	• Increase the efficiency of delivery and reduce administrative costs through simplified rules and procedures adapted to the needs of participants and projects (possibly easier to reach in RR option — projects managed and granted on cluster level) • Provide attractive and flexible funding to enable talented and creative individual researchers and	European Research Council: • Share of publications from ERC-funded projects which are among the top 1% highly cited • Number of institutional policy and national/regional policy measures inspired by ERC funding	European Research Council: • No change when compared to indicators for GE option • No change when compared to indicators for GE option
		Future and Emerging Technologies:	Future and Emerging Technologies:

compared to GE option) • encouraging cross-border training and career development (no change compared to GE option) • supporting research infrastructures (possible better performance than GE option)	their teams to pursue the most promising avenues at the frontier of science (no change) • Increase the trans-national training and mobility of researchers (no change) • Promote international cooperation with non-EU countries (no change)	• Publications in peer-reviewed, high impact journals • Patent applications in Future and Emerging Technologies • Marie-Curie actions on skills, training and career development • Cross-sector and cross-country circulation of researchers, including PhD candidates	• No change when compared to indicators for GE option • Possibly more patents from cluster-based research projects • No change when compared to indicators for GE option • No change when compared to indicators for GE option
		European research infrastructures: • Research infrastructures that are made accessible to all researchers in Europe and beyond through EU support	European research infrastructures: • Possibly better planning and use of new infrastructure in clusters.
Boost Europe's industrial leadership and competitiveness through: • stimulating leadership in enabling and industrial technologies	• Support the development and implementation of research and innovation agendas through public-private partnerships (possibly easier to reach in RR option) • Provide EU debt and equity	Leadership in enabling and industrial technologies: • Patent applications obtained in the different enabling and industrial technologies Access to risk finance: • Total investments mobilised	• Possibly more patents from cluster-based research projects, compared to GE option • More concentrated

(possible better performance) • improving access to risk finance (possible better performance in RR option) • stimulating innovation in SMEs (possible better performance in RR option)	finance for research and innovation (possibly easier to reach in RR option, better access to finance for SMEs on local level) • Ensure adequate participation of SMEs (possibly easier to reach in RR option due to better access to finance for SMEs on local level)	via debt financing and venture capital investments Innovation in SMEs: • Share of participating SMEs introducing innovations new to the company or the market (covering the period of the project plus three years)	direct investment from VC in excellence clusters; better use of RSFF • Possible bigger share of SMEs introducing new innovations due to closer cooperation within clusters
Increase the contribution of research and innovation to the resolution of key Societal Challenges (possible better performance in RR option due to natural concentration)	• Support market uptake and provide innovative public procurement mechanisms (possibly easier to reach in RR option — direct cooperation of cluster with public administration in the region)	• Publications in peer-reviewed, high impact journals in the area of the different Societal Challenges • Patent applications in the areas of different Societal Challenges • Number of EU pieces of legislation referring to activities supported in the areas of different Societal Challenges	• No change compared to GE option • Possibly more patents from cluster-based research projects • No change compared to GE option
Provide customer-driven scientific and technical support to	• Promote world-class research infrastructures	• Number of occurrences of tangible specific impacts on European policies resulting	• No change compared to GE option

Union policies (no change)	and ensure EU-wide access for researchers (no change)	from technical and scientific policy support provided by the Joint Research Centre • Number of peer reviewed publications	• No change compared to GE option
Help to better integrate the knowledge triangle — research, researcher training and innovation (possible better performance)	• Create trans-national research and innovation networks (knowledge triangle players, enabling industrial technologies, in areas of key Societal Challenges) (possibly easier to reach in 'radical reorientation' option, with use of already established efficient business links in clusters). • Strengthen public-public partnerships in research and innovation (possibly easier to reach in RR option — direct cooperation of cluster with public administration in the region).	• Organisations from universities, business and research integrated in KICs (EIT Knowledge and Innovation Communities) • Collaboration inside the knowledge triangle leading to the development of innovative products and processes	• More fruitful cooperation of cluster actors • More products and processes created through cluster initiatives
Source: Oxford Research AS			

CHAPTER 7. POLICY OPTIONS IMPACTS

An in-depth impact analysis has been conducted in the preparation process for Horizon 2020. The policy options that were assessed in comparison with the Horizon 2020 are 'business as usual' (BAU), 'business as usual improved' (BAU+) and 're-nationalisation of the EU R&D funds'.[100] A close look at these policy options allows us to conclude that 'business as usual' and Horizon 2020 are identical to the two policy options proposed in the Terms of Reference for this study. Consequently, in assessing the economic, social and environmental impacts of the policy options — business as usual, being a continuation of FP 7 and gradual evolution (GE), being Horizon 2020 — we will draw on the work done in the Commission and complement it with our findings.

Economic and competitiveness impacts

Based on the evidence collected through a large amount of ex-post, ex-ante and interim evaluations of FPs, thematic evaluations, studies and national evaluations, the current development of the FPs has led to considerable economic, social and environmental effects.[101]

Some examples[102] of the current macro-economic impacts of the FPs are presented below:

- EUR 1 of framework programme funding leads to an increase in industry added value of around EUR 13.
- Each EUR 1 of EU budget invested in the CIP venture capital facility has mobilised EUR 6,8 of other private or public funds.[103]
- The 275 RTOs (Research and Technology Organisations) in Europe, with a combined annual budget of around EUR 20 billion, generate an estimated economic impact of up to EUR 100 billion.
- On the basis of econometric modelling, the long-term impact of FP7 has been estimated at an extra 0,96% of GDP, an extra 1,57% of exports, and a reduction of 0,88% in imports.
- The long-term employment impact of FP7 was estimated at 900,000 jobs, of which 300,000 in the field of research.
- On the basis of the NEMESIS econometric model, the long-term FP7 macro-economic impact was estimated at an extra 0,96% of GDP, an extra

[100] EC. 2011. Impact Assessment Accompanying the Communication from the Commission 'Horizon 2020 – The Framework programme for Research and Innovation'. Commission Staff Working Paper.

[101] Ibidem

[102] EC. 2011. Impact Assessment Accompanying the Communication from the Commission 'Horizon 2020 – The Framework Programme for Research and Innovation. Commission Staff Working Paper. Annex 1

[103] EC, 2011g.

1,57% of exports, and a reduction by 0,88% of imports.

- The FPs have generated large numbers of patents and enabled participants to increase their budgets and profitability, raise their productivity, increase their market share, obtain access to new markets, reorient their commercial strategy, improve their competitive position, enhance their reputation and image, and reduce commercial risk.

Based on the evidence of what has been achieved and the lessons learned, it can be concluded that continuing with the BAU option will lead to positive economic effects at least to the same extent as before. According to the Commission's own impact study, BAU and BAU+ policy options will produce strong economic and competitiveness impacts, with slightly higher innovation impacts of the latter.

The GE policy option, based on the improvements proposed by Horizon 2020 through enhanced scientific, technological and innovation impacts, in combination with the *clarity of focus* and *high quality intervention logic,* is likely to produce larger economic and competitiveness impacts when compared with both BAU options. **The econometric analysis employed though Nemesis has shown that the Horizon 2020 policy option scored stronger on macro-economic effects compared to the BAU policy options.** Thus, by 2030, the Horizon 2020 scored over and above the BAU with a 0,53% increase for GDP, with 0,79% for exports, and 0,10% reduction for imports.

The radical reorientation (RR) proposed in this study, which is based on Horizon 2020 in terms of focus and intervention logic, but relies on European clusters as drivers of R&D and exploitation of the R&D results, can be expected to have a relatively higher economic impact, compared with the GE option, which is based on a multitude of consortia applying for EU funds. The main difference here is the effectiveness of consortia, often found in evaluations of FPs as being created artificially, with contradicting interest of partners from the very beginning. Through dynamic and competitive clusters proposed in the RR option, the economic effects created at the regional level should be considerably higher compared with the BAU and GE policy options. This will be due to employment of valuable knowledge spill-overs, a large and specialized labour pooling, involving entire value chains in the production process and intra- and inter-industry trade.

Empowering the clusters on implementation and exploitation of R&D in industrial technologies should lead to maintaining and consolidating Europe's current leading positions in industrial technologies on the global market and to raising competitiveness levels in those areas where Europe is lagging behind. A powerful potential for raising Europe's competitiveness in industrial technologies in the global market resides also in the clusters' capacity to exploit the R&D results more effectively and efficiently compared with the consortia's historical practice.

Social impacts

Social impacts include effects on the number of jobs, employment conditions, quality of life, and influence on social policy.

Based on current evidence from FPs evaluations at EU and national levels, some examples of current social impacts produced by the FPs are:

- On the basis of the NEMESIS econometric model, the FP7 ex-ante impact assessment identified large-scale FP7 employment effects. The long-term employment impact of FP7 was estimated at 900 000 jobs, of which 300 000 were in the field of research.
- According to an EC-commissioned evaluation of the FP5 growth programme, the number of jobs (expected to be) safeguarded amounted to 37 588 while the number of jobs (expected to be) created amounted to 8 038.[104]
- According to a survey among FP5-7 project coordinators in the area of 'Food, Agriculture and Fisheries, and Biotechnology' research, close to 5% of all projects resulted directly in the creation of a new company. Over the duration of the project 82% of all projects created jobs and 35% of all projects created new jobs after the end of the project. Of all projects 38% created at least one permanent S&T job.
- Through Marie Curie actions, the FP set a valuable benchmark for the working conditions and employment standards of EU researchers.[105]
- The FP produces indirect social benefits through relevant natural and life sciences research; all thematic priorities contribute substantially to a better quality of life.[106]
- The FP also produces indirect social benefits through social sciences research on relevant issues such as human rights, social cohesion, economic cohesion, employment, public health and safety, consumer interests, security and so on. Based on the evidence of what the FPs have achieved so far, their social impact in terms of creating more jobs is obvious. Thus it can generally be concluded that BAU, GE and RR will all have a positive social impact. According to the Nemesis economic model, the Horizon 2020 option indicates slighter stronger employment effects (a 0,21% increase) over the BAU option.[107]

[104] Rambøll Management and Matrix Knowledge Group, 2008.

[105] Annerberg, et al., 2010.

[106] DEA Consult, 2009c, Technopolis.

[107] EC. 2011. Impact Assessment Accompanying the Communication from the Commission 'Horizon 2020 – The Framework programme for Research and Innovation'. Commission Staff Working Paper.

However the major social impact that the FPs can produce depends directly on their outcomes in terms of solutions for addressing Grand Societal Challenges. Both GE and RR have targeted the Grand Challenges as a central priority, which is crucial in mobilizing R&D efforts to work on solutions. A central focus on Grand Challenges is expected to produce considerably more social impact compared with BAU policy options. It is however important to emphasize, as shown in this study that there is an array of critical bottlenecks of a political, legal and market nature that need to be addressed by governments at EU and national levels, so that R&D results could have a more visible social, economic and environmental impact.

Environmental impacts

Environmental impacts include effects on environmental policy and direct environmental consequences.

Based on current evidence from FPs' evaluations at EU and national levels, examples of current environmental effects produced by the FPs are:

- Contribution to the knowledge base and development of methods and tools for environment-related policy, through researchers involved in International Panel on Climate Change and through the outcomes of earth observation projects.
- Contribution to the knowledge base and development of methods and tools for addressing environmental challenges at national, regional and global level through the natural hazards projects, water and soil projects and earth observation projects.
- The average environmental impact per project funded in FP5 was substantial, reaching 6,08% expected reduction of waste and 4,06% expected energy saving.[108]

Based on what is observable and measurable today, it can be concluded that BAU has produced incremental and isolated effects on environmental issues. **The problem lies not in the outcomes of the R&D nor in the potential of the R&D in Europe to come up with solutions for environmental problems, but in the political, legal and market decisions and mechanisms that are lacking today in order to be strategic.** Neither BAU, as the reality shows, nor GE nor RR will be able to produce a large impact on environmental problems if the political, legal and market mechanisms will not provide the framework for that. However, the GE and the RR are better organised to address environmental challenges by focusing clearly and explicitly on Grand Challenges and by improving the intervention logic.

[108] Deloitte, 2006.

CHAPTER 8. COMPARATIVE VIEW OF POLICY OPTIONS

In this chapter we compare the three policy options Business as Usual (BAU), Gradual Evolution (GE) and Radical Reorientation (RR) using a range of key criteria that are important in assessing public funding of research and innovation: effectiveness, efficiency and coherence. A comparison is also made in terms of the different policy options capacity to respond to the lessons learnt from the experience of FP5, FP6 and FP7, namely the need for improved policy coordination, the need for improved intervention logic, the need for lowering barriers to participation and the need to increased exploitation and valorisation of R&D results.

The comparison was done on the basis of evidence collected from previous evaluations, foresight studies, assessment of STI indicators, as well as input from our interviews, hypothesis workshops and academic literature review. Table 13 presents the comparison between the three policy options

Table 14: Overview of cost effectiveness, efficiency and coherence of the policy options

Dimension	"BAU: Continuation of FP7"	"Gradual Evolution: Horizon 2020"	"Radical Reorientation Horizon 2020 + Clusters"
Effectiveness			
Focus	+	++	++
Intervention logic	=	+	+
Accessibility, reach	+	++	+
SMEs	+	++	++>
Excellence	=	+	+>
Critical mass	=	=	=
Structuring effect	+	++	++
Leverage effect	+	++	++
Innovation impact	+	++	++>
Economic and competitiveness impact	+	++	++>
Social impact	+	++	++
Environmental impact	+	++	++
Impact on EU policy	+	++	++

Efficiency			
Reduction of administrative costs	+	++	+
Reduction of participation costs	+	++	++>
Coherence			
Knowledge triangle coordination	+	++	++>
Broader horizontal policy coordination	=	+	+
Flexibility	=	+	+>
Source: Oxford Research AS. Adapted and supplemented from: EC. 2011. Commission Staff Working Paper. Impact Assessment. P. 34			

Policy options capacity to learn the lessons

There are a number of important lessons that can be drawn from the evidence and the experience of the FP participants and stakeholders.

Achieving economic competitiveness and addressing grand challenges will directly depend on the capacity of the R&D policy and activities to learn and respond to these needs.

Further policy development should therefore take into account the issue of policy coordination, the intervention logic, the participation and the exploitation and valorisation of R&D results, issues that still have to be improved at the EU level.

8.1.1 The need for improved horizontal and vertical policy coordination

Based on evidence from the evaluations of the FPs and OECD studies[109], it is still a matter of coordination between the FPs and other EU policies one the one hand and between the FPs and the research programmes in the Member States that needs to be addressed. The conclusions that are put forth by them are: **stronger and better connections between research, innovation and education in the so-called 'knowledge triangle'**[110], a clearer division of labour between the FP and the cohesion funds[111] and more coordination between the FPs and regulatory and demand-side policies. In terms of vertical policy coordination, division of labour between the EU and national levels should be further developed and explicitly defined, based on

[109] OECD (2010b), The OECD Innovation Strategy - Getting a Head Start on Tomorrow, ISBN 978-92-64-08470-4.

[110] Annerberg, R. et al. (2010), Begg, I., Acheson, H., Borrás, S., Hallén, A., Maimets, T., Mustonen, R., Raffler, H., Swings, J.P., Ylihonko, K., Interim Evaluation of the Seventh Framework Programme – Report of the Expert Group for the European Commission, Directorate-General for Research

[111] Rietschel, E. et al. (2009), Arnold, E., Antanas, C., Dearing, A., Feller, I., Joussaume, S., Kaloudis, A., Lange, L., Langer, J., Ley, V., Mustonen, R., Pooley, D., Stame, N., Evaluation of the Sixth Framework Programmes for Research and Technological Development 2002-2006 – Report of the Expert Group on the ex-post Evaluation of the Sixth Framework Programme, European Commission.

European strategic added value. This need is central in adopting a strategic, coherent joint effort that mobilizes the different policies in the EU and the Member States towards addressing grand challenges, as has been shown by the interviews in this study.

As the evidence from the ex-post evaluations shows, the BAU option has **insufficient focus on the knowledge triangle and has unclear or underdeveloped links to the other policies in the EU such as cohesion funds, the policies for transport, energy and agriculture in the EU**. According to the BAU option, although efforts are made to follow the policy development and priority setting in the Members States, it does not result in strategic coordination between the EU R&D policies and the national R&D policies. However good steps in this direction are taken though the establishment of the Joint Programming Initiatives.

The GE and the RR options are both more prepared to solve this challenge as they both emphasize and open for a strategic coordination between the R&D policy and the thematic or sectorial policies governing the EU. Through further development of Joint Programming Initiatives, an important mechanism is in place for a joint financial contribution, priority-setting and programme development that is expected to bring policy effects both at the EU and national levels.

The RR option has a strength in relation to improving the coordination between research, innovation and education, through leading, competitive and highly innovative cluster organizations that apply and run R&D projects. By involving the academia with the industry and SMEs through the clusters, the connection between research, innovation and education is expected to strengthen and develop considerably.

8.1.2 The need for focus and more robust intervention logic.

Another important lesson from the past is that the programme's design could be improved. The view held in the evaluations of FP6 and FP7, supported by the interviews in this study is that the FP lacks transparent, clear and robust intervention logic: the programme has too many objectives, and higher-level objectives are insufficiently translated into lower-level objectives.

The BAU option will still have to struggle to operationalize the general objectives and cope with the diversity of priorities, objectives and funding schemes. A raised awareness of this issue may lead in the BAU option to an effort to focus on strategic areas and simplify the programme design.

The GE is effectively addressing this need through explicitly focusing on three priority areas: Excellent Science, Industrial leadership and Societal Challenges. Through formulating a limited number of mutually consistent, higher-level objectives, closely connected to Europe 2020 Agenda, it created a common framework for the FP, the innovation part of the CIP and the EIT. The GE aims to simplify the programme design by effectively reducing the number of programmes and funding schemes.

The RR option is following the same logic as in GE, with the difference that innovative clusters would be the actors that are playing an important role in the programme implementation. By playing an operative role in the implementation of the programme, they are further operationalizing the objectives of the programme in relation to their specific projects and bring in the bottom-up input in addressing the need for focus and high quality of intervention logic.

8.1.3 The need to lower the barriers to participation

Evaluation of FP6 and FP7 are unanimous in their view that FP application, contract negotiation and project management procedures are too complex and burdensome and that this results in high barriers to FP application and participation, in general but in particular for first time, start-up, SMEs and EU12 applicants

Based on the evidence from the ex-post evaluations of FP5, FP6 and FP7, supported by the findings in this study, the BAU option is characterized by high administrative costs for applicants and participants that influence negatively accessibility, and support. This emerges a as an important shortage in the existing system.

The GE option introduces simplification and flexibility as well as enhanced accessibility to the programmes. Due to simplification, proposal preparation, application and project participation become less costly. This is expected to have a positive effect on lowering the barriers to project participation and coordination that will in turn lead to increased participation for the SMEs, first time applicants and EU 12 applicants. Simplification however does not imply that the quality of the proposals, the quality of the consortia and the quality of the projects shall suffer, as the peer review system and the research excellence scanning system shall be maintained. **The aim is simplification of the administrative procedures in favour of the quality of research and innovation in projects**.

The RR option opts also for a simplification of the application and participation procedures. The cluster organisations will take over the administrative burden currently lying on researchers, engineers and entrepreneurs, by employing professional resources to deal with management and administration of the projects.

8.1.4 The need to increase the production, dissemination and valorisation of project outputs

In achieving the strategic objective to support Europe's competitiveness, address grand challenges, an increased focus should be paid to what outcomes are coming out of the projects and how they are further exploited in order to produce value for the whole society at large, not only value for the participating institution or a specific research subject. The evaluations of FP6 and FP7 highlighted the absence in the FP of valorisation channels that enable the exploitation of research results and the linking of knowledge created through the FP with socially beneficial uses.

BAU policy option has obvious problems when it comes to exploitation of R&D results, as shown in the ex-post evaluation and in this study. The GE option and RR option, both suggest measures to increase the involvement of SMEs in the R&D projects, which will eventually lead to an increase in production, dissemination and valorisation of R&D results. This is done through the measures on simplification and decrease of administrative burden measures. A cluster driven R&D, proposed by the RR option will bring this development further through competitive clusters involving a large amount of SMEs, inter-and industry trade and valuable academia-industry knowledge spillovers.

8.1.5 Effectiveness in terms of critical mass, flexibility and excellence

As shown by ex-post evaluations, BAU option achieves critical mass, it is flexible to a certain extent and promotes excellence. In the GE option – enhances the flexibility - it maintains cross-thematic joint calls, problem-oriented work programmes promoting inter-disciplinary research, and the scope for integrating emerging priorities but also strengthens bottom-up schemes and makes work programmes less prescriptive and more open, with sufficient scope for smaller projects and consortia, that project implementation should be made more flexible; and that the new funding programme will need both curiosity-driven and agenda driven activities. It also enhances the promotion of excellence and it maintains pan-European competition for funding, screening for excellence of all projects.

The RR option follows the GE logic, with the difference that the clusters are the principal actors for valorising excellent research and innovation results coming out of the R&D projects.

8.1.6 Effectiveness in terms of innovation

According to the ex-post evaluations of the FPs, it can be concluded that BAU option produces considerable scientific and technological impact and substantial innovation impact. However the weakness lies in the exploitation and commercialization of the R&D results.

GE option aims to maximize the innovation impacts by promoting support for the entire innovation chain, from the idea to the market. This is to be achieved through: explicitly emphasizing the research project output; supporting more effectively research results dissemination, demonstration and piloting, strengthening support for market take-up; funding projects that cover several stages in the innovation process; supporting SME research and innovation all the way through the projects. A number of flexible funding schemes will be employed for this purpose: research and innovation grants, training and mobility grants, grants to public procurement of innovation, support grants, etc.

The RR option aims to achieve and valorise more innovation through competitive clusters, as drivers of R&D. **By their nature, the clusters are the strongest motors for creating and exploiting innovation in Europe, though the knowledge spillovers**, the highly competent labour pooling, inter- and intra-industry trade, inclusion of entire value chains of product/technology development.

CHAPTER 9. POLICY RECOMMENDATIONS

The Science-Technology Divide

The main objective of the present study is **to assess relations and significance of current NMP activities to the major technical concerns and hurdles associated with Grand Challenges**. The crucial point is to translate promising policy areas previously identified through workshop discussions into operational policy options and recommendations, in order to target bottlenecks currently hampering the employment of Key Enabling Technologies to counter Grand Challenges.

The current section specifically introduces the important issue of translating public research results into products in the market place, which is a cross-cutting concern that links the Key Enabling Technologies with answers to the Grand Challenges. The matter is directly connected with non-technical bottlenecks, including legal, financial, and organisational/inter-organisational frameworks in different political contexts on the EU, national and regional levels.

Here we'll consider the exploitation of publicly funded research carried out in academia and public research institutes.

9.1.1 The 'paradox' notion

At least since 1995 when the term 'European Paradox' was coined, it has been commonly agreed that in comparison with, say, the US, Europe has a lesser ability to exploit its public research results to reap technological and economic benefits: *'One of Europe's major weaknesses lies in its inferiority in terms of transforming the results of technological research and skills into innovations and competitive advantages'.*[112] Some commentators have subsequently adhered to this view: *'Europe's poor position is not a result of its performance in research or R&D. On this point, there is in fact a European paradox…',*[113] *while, as we shall see, others reject this perspective.*

Hasty generalised conclusions are to be avoided as diverse fields of publicly funded research may have different return on investments, and in the EU context, the situation will also differ between Member States. However, if one takes an overview of the European science base as judged by the number of published research papers (not sheer number but adjusted to population size) it is comparatively weaker than its US counterpart. In particular, controlling for population, the **outstanding EU output is still less than half that of the US**. On average, a researcher in the public sector in the United States produces 2,25 articles among the 10% most cited articles worldwide, compared

[112] EC Green Paper on Innovation (1995).
[113] Andreasen, Lars Erik (1995). Europe's next step: organisational innovation, competition and employment. Routledge.

to 0,79 highly cited articles per average researcher in the public sector in the EU.[114] A similar overcast situation is also true for corporate Europe in terms of R&D, where apparent fundamental factors underlying the declining performance of European firms are their lower commitments to research and international patenting and, in several sectors, their relatively weak participation to core international oligopolies. As Dosi *et al.*[115] put it: '*some descriptive evidence shows that, contrary to the "paradox " conjecture, Europe's weaknesses reside both in its system of scientific research and in a relatively weak industry*'.

Without entering into a more profound discussion regarding the situation in different research fields, it is noticeable that scientists in the US – at least in the field of biomedicine – also feel that there is an adverse science-technology divide: On being asked to describe the US performance in biomedical research, Bill Chin, executive dean for research at Harvard Medical School in Boston, responded: '*If the measure describes how much we understand about disease, I think we're on a good road. If it's how often we turn basic science ideas into potential medicines, we aren't doing that well.*'[116] In the UK there is a paradoxical situation of academic excellence and low and declining R&D spending and performance in various innovation metrics.[117] Thus, it is evident that several countries experience this problem, including the US, which is viewed by Europe as a front runner regarding public research commercialization.

So the notion of the European Paradox actually appears instead to hint at a more universal problem that transcends national and regional frontiers, that is, the difficulty to translate scientific discoveries into wealth-generating innovations that are useful to society.

9.1.2 Frontier science, applied academic research and the European industry

Research policy priorities have changed over time, in tandem with societal changes and a better understanding of knowledge creation and innovation. The earlier established view of the linear model of innovation, which emphasises the importance of scientific knowledge as the primary and direct source of technology and innovation,[118] has been challenged by evidence uncovered by social and economic research on science policy over the last 20 years,[119] which points to alternative and more indirect links between these divergent realms. Such research highlights that **the**

[114] http://ec.europa.eu/research/innovation-union/pdf/competitiveness-report/2011/chapters/part_i_chapter_6.pdf

[115] Dosi, G., Llerena, P., Sylos Labini, M: Science-Technology-Industry Links and the "European Paradox": Some Notes on the Dynamics of Scientific and Technological Research in Europe. LEM Working Paper Series. 2005.

[116] Nature 478, pp: S16–S18 (October 13 2011) http://www.nature.com/nature/journal/v478/n7368_supp/full/478S16a.html

[117] http://www.publications.parliament.uk/pa/ld200910/ldselect/ldsctech/104/10011207.htm

[118] Represented for example by 'Science The Endless Frontier', by Vannevar Bush (1945).

[119] For example, Dosi et al., Martin and Tang.

economic value of research funded by governments essentially comes indirectly from long-term improvements in the background knowledge, know-how and techniques that are used by industry, rather than directly from research findings, inventions, licensing or even spin-off firms. Growing evidence across a range of countries shows scanty returns on government investments on applied research.

A number of studies have pointed to the importance of indirect paths of influence, which among others include:[120]

- training of high-quality researchers;
- providing access to international research networks;
- solving key puzzles in technology;
- developing new instrumentation and methodologies that have wide industrial application;
- formation of new firms (spin-offs);
- social spill-overs from social and economic research.

In conclusion, both the linear and nonlinear models of innovation stress the importance of funding high-quality scientific research, however, they do so based on different assumptions. The linear model sees science as directly driving technology, which ultimately seeps down and creates innovation, while the indirect model emphasises funding of science for the development of background knowledge, skills and methods to be transferred to and used in industrial contexts. While the linear model also implies funding applied research, the **nonlinear model would rather stress the importance of a strong industry to develop technologies and markets while standing on the shoulders of scientific discoveries**.

The GMR case

One case that illustrates the important technological implications of a European scientific discovery is the *giant magnetoresistive* (GMR) *effect*. GMR was discovered in the late 1980s by two European scientists working independently and who were awarded the Nobel Prize for this in 2007: Peter Gruenberg of the KFA research institute in Julich, Germany, and Albert Fert of the University of Paris-Sud. They saw very large resistance changes – 6% and 50%, respectively – in materials comprised of alternating very thin layers of various metallic elements. Researchers at IBM's Almaden Research Centre were quick to realise the potential use of the effect in sensors even more sensitive than conventional magnetoresistive heads. They invented very efficient structures for GMR at low temperatures, and hence succeeded in a creating a room temperature, low-field version that worked as a super-sensitive sensor for disk drives, which packed a lot more

[120] Martin B and P Tang, (2007). "The benefits from publicly funded research," SPRU Electronic Working Paper Series 161, University of Sussex, SPRU.

information onto a hard disk than was possible with the MR head.[121]

This case also shows **that it is impossible to preclude companies in other parts of the world from being inspired by European scientific discoveries and technological developments**. A resourceful and innovative European industry backed by a well-trained work force, however, would potentially be able to better harness future scientific discoveries made in Europe and elsewhere.

Future Emerging Technologies (FET) Flagship Initiatives

The FET Flagships are large-scale, science-driven initiatives that aim to achieve very visionary research goals. As a minimum two finalist projects in 2012 will each be awarded a massive EUR 1 billion funding for research spanning over 10 years. The scientific research of the projects is designed to address problems that we can foresee, but do not yet know how to solve. The consortia themselves and the EC foresee that the achieved scientific advances should provide a strong and broad basis for future technological innovation and economic exploitation in a variety of areas, as well as novel benefits for society. While this aim is of course positive, one could argue that it is worrisome – especially in the light of the substantial funding – that so far there is no evidence of how the scientific outcomes will be harnessed for the benefit of the European Union. In projects of this magnitude and ambition a few superficial exploitation workshops explaining the workings of, for example, intellectual property and venture capital, would certainly not be satisfactory.

Recommendation: Each FET consortium should commit to and help **develop a substantial, operational exploitation initiative** intertwined with the scientific work throughout the project's lifetime. It is crucial that such a commercialisation programme does not just launch an inert commercialisation board, but instead includes professionals with proven effective skills in the translation of research into market-relevant solutions, including researchers with experience of both academic research and industrial R&D, entrepreneurs, venture capitalists, and seasoned legal counsels.

Frontier research screening

It is important to recognise the importance of financially supporting NMP 'blue sky' research projects, with minimal steering to increase radical breakthroughs in the long term. As we have seen, innovations with the potential to transform markets have been observed to emerge from discoveries spawned by such research, as opposed to more predictable incremental research advancements aiming to optimise materials and processes. It is a challenge in itself to defend the potential long-term effects, at the same time as we want rapid and measurable results, but this is crucial if new markets are going to be created from European research.

[121] http://www.research.ibm.com/research/gmr.html

The KETs have the potential to break down barriers between traditional disciplines (chemistry, physics, biology), and to create collaborations that in the short term — and particularly in the long-term — will give rise to disruptive innovations that are needed to create new European industries and markets.

Recommendation: Sustain or intensify support for frontier science projects that do not have any expectation to immediately impact the market. Results of **frontier research projects should undergo screening** by skilled engineers and other relevant professionals in the relevant field *before* publication, as there is a risk of intellectual property leakage. There is no contradiction in both patenting and publishing, but if publishing occurs first, the novelty element of the idea is ruined and the patentability is lost.

9.1.3 Policy in support of commercialisation

As we have seen, social and economic research into science, technology, and innovation has during the past two decades highlighted the complexities of the relation between these divergent realms. The relationship between science and technology differs from field to field and even from subfield to subfield, and this difference needs to be taken into account when designing research and innovation policies. This means that generalised and oversimplified explanations and conclusions stemming from earlier policy research need to be justified with a much higher level of granularity. This would include exploration by way of interviewing successful inventors, research managers, entrepreneurs, seed and venture capitalists, and so forth, as well as identifying good practises at translational centres with proven track records of commercialising academic research. For example, patent citation analysis,[122] looking at scientific papers cited in patents, while somewhat arbitrary, can provide rough estimates of the relative distance between scientific discoveries and related technologies.

Recommendation: The design of more effective policies and policy instruments for the benefit of European innovation and economic growth should **build on more comprehensive and well-informed social and economic studies** than has hitherto been the case. Such investigations should assess links and look into the relative strength and internal workings of science-technology fields and subfields in the EU, and, furthermore, **have a high level of detailed analysis.**

The implication is that financial support of frontier science at academic institutions is well-placed to generate background knowledge, know-how and methods, in contrast to funding for applied research at academic institutions, which are commonly out of tune regarding industrial product development processes. When it comes to

[122] Meyer, M: Does science push technology? Patents citing scientific literature. Research Policy 29, Issue 3, March 2000, pp. 409–434.

attempts at steering academic research towards a direct focus on industrial product development problems – which universities traditionally have not dealt with to any greater degree and therefore have little expertise of – this has as a general rule in the past given governments a low return on investment. However, specific examples of collaborative industry-academia work have yielded commercially relevant results and subsequent exploitation thereof, as industry collaborations with Stanford, MIT, Cambridge, and other universities demonstrate. Examples of successful start-up companies resulting from public research results certainly also show that academia is able to generate commercially relevant inventions.

Recommendation: Support for market-oriented public-private partnerships should be specifically implemented in areas that show strong science-technology linkages, such as chemicals, drugs, instrumentation and electronics, or other that may surface during thorough assessments of different research fields.

Recommendation: Partners participating in EC funded collaborative efforts to, e.g., solve Grand Challenges, should also sign up to a detailed and committing exploitation plan before embarking on the project, all the way down to who will build the pilot and who will carry out the manufacturing process. It has to be noted that a stronger focus on- and commitment to exploitation of project results with clear orientation towards the market have already been introduced under schemes in FP7 and, in line with our findings, should be further promoted in the subsequent framework programmes.

9.1.4 European industry

There is evidence in support of the view that industrial actors are generally better suited to bring technologies to the market place. If this notion is accepted, then it leads to the conclusion that the EU is in an unfavourable – in fact critical – situation in comparison with other regions and nations such as the US and Japan. Investments in industrial R&D by companies in the EU have steadily come down over the past many years and continue to slide. The EU industrial sector is negatively impacted by the lack of political commitment and vagueness regarding future support for manufacturing companies, and this influences companies' decisions whether or not to invest in Europe.

Recommendation: Policy measures should aim at strengthening European corporate actors, and find ways to support decreasing levels of R&D funding by European companies.

This would include **predictability of regulatory regimes, tax credit schemes, and other investment incentives**. In return for such more continual policies underpinned by the European Parliament and Council and preferably in collaboration with national governments, individual leading – and often globally present – companies should adhere to **equally**

stable commitments to invest in enhancing skills, innovation and infrastructure within the confines of the European Union.

Engineering skills and infrastructure are important policy planning dimensions for shaping future European innovation policies. This means that the use of the best facilities in Europe should be increasingly promoted and funded, regardless of the country in which they are situated. In connection with this, existing translational centres that bridge the gap between research and the market — for example, those facilitating the development of prototypes and concept demonstrators into batch/production runs — should be supported and developed. Scalability is a crucial issue for increasing industry uptake of technologies.

European patent

On 10 March 2011, following consent given by the European Parliament on February 15, the Competitiveness Council embraced the authorising verdict to establish unitary patent protection in the territories of the 25 participating Member States, with the exception of Spain and Italy. The European Council's approval in June 2011 of new legislative proposals has opened the way for the single European patent to be in place in one to two years.

The proposal for a single EU patent had been under discussion for over a decade but there had been an impasse in the Council over language rules. Much earlier, in the 1970s, the Community Patent Convention (CPC) was an early attempt to design a 'unitary' patent right across Europe, much like the Community Trademark and the Community Design. The Convention never came into force, but many countries in the European Union embraced it, and have since been using passages of the CPC, e.g., in relation to infringement (Arts 25 and 26).[123]

9.1.5 Present patenting situation in Europe

The current European patent system is connected with high costs and great complexity, particularly with regards to administration and legal requirements of granted patents. This situation has often been put forth as a hurdle for innovation in Europe. The European Patent Office (EPO) examines patent applications, and is responsible for granting European patents if relevant substantive conditions (novelty, inventive step, industrial applicability) are met. Currently, for a granted patent to be effective in a Member State, the patent assignee has to request validation in each and every country where patent protection is sought. This process involves considerable translation and administrative costs, reaching approximately EUR 32 000 if patent protection is required in the EU27, of which EUR 23 000 arises from translation fees alone. In total, obtaining patent protection in 27 Member States, including the procedural costs, could in the current situation lead to expenses at

[123] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:41989A0695(01):EN:HTML

the level of EUR 36 000. In comparison, a US patent on average costs EUR 1 850. Moreover, upholding patent rights in Europe requires the payment of annual renewal fees in each member state and every new assignment or licensing agreement relating to the patented invention must be registered in the nation(s) concerned.

9.1.6 Unitary patent protection

Under today's proposals, the translation and related costs of patent protection would drop radically, and it is not difficult to see the benefits this signifies for different types of organisations and private inventors, and not least for the deployment of KETs for tackling the Grand Challenges. The translation costs for a European patent with unitary effect in 25 Member States would, when procedures are fully implemented, be around EUR 680. Patent applications can be submitted in any language; however, building on its existing working procedures, the EPO will continue to examine and grant applications in English, French or German. For applicants residing in the EU who file their patent application in an EU language other than the three official EPO languages, the cost of translation to one of the official languages of the EPO will be compensated. Finally, the patent claims, which define the scope of the protection, are to be translated also to the other two official EPO languages.

If so much cheaper than currently, a single EU patent is expected to make great difference in patent numbers over coming years.

9.1.7 European Patent Court – the unified EU patent litigation system

Along with the process of creating a unitary European patent, there are also developments towards a common European legal procedure of dealing with cases of possible patent infringement. However, developing a court to enforce the EU patent will take longer than instating the new patent granting procedures. In 2009 a draft agreement on the European and EU Patents Court (EEUPC) was presented, which was held not compatible with EU law by the European Court of Justice (ECJ) on 8 March 2011. The chief point of criticism was the fact that the EEUPC would be interpreting and applying EU law despite being outside the EU framework. Based on this discrepancy the Hungarian EU Council presidency published a revised version of the draft agreement on what is now known as the 'Unified Patent Court' (UPC). The UPC will comprise a Court of First Instance, a Court of Appeal and a Registry. The Court of First Instance will be composed of a central division, as well as local and regional divisions in the contracting states.

The wording of the European statutory defence in Community Patent Convention (Article 27 – Limitation of the effects of the Community patent), as interpreted in leading cases from English and German Courts (*Monsanto v Stauffer* and *Clinical Trials I & II*) is viewed as the world's most appropriate legislative framework for striking a necessary balance between monopolies granted by patents on the one hand, and the quest to advance knowledge on the other. It distinguishes well between experimenting *on* a patented invention to derive underlying technology and invent around it (covered by the exemption); and experimenting *with* a patented invention to use it to study something wholly different (not covered by the exemption).

Recommendation: In the light of the foreseen unified European patent litigation system, it is of paramount importance that the EU continues to strike a balance so as not to either deprive many patents of their value or drive research offshore and out of jurisdictions that narrowly construe the defence.

Other policy recommendations

9.1.8 2020 targets just round the corner

Europe 2020 is the EU's growth strategy for the coming decade. The main reasoning behind this political document is to enable the EU to become a smart, sustainable and inclusive economy. These three mutually reinforcing priorities should help the EU and its Member States deliver high levels of employment, productivity and social cohesion. This political agenda has five key targets:

1. Employment: 75% of the 20-64–year-olds to be employed.
2. R&D/innovation: 3% of the EU's GDP (public and private combined) to be invested in R&D and innovation.
3. Climate change/energy: Greenhouse gas emissions cut to 20% (or even 30%, if the conditions are right) lower than 1990; 20% of energy from renewables; 20% increase in energy efficiency.
4. Education: Reduce school drop-out rates to below 10%; at least 40% of 30-34–year-olds to complete third level education.
5. Poverty/social exclusion: At least 20 million fewer people in or at risk of poverty and social exclusion.

Not all of these targets are directly linked to actions undertaken within the current NMP scheme in FP7, but in the cause-and-effect chain they are closely interconnected. Targets in climate change/energy as well as employment are directly linked to the successful implementation of industrial technologies in European industry. The third target directly influencing the overall level of future investments in KETs research is the R&D/innovation goal, which is an overwhelming policy issue for action undertaken by governmental and private actors. A key question therefore appears to be how KETs may contribute to achieving these targets in the relatively short perspective of 2020.

During the workshops undertaken within this study participating experts stated several times that many technologies for addressing the Grand Challenges are already invented. The research effort of FP6 and FP7 as well as many national programmes in Europe and around the world created large set of potential solutions that are still not implemented due to scalability problems of the technologies, or simply lack of demonstration, political support and many other factors unrelated to the science. In general terms those technologies 'just need to be implemented' if we plan to reach the development and sustainability goals before 2020. Taking this into regard, the discussion about new technologies and new areas for research reaches far beyond the 2020 perspective. As experience shows, it is almost impossible that an innovation financed from European funds allocation starting from 2014 (under Horizon 2020 mechanisms) will reach market implementation. Time-to-market indicators have never been that short for any research discovery.

Recommendation: In order to meet the target goals set up in the Europe 2020 growth strategy, the European Commission shall **focus on technologies already close to the market today, searching for demonstration and scaling up solutions**. The EC shall support actions for regulatory tools to implement existing technologies in need of a bigger market to become competitive.

9.1.9 More large scale European venture capital investments

The current business models for VC funds are operating within Member States, and are very seldom cross-border. This is due to limitations of the Single Market. The Report of Expert Group on removing tax obstacles[124] indicated several barriers and possible policy solutions for the creation of the Single Market for venture capital in Europe.

Another problem in the context of KETs is the size of possible investments. The European market is still very much limited in size compared to the United States, while

The early start-up Venture Capital markets in the US invest 50 times more than for example in the UK… (about £10 million in UK, $500 million in US). This then gets translated on to further funding from VCs'.

European venture funds are sometimes not able to provide funding for high risk, large scale investments in advanced technologies. European companies in need of large investments in enabling technologies have to reach outside Europe for the possible financing. In this way production is also moved outside Europe, and as a final result European industry competitiveness and employment fall.

[124] Report of Expert Group on removing tax obstacles to cross-border Venture Capital Investments, European Commission, Brussels 2010. http://ec.europa.eu/taxation_customs/resources/documents/taxation/company_tax/initiatives_small_business/venture_capital/tax_obstacles_venture_capital_en.pdf

Figure 24: Global quarterly venture capital investments by geography

Source: Dow Jones VentureSour
e Data: total investments in US$ bln

Recommendation: As already pointed out in the Europe 2020 strategy, **undertake actions create an open European VC market**. Then stimulate VC through European Commission agencies and European Investment Bank mechanisms supporting availability of large scale projects financing. Only large investments will enable innovation players in Europe to finance second stage development of innovative, complex and expensive technologies.

9.1.10 Supporting regional innovative clusters

The 20th century was all about cities competing with each other for corporate headquarters, highway connections, ports and airports, while gathering bragging points about sports teams, symphonies, universities and other municipal amenities. A more difficult challenge for the 21st century is how to keep cities and regions competitive when it's not the physical but the intellectual capital that will drive the new economy.

At the Innovation Convention some speakers highlighted the existence of highly innovative cities, small regions where new technologies sparkle at every corner and environmentally friendly solutions enhance the level of life and make the city more attractive for habitants and investors. The disillusionment underlined in this context is that the cities used as examples are not necessarily placed in Europe; most of the given examples were in Asia. A showcase example for Europe, can serve the project Stockholm Royal Seaport, a successful PPP that started in 2010 and aims to transform a brownfield industrial area into a modern living area combining high technologies and sustainable infrastructure (See Box). The case can be considered as a best practice example of public-private partnership engaging municipal, governmental, industry, SMEs and future inhabitants in the area, that cooperated successfully for creating sustainable city living and infrastructure.

In the context of policy options proposed in this study (Chapter 7.) with clusters as the main innovation driver for the development of a strong European economy in the future, these examples are screaming for consideration.

Similar long-term industry-academia partnerships have proven their ability to generate and follow common R&D agendas in close collaboration, for the benefit of product development and solutions to societal challenges through more open models of innovation within clusters. A best practice example in this kind of partnerships can be found in Finland, which has founded its SHOKs focusing on areas of strategic importance in terms of industrial competitiveness and Grand Challenges (See Box). These are strategic partnerships clustering public and private actors and are involved in strategic road mapping and priority setting for the different industries in Finland

Case Study — Finnish experience with dealing with Grand Societal Challenges through successful PPPs and innovative clusters

SHOKs, Strategic Centres for Science, Technology and Innovation, were created through a decision of the Finnish Science and Technology Policy Council in 2006. **These are Finland's strategic PPPs for carrying out research in strategic areas for the future**. The SHOKs are expected to produce breakthrough innovations of global importance that shall contribute to the growth and well-being of society.

The SHOKs are organized as not-for-profit limited companies with partners coming from the industry, universities and research institutes. SHOKs' partners decide upon the research programmes in their field, and are responsible for their implementation and funding management. On average 40% of research conducted by the SHOKs is co-funded by companies. The key public funders are Tekes and the Academy of Finland. Between 2008 and 2010, Tekes has funded the SHOK R&D programmes by a total of EUR116 million. SHOKs also apply for funding from EU programmes.

Companies, universities, research institutes and other partners in SHOKs agree on a joint strategic research agenda. Then, this agenda is jointly operationalized into several long-term research projects, where the partners develop shared know-how, technology and service platforms and utilize joint research environments and research tools. Finally, in case an invention emerges out of the innovations or discoveries in the joint research partnership, all partners in the given SHOKs are provided with the right to use it without having to provide any compensation to the original inventor of the IPR.

There are currently 6 SHOKs established in strategic areas:

- energy and the environment - CLEEN Ltd.;
- metal products and mechanical engineering - FIMECC Ltd.;
- forest products - Forest Cluster Ltd.;
- built environment innovations - RYM Ltd.;

- health and wellbeing - SalWe Ltd.;
- information and communication industry and services - TIVIT Ltd.

Bioeconomy is one of the areas covered by the Forest Cluster. Based on its access to wood resources, strong industrial development in the field and a high level of expertise in modern wood processing, Finland has a strong position to carry advanced R&D and innovation laying the fundament for the future bioeconomy, through a wide application of wood related materials such as paper, packaging, buildings for producing biofuels, biomaterials and bioproducts. The cluster, that was created in 2007, has the goal to contribute among others to building a sustainable bioeconomy, through developing industry expertise by facilitating and providing opportunities for networking among companies and research organizations; and channeling financing to goal-oriented research The SHOK has defined clear targets for 2030 in the bioenergy field that followed to be supported by a number of biorefinery operating models.

Sources:
Strategic Centres for Science, Technology and Innovation webpage:
http://www.shok.fi/en/activities/background-and-objectives/

Cases for Policy Implication; Strategic Centres for Science Technology and Innovation
http://www.newnatureofinnovation.org/strategic_centres_for_science_technology_and_innovation_-_shoks.html

Many difficult political issues will appear when considering the idea of financing highly innovative clusters (with smaller or bigger agglomeration being their natural core). These urban centres will require complex programmes addressing all fields of life with a focus on advanced technologies development. Possible Commission's support for the emergence of more such clusters in Europe should be considered. The first and most striking politically sensitive issue will become the selection dilemma: which clusters/agglomerations to choose and what shall be the basis for selection. Historically framework programmes were never oriented towards ambiguous growth, they were always aimed at excellence, choosing the best and financing the most promising ideas. This approach should be continued, if the idea itself is to prevail.

Recommendation:

In the view of the cluster-oriented policy option described in the chapters above, the European Commission shall consider introducing a new actor for industrial technologies under Horizon 2020. The new approach shall include **cluster-driven, large scale regional programmes**. By adjusting existing mechanisms of FP7, clusters may contribute to solving the Grand Challenges through a focus on research commercialization. This may especially be supported by using pre-commercial public procurement on a regional level as well through extensive use of equity financing and RSFF mechanisms.

The European Commission shall consider **concentrated investments in limited number of excellence centres in Europe with a clear focus to create intensive innovative growth agglomerations**. The intervention can integrate all available European Commission mechanisms on a limited geographical area. The scope shall cover such elements as: general infrastructure, research facilities, SME support projects (incubators), venture capital market support, access to finance support through RSFF, education facilities, educational programmes, labour market intervention, concentration of demonstration projects, cultural activities and other social and economic dimensions.

Case Study — Swedish experience with dealing with Grand Societal Challenges and successful PPP

Stockholm Royal Seaport: towards a modern, world-class, sustainable urban district

Stockholm Royal Seaport (SRS) is one of the city's three urban development areas with a specific environmental profile. The project started in 2010 aiming to transform a brownfield industrial area consisting of a container terminal, harbour and gas work into 235 hectares of urban sustainable city by 2030, with of 10.000 new residences, 30.000 new workspaces, 600.000m2. commercial locales and a modern city harbour. The first residents are moving in in 2012. For Stockholm city this is an unprecedented enterprise mobilizing organisations from many arenas to think systemically and work on holistic solutions. ”The investment in Stockholm Royal Seaport is a powerful environmental initiative where holistic solutions and systematic thinking are the results of a close collaboration between governments, developers, policy makers and industry”, said Sten Nordin, mayor of Stockholm.

The parties behind SRS are the city of Stockholm, the Royal Institute of Technology and a constellation of larger enterprises and SMEs. VINNOVA (the Swedish governmental agency for innovation systems) and the Clinton Climate Initiative are development partners and among the financiers. The PPP involves a strong commitment from the stakeholders and operates on a consensus basis. One of the actors involved, WSP Group, writes on their webpage: 'All organisations involved in the vision and development of Stockholm Royal Seaport are fully committed to achieving consensus at every step. Everyone, including architects, developers and the energy providers is committed to the success of this project. Thanks to close working relationships the designs now being produced go well beyond the requirements we set out at the beginning.'

The overall goals for the SRS are to decrease CO2 emissions to less than 1,5 t per person by 2020 and to be fossil-fuel free and Climate+ by 2030. The focus areas in the project are:

- sustainable energy use,
- sustainable transportation,
- ecocycle systems,
- sustainable lifestyles,
- adaptation to climate changes.

At the same time the city acknowledges that: 'Developing an environmentally sustainable city district with a genuine city environment puts extra demands on technological innovations, building work using energy efficient materials, as well as finding new ways of handling energy as a whole'. Among the projects involved in SRS are: the Smart Grid project, ICT for Sustainability, Climate+ Development Program, Sustainable Lifestyle Project and Evaluation Model Research program.

One of the projects involving a wide range of actors from industry, academia and governmental agencies is the Smart Grid Project. The partners in this project aim to study and develop a Smart Grid system for the urban environment.

Industry is highly committed and a key driver in the process, which is illustrated by the declarations of the two industry leaders:

'One objective of the project is for us to find a way to lead and drive the conversion to a more sustainable energy system. A developed smart electricity grid means that the consumers, society and we as a company all will receive benefits. In the future we will need to use our resources more efficiently and a smart electricity grid will make it possible for both large-scale and small-scale production to benefit from each other', said Per Langer, managing director Fortum, Sweden.

'We look forward to participating and creating the first urban district in the world that is being built with a complete Smart Grid. For us it is important as well natural to participate in the conversion to an energy system that is sustainable in the long-term, both within Sweden as well as in other markets', said Sten Jakobsson, president and CEO of ABB Sweden.

Sources:
Stockholm Royal Seaport: http://www.stockholmroyalseaport.com/
VINNOVA presentation at Global Green Growth Summit, Seoul, June, 2011: http://www.gggsummit.org/02_program/files/20/20_Concurrent%201_Peter%20Nou.pdf
Stockholm: http://www.stockholm.se/

Energy Agency:h*ttp://energimyndigheten.se/en/Press/Press-releases/Smart-Grid-in-The-Stockholm-Royal-Seaport-will-integrate-the-entire-electricity-supply-syst*em--from-refrigerator-to-harbour/
WSP Group:http://www.wspgroup.com/en/Sectors/All/A-Renewable-Vision-for-Stockholm-Royal-Seaport/

9.1.11 Joint programming

European national research programmes are among the first and best in the world, but they cannot tackle some of today's major societal challenges alone. Such challenges include, for example, addressing climate change, ensuring energy and food supply and a healthy aging of citizens.

Different evaluations of European programmes, as well as discussion regarding the so-called European Paradox, reveals that research programmes in Europe are run in an isolated way, leading to unwanted fragmentation or ineffectiveness. In order to tackle this problem the European Council elaborated

Conclusions on Joint Programming[125] which encouraged Member States, with the support of the Commission, to consider how best to find common approaches to a number of horizontal matters, usually referred to as 'Framework Conditions', essential for effective development and implementation of Joint Programming in Research. These conclusions were published in December 2008 and were later on followed by 'Voluntary guidelines on Framework Conditions for Joint Programming in Research' in 2010.

While Joint Programming is not an FP7 instrument, the Expert Group evaluating FP7 sees it as key to the success and influence of coordination measures in FP7 such as ERA-NETs and ERA-NET Plus.[126]

Recent experiences with ERA-NETs, Joint Technology Initiatives and Article 185 (ex Article 169) Initiatives seem to indicate that striking the right balance between developing a 'standard model' and 'flexibility within the model' is crucial to prevent a fragmented landscape that results from a completely different set of rules applied to each initiative. A supple approach therefore appeared to be the preferable option in 2010, whereby the Framework Conditions could be implemented as a set of non-binding recommendations, listed in the present 'Guidelines', based on available best practices and identifying the possible alternatives for supporting common policy actions.

In accordance with this view a communication from the Commission on 'Partnering in

[125] 'Towards Joint Programming in Research: Working together to tackle common challenges more effectively' (COM (2008) 468).

[126] Interim Evaluation of the Seventh Framework Programme; Report of the Expert Group; Final Report 12 November 2010.

research and innovation'[127] was issued in September 2011 underlying the need for increased long-term commitment from all partners, including Member States and industry, to partnering. The partnering landscape was declared to be simplified, including limitation of the number of partnering instruments.

The data gathered from interviews in this study indicate that Member States obviously prefer and support the voluntary approach to joint programming and do not want to commit too much to this joint effort.

Quite an opposite recommendation appeared in the European Research Area Board works in 2011 which indicated that the supple system is not sufficient to address the European commercialization problems and Member States' nationalistic tendencies in industrial policies. It is postulated that shared responsibilities should be strengthened in the context of the Grand Challenges.

Recommendation: Act more proactively as facilitator in the context of the Grand Challenges while attracting and **pooling more national funds for joint activities in the area of key enabling technologies**. This mechanism shall be intensified in the NMP theme and shall not only be declaratory but also contain formal commitments from both the European Commission and the Member States.

9.1.12 The societal fear

The societal dimension of KETs' impact will become extremely important in the future.

During recent an industrial technologies conference in Brussels (December 2011) the meeting titled 'Innovating out of the crisis', hosted by the European Research Area Board, together with the European Forum for Forward Looking Activities and the Innovation for Growth group, brought out an interesting discussion about missing social dimensions in the entire context of Horizon 2020's planned research and European innovation in general. The introduction of new technologies must be followed by observation of society's reactions. Innovation and fast development requires support from social sciences and culture.

Technology is a social practice that embodies the capacity of societies to transform themselves by creating and manipulating not only physical objects, but also symbols and cultural forms. It is an illusion that scientific and socio-economic drivers are the sole elements determining the destiny of a technology. Although they are important, what is really crucial is the way in which a human community 'metabolizes' a new technology, that is the way in which a new technology becomes part of the mental landscape of people living in that society. Fear of technology mainly emerges from a lack of meaning surrounding the technology revolution. Present technology is developing without a sound cultural framework that could

[127] 'Partnering in Research and Innovation' SEC (2011) 1072 final.

give technology a sense beyond mere utilitarian considerations.[128]

Under NMP FP6 evaluation at strategic level, the interviews revealed that society's approach to nano products is somehow becoming characterized by lack of trust and some fear signs. Actions are to be continued and more projects are to be undertaken for other technologies to avoid a 'witch-hunt' with regards to new coming advanced innovations. The example of GMO is a case where a negative society perception is shaping today's reality.

FP7 portfolio of NMP project contains a number of initiatives aiming at communicating nanotechnologies to different societal groups. Examples here are:

- NANOYOU being a communication and outreach program in nanotechnology aimed at European youth.
- NANO-TV contributing to the development of public awareness on European research on nanosciences and nanotechnologies in all European countries through the professional use of television media and the internet.
- NANOPINION - a multi-tasking and enlivening online science-technology-social media-based platform for enhanced communication and dialogue between science and society for successful technology development and societal acceptance.

[128] Emilio Mordini; Technology and fear: is wonder the key? TRENDS in Biotechnology Vol.25 No.12 .http://www.cssc.eu/public/Technology%20and%20fear.pdf

The safety of nanotechnology is continuously being tested. The small size, high reactivity, and unique tensile and magnetic properties of nanomaterials — the same properties that drive interest in their biomedical and industrial applications — have raised concerns about implications for the environment, health and safety. However, the majority of available data indicate that there is nothing uniquely toxic about nanoparticles as a class of materials. An interim target regarding nanotechnologies should therefore be developed with the goal to widely spread knowledge about reliable testing and standardization projects' results to assure safety of nanotech products in long term, and therefore build public awareness of the subject. If possible European certification procedures are to be established in order to assure a reliable GO/NO-GO procedure before allowing products to enter the consumer market. The goal in development of these new testing methods and certification is to have proven safe and reliable the large scale manufacturing of KETs products and their deployment in health care devices and other close-to-body sensors and similar applications. As a consequence it will be therefore possible to reduce time for medical testing and development system.

Recommendation: Societal fear about advanced technologies has to be addressed through NMP programme financed projects. Knowledge diffusion about KETs and their possible influence on humans must be obligatory and inherent in close-to-market projects financed by the European Commission, with a strong PR dimension. Separate projects related to **awareness building, testing and education need to be financed across Europe**.

Recommendation: The European Commission shall consider financing European-wide projects oriented towards **integrating innovation results with cultural expression and social science investigation**. This can be undertaken in the form of joint calls or different new forms of cooperation with other relevant Directorates General, including Education and Culture and Information Society and Media.

Recommendations based on morphological analysis

The outcome of the workshop and conducted morphological exercise indicated many directions on the border of NMP programme activity.

The main finding in this regard, already described above, is that many of existing technologies need market uptake not necessarily through further research but rather through other actions, including:

- education,
- information, awareness building,
- legislation,
- price policies supporting technology-enabled, environmentally friendly solutions,
- standardisation,
- procurement,
- habits,
- regulation,
- PPP initiatives for implementation of KETs,
- best practices,
- building European facilities to enable production of KET based products.

Many of the statements made during the workshops were regarding non-research oriented actions. This section is composed of a list of additional findings and recommendations formulated during the morphological analysis undertaken in this project.

1. <u>Health issues:</u> Collected experts' opinions confirm that there is a need for low cost and effective internet-based sensor technologies for the human body. The real goal is to provide monitoring assistance that is not intrusive to the users (for example, HIV-positive patients or people with other specific illnesses). The systems are to be integrated with health authorities' databases to enable monitoring of patients with very low cost and high quality. In fact all technologies are already available, but require mass implementation in order to reach reasonable costs levels.

   Recommendation: Integration, regulation and standardization actions are to be implemented in the future to make this vision into reality. This recommendation is also directly connected with other remarks in this chapter on public awareness and acceptance of modern technologies.

2. Climate action and energy challenges: Experts indicated the need for scrutinizing and analysing existing large-scale industrial processes that are most polluting and that use most of the energy consumed in Europe currently. This analysis shall cover such product life cycle elements as the production process itself, distribution and recycling. This is to be fostered especially in those industries where the biggest environmental impact and energy losses appear. Simultaneously another screening analysis is needed of existing key enabling technologies to understand where technologies can change their current production approaches. These two analyses are to be connected to draw conclusions and finance projects that target the issue of energy consumption in industrial processes. To regulate this approach, a model shall be developed that defines development and implementation of relevant KETs into industries where they can bring highest benefits (including such tools as pre-commercial procurement). By acting as technologically demanding first buyers, public procurers can drive innovation from the demand side. In addition to improving the quality and effectiveness of public services, this can help create opportunities for European companies to take international leadership in new markets. Much is still to be done in terms of public procurement regulations to enable this feature in Europe.

   Recommendation: Analytical studies dedicated to detailed analysis of industrial processes and their possible reorientation using KETs aimed at reduction of environmental impact and energy consumption shall be conducted.

3. Climate action: Promotion of eco-innovation technologies and wise energy consumption habits in the populace can also be forced into practice by legislation and projects designed to foster such approaches, including awareness building and habits adjustment.

   Recommendation: Promote self-sustainability by introduction of regulations and other support measures regarding consumption of energy at home. This may boost such trends as home composting or reduced usage of fossil fuel cars.

4. Regulation of energy consumption: The optimal temperature for work is between 21 and 25, and therefore heating and cooling of public buildings shall be limited in between these values. This practice shall later on be transferred to private buildings with appropriate incentives.

   Recommendation: Introduce public policies for better rationalization of heating and cooling in public institutions.

5. Food consumption: To reduce the amount of food wasted and thrown away, introduce the use of new technologies enabling food waste reduction by supporting the development and use of active and intelligent packaging systems. Existing technologies enable us already today to better manage home food supplies; they require implementation. This will include typically anti-microbial packaging and should expand food availability for consumption. The KETS are also to be more employed to offer freshness indicators on packaging and integration/interaction of intelligent packaging with other domestic appliances such as refrigerators.

   Recommendation: Support market implementation of KETs-based food packaging and management solutions.

6. Quality of life and food security issues: More sustainable ways of producing and living can be channelled by fostering new industries that are based on microbial technology and utilization of by-products.

   Recommendation: Facilitate measures and support for these industries in order to introduce those products to the market.

7. Water sustainability: Promotion of systems for rainwater use for non-food domestic applications may reduce the water consumption problems in Europe and elsewhere. Existing technologies to this regard require system uptake through regulation and incentives.

   Recommendation: Consider actions that support collection of rainwater and in-house distribution on the regulatory side (buildings construction, promoting appropriate installations).

8. Life cycle of raw materials: An option offered on the border of NMP activities is the identification of industrial waste and the re-use of materials for application in the industrial processes, to reduce the need for raw materials. The postulate formulated during the workshop is to have an institution responsible for managing identification of available resources for recycling of materials and developing necessary procedures along product life cycle to connect them with existing technologies. Such an institution would have the responsibility to gather and analyse information regarding the material users. So far the JRC's Institute for Environment and Sustainability (IES) which leads the European Platform on Life-Cycle Assessment, has developed 3 sets of indicators on resources, products and waste, which it hopes will serve the implementation of modern lifecycle-based environmental policies, like the EU's Sustainable Consumption and Production Action Plan.

   Recommendation: Undertake possible further steps in the direction of facilitating the re-use of materials from existing sources as well as associated technologies.

9. Substituting raw materials: Technologies aiming at creation of substitutive materials for those in scarcity should be prioritized, and technologies already available on the market should be used.

   Recommendation: Continue the focus on research programmes and appropriate IP management and protection, as well as demonstration projects at the level of product development in Europe (e.g. industrial production of graphene). The industrial partners will have to allocate investment into new equipment needed for production of these new materials. Therefore it is suggested that public- private partnerships be created targeted for this purpose as well as to support VC investments in the field.

Recommendations based on findings from interviews

1. Research stakeholders' involvement: The Interim Evaluation of FP7 has documented that the success of the ETPs, followed by the JTIs and the PPPs, depend on the active and committed involvement of stakeholders from the industries and their simple and efficient governance.[129] This insight is supported by the interviews in this study as well.

A complementary insight came out of the interviews with informants from different industries (which actually leads into our discussion of 'weaknesses' in the current system). Not only is industry engagement important for the project consortium partners, but also the full engagement of academia partners in delivery of commercialised project results.

Industry partners' view to this regard was a basis for complaints. Academic researchers in the projects were claimed to care solely about publications of the results and not so much about industrial applications or commercialisation. An explanation for this, according to the same informants, was that evaluating research excellence at universities is mainly based on publications in top-tier journals and the numbers of citations per article or per researcher.

Recommendation: A change in the means of evaluations and grading of research and science quality at universities is therefore needed, so as to include exploitation of research results, social and industrial applications, knowledge transfer and commercialisation of research.

[129] European Commission. 2010. Interim Evaluation of the Seventh Framework Programme. Report of the Expert Group.

2. Results exploitation: A strong finding is that exploitation of the R&D results coming out of the FPs does not happen in an effective and efficient way, although certain commercial exploitation support tools, such as ESIC, are under development at the Commission. According to the interviewees, there is much unutilised R&D material lying in the FPs that is systematically filed up on the Commission's shelves. These data may have potential industrial and social applications, but are not sufficiently taken care of or exploited in practice.
   Measures indicated by our informants that could solve this problem are not precise:

   - Allocate dedicated resources for the exploitation of all R&D results with potential;
   - Create a mechanism within the Commission or in collaboration with other institutions to follow up the most promising R&D results;
   - Provide opportunities for those interested actors who are willing to exploit these results.

   Cooperation along the value chain should be a given in projects that apply for EU funds. The logics and potential for exploitation of the results should be taken into account in the early phase of establishing the consortium. The consortium should be able to prove real interest and commitment for further exploitation of the results produced in the project. Interviews conducted within another project by Oxford Research indicate that many established consortia in FP6 did not have a clear commercialisation strategy from the very beginning, and therefore a successful innovation simply could not appear. A much more effective approach is reported by interviewees in FP7 projects where much work has been done to focus the approach towards results exploitation. Accentuating this problem in the project preparation and implementations process seems to bring significant results.

   Also, considering the complex and sometimes sensitive political, legal and market nature of the different bottlenecks that are in the way of exploitation of R&D results, the mechanisms created by the Commission and the resources invested in this endeavour would be insufficient as long the Member States are not committed to creating the necessary framework conditions and instruments for efficient, effective and timely exploitation of R&D results. Thus, an all-level collaboration, strategic and operative, between the Commission and the Members States should be considered in this effort of facilitating and supporting all worthy R&D results. This finding and recommendation is very much in line with the communication from the Commission on

'Partnering in Research and Innovation'.[130] Based on the picture drawn by the interviewees, the potential and capacity for addressing the Grand Challenges lie not so much in the strengths or efficiency of individual countries' R&D programmes or instruments, but in the effective cooperation between the priorities, programmes and instruments at the EU level with those at the national level. Some interviewees explained that their institutions or businesses rely on two pillars: national funding and EU funding. There are therefore incentives to foster coordination between the two. Joint Programming Initiatives and ERA-NETs have been named as good instruments to achieve this in the area of Key Enabling Technologies, especially in the context of addressing Grand Challenges. A recommendation to this regard is already presented in chapter 10.3.4 above.

130 SEC(2011) 1072 final; http://ec.europa.eu/research/era/pdf/partnering_communication.pdf

CHAPTER 10. ANNEXES

Annex 1. Study 'Terms of Reference' and methodology

Terms of reference for the study

The overall objective of the study is to assess the links and relevance of present NMP activities to the major technical issues and bottlenecks associated with grand challenges, providing a set of operational recommendations.

Reference was to be made to activities of the NMP theme and its predecessor under FP5, FP6 and FP7, as well as the experience of Member States and third countries. This activity is to help to identify and justify future priorities and actions in research, demonstration and innovation in the field of industrial and enabling technologies, evaluating their potential socio-economic and environmental impact. Originally the study was to borne in mind the possible reorientation of future research activities towards grand challenges, a possible move towards joint programming and that the relevance of innovation is already underlined. During the project durations these aspects become reality.

More concretely, the study is to:

- Identify the critical bottlenecks regarding the grand societal challenges, by establishing a linkage between research and innovation topics and the grand challenges, especially in the fields related to industrial technologies. For this, the relevant industrial, technological, societal and market-related trends during the last 10 years have been taken into account, as well as the possible future role of NMP.
- Analyse the role, strength and weaknesses of European Union's research activities. Especially through the FPs, in the development of NMP towards solving grand challenges. Such research activities was to be compares to those of a sample of Member States and third countries, analysing potentialities.
- Develop and analyse different **policy options for the future development of the FPs ("business as usual", gradual evolution of current practices, and a cluster approach)**. This includes the possibility and impact of considering a longer chain of activities encompassing research, demonstration, testing and innovation.

It should be noted that the **development of technological roadmaps was outside the scope of this study**. The study focused on horizontal issues such as the best conditions for technology transfer and innovation; the interplay between fundamental research, enabling technologies and industrial applications; the role of education and skills and the leverage effect of the European Union's research policy.

Study methodology

Different methods have been used gather the information needed to conduct this study: desk research, morphological analysis, workshops on policy recommendations and semi-structured interviews. Following is a short description of the different methodologies and the work undertaken.

10.1.1 Desk research

An extensive desk research – literature review was conducted in the beginning of this study. This was a comprehensive review of recent literature and documents (incl. web-based material), covering not only the European Union but also work published in individual Member States. In addition to the official documents, a scientific literature analysis was conducted. This provided important background information for the rest of the study.

Another extremely important part of the desk research phase was to identify, address and engage relevant experts for the participation in the workshops.

10.1.2 Morphological analysis and the workshops

Morphological analysis is a method for creative problem-solving that can be used to widen the search for ideas and solutions. We have used this methodological approach in this study as it is particularly well suited to unravelling and restructuring complex policy issues. Morphological analysis seeks out systematic coverage of a field or a problem where the aim being to explore «all» possible solutions. It is a valuable element in the repertoire of methods and techniques in futures research and foresight.

In simple terms, morphological analysis consists of three basic steps:

- List main dimensions of the problem
- Generate a list of attributes under each dimension
- Combine attributes from the dimensions and use these as stimuli for new ideas

It is a complex task to better understanding how industrial technologies can be used to address Grand Challenges, and there is an inherent risk that discussions will be rather abstract (i.e. superficial), unsystematic, and/or a repetition of well-known arguments. By using this morphological analysis we broadened «the solution space»

The morphological methodology has been used in both the workshops undertaken in this study, and the methodology has served as a vehicle for engaging EU experts in dialogue and joint problem-solving. In both instances, the work was specifically geared to generate concrete, novel ideas. Combined with desk research and interviews, we have identified interesting policy recommendations in an effective, unbiased - and fruitful way.

The morphological analysis was also used with regard to the mapping of existing and future trends that may influence the feasibility of using NMP to tackle the Grand Challenges, and the factors that may hinder or facilitate the development of appropriate technologies. Using a morphological approach, the experts participating in workshops were able to develop valuable insight through facilitated brainstorming.

The workshops focused on the exploring the «big picture», i.e. the context, future developments and expectations related to the use of NMP in solving Grand Challenges. Through working in groups, the participants generated specific ideas on how one can bridge the gap between technologies and Grand Challenges.

The workshops produced a high number of policy recommendations, some of which have been elaborated in great detail after the workshop. It also supplemented the study with valuable crosscutting discussions.

Through the workshop we were also able to verify the accurateness of the research already conducted, and to validate the initial findings. The most important outcome was nevertheless insight on the further development of the possible solutions and future trends influencing the feasibility of NMP, and the list of factors influencing the development of the appropriate technologies. The comments from the experts allowed for fine-tuning the work with elaboration of policy recommendations based on the morphological analysis approach.

10.1.3 Semi structured interviews

The qualitative interview "gives an authentic insight into people's experiences" (Silverman 1993:91[131]), and we have used the methodology to obtain the detailed understanding of experts and stakeholders view on Grand Challenges, and the contribution of FP to solve them as well as to obtain a full picture of possible policy options in relation to the strategy.

To enhance credibility of the strategy development, we have chosen interviewees who are knowledgeable and whose combined views present a balanced perspective on the topic of industrial technologies response to Grand Challenges, present and in the future.

The interviews have been carried out on the basis of a semi-structured guideline.

[131] Silverman, D. (1993). Interpreting qualitative data : methods for analysing talk, text and interaction. Sage Publications, London.

Annex 2. Bibliography

10.1.4 Morphological analysis

Bailey, K. (1994) Typologies and Taxonomies - An Introduction to Classification Techniques, Sage University Papers: Sage Publications, Thousand Oaks.

Coyle, G. (2004) Practical Strategy. Structured Tools and Techniques, Harlow, England: FT Prentice Hall (Pearson Education)

Godet, M. (1994) From Anticipation to Action: A Handbook of Strategic Prospective, UNESCO Publishing, Paris.

Ritchey, T. (2011) Wicked Problems - Social Messes. Decision Support Modelling with Morphological Analysis. Risk, Governance and Society, Vol. 17. Berlin: Springer.

JRC (European Commission) FOR-LEARN. Online foresight guide (forlearn.jrc.es.europa.eu/guide)

Zwicky, F. (1969) [1948] Discovery, Invention, Research - Through the Morphological Approach, Toronto: The Macmillan Company.

Zwicky, F. & Wilson A. (eds.) (1967) New Methods of Thought and Procedure: Contributions to the Symposium on Methodologies, Berlin: Springer.

10.1.5 Bottlenecks

Ashby, M. F., and D, R, H. Jones, *Engineering Materials 2: An Introduction to Microstructures, Processing and Design*, third edition. Elsevier: Oxford, 2006.

European Commission, *FP7 NMP Work Programme,* 2011.

Fisher, E., C. Selin, and J. M. Wetmore, *The Year Book of Nanotechnology in Society. Vol. 1: Presenting Futures.* Springer: USA, 2008.

Hannink R., H. J. and A. J. Hill (eds.), *Nanostructure control of materials.* Woodhead Publishing Limited: Cambridge, 2006.

Holley, S. E., 'Nano Revolution — Big Impact: How Emerging Nanotechnologies Will Change the Future of Education and Industry in America (and More Specifically in Oklahoma), an Abbreviated Account'. *Journal of Technology Studies: 9-19*.

Joachim, C., and L. Plevert, *Nanosciences. The Invisible Revolution.* World Scientific Publishing Co. Pte. Ltd., 2009.

Kelsall, R., I. Hamley, and M. Geoghegan (eds.,) *Nanoscale Science and Technology.* John Wiley & Sons, Ltd.: UK, 2005.

Krueger, A.,. *Carbon Materials and Nanotechnology.* Wiley-VCH Verlag GmbH & Co. KGaA, 2010.

Linton., J. D., 'Determining demand, supply, and pricing for emerging markets based on disruptive process technologies'. *Technological Forecasting & Social Change 71* (2004):105–120. 2003.

Moskowitz, Sanford L. 2009. *Advanced Materials Revolution Technology and Economic Growth in the Age of Globalization.* A. John Wiley & Sons, Inc., 2009.

Pinciotta, F. (ed.), *Global Climate Change – The Technology Challenge.* Springer: USA, 2011.

Rensselaer, *Advanced Materials Sector Report, Lally School of Management and Technology.* Center for Economic Growth, 2004.

Schulte, J. (ed.), *Nanotechnology: Global Strategies, Industry Trends and Applications*. John Willey & Sons: West Sussex, Ltd. 2005.

Waqar A., and M. J. Jackson. *Emerging Nanotechnologies for Manufacturing.* Elsevier:2009.

Weng, Y., H. Dong, and Y. Gan (eds.), *Advanced Steels: The Recent Scenario in Steel Science and Technology.* Springer and Metallurgical Industry Press, 2011.

European sources: European Technology Platfotms (ETPs) documents

'Investing in the Development of Low Carbon Technologies' (SET-Plan). 2009.

EGCI Ad-hoc Industrial Advisory Group, 'European Green Cars Initiative PPP; Multi-annual roadmap and long-term strategy'. 2010.

'Strategic Research Agenda, European Space Technology Platform', 2006.

'Roadmap, European Technology Platform for Advanced Engineering Materials and Technologies', 2006.

'Strategic Research Agenda, European Technology Platform on Sustainable Mineral Resources', 2009.

'Strategic Research Agenda, Waterborne Technology Platform', 2011.

'Strategic Research Agenda, European Technology Platform Smartgrids', 2007.

'Strategic Research Agenda, European Technology Platform for Zero-Emission Fossil Fuel Power Plants', 2006.

'Strategic Applications Research Agenda, eMobility Technology Platform', 2010.

'Common Vision for the Renewable Heating and Cooling Sector in Europe, European Technology Platform on Renewable Heating and Cooling', 2011.

'Strategic Research Agenda, Sustainable Nuclear Energy Technology Platform', 2009.

'Strategic Research Agenda, European Photovoltaic Technology Platform', 2007.

'Strategic Research Agenda, European Biofuels Technology Platform', 2010.

‘Strategic Research Agenda, European Nanoelectronics Initiative Advisory Council’, 2007.

‘Strategic Research Agenda, Networked European Software and Service Initiative’, 2011.

‘Strategic Research Agenda, European Technology Platform Photonics21’, 2010.

‘Strategic Research Agenda, European Technology Platform for Sustainable Chemistry’, 2005.

‘Strategic Research Agenda, European Wind Energy Technology Platform’, 2008.

‘Strategic Research Agenda, ARTEMIS European Technology Platform’, 2011.

‘Strategic Research Agenda, Integral Satcom Initiative’, 2006.

‘Strategic Research Agenda, European Technology Platform on Smart Systems Integration’, 2009.

‘Strategic Research Agenda, European Technology Platform on Nanomedicine’, 2006.

‘Strategic Research Agenda, European Technology Platform “Plants for the Future”, 2007.

‘Strategic Research Agenda, Forest-based Sector Technology Platform’, 2007.

‘Strategic Research Agenda, European Construction Technology Platform’, 2005.

‘Strategic Research Agenda, Manufuture Technology Platform’, 20006.

‘Strategic Research Agenda, European Technology Platform for the Future of Textiles and Clothing’, 2006.

‘Strategic Research Agenda, Water Supply and Sanitation Technology Platform’, 2010.

‘Strategic Research Agenda, Advisory Council for Aeronautics Research in Europe’, 2004.

‘Strategic Research Agenda, European Rail Research Advisory Council’, 2007.

‘Strategic Research Agenda, European Road Transport Research Advisory Council’, 2010.

European sources: other documents

‘Ageing well in the Information Society: An i2010 Initiative. Action Plan on Information and Communication Technologies and Ageing’, European Commission, 2007.

‘Europe 2020: A European strategy for smart, sustainable and inclusive growth’, European Commission, 2010.

High Level Group on Key Enabling Technologies, ‘Mastering and deploying Key Enabling Technologies (KETs): Building the bridge to pass across the KETs' “Valley of death” for future European innovation and competitiveness’ (working document).

High Level Group on Key Enabling Technologies, 'Thematic report by the Working Team on Advanced Manufacturing Systems'. 2010.

High Level Group on Key Enabling Technologies, 'Report by the working group on advanced materials technologies' (working document).

'Preparing for our future: Developing a common strategy for key enabling technologies in the EU' COM: 512-3, 2009.

'Research for a Secure Europe: Report of the Group of Personalities in the field of Security Research', 2004.

Extra-European sources: research priorities in the USA, Japan, China and South Korea

CHINA: 'China's 12th Five-Year Plan: Overview', March, 2011. http://www.kpmg.com/CN/en/IssuesAndInsights/ArticlesPublications/Publicationseries/5-years-plan/Documents/China-12th-Five-Year-Plan-Overview-201104.pdf

JAPAN: 'White Paper on Science and Technology 2010— , Chapter 2: Strategic priority setting in Science and Technology' (provisional translation).http://www.mext.go.jp/english/whitepaper/1302537.htm

SOUTH KOREA: Korean Ministry of Science and Technology, 'Nanotechnology Korea' (no date).

SOUTH KOREA: Korea Photonics Technology Institute, 'R&D activities'. http://www.kopti.re.kr/english/rndactivities/leddevice.jsp (accessed 05/08/2011).

SOUTH KOREA: 'Korea's Nanotechnology Roadmap for the next ten years', TWA, March, 2011.

USA: National Science and Technology Council, Committee on Technology, 'National Nanotechnology Initiative Strategic Plan', February, 2011.

USA: NSCT Committee on Technology, 'Nanoelectronics for 2020 and beyond', July, 2010. USA: NSCT Committee on Technology, 'Nanotechnology for Solar Energy Collection and Conversion', July, 2010.USA: NSCT Committee on Technology, 'Nanomaterials and Human Health & Instrumentation, Metrology, and Analytical Methods: Report of the National Nanotechnology Initiative Workshop', November, 2009.

Extra-European sources: international organisations

International Energy Agency (IEA), 'Technology roadmaps'. http://www.iea.org/subjectqueries/keyresult.asp?KEYWORD_ID=4156

IEA, 'Technology Roadmap: Biofuels for Transport', OECD/IEA, 2011.

IEA, 'Carbon Capture and Storage: Progress and Next Steps', OECD/IEA, 2010.

IEA, 'Technology Roadmap: Solar photovoltaic energy', OECD/IEA, 2010.

IEA, 'Technology Roadmap: Wind energy', OECD/IEA, 2009.

IEA, ‘Technology Roadmaps: Smart grids’, OECD/IEA, 2011.

IEA, ‘Technology Roadmap: Nuclear energy’, OECD/IEA and OECD/NEA, 2010.

IEA, ‘Technology Roadmap: Geothermal heat and power’, OECD/IEA, 2011.

IEA, ‘Technology Roadmap: Energy-efficient Buildings: Heating and Cooling Equipment’, OECD/IEA, 2011.

IEA, ‘Technology Roadmap: Electric and plug-in hybrid electric vehicles’, OECD/IEA, 2011.

IEA, ‘Technology Roadmap: Concentrating solar power’, OECD/IEA, 2010.

IEA, ‘Cement Technology Roadmap 2009: Carbon emissions reductions up to 2050’, OECD/IEA and The World Business Council for Sustainable Development, 2009.

World Health Organization (WHO), ‘Innovative technologies that address global health concerns: Outcome of the call “Global initiative on health technologies”, WHO, 2010.

Intergovernmental Panel on Climate Change (IPCC), ‘Special Report on Renewable Energy Sources and Climate Change Mitigation: Summary for Policy Makers’, IPCC, 2011.

Food and Agriculture Organisation of the United Nations (FAO), ‘Biotechnologies for agricultural development: proceedings of the international technical conference on agricultural biotechnologies in developing countries’, FAO, 2011.

Annex 3. Interview sample and workshops participants

Table 15: Interview sample

Name	Institution	Position
Prof. Dr. Michael Zürn	Social Science Research Center Berling	Director of the Research Unit "Transnational Conflicts and International Institutions"
Prof. Dr. Carsten Dreher	Freie Universität Berlin	Director of Center for Cluster Development
Dr. Kerstin Cuhls	Fraunhofer Institute for Systems and Innovation Research (ISI), Karlsruhe	Scientific project manager
Dr. Heinrich Höfer	Federation of German Indusrties (BDI)	Managing Director Research, Innovation, Technology and Health
Dr. Lothar Behlau	Fraunhofer-Gesellschaft	Head of the "Stratgy and Programs" Department
Prof. Dr. Jens Oddershede	University of Southern Denmark	Rector(University of Southern DK)) and Chairman of Universities Denmark
Prof. Dr. Micheal Decker	Institute for Technology Assement and and System Analysis (ITAS) at the Research Centre Karlsruhe (now KIT)	Professor
Prof. Dr. Narayanaswamy Balakrishnan	Indian Institute of Science	Assosiate Director
Prof. Dr. Rongping Mu	Chinese Acadamy of Science, Intitute og Policy and Management	Director General and professor
Prof. Dr. Seeram Ramakrishna	National University of Singapore (NUS)	Director and Professor
Ernst-Udo Sievers	i.con. innovation GmbH	Managing director
Dr. Daniele Pullini	Centro Ricerche Fiat S.C.p.A.	Strategic Innovation Program Manager
Prof. Juan J. de Damborenea	National Centre for Metallurgical Research (CENIM)	Professor
Prof.ssa. Luisa Torsi	Dipartimento di Chimica - Università di Bari "Aldo Moro"	Professor, Chairman of the Doctoral Program in Materials Science
Dr. Katharina Flaig	Laser&Optics Research	Consultant/ Junior project manager

Dr. Kathrine Angell-Hansen	JPI Healthy and Productive Seas and Oceans	Director of the secretariat of JPI OCEANS
Dr. Jos Leijten	TNO	Head of the Joint Institute for Innovation Policy (JIIP)
Dr. Miguel Ángel Bengochea	KERABEN GRUPO, S.A.	Director I+D
Dr. Vicente Sanz Solana	ECTP -European Construction technology Platform	Co-leader of the Working group on Ceramics within the Focus Area on Materials
Dr. Arun Junai, A.	EU Research Programs, TNO Science and Industry	Co-ordinator
Dr Schroeder Thomas	Materials Research, IHP	Acting Department Head
Prof. Gian Marco Revel	Università Politecnica delle Marche	Professor
Prof.Dr. Lutz Walter	The European Apparel and Textile Confederation	Head of R&D, Innovation and Projects Department EURATEX
Dr. Anders Haugland	BTO	Managing director
Dr. Charles Hirsch	NUMECA International	President
Dr. Chris Decubber	European Factories of the Future Research Association	Research Programme Manager
Dr. Masahiro Takemura	National Institute for Materials Science (NIMS)	Office Chief, Research and Analysis Office
Dr. Peter Thostrup	University of Aarhus	Research Associate
Dr. Andreas Wild	ENIAC Joint Undertaking	Executive Director
Dr J.W. Hans Hofstraat	PHILIPS	Vice President of Healthcare Strategic Partnership
Dr. Willem Jonker	EIT ICT Labs KIC	CEO
Dr. Dag Høvik	The Research Council of Norway	Special Adviser
Source: Oxford Research AS		

Table 16: Workshop participants

Title	Name	Institution/Position
Dr.	Alfred J. van Roosmalen	NXP Semiconductors, Vice President Central R&D
Dr.	Antje Wittenberg	DG ENTR, Metals, Minerals, Raw Materials
Dr.	Axel Thielmann	Deputy Head of the Competence Center Emerging Technologies. Researcher and project manager at the Fraunhofer ISI
Prof.	Bart Blanpain	Department of Metallurgy and Materials Engineering, Leuven, Belgium.
Dir.	Bill Macbeth	Textile Centre of Excellence, Huddersfield.
Dr.	Brian More	Coventry University Technology Park, Intellectual Property Policy
Dr.	Cecilia Warrol Ersson	Director Production technology. Teknikföretagen, The Association of Swedish Engineering Industries
Dir.	Ebby Shahidi	Technical Director Umeco Composites Structural Materials, Advanced Composites Group Ltd
Prof. Dr.	Ehrenfried Zschech	Division Director, Fraunhofer Institute for Non-Destructive Testing IZFP
Prof.	Francesco Jovane	Manufuture. Vice precident.
Prof.	Gabriel Crean	Scientific Director of the Division of Technological Research of the Atomic Energy and Alternative Energies Commission, CEA, France
Prof. Dr.	George Kaptay	Vice-Director on Scientific Affairs of the BAY-NANO Research Institute on Nanotechnology
Dr.	Gianfranco Burzio	Co-leader of the Road Transport Safety & Security working group at ERTRAC
Dr.	Giuseppina Padeletti	Director of the Institute for the Study of Nanostructured Materials (ISMN-CNR)
Dr.	Gudrun Kissinger	IHP, Frankfurt. European Materials Research Society
Prof. Dr.	Hanns-Ulrich Habermeier	European Materials Research Society
Prof.	Hans Richter	E-MRS Vice President
Dr.	Hector Morales	ECTP - ceramics , construction
Dr.	Håkon Finne	Research Manager, Sintef Innovation and Industrial Development
Dr.	Jacques Amouroux	Head of the laboratory Plasma processes for a new chemical engineering
Dr.	Jean-Pierre Massue	E-MRS Headquarters. European Materials Research Society - executive committee member (president 2006-7)

Dr.	Joachim Pelka	Managing Director, Fraunhofer Group for Microelectronics, Germany
Dr.	Joerg K.N. Lindner	Fakultät für Naturwissenschaften, Department Physik, Paderborn University, Germany.
Eng.	Jon Agirre Ibarbia	EUROP: European Robotics Technology Platform
Dr.	José María Lagarón	IATA-CSIC, Valencia, Materials Science, Novel Materials and Nanotechnology
Prof.	Jose Martinez-Duart	Department of Applied Phisics, Madrid Univ. Autonoma, Spain.
Dr.	Luc Federzoni	Research Program manager CEA (France), materials and processes, micro and nanotechnology connected with new energy applications
Prof.	Malgorzata Kujawinska	Warsaw University of Technology, Poland, Vice President ETP Photonics
Dr.-Ing.	Margarethe Hofmann	MAT SEARCH Consulting, Switzerland. FEMS (Federation of European Materials Societies) - Executive officer
Dr.	Maria Cristina Tanese	University of Bari, nanostructured organic based devices.
Dr.	Patrick Bressler	Fraunhofer-Gesellschaft, Director, Brussels Office
Dr.	Paulo Calçada	Chairman of Eurocloud Portugal and Business Development Lead for Instituto de Telecomunicações, telecommunications and business development
Dr.	Pedro Dolabella Portella	President of The Federation of European Materials Societies, c/o BAM Federal Institute for Materials Research and Testing
Prof.	Prof. Claudio Roveda	Consultant of the President in Charge of the Italian National Research Council
Prof.	Rodrigo Martins	Professor at New University of Lisbon, head of the Materials Science Department and the President of the European Materials Research Society
Dr.	Stefan Kaierle	Fraunhofer Institute for Laser Technology, European Technology Platform Photonics21.
Dr.	Stefano de Panfilis	Director of the Research & Development Laboratories Department of Gruppo Engineering
Dr.	Tapasztó Levente	Hungarian Academy of Sciences,Research Institute for Technical Physics and Materials Science
Prof.	Urszula Narkiewicz	Faculty of Chemical Eng. Szczecin Univ of Technology, Poland.
Dr.	Uwe Möller	Advisory Council for Aeronautics Research in Europe

Dr.	Wanda Wolny	R&D managing director of Ferroperm Piezoceramics A/S, and InSensor A/S. Previous convenor for a Standardisation Committee of CENELEC
Dr.	Yves Wyser	Nestlé Research Center - engineered nanomaterials in food
Source: Oxford Research AS		

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Annex 5. Glossary

Applied research: Original investigation undertaken in order to acquire new knowledge. Compared to basic research, it is directed primarily towards a specific practical aim. The results of applied research are intended to be valid for a single or limited number of products, etc. The knowledge or information derived from it is often patented but may also be kept secret.

Basic research: Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view (contrary to applied research). The results of basic research are not generally sold but are usually published in scientific journals. Basic research can be split into two categories: 1) Pure basic research that is carried out for the advancement of knowledge, with no positive efforts being made to apply the results to practical problems. 2) Oriented basic research that is carried out with the expectation that it will produce a broad base of knowledge likely to form the background to the solution of recognised or expected current or future problems or possibilities.

Competitiveness and Innovation Framework Programme (CIP): The Competitiveness and Innovation Framework Programme (CIP) supports innovation activities (including eco-innovation), provides better access to finance and delivers business support services in the regions, targeting mainly small and medium sized enterprises (SMEs).

Entrepreneurship and Innovation Programme (EIP): The EIP is one of the specific programmes under the CIP, supporting innovation and SMEs in the EU. It focuses on access to finance for SMEs, business services (Enterprise Europe Network), support for improving innovation policy, eco-innovation and SME policy-making through contracts and grants.

ERA-NET: European Research Area Network. The principal means for the FP to support the coordination of national and regional research programmes.

EURATOM: The European Atomic Energy Community (EURATOM) is one of the building blocks of the EU. In relation to Community research policy, the EC Framework Programme is complemented by a EURATOM Framework Programme under the Euratom Treaty which covers training and research activities in the nuclear sector.

European Institute for Innovation and Technology (EIT): The EIT is an institute of the European Union, established in March 2008. Its purpose is to increase the sustainable growth and competitiveness of Member States and the EU by developing a new generation of innovators and entrepreneurs. The EIT has created integrated structures, Knowledge Innovation Communities

(KICs), which link the higher education, research and business sectors to one another The KICs focus on priority topics with high societal impact.

European Patent Office (EPO): The European Patent Organisation is an intergovernmental organization that was set up on 7 October 1977 on the basis of the European Patent Convention (EPC) signed in Munich in 1973. It has two bodies, the European Patent Office and the Administrative Council, which supervises the Office's activities.

European Research Area (ERA): A general concept proposed by the Commission and endorsed by the European Parliament and Council in 2001 to overcome the fragmentation of European research and innovation efforts. The concept comprises organising cooperation at different levels, coordinating national or European policies, networking teams and increasing the mobility of individuals and ideas.

European Research Council (ERC): Introduced in FP7, it will be the first pan-European funding agency for frontier research. Early-stage as well as fully established investigators from across Europe will be able to compete for grants with scientific excellence as the sole criterion for funding. The independent Scientific Council will direct the ERC's scientific operations and ensure that its support is in accordance with the highest standards of science and scholarship.

European Technology Platform (ETP): ETPs are industry-led stakeholder fora charged with defining research priorities in a broad range of technological areas. They provide a framework for stakeholders, led by industry, to define research priorities and action plans on a number of technological areas where achieving EU growth, competitiveness and sustainability requires major research and technological advances in the medium to long term. Some ETPs are loose networks that come together in annual meetings, but others are establishing legal structures with membership fees.

Framework Programme (FP): Since 1984, research and innovation activities of the EU are grouped in one big multiannual programme, the Framework Programme for Research and Technical Development. While FP1 to FP6 were each conceived for a period of 4 years, FP7 is synchronised with the duration of the EU's financial perspective and covers the period 2007-2013. The FPs are elaborated and proposed by the Commission and have to be adopted by the European Parliament and the Council in co-decision.

Frontier research/science: Intrinsically risky endeavours at the forefront of creating new knowledge and developing new understanding. Frontier research brings about fundamental discoveries and advances in theoretical and empirical understanding, and even achieves the occasional revolutionary breakthrough that completely changes our knowledge of the world. Frontier science brings new knowledge about the world, while generating potentially useful knowledge at the same time. Therefore, there is a much closer and more intimate connection between the resulting science and technology, with few of the barriers that arise when basic research and applied research are carried out separately.

Future and Emerging Technologies (FET): FETs are the incubators and pathfinders for new ideas and themes for long-term research in the areas of information and communication technologies. They promote high-risk research, offset by potential breakthroughs with high technological or societal impact.

Gross domestic Expenditure on R&D (GERD): Total intramural expenditure on R&D performed on the national territory during a given period. GERD includes R&D performed within a country and funded from abroad but excludes payments made abroad for R&D.

Gross Domestic Product (GDP): This aggregate represents the result of the production activity of resident producer units. It corresponds to the economy's output of goods and services, less intermediate consumption, plus taxes linked to imports. The sum of the regional values of the GDP at market prices might differ from the national values for some countries.

Industrial technologies are most of all represented in European Framework Programmes under the 'NMP' theme, covering Nanosciences, Nanotechnologies, Materials and New Production Technologies.

Information and Communication Technologies (ICT): Information and Communication Technologies are critical to improve the competitiveness of European industry and to meet the demands of its society and economy.

Innovation (Oslo Manual): Both OECD and Eurostat refer to the Oslo Manual for measuring innovation, which identifies four types of innovation: product innovation, process innovation, marketing innovation and organisational innovation. See below: 'Invention vs. innovation'.

Intellectual Property Rights (IPR): Legal rights covering all aspects of owning, protecting and giving access to knowledge and pre-existing know-how.

Internet of Things: refers to uniquely identifiable objects (things) and their virtual representations in an Internet-like structure. Radio-frequency identification (RFID) is often seen as a prerequisite for the Internet of Things. If all objects of daily life were equipped with radio tags, they could be identified and inventoried by computers.

Invention vs. innovation: Both terms are used in similar context, therefore it is important to distinguish the difference even if both have a 'uniqueness' imprint. Invention is defined as the first occurrence of the very idea of a new product or process, while innovation carries an undertone of profitability and market performance expectation. Innovation is a product or process put to use (usability factor) that effectively causes a social and commercial reorganization.

Joint Research Centre (JRC): As a service of the European Commission, the mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. It functions as a reference centre of science and technology for the Union. The JRC has a network of research institutes in different member countries (Belgium, Germany, Italy, Netherlands, Spain). Its activities are financed by the Framework Programme via the direct actions.

Joint Technology Initiative (JTI): JTIs are a means to implement the Strategic Research Agendas (SRAs) of a limited number of European Technology Platforms (ETPs). In these few ETPs, the scale and scope of the objectives is such that loose coordination through ETPs and support through the regular instruments of the Framework Programme for Research and Development are not sufficient. Instead, effective implementation requires a dedicated mechanism that enables the necessary leadership and coordination to achieve the research objectives. To meet the needs of this small number of ETPs, the concept of Joint Technology Initiatives has been developed.

Key Enabling Technologies (KET): KETs are knowledge intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration. KETs can assist technology leaders in other fields to capitalise on their research efforts. KETs include: nanotechnologies, micro- and nanoelectronics, biotechnology, photonics, advanced materials, and a cross-cutting to all above advanced manufacturing systems.

Marie Curie Actions: The main objective of the FP’s Marie Curie Actions is to strengthen the training, career prospects and mobility of European researchers in order to provide support for the development of world-class human resources.

NMP Nanotechnologies and nanosciences, knowledge-based multifunctional materials, and new production processes and devices. NMP is a thematic priority in Framework Programmes of European Commission. The primary objective is to promote real industrial breakthroughs, based on scientific and technological excellence.

More than Moore - technology where added value to devices is provided by incorporating functionalities that do not necessarily scale according to "Moore's Law‟. Moore’s Law is a rule of thumb in the history of computing hardware whereby the number of transistors that can be placed inexpensively on an integrated circuit doubles approximately every two years.

Organisation for Economic Development and Cooperation (OECD): The OECD is an international economic organisation of 34 countries founded in 1961 to stimulate economic progress and world trade. It is a forum of countries committed to democracy and the market economy, providing a platform to compare policy experiences, seek answers to common problems, identify good practices, and coordinate domestic and international policies of its members.

Peer review: The evaluation of proposals with the help of independent external experts (peers). For FP6, the procedures for the evaluation of proposals are described in detail in a Commission decision on 'Guidelines on proposal evaluation and selection procedures'.

Public-Private Partnership (PPP): Public-private partnerships are forms of cooperation between public authorities and businesses, in general with the aim of carrying out infrastructure projects or providing services for the public. These arrangements have been developed in several areas of the public sector and within the EU are used in particular in the areas of transport, public buildings or environment.

R&D intensity: Gross Domestic Expenditure on R&D (GERD) expressed as a percentage of Gross Domestic Product (GDP).

Regions of knowledge: This initiative aims to strengthen the research potential of European regions by encouraging and supporting the development across Europe of regional 'research-driven clusters', associating universities, research centres, enterprises and regional authorities.

Research and Development (R&D): R&D comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of humanity, culture and society, and the use of this stock of knowledge to devise new applications. This term covers three activities: basic research, applied research and experimental development.

Risk-Sharing Finance Facility (RSFF): RSFF is an innovative scheme set up by the European Commission and the European Investment Bank to improve access to debt financing for private companies or public institutions promoting activities in the field of research and innovation.

Small and Medium-sized Enterprises (SMEs): Enterprises having fewer than 250 employees and with either an annual turnover of no more than ECU 40 million or a balance sheet total of no more than ECU 27 million.

Technology platforms: Introduced in FP7, these bring together companies, research institutions, the financial world and regulatory authorities at European level to define a common research agenda to mobilise a critical mass of public and private resources, national and European.

Annex 6. List of acronyms

BAU	Business as usual
BMBF	Federal Ministry of Education and Research in Germany
CAHP	Community Animal Health Policy
CAP	Common Agricultural Policy
CEO	Chief Executive Officer
CFP	Common Fisheries Policy
CH4	Methane
CIP	Competitiveness and Innovation Framework Programme
CLEEN	Cluster for Energy and Environment
CO2	Carbon dioxide
CPC	Community Patent Convention
DER	Distributed Energy Resources
DG	Directorate-General
EAV	European Added Value
EC	European Commission
ECCP	European Climate Change Programme
ECJ	European Court of Justice
EEUPC	European and European Union Patents Court
EIT	European Institute of Innovation and Technology
EPO	European Patent Office
ERA	European Research Area
ERA-EG	European Research Area Expert Group
ERA-NET	European Research Area Network
ERC	European Research Council
ETP	European Technology Platform
EU	European Union
EU-27	27 Member States of the European Union
EUR	Euro
EV	Electric vehicle
FAFB	Food, Agriculture and Fisheries, and Biotechnology
FET	Future Emerging Technologies
FIMECC	Finnish Metals and Engineering Competence Cluster

FP	Framework Program
GDP	Gross domestic product
GE	Gradual evolution
GHG	Greenhouse Gas
GmbH	Gesellschaft mit beschränkter Haftung; limited company
GMO	Genetically modified organisms
GMR	Giant magnetoresistive
GPP	Green Public Procurement
HEV	Hybrid electric vehicle
ICT	Information and Communication Technology
IEG	International Environmental Governance
IES	Institute for Environment and Sustainability
IMP	Integrated Maritime Policy
IP	Intellectual Property
IPR	Intellectual Property Rights
IT	Information Technology
JP	Joint Programming
JRC	Joint Research Centre
JTI	Joint Technology Initiative
JU	Joint Undertaking
KBBE	Knowledge-Based Bio-Economy
LIB2015	The Innovation Alliance 'Lithium Ion battery LIB2015'
MEMS	Micro Electro Mechanical Systems
MOEMS	Optical MEMS
MS	Member State
MtM	More than Moore
NGO	Non-Governmental Organization

NMP	Nanosciences, Nanotechnologies, Materials and new Production Technologies
OECD	Organisation for Economic Co-operation and Development
PCM	Phase change materials
PPP	Public-Private Partnership
R&D	Research and Development
RDI	Research Development and Innovation
RE	Renewable Energy
RES	Renewable Energy Sources
RF	Radio Frequency
RR	Radical reorientation
RSFF	Risk-Sharing Finance Facility
RTD	Research and Technical Development
RTO	Research and Technology Organisations
RYM	Built Environment Innovation Cluster
S&T	Science and Technology
SET	Strategic Energy Technology
SHOK	Strategic Centres for Science, Technology and Innovation
SME	Small and Medium-sized Enterprise
SRS	Stockholm Royal Seaport
STI	Science, Technology and Innovation
TIVIT	One of Finnish Strategic Centres for Science, Technology and Innovation (SHOKs)
UPC	Unified Patent Court
US	United States
VC	Venture Capital
VINNOVA	The Swedish Government Agency for Innovation Systems
WP	Work Programme

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