The Grand Challenge

The design and societal impact of Horizon 2020

Research and Innovation

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The design and societal impact of Horizon 2020

With a preface by the Commissioner for Research, Innovation and Science
Máire Geoghegan-Quinn

Directorate-General for Research and Innovation
June 2012 European Research Area EUR 25271

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Foreword

When the European Commission proposes a new initiative, we expend considerable effort to conduct an in-depth *ex ante* impact assessment involving rigorous analysis of all the evidence and a careful consideration of all policy options. This is especially important when EU financial support is under discussion because, more than ever, we have to make sure that every euro spent at EU level gives maximum return in terms of benefit for European citizens.

I am confident that the impact assessment presented here lives up to this challenge. Horizon 2020 — the Commission's proposal for the next EU programme for research and innovation — is a pivotal part of the Europe 2020 strategy for smart, sustainable and inclusive growth. Only through sufficient investment in developing our research and innovation capacity can we create the new jobs and growth to overcome the current economic crisis.

The challenge is, of course, to make sure that such investment delivers tangible impacts: to help accelerate the development of new technologies and innovations; to generate new markets for innovative products and services; and to provide concrete solutions to society's greatest challenges such as climate change, health, transport, energy and food security.

Our proposal — Horizon 2020 — will support Europe's science base by funding the best fundamental research that leads to the greatest innovations, while helping talented and creative researchers to pursue promising avenues at the frontier of science. It will provide researchers with access to priority research infrastructure, and make Europe an attractive location for the world's best researchers. It will secure Europe's lead in developing the key enabling technologies that will underpin the economic recovery, and will maximise the growth potential of our innovative companies by providing them with adequate finance when they need it.

It will not be business as usual. We are bringing together all EU support for research and innovation within a single programme. We are cutting 'red tape' through the introduction of a single set of rules and simpler programme architecture to allow researchers to spend more time doing what they do best, and not wasting time filling out forms. And, we have introduced new measures to support Europe's fast growing and innovative SMEs.

This impact assessment presents and analyses a number of policy options, and sets out clearly why we believe that the one we have chosen is the best possible option for the EU.

Máire Geoghegan-Quinn
Commissioner for Research, Innovation and Science

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Introduction

'Horizon 2020' is the proposed new seven-year research and innovation programme of the European Union. It is the financial instrument for implementing the Innovation Union, a Europe 2020 flagship initiative set up to strengthen the EU's global competitiveness and create future jobs and growth. Horizon 2020 aims to strengthen the EU's position in science, strengthen industrial leadership in innovation, and address major societal concerns such as climate change, sustainable transport and mobility, and food safety. Horizon 2020 brings together EU research and innovation funding under a single programme: that is, it combines the funding previously separately available from the framework programme for research and technological development (FP), the innovation-related activities of the competitiveness and innovation framework programme (CIP) and the European Institute of Innovation and Technology (EIT). More details can be found on the official website (http://ec.europa.eu/research/horizon2020).

This report presents the results of one of the impact assessments carried out as part of the Horizon 2020 policy formulation process. It explains the problems that the programme aims to tackle, why it is structured as it is, and what it is expected to achieve in terms of impact on Europe's economy and society.

Impact assessment is obligatory for all legislative proposals of the European Commission. The purpose of impact assessment is to ensure that new initiatives and legislation are prepared on the basis of a transparent analysis of robust and balanced evidence. The methodology and procedures used in this report are in line with the European Commission's Impact Assessment Guidelines. The impact assessment is based on robust qualitative and quantitative evidence from numerous sources, including *ex post* and interim evaluations, foresight and forward-looking studies, analyses of science, technology and innovation indicators, econometric modelling, academic literature reviews, sectoral competitiveness studies, expert panels and hearings, and online surveys of FP and CIP beneficiaries.

The report is organised as follows. Chapter 1 presents the outcome of the extensive stakeholder consultations carried out for Horizon 2020 while Chapter 2 goes on to outline the problems that the new programme will seek to tackle. After a summary of the main objectives of the new research and innovation programme in Chapter 3, a number of potential policy options are described in Chapter 4. The foreseen economic, social and environmental impacts of each of the policy options are then analysed in Chapter 5. Chapter 6 concludes with a description of the new monitoring and evaluation system foreseen for Horizon 2020.

1 — Consultation of stakeholders and interested parties

An important element of the impact assessment process is the consultation of stakeholders and interested parties through a variety of methods. The main outcomes of these consultations are presented in this section.

1.1. Consultation and expertise

Early discussions on the future of EU research and innovation funding

Some early views relating to future research and innovation funding were included in the 2009 and 2010 interim evaluations of the CIP (EC, 2010), the FP6 *ex post* evaluation report (Rietschel et al., 2009) and the FP7 interim evaluation (Annerberg et al., 2010). The external experts involved in these evaluation studies identified achieving excellence in research, the importance of innovation for competitiveness, and the role of research and innovation in tackling societal challenges such as ageing, energy dependence, climate change, etc., as key themes for any future EU research and innovation funding programme.

Several forward-looking conferences were organised by the various EU presidencies (e.g. the Swedish Presidency in July 2009; the Hungarian Presidency in February 2011). In 2011, two major stakeholder conferences were organised in Brussels. The first conference, *Ready to Grow? Shaping future EU support for business*, was held on 25 January 2011 and attended by over 550 participants including innovation agencies, industries, universities, NGOs, intermediary associations. The second conference on funding for the framework programme for research and innovation was held on 10 June 2011. The conference concluded the public consultation on the Green Paper (see the next section) and was attended by over 650 participants from Europe's research and innovation community.

Throughout 2010, and in anticipation of the debate on the next EU multiannual financial framework (MFF) 2014–20 and the related future funding programmes, a wide range of stakeholders published position papers on the future of EU research and innovation funding. This included Member States and associated countries, regional governments, national research councils and a number of European representative organisations.

Different methods employed to consult stakeholders and interested parties

- Public consultation on the Green Paper *From Challenges to Opportunities: Towards a Common Strategic Framework for future EU Research and Innovation funding*
- Public consultation on the successor to the competitiveness and innovation framework programme (CIP)
- FP6 *ex post* evaluation (chair: Ernst Rietschel) with a view on the future, February 2009
- FP7 interim evaluation (chair: Rolf Annerberg), November 2010
- CIP interim and final evaluations, *ex ante* evaluations and impact assessment studies for the ICT-PSP, IEE and innovation-related parts of the EIP programme
- Large stakeholder conferences for successor of CIP (January 2011) and CSF (June 2011) held in Brussels
- Expert Panels and Stakeholder Conferences for European Research Council, Marie Curie Actions, European Institute of Innovation and Technology ...
- EU Presidencies: Lund conference on future of EU research (Sweden, July 2009); FP7 interim evaluation conference (Hungary, February 2011)
- Wide range of position papers on future EU research and innovation funding during EU budget preparations
- Thematic stakeholder consultations: ICT, transport, health, biotechnology, space ...
- Discussion with representatives of national administrations (CIP Joint Management Committees meeting)

The Green Paper stakeholder consultation

After these early discussions, the Commission took the initiative to launch a public consultation on the future of EU research and innovation funding (EC, 2011b). The consultation was based on the Green Paper *From Challenges to Opportunities: Towards a Common Strategic Framework for Research and Innovation Funding*. Stakeholders were asked for their views on how best to adapt the EU's research and innovation funding in the new policy context of Europe 2020 and the Innovation Union.

The public consultation was launched on 9 February 2011. A dedicated consultation website and an interactive blog were set up. The deadline for submitting responses was 20 May 2011. A conference was organised on 10 June 2011 in Brussels to present and discuss the outcome of the consultation.

The consultation was met with an overwhelming response. Some 2 078 responses were received in total, including an unprecedented 775 position papers and 1 303 responses to the online questionnaire. Contributions were received from a wide range of stakeholders, the highest numbers coming from the research and higher education sectors (50 %), followed by associations and interest groups (29 %), the business sector (12 %) and government bodies (9 %). There was a broad coverage of all EU-27 Member States as well as a significant number of other countries.

Complementary consultations

In addition to the dedicated consultation on the basis of the Green Paper, complementary consultations have been organised on particular aspects of the EU's research and innovation funding. These include public consultations on the future of the current competitiveness and innovation framework programme and on the future strategy for the European Institute of Innovation and Technology (EIT). According to the provisions laid down in the EIT Regulation, the specific EIT-related aspects are dealt with in a dedicated impact assessment.

1.2. The views of stakeholders on future policy options

These various discussions and consultations revealed striking similarities within each group of actors. The key messages to emerge follow.

- **The private sector** emphasised the need for more simplification combined with more attention dedicated to innovation-supporting actions. A broad concept of innovation should be applied including non-technological and non-research-based innovation and activities such as design, creativity, service, and process and business-model innovation. EU funding for research and for innovation should be brought closer together in order to enhance its impact and bring new ideas to the market in a more efficient manner. As such, they welcomed a policy option aimed at decreasing implementation costs due to more integration and simplification through, for example, a common set of rules for participation in the different strands of action. They also welcomed a policy option that would bridge research and innovation vigorously and focus strongly on the dissemination of the results of research projects to allow for their valorisation into new products, processes and services.

- **Universities and research centres** equally emphasised the need for further simplification but also expressed strong support for research actions linked to societal challenges as well as basic research funding through the European Research Council. Distributing EU research and innovation funding based on excellence was considered, by the academic research community (but other actors also emphasised this), a key principle of any future EU research and innovation framework. An improved business-as-usual option was seen as the minimum requirement: improved in terms of simplification, but continuation in terms of scope covering the current wide range of thematic research areas and types of research (basic and applied).

- **Public organisations and government bodies** all emphasised the need for a European-level framework for research and innovation support actions, thereby discarding the 'renationalisation' option. Several Member States emphasised the need to continue with those aspects of the current programme that work well and are very much appreciated, such as the Marie

Curie Actions, the Risk-Sharing Finance Facility and transnational collaborative research (the academic community added the European Research Council to this list). The Structural Funds should be used to unlock the full research potential of Europe's less-favoured regions.

The common denominator among all actors was their agreement on the need to further simplify participation in European research and innovation framework programmes, which would argue against a simple continuation of the current system (business-as-usual).

2 — Problem definition

2.1. The problem that requires action and its underlying drivers

The problem

In this the second decade of the 21st century, with a backdrop of a changing world order, Europe faces a series of crucial challenges: low growth, insufficient innovation, and a diverse set of environmental and social challenges. Europe 2020, the EU's comprehensive long-term strategy, recognises these challenges and argues that Europe faces a moment of transformation. This perspective is taken up in the Commission's communication of June 2011 introducing the proposal for the next EU multiannual financial framework 2014–20, which underscores the pivotal role of Horizon 2020 in addressing these challenges.

The solutions to all of these problems are linked: it is precisely by addressing its environmental and social challenges that Europe will be able to boost productivity, generate long-term growth and secure its place in the new world order. The OECD (2011) has acknowledged that 'green and growth can go hand-in-hand'. The United Nations, too, has observed that there is no inescapable trade-off between environmental sustainability and economic progress: the greening of economies creates growth and employment (UNEP, 2011). In the same vein, the European Commission published the communication *GDP and beyond — Measuring progress in a changing world* (EC, 2009a) and is pursuing sustainable and inclusive growth through Europe 2020.

The key problem driver

Science and innovation are key factors that will help Europe move towards smart, sustainable, inclusive growth, and along the way to tackle its pressing societal challenges. Box 1 shows why research and innovation are key engines of productivity and growth.

Europe suffers from a number of critical weaknesses in its science and innovation system, however, which contribute to the above problems of low productivity, declining competitiveness, inadequate response to societal challenges, and the inability to move to a new sustainable economic model.

The key weakness driving the problem above is Europe's **innovation gap.** To boost future productivity and growth, it is critically important to generate breakthrough technologies and to translate them into innovations (new products, processes and services) that are taken up by the wider economy. However, while Europe has taken an early technological lead in many 'green' and 'quality of life' (health, security, etc.) technologies, its advantage is tenuous in the face of growing competition, and has not translated into an innovative and competitive lead. It is imperative to establish a timely and targeted European policy in bridging the 'valley of death' for Europe to remain competitive. Many of Europe's global competitors, including China, Taiwan and the United States, have already developed policy measures in strategically important areas by bringing together different academic and industrial actors along the length of the innovation chain.

The underpinning structural problem drivers

Underlying the key problem driver is a series of structural problems.

Insufficient contribution of research and innovation to tackling societal challenges

Although many major societal challenges will have the same profound effects on all EU countries, there is still a relatively weak coordinated response at a pan-European level in the field of science and innovation. If each Member State provides its own response in an uncoordinated way, there is a danger of missing important opportunities for generating scale and interactions. To be successful, Europe must stimulate coordinated research aimed at addressing these challenges and improve the way it is transformed into new products and processes and it must enhance the interaction between research and innovation actions and the sectoral policies related to the challenges.

Box 1: **Research and innovation — Key engines of productivity and growth**

A wealth of evidence demonstrates the crucial role that research and innovation play in the sustainable growth of productivity and thus in economic growth.

- Modern economic theory unanimously recognises that research and innovation are prerequisites for the creation of more and better jobs, for productivity growth and competitiveness, and for structural economic growth.
- The key role played by research and innovation in structural economic growth is highlighted by the modern 'growth accounting' literature, which integrates the concept of intangible assets (INNODRIVE, 2009).
- An extensive body of macro and microeconomic literature has produced a number of clear conclusions:
  - *the returns on total R & D are high:*
    - a 0.1 percentage point increase in R & D could boost output per capita growth by some 0.3–0.4 % (Bassanini and Scarpetta, 2001);
    - an analysis by the JRC based on the Regional Holistic Model (RHOMOLO) shows a positive impact of increasing R & D intensity on real GDP growth in all countries and regions;
  - *the returns on public R & D are high*:
    - the rate of return on publicly funded R & D usually exceeds 30 %;
    - each extra 1 % in public R & D generates an extra 0.17 % in productivity growth (Guellec and van Pottelsberghe de la Potterie, 2001 and 2004);
  - *the returns on private R & D are high*:
    - firms' returns on their own investment in research usually range from 20 % to 30 % — societal returns on firms' investment in research usually range from 30 % to 40 %;
    - each extra 1 % in business R & D generates an extra 0.13 % in productivity growth (Guellec and van Pottelsberghe de la Potterie, 2001, 2004);
  - *research and innovation are vital for industrial competitiveness:*
    - the ability to innovate is positively related to firms' export performance; it also supports more complex internationalisation strategies, such as exporting to a larger number of markets, to more distant countries and producing abroad through FDI or international outsourcing (Navaretti et al., 2010);
  - *technological change boosts employment*:
    - the often accepted view that innovation destroys jobs is wrong; innovations have a positive and significant effect on employment, which persists over several years (Van Reenen, 1997);
    - for example, an increase in business R & D of 1 % is associated with an increase in business employment of 0.15 % (Bogliacino and Vivarelli, 2010).

Insufficient technological leadership and innovation capability of firms

Europe faces a declining share of global patents, a rising high-technology trade deficit and an insufficient number of high growth innovative companies in the high-tech sector. If it is to address its innovation gap, Europe needs to improve its performance in key enabling technologies which will provide the basis for important new markets. And, if it is to get its good ideas to market, it must improve the capability of firms to innovate, in particular SMEs. Access to finance for pulling innovations through to the market is still a major problem for companies, and SMEs still face special problems in this context. Box 2 and Figure 1 show how Europe currently lags in terms of patents in specific areas and is likely to start lagging in terms of its overall share of global patents.

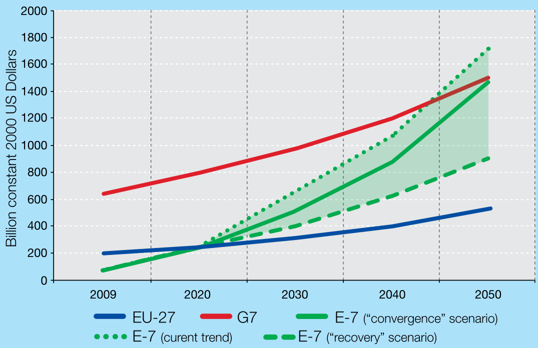
The need to strengthen the science base

Europe has a historically strong science base, but when it comes to highly cited science or top ranking universities, it often lags behind the United States. For example, 15 % of US scientific publications are among the top 10 % most cited publications worldwide, only 11 % of EU publications fall into this category. And Europe now faces increasing competition as well from the emerging countries. If it is to strengthen its scientific and technological performance, and to provide the basis for future competitiveness, it needs to increase its spending — in 'blue sky' frontier research, in associated infrastructure, in training and education — and to make this spending more effective. Box 2 shows how Europe lags in terms of its share of global R & D investment.

Box 2: **Long-term global trends in research spending and technological performance**

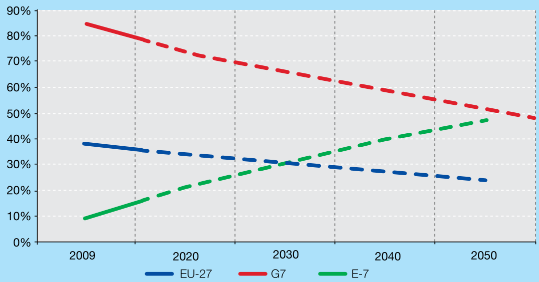
Emerging economies are growing at a rapid pace and will soon transform the global landscape for research and innovation. The figure on the left in this box shows the potential trends in R & D spending. Under conservative assumptions for growth and R & D spending ([1]), the emerging economies (Brazil, China, India, Indonesia, Mexico, Russia and Turkey) could be investing the same volume of R & D as the G7 countries by 2050 and, by 2020, they could already be investing more than the EU. This expansion of R & D spending by the emerging countries should inevitably lead to their producing more patents in the coming decades. As seen in the figure on the right in this box, whereas the G7 currently account for 85 % of PCT patent applications compared with only 8 % for the E7 countries, by 2050, the G7 share could have diminished to 50 %, with the E7 countries at nearly the same level (46 %).

Long-term trends in R & D spending — emerging economies, G7 countries, EU-27



Source: Directorate-General for Research and Innovation.
Data: HSBC estimates of GDP growth, the OECD, World Bank.

World shares of PCT patents ([2]) — emerging economies, G7 countries, EU-27



Source: Directorate-General for Research and Innovation.
Data*:* OECD patent database.

1. The graph is based on GDP growth forecasts made by HSBC (*The World in 2050 — Quantifying the Shift in the Global Economy*, HSBC, January 2011), and uses data from the OECD and World Bank. The G7 is the group of seven industrialised nations: Canada, France, Germany, Italy, Japan, United Kingdom and the United States; the E7 is a group of rapidly emerging economies: Brazil, China, India, Indonesia, Mexico, Russia and Turkey. The three scenarios are: (i) the Current trend scenario where the projections are based on the trend observed during the period 1996–2007 (the maximum R & D intensity for each country is limited to 5 %); (ii) the Convergence scenario assumes that R & D expenditures for all countries will continue along the current trend but, for E7 countries once an R & D intensity of 3 % is reached, the annual R & D intensity growth for that country is limited to 1 %; (iii) the Recovery scenario assumes that G7 countries will — by 2020 — spend at least 3 % of GDP on research and will continue to increase their investments. After 2020, it is assumed that the annual growth rate of R & D intensity in the G7 will be the average annual growth rate during the period 1990–2020.
2. The graph is based on the assumption that R & D spending in the E7 and G7 will evolve in line with the 'convergence scenario' in the left figure above. It assumes a gradually increasing propensity to patent (patent/business R & D ratio) for the E7 countries and a stable propensity for the G7. Data are for patent applications filed under the PCT, at international phase, designating the European Patent Office (the PCT is a system facilitating the worldwide filing of patent applications).

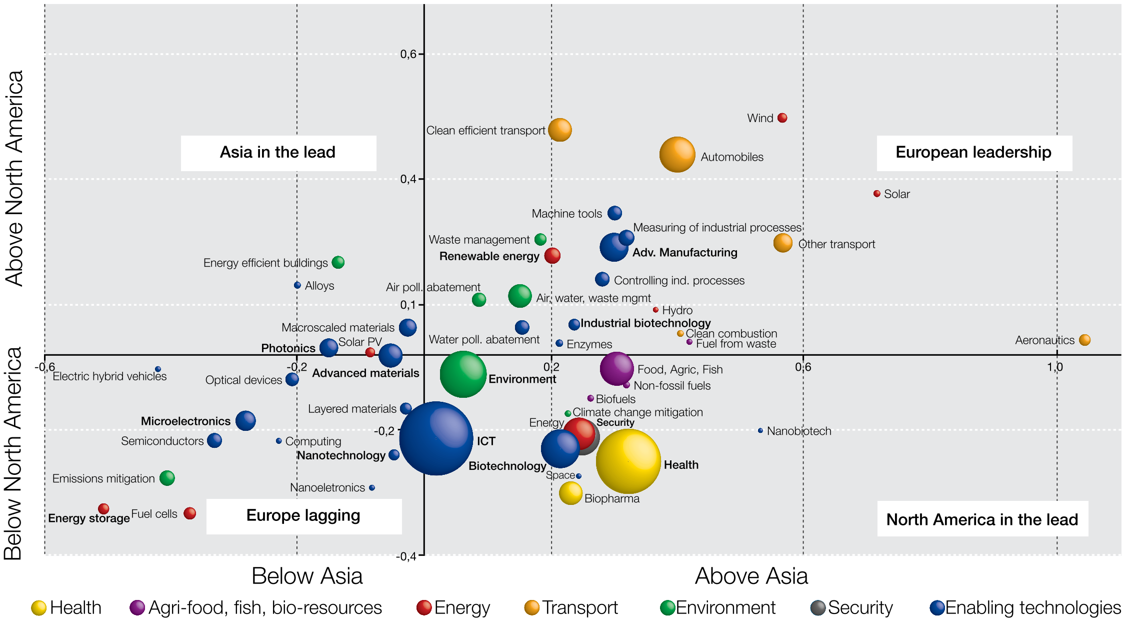
Insufficient cross-border coordination

The European Research Area is not yet achieved: Europe's research and innovation system remains constrained by national borders. Research funding is often dispersed, leading to duplication and inefficiencies. In spite of the benefits of coordination, almost 90 % of R & D budgets are spent nationally without coordination across countries. Box 3 shows how fragmentation negatively affects the efficiency of public funding of research and innovation in Europe.

Of course, it should be understood that a model that is at once sustainable, inclusive and smart will not depend solely on S&T but also on governance and on the involvement of the citizens who will make up our society — and shape it. A shift towards the 'demand side' together with users' (and, more broadly, citizens') involvement is not only a prerequisite for more robust and flourishing technologies, it is also a prerequisite for more robust and flourishing societies.

In addition, though a large part of the solution, science, technology and innovation are not a panacea. For greening the economy, for example, recycling will need to be stepped up, business incentives will need to be changed (e.g. by shifting taxation from labour to resource use); business models will need to be adapted (e.g. by paying for services instead of products); consumers will need to be incentivised to mend

Figure 1: **Europe's technological performance compared with North America and Asia** (3)



Source: Directorate-General for Research and Innovation.
Data: OECD patent database and specific studies (4).

and renew rather than discard; labourers will need to be retrained and citizens will need social protection (Friends of Europe et al., 2011). Specific research on these aspects will be needed as well.

2.2. Who is affected by these problems?

The problems identified above affect all groups in society in diverse ways, and if nothing is done, the negative impacts will continue to grow.

European citizens are affected across a range of issues: they require and expect high-quality healthcare and solutions to fatal and debilitating illnesses; they hope that science and innovation can tackle problems such as climate change, clean energy, clean transport, an ageing population; and they look to Europe's research and innovation system to come up with new sources of jobs and higher standards of living.

Europe's Enterprises require a strong science and innovation system if they are to compete, expand and move into the emerging markets of the future. The problem of poor knowledge triangle coordination means that they have difficulties in linking to, and exploiting, basic research and in tapping into a pool of trained researchers. European companies, and notably SMEs, also face problems in accessing the finance they need for innovation.

EU Universities and public research centres must perform in an ever more global environment by raising the quality of their research and attracting the best scientists worldwide. But competition for funding is still very nationally based, as are the research projects themselves and — when scale is a factor for success — they face limits as to what they can achieve in terms of breakthroughs. They have mixed success in forging links with innovation, and creating spin-off companies.

3. (i) For each technology field, the X-axis of the graph shows the global market share of Europe in terms of EPO/PCT patents compared with the market share of Asia (expressed as a logarithm), and the Y-axis shows the market share of Europe compared with the market share of North America (expressed as a logarithm); (ii) the broad technology domains are shown in bold.
4. Data for the broad technology domains were taken from a study by the Research Division INCENTIM (MSI, Faculty of Business & Economics, KU Leuven), and Università Commerciale Luigi Bocconi, KITeS; data for enabling technologies taken from the 'European Competitiveness in Key Enabling Technologies' project, Birgit Aschhoff, Dirk Crass, Katrin Cremers, Christoph Grimpe, Christian Rammer (ZEW, Mannheim), Felix Brandes, Fernando Diaz-Lopez, Rosalinde Klein Woolthuis, Michael Mayer, Carlos Montalvo (TNO, Delft), 28 May 2010, Study commissioned for the European Commission, Directorate-General for Enterprise and Industry; all other data from the OECD Patent Database.

Box 3: **Fragmentation versus inefficiency of public funding of research and innovation in Europe**

Among the various factors that can explain the efficiency of public support for S&T, one is specific to the EU: the fragmentation of public funding. Almost 90 % of public support for civil R & D is decided directly by the Member States without any prior cooperation or even coordination. Only 12 % of public funding is allocated through cooperative schemes — such as EU framework programmes, EUREKA or intergovernmental collaborative measures — which help avoid duplication between different national and regional funding actions. This suboptimal situation is often tolerated, and sometimes seen as unavoidable, or even as a natural result of the competition between different national systems. However, a number of expert commentators have described this situation as a 'fragmentation' of public financing. They maintain that competition should occur at the stages of research execution and of the dissemination/commercialisation of the results of national research programmes, and not at the public funding stage, because this leads to inefficiencies and duplication between uncoordinated funding schemes.

The case of nanotechnology is a perfect illustration of the negative impact of fragmentation of public resources on scientific and technological performance. In this key enabling technology, which is critical for future international competitiveness, the EU spends more public money annually than other developed or emerging countries.

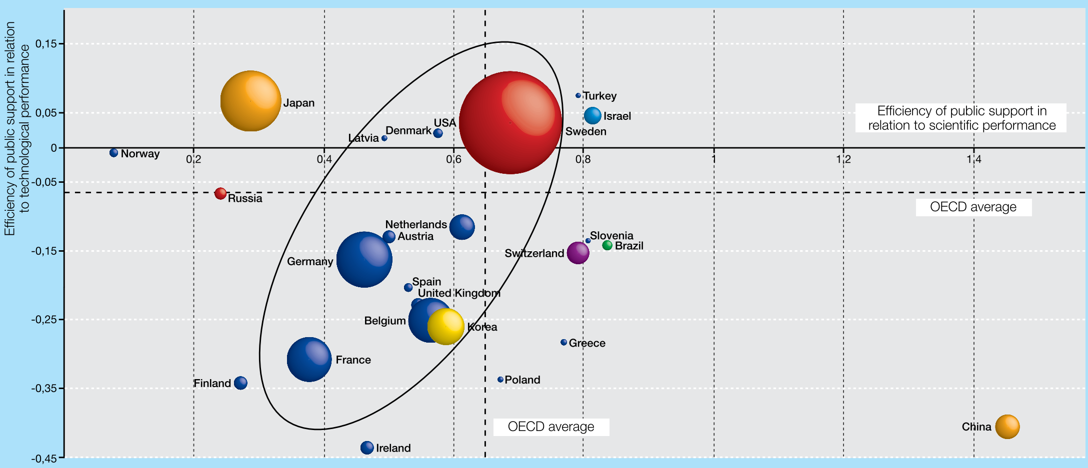
According to several recent estimates (NMP Scoreboard, 2011; Roco et al., 2010; OECD, 2009), the Union spends around EUR 1.5 billion annually (including the 27 Member States' national funding and EC funding), which is considerably more than the United States (EUR 1 billion), Japan (EUR 0.47 billion) and China (EUR 0.1 billion).

However, as highlighted in a recent communication from the European Commission (EC, 2009), 'despite these relatively high levels of funding, the EU is not as successful in deploying nanotechnology as, for example, the United States, when looking at the ability to transfer knowledge generated through R & D into patents'.

The situation is similar if one looks at highly cited scientific publications, where 10 % of EU publications are in the top 10 % most cited publications, compared with 16.1 % for the United States, 5.4 % for Japan and 8.1 % for China. Another indication of Europe lagging behind is the market introduction of nanotechnology-based products and applications. According to a recent nanotechnology product inventory compiled by the Project on Emerging Nanotechnologies at the Woodrow Wilson International Centre, a total of 53 % of identified nanotechnology-based products come from the United States, followed by companies in East Asia (24 %), Europe (15 %), and other world regions (8 %).

The figure in this box shows the scientific and technological performance of selected developed and emerging countries (expressed in terms of the number of patents per EUR 1 million of public R & D support (2000–05) and the number of highly cited publications per EUR 1 million of public R & D, with the size of the bubble representing the volume of public R & D funding). Fragmented public funding in Europe leads to lower scientific and technological outputs per euro invested: the efficiency of EU countries can be seen lagging behind the United States and the OECD average. Given the relatively low numbers involved, the performances of those countries with low funding levels should not be over-interpreted.

Efficiency and fragmentation of public support in Europe: the case of nanotechnology ([5])



Source: Directorate-General for Research and Innovation.

5. National funding is calculated as the annual average over the period 1999–2005. For the European countries, public funding includes both national funds and EU framework programme funding. Data are taken from the following sources: Larsen et al., 2011; Roco et al., 2010; OECD, 2008, 2009.

At the same time, governments increasingly expect universities and public research centres to prove the societal and economic impacts of their research.

Government ministries and agencies responsible for science and innovation across Europe need to develop more effective policies to address societal challenges, and to stimulate competitiveness, through intervention in research, education and innovation. Policies to promote knowledge triangle linkages remain problematic. Government bodies increasingly recognise the need to promote excellence by increasing competition for public research and innovation funding, and face the limitations of doing this at a purely national level. More and more, they stress value for money and impact as key funding aims, and look to transnationally coordinated programmes and projects as an important channel for achieving them — through access to complementary knowledge, resources and networks.

2.3. The policy context

The European Union recognises the urgency of the situation, and is responding with new policy strategies. Europe 2020 and the Innovation Union flagship initiative have given a clear signal that the EU intends to rise to the challenge. Europe 2020 focuses on achieving smart growth, while the Innovation Union sets out measures to contribute to this aim. These include increasing investment in R & D and innovation to 3 % of EU GDP by 2020, improving conditions for R & D and innovation (with the development of a new Europe 2020 headline indicator related to the weight in the economy of fast growing innovative companies, underpinning the capacity of Europe to transform its economy), refocusing R & D and innovation policy on major challenges for our society (e.g. climate change, energy and resource efficiency, health and demographic change), and strengthening the links in the innovation cycle (from frontier research right through to commercialisation). In addition, the European Council has called for a completion of the European Research Area by 2014 in order to create a genuine single market for knowledge, research and innovation, which will require both funding and non-funding measures: funding is not always the appropriate solution and there is also a need for regulation, self-organisation, etc. A key challenge for the EU in implementing its strategy will be to build a next-generation expenditure programme which matches this level of ambition in both its budget and its aspirations.

2.4. The need for EU intervention — subsidiarity and European added value

The need for public intervention

Markets alone will not deliver European leadership in the new techno-economic context. The need for public intervention in research and innovation has never been in doubt. Research and innovation suffer from important market and systemic failures, in particular the further one is removed from the market, justifying public intervention at the best of times (see Annex 2 for more details). These always present failures are magnified, however, in times of systemic shifts in basic technologies. Locked-in investments, vested interests, high risks, and the need for significant investments in less profitable alternatives mean that change will be slow without a major push. In the case of eco-innovation, for example, on top of generic innovation barriers, there are additional barriers that slow down development in the market and that justify additional policy efforts. Examples of these specific barriers are the failure to price environmental externalities, the lack of appropriate and credible information on the performance of some eco-innovative solutions or the additional difficulties in accessing and providing finance to these types of businesses. Large-scale public intervention in research and innovation is needed, through both supply and demand measures, such as pre-commercial public procurement of innovation.

The need for EU-level intervention

There is compelling evidence that Member States acting alone will not be able to make the required public intervention. Their funding of research and innovation was low when the economy was doing well, and is unlikely to increase in the near future as the economic-financial crisis continues to constrain public budgets (see Box 2). When investment does take place, it suffers from fragmentation and inefficiencies (see

Box 3 and Annex 3). Security research constitutes a good example: total Member State public investment in security research does not exceed the FP7 budget for security research and suffers from fragmentation (highlighting clearly the added value of EU-level intervention in terms of achieving an appropriate, 'critical mass' level of investment and battling fragmentation).

The added value of EU-level intervention

The EU is well positioned to add value by delivering the large-scale investment in 'blue sky' frontier research, in targeted applied R & D, and in the associated education, training and infrastructures which will help strengthen our performance in thematically focused R & D and enabling technologies; by supporting companies' efforts to exploit research results and to turn them into marketable products, processes and services; and by stimulating the uptake of these innovations. A series of cross-border actions — concerning the coordination of national research funding, EU-wide competition for research funding, researcher mobility and training, coordination of research infrastructures, transnational collaborative research and innovation, and innovation support — are most efficiently and effectively organised at European level (see Box 4 and Annex 2). *Ex post* evaluation evidence has convincingly demonstrated that EU research and innovation programmes support research and other activities that are of great strategic importance for participants, and that in the absence of EU support would simply not take place (see Box 5). In other words, there are no substitutes for EU-level support.

Evidence also demonstrates the European added value of policy support actions, which derives from bringing together knowledge and experience from different contexts, supporting cross-country comparisons of innovation policy tools and experiences, and providing the opportunity to identify, promote and test best practices from over the widest possible area.

The challenge facing the EU now is to design the next multiannual financial framework 2014–20 so as to propel Europe into the premier position in establishing a green, healthy and secure economy. And, to do this, it must build a next-generation expenditure programme for research and innovation which is equal to the level of ambition of Europe 2020 and the Innovation Union.

2.5. The EU's right to act

The EU's right to act in this area is set out in the Treaty on the Functioning of the European Union. Firstly, Community research policy has a number of overall objectives as stated in the Treaty on the Functioning of the European Union, which include: under Article 179, the strengthening of its scientific and technological bases by achieving a European research area in which researchers, scientific knowledge and technology circulate freely, and encouraging it to become more competitive, including in its industry, while promoting all the research activities deemed necessary by virtue of other chapters of the Treaties; and under Article 180, implementing research, technological development and demonstration programmes, by promoting cooperation with and between undertakings, research centres and universities; promoting research cooperation with third countries and international organisations; disseminating and optimising the results of EU research, technological development and demonstration activities; and stimulating the training and mobility of researchers in the Union.

In addition, Article 173 of the Treaty sets out the objective to ensure that the conditions necessary for the competitiveness of the Union's industry exist. It includes fostering better exploitation of the industrial potential of policies of innovation, research and technological development.

The European Atomic Energy Community Programme (2014–18) contributing to Horizon 2020 has its legal basis in the Euratom Treaty (in particular Article 7).

2.6. Experience from previous programmes: achievements

The next-generation EU programme in the field of research and innovation can build on the extensive experience accumulated through the implementation of the framework programme (FP), the innovation-related part of the competitiveness and

Box 4: **European added value — Why fund research and innovation at EU level?**

EU support to research and innovation is provided only when it can be more effective than national funding. This is achieved through measures to coordinate national funding, and through implementing collaborative research and mobility actions.

Coordinated funding and agenda-setting

EU initiatives help coordinate funding across national borders and to restructure the R & D and innovation landscape in Europe.

- The EU has created the European Research Council. Without it, the EU would have a landscape of compartmentalised national research councils, but no mechanism to promote EU-wide competition for funds and to encourage higher scientific quality.
- As a result of EU leadership, for the first time, a pan-European strategy on research infrastructures is now being implemented.
- The EU helps private companies come together and implement joint strategic research agendas through tailored instruments, such as European Technology Platforms and Joint Technology Initiatives.
- The EU brings together compartmentalised national research funding using instruments such as ERA-NETs and Article 185 initiatives, which set common agendas and achieve the funding scale required for tackling important societal challenges.
- The EU brings Member States together to test the deployment of innovative technologies (i.e. ICT applications at real-scale or large demonstration programmes in security — maritime surveillance, transport, crisis management, etc.).
- The EU brings together the public and private sectors to exchange best practices, share knowledge and, thereby, influence the innovation and other policies of Member States (PRO INNO Europe®, Europe INNOVA initiatives, environmental policies, security policies, etc.).
- Through its Marie Curie Actions, the EU sets standards for innovative research training and career development and puts in place a framework for the free movement of knowledge.

Coordinated funding reduces duplication and increases efficiency. EU support is vital — none of the above measures would have seen the light of day without an EU initiative.

Collaborative research projects and mobility actions

When it comes to implementing research and innovation projects, EU actions add value by stimulating transnational collaboration and mobility.

These actions generate a series of benefits that could not be achieved by Member States acting alone.

- Support for collaboration helps achieve the critical mass required for breakthroughs when research activities are of such a scale and complexity that no single Member State can provide the necessary resources (space, security, etc.).
- The EU supports research which addresses pan-European policy challenges (e.g. environment, health, food safety, climate change, security), and facilitates the establishment of a common scientific base and of harmonised laws in these areas.
- Working in transnational consortia helps firms to lower research risks, enabling certain research to take place. Involving key EU industry players and end-users reduces commercial risks, by aiding the development of standards and interoperable solutions, and by defragmenting existing markets.
- Collaborative research projects involving end-users enable the rapid and wide dissemination of results leading to better exploitation and a larger impact than would be possible only at Member State level.
- SME involvement in research and innovation at EU level improves their partnerships with other companies and laboratories across Europe, and enables them to tap into Europe's creative and innovative skills potential, to develop new products and services, and to enter new national, EU or international markets.
- Companies can collaborate with foreign partners and end-users on a scale not possible at national level, in projects tested for excellence and market impact, which induces them to invest more of their own funds than they would under national schemes.
- Cross-border mobility and training actions are of critical importance for providing access to complementary knowledge, attracting young people into research, encouraging top researchers to come to Europe, ensuring excellent skills for future generations of scientists, and improving career prospects for researchers in both public and private sectors.
- Cross-border innovation support leads to better policies and tools to help businesses bring innovation to the market.

Pilot and market replication projects focused on societal challenges

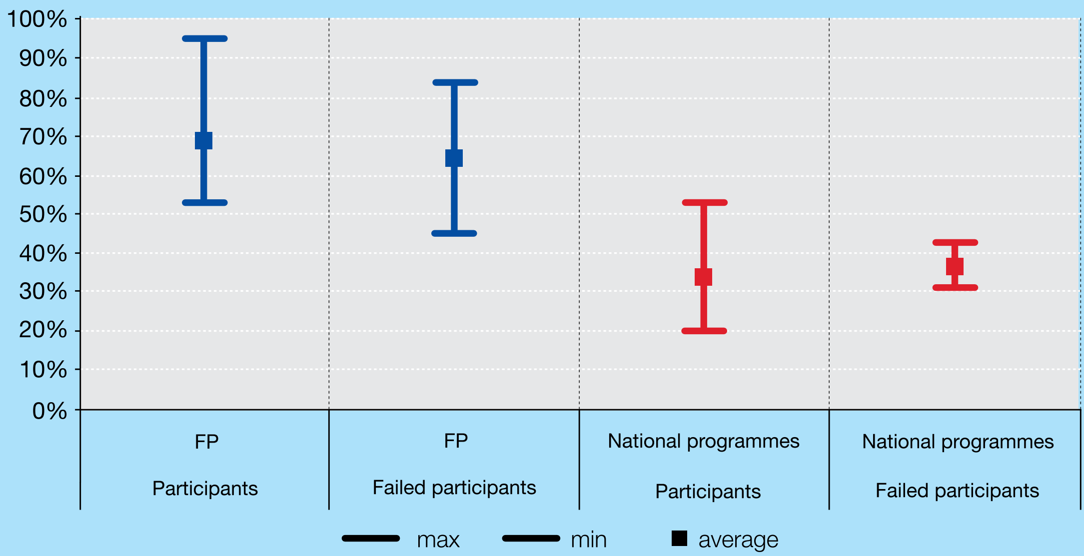
- The CIP supports eco-innovation addressing societal challenges such as resource efficiency and climate change. Pilot and market replication projects help European SMEs to partner, overcome market barriers, and position themselves successfully in the European market.

Source: Directorate-General for Research and Innovation, Directorate-General for the Environment.

Box 5: **Assessing the added value of EU research and innovation programmes: Measuring additionality**

Because of the benefits offered by EU cross-border research, innovation and mobility actions — critical mass, addressing pan-European challenges, reducing risk, setting up European standards — it is not surprising to find that EU projects tend to be of strategic importance to participants. There is solid evidence of this from numerous recent studies. For example, a survey covering FP6 (IDEA Consult, 2009) found that 'the average research project funded under FP6 [concerns] long-term, strategically highly important, technically highly complex R & D in a core technological area of the organisation … It is tightly linked with other in-house projects but mainly considered only feasible with external collaborators'.

Project additionality — comparison of FP and national programmes
(% respondents who did/would abandon the project without programme funding)



Source: Directorate-General for Research and Innovation.
Data: FP data is based on 20 studies of additionality of EU support; national programme data based on studies for Member State programmes in Austria, Belgium (two), Finland, and Norway (see Annex 2 for details).

But, EU projects are not just strategically important. Without the FP, most of them would simply not take place at all, or would be far less ambitious. The graph in this box summarises the findings from 25 recent studies on the additionality of public R & D funding ('additionality' means looking at what would have occurred without public funding). What is clear is that the FP achieves very high levels of overall 'project additionality' (i.e. the great majority of FP participants would not have carried out their projects at all without FP funding). This finding also holds true for rejected applicants for FP funding, the great majority of whose rejected FP proposals were never subsequently implemented. However, it is also apparent from the graph that the 'project additionality' achieved by the FP is much higher than that of most national R & D funding schemes. In other words, it seems that there are far fewer substitutes for EU funding than there are for national schemes.

When it comes to those projects that would have been carried out even in the absence of EU funding, the great majority would have changed dramatically, thus undermining their strategic importance. They would have been carried out on a smaller scale (with less money, with fewer partners), with a reduced scope (less ambitious), or at a later stage or over a longer period of time (such effects are referred to as 'behavioural additionality'). Moreover, this 'behavioural additionality' is also higher for the FP than for national R & D schemes.

Similarly, participants in the CIP eco-innovation projects indicate that they would not have benefited from the cross-border cooperation, learning and resulting EU-wide market scope if they only had access to national support programmes.

innovation programme (CIP), and the European Institute of Innovation and Technology (EIT) (see Annex 1 for a comprehensive analysis of past achievements and impacts). Over a period spanning several decades, EU research and innovation programmes have succeeded in involving Europe's and, indeed, the world's best researchers and public and private institutes and produced large-scale structuring effects, scientific, technological and innovation impacts, microeconomic benefits, and downstream macroeconomic, social and environmental impacts in and for all EU Member States (see Box 6).

The FP has, first of all, achieved a vast reach, involving Member States and associated countries in accordance with their economic and research capabilities, and provided them with large-scale knowledge returns. It has also been successful in attracting large numbers of top EU and extra-EU researchers into thousands of high-quality cross-border projects which enable interaction between firms, universities and research institutes. Without EU funding, these projects would not have been carried out, or would have been postponed or scaled down (financially, in scope and ambition, or in terms of the number of partners). The FP has funded excellent, often interdisciplinary, collaborative research on a very wide range of topics.

The FP has also facilitated the training and pan-European/extra-European mobility of researchers and enhanced the quality of doctoral training (including through industrial doctorates). It has added to the research capabilities of participating institutions and formalised and oriented the R & D and innovation processes of organisations, notably organisations that are small (e.g. SMEs), young (e.g. start-ups) and from recently acceding Member States and candidate countries. The example of FP6 and FP7 Future and Emerging Technologies (FET) is illustrative. FET fulfils its mission of triggering explorative research, and has a strong effect on strengthening the competitiveness of participating organisations. It also contributes to a high degree to the enhancement of skills and capabilities of R & D staff and linkages between universities and research institutes (Wing, 2009).

In addition to producing new knowledge embodied in large numbers of influential (highly-cited) publications, the FP has enhanced the development of new products and processes, the development and use of new tools and techniques, the design and testing of models and simulations, and the production of prototypes, demonstrators, and pilots. The FP has generated large numbers of patents and enabled participants to increase their turnover and profitability, raise their productivity, expand their markets, reorient their commercial strategy, improve their competitive position, enhance their reputation and image, and reduce commercial risk. In addition, the results of FP direct and indirect actions have supported EU-level policy formulation. The FPs' positive impacts on innovation have translated, down the line, into large-scale positive macroeconomic, social and environmental impacts.

More broadly, the FP has produced durable changes in the EU research and innovation landscape contributing to the achievement of the European Research Area — so-called structuring effects. If it were not for the FP, the European Research Council, promoting excellence across Europe, would not have been created; the EU would then have been left with a landscape of compartmentalised national research councils, but would have had no funding mechanism to promote EU-wide competition for funds and to encourage higher scientific quality in frontier research. As a result of the FP, the EU leads in the creation and use of research infrastructures of pan-European importance. As a result of EU leadership, for the first time, a pan-European strategy on research infrastructures (the so-called ESFRI roadmap) has been developed and is now being implemented. Marie Curie Actions have created a framework for researcher career development and the free movement of knowledge. Collaborative research projects, international cooperation actions, mobility actions, and research infrastructure actions have generated durable, cross-sectoral, and interdisciplinary research and innovation networks across Europe, as well as with the world's fastest growing research nations. And many of these networks have remained active after the end of EU funding. European Technology Platforms and ERA-NETs have served as useful focusing devices that have helped stakeholders identify and explain their R & D needs jointly, easing the process of developing mutually supportive policies at EU and Member State levels. Joint Technology Initiatives have focused and aligned key actors in their respective areas, serving as a support to develop coherent sectoral strategies. Article 185 and joint programming initiatives have

Box 6: **Member States assess EU research and innovation programmes positively**

- According to a **German** evaluation of FP6 (Federal Ministry of Education and Research, 2009), scientific personnel participating in FP6 stated that a substantial part of their publications and of their patent applications was due to their participation in the FP: 'Large, export-oriented companies as well as companies in the field of cutting-edge technology and the knowledge-intensive service sector were more likely to take part in European programmes than in federal or *Länder* programmes among other reasons because participation tended to have a positive effect both with regard to the extent of their own R & D activities and the commercial success of innovations'.
- A **UK** evaluation of FP6 and FP7 (Technopolis, 2010c) found that the FP has a large impact on the nature and extent of UK researchers' international relationships and networks, as well as on their knowledge base and scientific capabilities. A majority of UK business participants stated that their involvement in the FP had yielded important commercial benefits: 'Around 20 % of businesses stated that their participation had made significant contributions to the development of new products and processes and in around 10 % of cases organisations reported increased income and market share'. Lastly, company interviews suggested that FP participation had made a significant contribution to the competitiveness of leading players in several niche technology markets, from inkjets to photonics.
- A **Swedish** long-term evaluation of the FP (VINNOVA, 2008) found significant impacts on the ability to compete in vehicles and in electronics (especially telecommunications). In ICT, FP participation in European and global standardisation had been a key factor in building the Swedish telecommunications industry's position in mobile telephony, while in vehicles, the FP had, together with complementary national programmes, been instrumental in supporting the Swedish industry's technical specialisations, especially in safety and combustion: 'FP money has been one of the factors enabling the [automotive] industry in general, and Volvo AB in particular, to maintain the high level of technological capabilities that have so far protected vehicles design and production activities in Sweden, which from a scale logic are anomalous'.
- According to a **Finnish** evaluation of FP6 (TEKES, 2008), 'Commercialisable output is not the core objective of the FPs but EU collaboration nonetheless contributes significantly to the creation of innovation'.
- According to an **Irish** evaluation of FP6 (Forfás, 2009), each project produced, on average, 0.1 patent applications and 0.4 new or significantly improved commercial product or service. Some 80 % of participating organisations or research groups improved their ability to attract staff or increased employment (low impact: 27 %, medium impact: 42 %, high impact: 11 %).
- According to a **Dutch** FP impact study, 'The [FP's] impact on the human research capital in the Netherlands is considerable, with approximately 1 200 researchers in the public sector alone funded by the FPs annually. For many research groups, this is an important factor to guarantee the continuity of the group'.
- A **Spanish** evaluation of FP6 participation (Zabala Innovation Consulting SA, 2010) found that 'For 52 % of the surveyed researchers, participation in the FP contributed to strengthening their research teams, above all due to the scientific excellence offered by the acquisition of capabilities and abilities during the project'. With regard to the creation of university posts, the FP performed better than national or regional programmes according to 38.89 % of respondents and equally well according to 50 % of respondents.
- According to a **Swiss** evaluation of FP5 and FP6 (State Secretariat for Education and Research, 2009), participation generated both knowledge and jobs: 'While certain significant benefits of Switzerland's participation in FPs are not measurable, there is no doubt that FPs have various impacts in social (welfare, security, equality, education ...) and employment ... even if it is not known to what extent or in what way, precisely'.
- 'Do not fix what is not broken' is a message coming from the public consultation on the future of the competitiveness and innovation framework programme. There is general agreement that the areas covered by the current innovation programmes are important and with cross-cutting relevance. Given that a majority of the existing measures work well, it is recommended to base the future programme on current achievements.

achieved a better coordination of R & D in Europe and supported a more coherent use of resources.

The CIP has increased innovation by SMEs by fostering sector-specific innovation, clusters, networks, public-private partnerships and cooperation with international organisations, and the use of innovation management. New types of innovation services have been developed and explored. Support for eco-innovation is contributing positively to the achievement of the Europe 2020 objective of smart and sustainable growth by facilitating access to finance for businesses marketing eco-innovations in areas related to resource efficiency and climate change through pilot and market replication projects and financial instruments.

In the same spirit, the evaluation of the Risk-Sharing Finance Facility (RSFF), the FP7 debt-financing financial instrument, published in November 2010, and carried out by an independent expert group concluded that the RSFF appears as an innovative, anti-cyclical demand-driven financial instrument, efficiently managed by the Commission and the EIB. The Expert Group considered that it helped to expand drastically the financing for research, development and innovation, highlighting in particular that considerable results exceeding initial expectations had been achieved on an EU-wide scale.

2.7. Experience from previous programmes: learning lessons and the need for change

However, while European research and innovation programmes have been successful, there are important lessons to be learned from the past, academic insights and stakeholder feedback.

A first key lesson learned is that current EU research and innovation funding suffers from weak horizontal policy coordination in two respects. The coordination among research, innovation and education policies is too weak since research, innovation and education is the subject of three separate programmes and initiatives — the FP, the innovation-related part of the CIP, and the EIT — and there are hardly any coordination arrangements between the three. The broader horizontal policy coordination between these knowledge triangle policies and other policies is weak since the links between, on the one hand, the FP, the CIP and the EIT, and, on the other hand, cohesion funding and the energy, transport, agriculture, etc., policies are not explicitly considered, which hampers the valorisation of research results into new products, processes and services. With regard to horizontal policy coordination in the narrow sense, the FP7 interim evaluation (Annerberg et al., 2010) noted that a strategic shift is needed to establish stronger and better connections between research, innovation and education. As for broader horizontal policy coordination, the FP6 *ex post* evaluation (Rietschel et al., 2009) called for a clearer division of labour between the FP and the cohesion funds. It also stated that other EU policies such as transport and energy would benefit from a more coordinated interface between FP research activities and regulatory and demand-side policies. Stakeholders have also called for closer knowledge triangle and broader horizontal policy coordination.

A second key lesson learned is that current EU research and innovation funding suffers from a lack of clarity of focus and weak intervention logic. The lack of clarity of focus is situated, first of all, at the aggregate level of EU support for research, innovation and education. The FP, the innovation related part of the CIP and the EIT constitute three separate programmes and initiatives; their objectives are not fully aligned and, together, they account for many specific programmes and funding schemes. The lack of clarity of focus is also apparent at the level of individual programmes. The FP, for example, suffers from a plethora of too general higher-level EU objectives, and is fragmented into 10 comparatively stand-alone thematic priorities. In addition, the FP, for example, lacks an explicit breakdown of higher-level objectives into intermediate and operational objectives and is focused on sectors and technologies rather than on the achievement of objectives.

Other important lessons learned are that programme access should be improved and participation increased from start-ups, SMEs, industry, less-performing Member States and extra-EU countries, and that monitoring and evaluation need to be strengthened (see Annex 1).

In order to tackle the problems identified in Section 2.1, it is important to clarify the objectives of EU action in the field of research and innovation. The following objectives have been identified.

3 — Objectives

General objective

To contribute to the objectives of the Europe 2020 strategy and to the completion of the European Research Area

Specific objectives

In order to achieve the general objective, there are five specific objectives:

- strengthen Europe's science base by improving its performance in frontier research, stimulating future and emerging technologies, encouraging cross-border training and career development, and supporting research infrastructures;
- boost Europe's industrial leadership and competitiveness through stimulating leadership in enabling and industrial technologies, improving access to risk finance, and stimulating innovation in SMEs;
- increase the contribution of research and innovation to the resolution of key societal challenges;
- provide customer-driven scientific and technical support to EU policies;
- help to better integrate the knowledge triangle — research, researcher training and innovation.

Operational objectives

To reach the specific objectives, the following operational objectives have been set:

- increase the efficiency of delivery and reduce administrative costs through simplified rules and procedures adapted to the needs of participants and projects;
- create transnational research and innovation networks (knowledge triangle players, enabling and industrial technologies, in areas of key societal challenges);
- support the development and implementation of research and innovation agendas through public-private partnerships;
- strengthen public-public partnerships in research and innovation;
- support market uptake and provide innovative public procurement mechanisms;
- provide attractive and flexible funding to enable talented and creative individual researchers and their teams to pursue the most promising avenues at the frontier of science;
- increase the transnational training and mobility of researchers;
- provide EU debt and equity finance for research and innovation;
- promote world-class research infrastructures and ensure EU-wide access for researchers;
- ensure adequate participation of SMEs;
- promote international cooperation with non-EU countries.

Chapter 6 sets out a series of indicators that can be used for measuring the achievement of the above objectives.

4 — Policy options

The Commission's communication presenting the results of the EU budget review (COM(2010) 700 final of 19 October 2010) put forward some general key principles in relation to EU expenditures that are of particular importance for the area of research and innovation — focusing on instruments with proven European added value, becoming more results-driven, and leveraging other public and private sources of funding. More specifically, the budget review identified research and innovation spending as a key priority and called for future EU instruments to work together in a framework programme for research and innovation (in line with the European Court of Auditors' Special Report 9/2007). Against this background, a range of options have been examined to reform the EU research and innovation funding framework. This Impact Assessment considers four policy options in particular: business-as-usual; improved business-as-usual; Horizon 2020 — framework programme for research and innovation; and renationalisation. The complete discontinuation option is also considered but to a lesser extent (when assessing macroeconomic impacts). Assessing the business-as-usual option is in accordance with Commission's Impact Assessment Guidelines (EC, 2009b), which clearly specify that the set of options considered should include, amongst others, the 'no policy change' baseline scenario. Assessing renationalisation and complete discontinuation options are in accordance with Commission Impact Assessment Guidelines (EC, 2009b) recommendations and with Commission President Barroso's commitment to evaluate the cost of non-Europe for Member States and national budgets.

Option 1: Business-as-usual: maintaining the current plurality of programmes for R & D and innovation

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 multiannual financial framework 2014–20 as separate instruments, with separate objectives, and in their current formats. The next multiannual 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 the other on the activities of the Joint Research Centre in the field of nuclear energy); a CIP including innovation-related actions; and the EIT.

Option 2: Improved business-as-usual: loose integration and stand-alone simplification

In this scenario, the three currently stand-alone programmes and instruments — the FP, the innovation-related part of the CIP, and the EIT — remain separate and basically retain their current formats. This means that, as under the business-as-usual option, the next multiannual 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 the other on the activities of the Joint Research Centre in the field of nuclear energy); a CIP including innovation-related actions; and the EIT. However, a certain measure of integration is pursued as these programmes and instruments are put together under a 'common roof'. This means, firstly, that the higher-level objectives of the three programmes and instruments are loosely aligned and broadly oriented towards the achievement of the objectives of Europe 2020 and the maximisation of the contribution of research and innovation to the resolution of societal challenges. However, there is no single overarching integrated intervention logic covering the three programmes and instruments. Secondly, loose coordination mechanisms are established between the three programmes and instruments and a rough division of labour is established between them. However, the different programmes and instruments are not tightly integrated with each other in a perfectly complementary manner, leaving gaps in the support portfolio and preventing the provision of 'seamless support'. Thirdly, in order to meet stakeholder demands, each programme and instrument simplifies its own rules and implementing modalities. However, no attempts are made to harmonise rules and implementing modalities across the three programmes and instruments resulting in a single set of administrative procedures.

Option 3: Horizon 2020 — establishing a 'framework programme for research and innovation'

In this scenario, the FP, the innovation-related part of the CIP, and the EIT are combined in 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 of 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: (i) Excellent Science, (ii) Industrial Leadership, (iii) Societal Challenges; and two additional parts supporting these priorities: Joint Research Centre 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. As stated earlier, a separate impact assessment has been undertaken dealing explicitly with the future rules for participation and the reader is referred to this staff working document.

For details on the proposal of the European Commission on Horizon 2020, see Annex 7.

Option 4: Bring to an end EU-level R & D financing and renationalise R & D and innovation policies

The renationalisation option consists of discontinuing EU research and innovation programmes and spending those funds at Member State level, either on domestic issues or to engage in intergovernmental collaboration. The complete discontinuation option, on the other hand, which, as already mentioned, will be assessed to a lesser extent (when assessing macroeconomic impacts), consists of discontinuing EU research and innovation programmes altogether, so not spending those funds at Member State level either.

5 — Analysing the impacts and comparing the options

5.1. How the options were compared

The four policy options identified and presented in Chapter 4 — business-as-usual, improved business-as-usual, Horizon 2020, and renationalisation — were compared along a range of key parameters selected for their relevance in assessing public intervention in research and innovation. The comparison along these parameters was carried out in an evidence-based manner. A range of quantitative and qualitative evidence was used, including *ex post* evaluations; foresight studies; statistical analyses of FP application and participation data and Community Innovation Survey data; analyses of science, technology and innovation indicators; econometric modelling exercises producing quantitative evidence in the form of monetised impacts; reviews of academic literature on market and systemic failures and the impact of research and innovation, and of public funding for research and innovation; sectoral competitiveness studies; expert hearings; etc.

5.2. Comparing the options and assessing cost-effectiveness

Coherence in terms of focus and intervention logic

The business-as-usual option suffers from a lack of clarity of focus and an underdeveloped and non-transparent intervention logic, as evidenced by *ex post* evaluations. The Horizon 2020 option responds best to these concerns: it focuses on a limited number of mutually consistent and concrete higher-level objectives that are closely related to Europe 2020 (i.e. on growth and the resolution of six societal challenges through research, innovation, and the training and skills development of researchers). It combines the FP, the innovation-related part of the CIP, and the EIT into a single framework, reduces the number of programme pillars and funding schemes and, thereby, facilitates the gearing of all programme components towards the achievement of those common objectives. The Horizon 2020 option is also marked by a more developed and transparent intervention logic, which reflects closely the breakdown of general objectives into specific and operational objectives in Chapter 3. The Horizon 2020 option has the support of all types of stakeholders, who agree on the need to orient EU research and innovation funding towards the resolution of societal challenges and the achievement of ambitious EU policy objectives in areas such as climate change, resource efficiency, energy security and efficiency, demographic ageing, etc., and who support the centring of EU research and innovation funding around three objectives: tackling societal challenges, strengthening competitiveness, and raising the excellence of the science base.

Critical mass, flexibility, excellence

Ex post evaluations have shown that the business-as-usual option (and, therefore, also the improved business-as-usual option) achieves critical mass (6), is flexible to a certain extent, and promotes excellence. Horizon 2020 goes further by enhancing programme flexibility. It maintains cross-thematic joint calls, problem-oriented work programmes promoting interdisciplinary research, and the scope for integrating emerging priorities but also strengthens bottom-up schemes and makes work programmes less prescriptive. The Horizon 2020 option, there-

6. The concept of critical mass is of key importance for EU research and innovation programmes. Critical mass can be looked at from both a programme and a project perspective: achieving critical mass at the programme level means being able to fund a sufficiently broad portfolio of relevant technologies (at this point in time, it is not necessarily clear what technologies are the most promising ones for addressing each one of the societal challenges) and, for each technology, a sufficiently large body of complementary R & D & I projects that can build on each other. Achieving critical mass at the project level means being able to fund projects large enough to bring together across countries, sectors and disciplines, all partners and complementary knowledge resources required to achieve certain technological objectives. For example, a dedicated study on advantages of scale and scope at the research project level has revealed that there is an inverse U-shaped relation between project scale and project output and that the maximum of this inverse U-shaped relation depends on the objective pursued. For some objectives, one needs higher numbers of partners and, for some objectives, one needs smaller numbers of partners. The results of this study are being taken account of in the design of Horizon 2020 with, for example, less emphasis on artificially large consortia.

fore, responds better than the business-as-usual and improved business-as-usual options to demands from all types of stakeholders that funding opportunities be less prescriptive and more open, with sufficient scope for smaller projects and consortia, as these allow for more innovation; that project implementation should be made more flexible; and that the new funding programme will need both curiosity-driven and agenda-driven activities, working in tandem. Horizon 2020 also enhances the promotion of excellence. It maintains the pan-European competition for funding, as well as the screening for excellence of all proposals, but allocates a larger share of the budget to the European Research Council.

Accessibility and reach

The business-as-usual option is associated with high administrative costs for applicants and participants that compromise accessibility, reach, and support from all types of stakeholders. This emerges from all FP *ex post* evaluations. The Horizon 2020 option introduces simplification and flexibility as appropriate, as well as enhanced accessibility, extended reach, and higher levels of support from all types of stakeholders. Due to programme consolidation and simplification, proposal preparation and project participation become less complex and costly, there are no learning costs associated with different procedures for different programmes, and similar sets of documents do not have to be submitted multiple times. This results in lower barriers to project participation and coordination. As a result, programme accessibility is improved and programme reach is extended. A study carried out by Deloitte points to Horizon 2020's potential to save applicants and participants time and money when preparing their proposals or administratively managing their projects (Deloitte, 2011). The Horizon 2020 option responds best to demands from all types of stakeholders that simplification be a key priority for any future EU funding programme for research and innovation (see Chapter 1 for full details).

Small and medium-sized companies

As shown by *ex post* evaluation material, the business-as-usual option is associated with high levels of administrative burden. SMEs are particularly affected by the resulting barriers to programme application and participation (see Box 7). At the same time, the business-as-usual option is associated with weak knowledge triangle coordination and this affects, in particular, the research, research result valorisation, and innovation efforts of SMEs, who are often unable by themselves to move along the complete innovation chain. The Horizon 2020 option consolidates and simplifies across programmes and initiatives, making proposal preparation and project participation less complex and costly, and lowering barriers to project participation in particular for SMEs. At the same time, Horizon 2020 addresses the business-as-usual and improved business-as-usual options' lack of knowledge triangle coordination by establishing a single framework facilitating close coordination between research, innovation, and researcher training and skills development, while enabling the provision of 'seamless' supply-side and demand-side research and innovation support. The Horizon 2020 option squares best with views from SME stakeholders that all SMEs with innovation requirements should be able to benefit from EU research and innovation funding.

Coherence in terms of knowledge triangle and broader horizontal policy coordination

As demonstrated by *ex post* evaluations, under the business-as-usual option, knowledge triangle coordination is weak: research, innovation, and researcher training and skills development are the subject of three separate programmes and initiatives — the FP, the innovation-related part of the CIP, and the EIT — and there is little coordination between the three. When it comes to broader horizontal policy coordination, the business-as-usual option is also very limited: the links between, on the one hand, the FP, the innovation-related part of the CIP, and the EIT, and, on the other hand, cohesion funding and the energy, transport, agriculture, etc., policies are not explicitly considered. The Horizon 2020 option responds best to concerns about knowledge triangle and broader horizontal policy coordination. A single framework consisting of three complementary priorities with strong links between them promotes close coordination between research, innovation, and researcher training and skills development, and ensures the provision of 'seamless support from research to innovation, from idea to market'. The creation under Horizon 2020 of a priority explicitly focused on the resolution of societal

Box 7: **Assessing SME participation in EU research and innovation programmes**

EU research and innovation programmes involve large numbers of SMEs

- About 11 200 SMEs (16.9 % of the total number of participating entities) participated in FP6. Some 7 000 individual SMEs have so far participated in FP7. If current trends continue, 20 000 SMEs will have received EUR 6 billion of FP7 funding (± 11 % of the total) by the end of the programme. Some 14.4 % of the 'Cooperation' collaborative research budget (EUR 1.77 billion) has been granted to SMEs during the first 4 years of FP7 (2007–10). SME dedicated calls are expected to increase the EU contribution to SMEs towards the 15 % target set by the FP7 decision. Some thematic priorities such as security achieve high levels of SME participation (> 20 %).
- Under the CIP, 137 highly innovative SMEs benefited from financial instruments/venture capital, 25 of them in the eco-innovation sector.
- CIP pilot and market replication projects aim at testing in real conditions innovative solutions that have not yet significantly penetrated the market due to high residual risks. In the area of ICT-based services, 125 projects have been funded to date, reaching around 530 SMEs. Regarding eco-innovation projects, almost 70 % of final beneficiaries are SMEs. In the field of intelligent energy dissemination and information projects, SME participation is also high reaching almost 50 %. In absolute numbers, 235 projects funded by the calls published so far, involve about 1 000 SMEs directly and spread the results through large multiplier associations far beyond this scope.
- With regard to the helpdesk on Intellectual Property Rights (IPR), more than 2 300 SMEs have participated in awareness-raising events and tools and more than 600 SMEs have taken part in IPR training.

  About 4 000 queries on IPR coming from SMEs have been dealt with (data for the entire project from December 2007 to February 2011).

Europe's best performing SMEs participate

A SME profiling exercise (120 case studies) has revealed that 21.7 % of all SME participants are strategic innovators; approximately 30 % seek exploitation opportunities and translate research results into products and services; more than 40 % conduct technology intelligence and networking activities, not being positive about marketable results. Some 34 of the 500 fastest growing enterprises in Europe in the year 2010 participated in the FP, almost all of them several times.

Europe's SMEs derive substantial benefits

More than 70 % of SMEs report a positive impact on their operations, processes, methods, tools or techniques; 75 % have introduced one new technology to the company and half of the SMEs claim to have increased turnover due to their project involvement.

SMEs are concerned

SME access to EU funding is currently hampered by the fragmentation and multitude of support instruments with varying objectives. The programming, implementation and monitoring of EU research and innovation programmes are not synchronised and fail to provide coherent support promoting the whole chain to turn ideas and research results into new products and services. Administrative rules and procedures are not adapted to small players, and they lack targeted information and coaching (one-stop-shop).

challenges aids the interaction with other policy domains. Horizon 2020 constitutes, for these policy domains, a single, consolidated counterpart, which facilitates the execution of the research and innovation components of ambitious sectoral agendas such as the European Strategic Energy Technology Plan (SET Plan). For these reasons, the Horizon 2020 option responds best to demands from all types of stakeholders for closer knowledge triangle and broader horizontal policy coordination.

Structuring and leverage effects

The business-as-usual option produces strong structuring effects (permanent changes in the European R & D landscape) and large leverage effects (which concern the ability to mobilise additional amounts of public and private research and innovation funding, see Box 8). The Horizon 2020 option maximises these structuring and leverage effects by achieving large-scale simplification, thereby maximising the programme's attractiveness to industry, science-industry linkages, and private sector crowding-in, and through the greater use of structuring instruments such as joint technology initiatives and joint programming actions. At the same time, it provides for the necessary flexibility to cater for the specific needs of the business community.

Innovation impacts

The business-as-usual option produces very strong scientific and technological impacts and substantial innovation impacts (see Box 9). Nevertheless, evaluations have concluded that more attention should be paid to the production of project outputs and to their dissemination and economic valorisation, in particular since the FP aims to support Europe's competitiveness. Horizon 2020 is designed to maximise innovation impacts by providing 'seamless support from research to innovation, from idea to market'

Box 8: **Leverage effects of EU research and innovation financial (and other) instruments**

EU research and innovation financial instruments leverage private funding

- The **Risk-Sharing Finance Facility** (RSFF) is an innovative debt financing instrument jointly set up by the Commission and the European Investment Bank that provides loans and guarantees to private companies or public institutions with a higher financial risk profile for their research, technological development and innovation activities (RDI). Commercial banks are largely absent from higher-risk lending for RDI investments due to its riskiness and uncertainty of repayment and this situation has even worsened during the ongoing financial crisis. The RSFF, therefore, fills the market gap in high-risk loans for RDI activities. As evidenced by *ex post* evaluations, the multiplier effect of the FP7 RSFF is expected to be 12 between the EU contribution and the volume of loans, and over 30 between the EU contribution and the additional leveraged investment in RDI.
- **CIP financial instruments** supporting innovation in collaboration with the European Investment Fund (EIF) address market gaps in equity finance, notably early-stage venture capital and access to finance for SMEs in general (through guarantees for loan portfolios of financial intermediaries). The recent *ex post* evaluation demonstrates that they have acted as a cornerstone investor in 17 venture capital funds leveraging EUR 1.3 billion of total investment in growth-oriented SMEs. The leverage effect of this instrument, which concerns equity investments, is 6 to 1.

Other activities within EU research and innovation programmes also have a strong leverage effect on private investments, as demonstrated by a wealth of evidence

- An extensive body of academic economic literature has demonstrated that public subsidies for R & D produce crowding-in effects (i.e. have a positive net effect on the total availability of R & D funding, and that these crowding-in effects are larger for collaborative research).
- An econometric analysis of Community Innovation Survey micro-data carried out by JRC in collaboration with the Directorate-General for Research and Innovation has concluded that FP support has a crowding-in effect on the level of companies' R & D investments.
- These findings are confirmed by a wide range of *ex post* evaluations:
  - the Clean Sky Joint Technology Initiative mobilises about EUR 800 million in private in-kind contributions to achieve the single largest aeronautics research venture in Europe so far;
  - the space innovation project KIS4SAT (start-ups, business support schemes, vouchers for innovation activities) leveraged EUR 10–20 million via involvement in supporting fund raising activities;
  - a recent external evaluation by the European Institute for Innovation and Technology (EIT) suggests that the overall leverage effect of its Knowledge and Innovation Communities (KIC) funding will be between 4 and 5 to 1 (EUR 1 of EIT funding produces EUR 4–5 of additional funding) by the end of 2013; the EIT provides, on average, up to 25 % of KIC budgets, which leverages 75 % of supplementary investment emanating from a range of public and private sources;
  - some 60 % of all surveyed FP7 health research participants stated that EU funding helped access other research funding; 15 % of the SMEs that leveraged additional research funds did so from business angels or venture capitalists.

EU research and innovation programmes also leverage public funding

- For ERA-NETs, the leverage effect of FP funding is close to 5, while for ERA-NET Plus, it is 2.5. More than 15 of the initial FP6 ERA-NETs achieved leverage effects of 10 and more: EUR 1 of FP funding resulted in EUR 10 of coordinated research funding.
- A survey among FP6 information society technologies programme participants (WING, 2009) showed that about two thirds (approximately 65 %) of industry participants increased their ability to get further R & D funding not only in-house but also (and especially for SMEs) from other EU or national sources.
- FP participation in Socio-economic Sciences and Humanities (SSH) facilitated access to additional funding in 68 % of the projects.
- Marie Curie Actions leverage additional regional, national and international funds through the co-funding mechanism of individual fellowships such as COFUND. The total budget of the 81 COFUND programmes selected amounts to EUR 528 million, of which only EUR 211 million is contributed by the EU.
- The Euratom SARNET-2 Network of Excellence defines joint research programmes and develops common computer tools and methodologies for the safety assessment of nuclear power plants. With an EU contribution of just EUR 5.75 million out of a total budget of EUR 38 million, it generates more than EUR 6 additional research funding for each EUR 1 FP funding.

Box 9: **Assessing the innovation impacts of EU research and innovation programmes**

For firms, FP collaborative research projects are — more than self-financed collaborative research projects — more focused on complex, long-term, risky exploration than short-term exploitation. Firms participate in the FP mainly to achieve knowledge and technology-related objectives, less to achieve direct commercialisation-related objectives. FP projects are not, and should not be, assessed as stand-alone R & D activities; they form part of a wider portfolio of R & D projects. The FP, nevertheless, has a significant positive impact on innovation and competitiveness: FP-funded research produces large numbers of patents, innovations and microeconomic benefits. These innovation impacts were assessed on the basis of the following range of evidence.

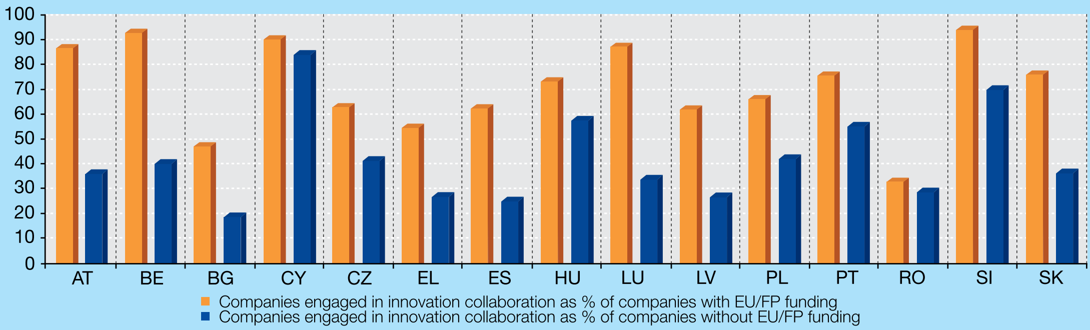
Cross-cutting EC *ex post* evaluations of EU programmes

- For example, according to the FP5 and FP6 Innovation Impact study, a great majority of FP participants reported at least one form of commercialisable output (new or improved processes, products, services, standards) stemming from their FP project and a large number even recorded more than one such output; an econometric analysis showed that the FP produces output additionality — a positive impact on the innovative sales of firms participating in the FP; and small and medium-sized enterprises indicated the most positive results in terms of innovation in FP projects.
- For example, according to an FP6-wide survey (IDEA Consult, 2009c), industrial organisations clearly expected commercial returns. Almost half (47 %) stated commercial returns were likely to very likely, and 60 % of this group expected these returns within 2 years (90 % within 5 years).

Statistical and econometric analyses of Community Innovation Survey micro-data

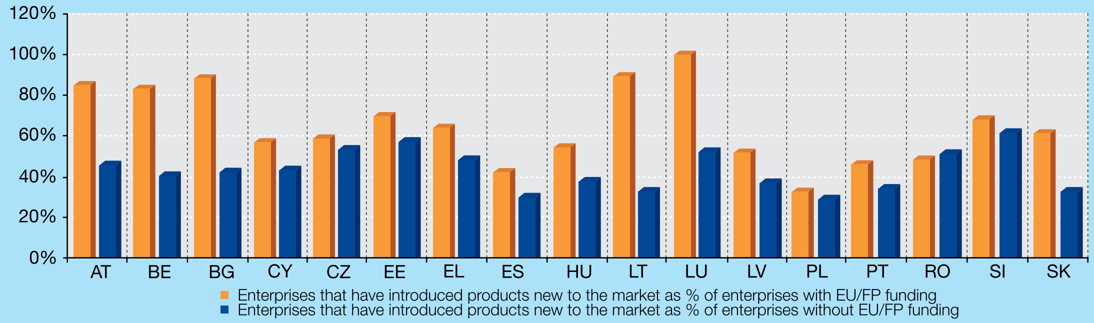
- In collaboration with the Directorate-General for Research and Innovation, the Joint Research Centre carried out a dedicated analysis of micro-data for 13 Member States available from the third round of the Community Innovation Survey. Data of the fourth and fifth rounds were of insufficient quality. Through a multi-equation model, the impact of FP funding on company R & D expenditure, research and innovation collaboration, and innovation was assessed. Key conclusions were that:
  - the FP increases total R & D investment: FP funding has a positive net effect on total company R & D expenditure meaning that when companies receive FP support, they do not just substitute for own R & D funding;
  - the FP promotes innovation: FP funding has a positive and statistically significant effect on companies' innovative sales and the impact is stronger for radical innovation (new to the market products) than for incremental innovation (new to the firm products);
  - the FP promotes collaboration: the positive effect of FP funding on R & D expenditure is partly due to the positive effect of FP funding on collaboration; the FP has positive and significant effects on company collaboration, not only at EU level (something required by the FP itself) but also at national and, more significantly, international (beyond Europe) levels.
- In addition, Eurostat, in collaboration with the Directorate-General for Research and Innovation, carried out a dedicated analysis of 2006 Community Innovation Survey micro-data, which confirmed the above results by showing that FP participants collaborate more, patent more, and are more innovative than non-participants — see the figures in this box.

FP Participants collaborate more than non-participants



Source: Eurostat.
NB: Data concern the manufacturing sector.

FP participants are more innovative than non-participants



Source: Eurostat.
NB: Data concern the manufacturing sector.

in a number of ways: by increasing the emphasis on research project output; by proactively supporting research result dissemination, demonstration, and piloting; by strengthening support for market take-up; by funding projects that cover a number of stages in the innovation chain; by supporting SME research and innovation throughout; and by including supply as well as demand measures. This is achieved through a number of flexible funding schemes such as research and innovation grants; training and mobility grants; programme co-funding grants; grants to public procurement of innovation; support grants; debt finance and equity investments; prizes; and procurement. The Horizon 2020 option, therefore, responds best to the message from stakeholders (especially those involved in industry) that, in terms of creating more innovation, the EU should support all stages in the innovation chain. In this context, there is frequent mention of the need to include more support for closer-to-the-market activities (such as demonstration, piloting and market replication) and to improve the framework for public-private partnerships.

Economic and competitiveness impact

Economic and competitiveness impacts include impacts on GDP, productivity, exports, imports, etc. As discussed in detail in Box 10 and Annexes 1 and 5, the business-as-usual option produces strong economic and competitiveness impacts, which through slightly better innovation impacts are marginally enhanced under the improved business-as-usual option. Under the Horizon 2020 option, enhanced scientific, technological and innovation impacts in combination with the aforementioned clarity of focus and high-quality intervention logic translate into larger downstream economic and competiveness impacts. The results for the Horizon 2020 option of the NEMESIS econometric model point to strong macroeconomic effects over and above the business-as-usual option by 2030: + 0.53 % for GDP, + 0.79 % for exports, and – 0.10 % for imports. Comparing the positive effects of the Horizon 2020 option with the negative effects of the discontinuation option demonstrates its true added value: by 2030, Horizon 2020 is expected to generate an extra 0.92 % (0.53 + 0.39) of GDP, 1.37 % (0.79 + 0.58) of exports and – 0.15 % (0.10 + 0.05) of imports.

Social, environmental and EU policy impact

Social impacts include impacts on numbers of jobs, employment conditions, and quality of life, impacts on social policy. Environmental impacts include impacts on environmental policy and direct environmental impacts. EU policy impacts concern the extent to which research results succeed in informing EU policy design.

As discussed in detail in Annex 1, the business-as-usual option produces strong social, environmental and EU policy impacts. As for social impacts, according to a survey among FP5–7 project coordinators working in the research theme 'Food, Agriculture and Fisheries, and Biotechnology', close to 5 % of all projects resulted directly in the creation of a new company. Some 82 % of all projects created jobs for the duration of the project and 35 % of all projects created new jobs after the end of the project; 38 % of all projects created at least one permanent S&T job. According to a Dutch FP impact study (Technopolis, 2009), 'the [FP's] impact on the human research capital in the Netherlands is considerable, with approximately 1 200 researchers in the public sector alone funded by the FPs annually. For many research groups, this is an important factor to guarantee the continuity of the group'. According to an Irish evaluation of FP6 (Forfás, 2009), 80 % of participating organisations or research groups improved their ability to attract staff or increased employment (low impact: 27 %; medium impact: 42 %; high impact: 11 %). Through Marie Curie Actions, the FP set a valuable benchmark for the working conditions and employment standards of EU researchers (Annerberg et al., 2010). The FP also produces indirect social benefits through relevant natural sciences research. According to an FP6-wide participation survey (IDEA Consult, 2009c), all thematic priorities contribute substantially to a better quality of life while life sciences, genomics and biotechnology for health, nanotechnologies and nanosciences, knowledge-based multifunctional materials and new production processes and devices, and food quality and safety contribute to better healthcare. According to a Dutch FP impact study (Technopolis, 2009), 'societal impact is demonstrated in domains with a strong societal mission such as health, sustainability and food safety'. The FP also produces indirect social benefits through social sciences research on relevant issues. An evaluation of FP5 and FP6 social and environmental effects (EC, 2005) lists research on the following socially relevant issues: human rights, social cohesion, economic cohesion, employment, human capital formation, public health and safety, social protection and social services, liveable communities, culture, consumer interests, security, governance, international cooperation, role of SMEs.

The clearest environmental impact is produced by FP-funded environmental research. According to an EC-commissioned evaluation of FP6 environmental research (EPEC, 2008), for example, EU environmental research contributed to the knowledge base and development of methods and tools for environment-related policy. The study found, for example, that at the international level, EU research related to climate change contributed to the International Panel on Climate Change (IPCC), either directly, through individual researchers involved in the IPCC review, or through references to EU-funded projects in IPCC reports; that in the domain of environment and health, there were strong links with EU policy priorities, most notably with the implementation of the Environment and Health Action Plan 2004–10 as well as with the implementation of European directives; that water and soil projects played a large role in the formulation and implementation of the Water Framework Directive; and that earth observation projects had direct impacts on policymaking through the use of their outcomes by stakeholders such as the IPCC and World Meteorological Organisation. Yet other kinds of FP-funded research also produce clear environmental impacts. According to an FP6-wide participation survey (IDEA Consult, 2009c), for example, the thematic priorities 'Sustainable development, global change and ecosystems' and 'Nanotechnologies and nanosciences', etc., contributed to the sustainable use or production of energy, while the thematic priorities 'Sustainable development, global change and ecosystems', 'Nanotechnologies and nanosciences', 'Aeronautics and space', and 'Food quality and safety' contributed to the environment. National evaluations of the FP arrive at similar conclusions. According to an Irish evaluation of the FP (Forfás, 2009), for example, 50 % of all projects made a contribution to 'improved environmental preservation or protection'. And a Swedish evaluation of the FP (VINNOVA, 2008) found that 'framework programmes have positive effects on the behaviour of the research community, competitivity, jobs, regulation and the environment'.

Under the Horizon 2020 option, enhanced scientific, technological and innovation impacts in combination with the aforementioned clarity of focus and high-quality intervention logic translate into larger downstream social, environmental and EU policy impacts. The results for the Horizon 2020 option of the NEMESIS econometric model (see Box 10), for example, point to strong employment effects

Box 10: **Assessing the macroeconomic impacts of EU research and innovation programmes**

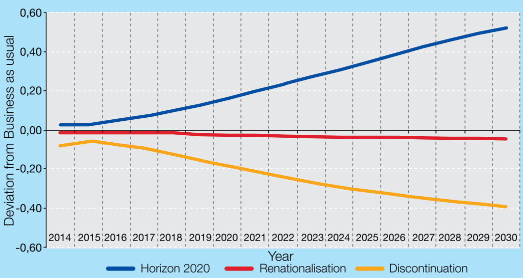
The aggregate macroeconomic impacts of an expenditure programme can be assessed by making use of a mathematical model based on known, inferred, and assumed parameters. Over the past few years, the use of mathematical models for the *ex ante* evaluation of policy effects has increased significantly within the Commission, and also at national level. For the Horizon 2020 *ex ante* impact assessment, use was made of three models: NEMESIS, an OECD model and Quest III.

NEMESIS is a macroeconometric model built by a Commission-funded consortium of European research institutes under the fifth framework programme. NEMESIS has also been used by the Commission for the *ex ante* impact assessment of FP7 and to assess the macroeconomic impacts of achieving the 3 % objective, by the OECD, and by a number of French government institutions, etc. For the Horizon 2020 impact assessment exercise, the Directorate-General for Research and Innovation developed, in collaboration with the DEMETER consortium running NEMESIS, a number of scenarios including the Horizon 2020, renationalisation and discontinuation scenarios. For each of these scenarios, the DEMETER consortium produced results on GDP, exports, imports, and employment until 2030 compared with the business-as-usual scenario. These results are presented in the figures in this box. Annex 5 provides more detail on the different NEMESIS scenarios, the detailed and carefully considered and conservative assumptions underpinning them, and their results. The difference between the BAU and Horizon 2020 scenarios hinges mainly on the scale of EU research and innovation funding, and on the size of the crowding-in effect and the economic multiplier associated with the intervention. As explained in detail in the text and in Annex 5, because of simplification and, therefore, enhanced industrial participation, and because of closer knowledge triangle coordination and, therefore, enhanced valorisation of research results, crowding-in effects and economic multipliers can be assumed to be higher under Horizon 2020 than under ‘business-as-usual’.

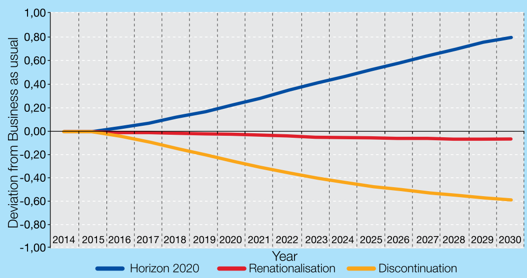
The OECD model was originally developed by Guellec and van Pottelsberghe (2004) to assess the effect of public, business and R & D carried out abroad on the growth of total factor productivity (TFP) of industry. This model has been adapted by the Joint Research Centre in Ispra to estimate the effects of the sixth and seventh framework programmes on the growth of total factor productivity of the EU and associate countries. Results indicate that every EUR 1 invested by the FP generates, on average, EUR 13 in increased value added of the business sector. The impact of the FP on total factor productivity varies between countries, and depends, among other things, on the size of the country, its industry structure and its R & D structure (business versus public). Since these results are for FP6 and FP7, they shed some useful light on the impact of the business-as-usual option.

Simulations were also carried out using the Quest III model developed by the Directorate-General for Economic and Financial Affairs. This is a model used for macroeconomic policy analysis and research, and belongs to the class of New-Keynesian Dynamic Stochastic General Equilibrium (DSGE) models. Assuming that there is a new Horizon 2020 programme, that the EU Member States increase their investment in R & D in accordance with the Europe 2020 targets, and that they combine this with efforts to close the high-skilled education expenditure gap, the resulting impact is an extra 2.34 % of GDP by 2050, converging on a long-term steady-state addition of 5.64 % to GDP.

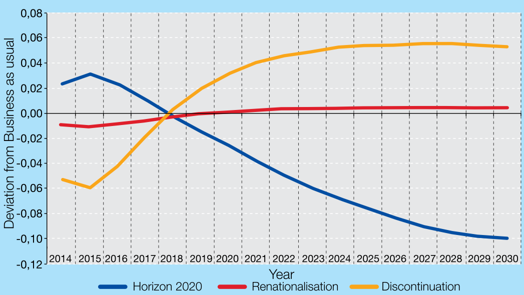
Impact of the different options on GDP



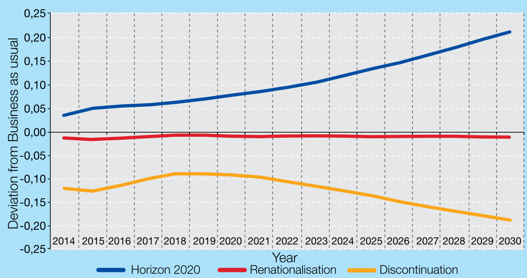
Impact of the different options on exports



Impact of the different options on imports



Impact of the different options on employment



(+ 0.21 %) over and above the business-as-usual option by 2030. Comparing the positive effects of the Horizon 2020 option with the negative effects of the discontinuation option demonstrates its true added value: by 2030, Horizon 2020 is expected to generate an extra 0.40 (0.21 + 0.19) % employment.

Cost-effectiveness

Per euro disbursed, implementation costs are lower under the Horizon 2020 option than under the business-as-usual and common roof options because of far-reaching integration, simplification and harmonisation (common rules benefit stakeholders but also lower the Commission implementation cost), and externalisation. On the other hand, it is the Horizon 2020 option that maximises the benefits. Through its close integration of research, innovation and researcher training, the Horizon 2020 option provides the best assurance that investments made at EU level in research projects are fully valorised into patents and new products, processes and services. Under the business-as-usual and common roof options, it is conceivable that, because of a lack of research and innovation bridging mechanisms and dedicated innovation support, EU-funded research projects are unable to valorise their research results into patents and new products, processes and services, which would amount to considerable losses with respect to the societal benefits that can be expected from such research projects.

Three kinds of **costs** have to be taken account of with respect to the implementation of Horizon 2020.

- *Direct financial outlays from the EU budget or from other public funds*: A series of figures for the direct financial outlays relating to each option were used for the cost-effectiveness analysis (see Annex 5 for full details). These included outlays from the EU budget for 2014–20, and projected future outlays for 2021–30. Assumptions were also made about the growth of national funding for research and innovation.

- *Administrative costs for the Commission*: Regarding administrative costs for the Commission of the options, a series of projections were made based on different assumptions regarding the simplification rules regarding EU research and innovation funding (see separate impact assessment of the rules for participation). These costs were considered for the business-as-usual/improved business-as-usual scenarios under which the existing rules are applied without change, and for a scenario under which the rules are simplified — as envisaged for Horizon 2020. This simplification would involve simplified cost-based funding (with simplified cost eligibility criteria and single reimbursement rate per project), combined with a flat rate on personnel costs for indirect costs.

- *Administrative costs for applicants and participants*: An analysis was also carried out on the effects of administrative simplification on the costs for applicants/participants for the different options (see separate impact assessment of the rules for participation). These participation costs do not consist only of 'information requirements' or purely administrative tasks (form filling, financial accounting, etc.), they represent the overall effort of the beneficiaries (i.e. they also include tasks such as developing the scientific-technical content of a proposal, adapting this content during the negotiation phase, managing the consortium or dealing with scientific reporting, ethics, gender, dissemination and stakeholders involvement at project implementation phase). It can be seen from the separate impact assessment of the rules for participation that under the simplified rules envisaged for Horizon 2020, the costs to participants are reduced substantially (by around 15 % to 20 %).

As detailed above, **benefits** are maximised under the Horizon 2020 option; in particular, compared with the other options, Horizon 2020 would offer the following improvements.

- Provide greater effectiveness by maximising structuring and leverage effects through large-scale simplification, thereby maximising the programme's attractiveness to industry, science-industry linkages, and private sector crowding-in, and through the greater use of structuring instruments; maximising critical mass at programme and project level; enhancing the promotion of scientific and technological excellence and providing stronger benefits to SMEs notably from administrative simplification and also from closer knowledge triangle coordination, particularly concerning research and innovation finance; enhancing S&T and innovation impacts through the seamless support from idea to marketable product, stronger output orientation, better dissemination of research results, clearer technological objectives, enhanced industrial and SME participation and, thus, higher leverage, funding of demonstration activities, and innovation financing and support; producing larger downstream economic, competiveness and social impacts, as well as environmental and EU policy impacts.

- Improve efficiency by reducing the administrative costs for the Commission and reducing the administrative burden for participants, significantly improving accessibility.
- Offer greater coherence by enhancing the coordination in the knowledge triangle and broader policies through a single framework seamlessly integrating research, education and innovation aspects and explicitly defining links with other policies, and allowing for more flexibility.

The issue of cost-effectiveness has also been taken into account in the design of the instruments for Horizon 2020. One of the key criteria for designing the toolbox of instruments has been the need to have a close link to the objectives and, in particular, to increase exploitation of the results of research: new instruments have been introduced and existing instruments have been simplified. The overall number of instruments has been reduced with a view to further rationalising and simplifying support measures — this should facilitate the management of projects, and the use of harmonised rules should reduce the burden on participants (see the cost estimates above).

Under previous EU programmes, the evaluation of instruments has yielded important insights, and has led to improvements (e.g. the adaptations following the reviews of Networks of Excellence and Integrated Projects). It is therefore envisaged that the instruments of Horizon 2020 would be subject to monitoring and evaluation in order to ensure that the lessons from implementation are identified and that the instruments adapt over time to increase efficiency and effectiveness.

The conclusion of our assessment is that Horizon 2020 offers the greatest returns per euro invested in terms of efficiency, effectiveness and coherence.

5.3. Choosing the preferred option

Based on the aforementioned comprehensive in-depth comparison of the policy options, it emerges that the Horizon 2020 option would be the most appropriate policy option, the preferred option, to achieve the objectives formulated in Chapter 3. Table 1 summarises the comparison of the improved business-as-usual, Horizon 2020, and renationalisation options with the business-as-usual option.

Compared with the business-as-usual option, the Horizon 2020 option would have clarity of focus and benefit from well-developed intervention logic. As in the business-as-usual option, Horizon 2020 would achieve critical mass at programme and project level. At the same time, it would enhance the promotion of scientific and technological excellence and allow for more flexibility. Administrative costs for applicants and participants would be reduced drastically, which would significantly improve accessibility, in particular for SMEs, and increase levels of support from all types of stakeholders. Knowledge triangle and broader horizontal policy coordination would be enhanced through a single framework integrating, in a seamless manner, research, innovation, and researcher training and skills development, and explicitly defining links with other policies. Scientific, technological and innovation impacts would be enhanced through the provision of seamless support from scientific idea to marketable product, stronger output orientation, better dissemination of research results, clearer technological objectives, enhanced industrial and SME participation and, thus, enhanced leverage, funding of demonstration activities, and provision of innovation financing and support. In combination with the aforementioned clarity of focus and high-quality intervention logic, enhanced scientific, technological and innovation impacts would translate into larger downstream economic and competiveness, social, environmental and EU policy impacts.

The improved business-as-usual option would allow for some alignment of objectives and achieve a certain measure of simplification producing positive

Table 1: Summary comparison of cost-effectiveness, efficiency and coherence of options

Dimension	Improved business-as-usual	Horizon 2020	Renationalisation
Effectiveness			
Focus	+	++	+(1)
Intervention logic	=	+	+/-(2)
Accessibility, reach	+	++	++(4)
SMEs	+	++	++(5)
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	+	++	++(3)
Reduction of participation costs	+	++	++(3)
Coherence			
Knowledge triangle coordination	+	++	+/-(2)
Broader horizontal policy coordination	=	+	+/-(2)
Flexibility	=	+	++(3)

NB: (1) Easier to focus programmes, but more difficult to focus them on pan-European objectives; (2) in theory, easier to achieve/enhance: in practice, mixed Member State and regional performance; (3) but reduced critical mass, excellence; (4) but reduced critical mass and ability to pool resources; (5) but reduced access to foreign partners, capabilities, markets.

feedback effects on administrative burden, accessibility, reach, structuring effects, leverage effects, innovation impacts and downstream economic, social, environmental and EU policy impacts.

In the case of the renationalisation option, it would be more difficult to orient European research and innovation programmes to commonly agreed objectives. In theory, it would be easier to enhance the quality of the intervention logic, the level of flexibility, accessibility and reach, and the extent of knowledge triangle and broader horizontal policy coordination but, in practice, this is not the case and there would be important trade-offs. EU initiatives that fundamentally restructure the European R & D landscape would not be taken. Research that only takes place through EU-funded collaborative research projects would not take place. In the aggregate, this would compromise the return on investment in research as scientific, technological and innovation impacts would be reduced, which would translate into smaller economic and competitiveness, social, environmental and EU policy impacts.

See Annex 7 for the Commission's communication on the Horizon 2020 legislative proposal (COM(2011) 808 final).

5.4. Risks and risk mitigation strategies for Horizon 2020

The various impacts estimated above are those that can be achieved if Horizon 2020 is implemented successfully. But these are not guaranteed. In order for Horizon 2020 to tap its full potential, a number of conditions have to be met and a number of risks have to be mitigated.

- **Simplification:** Ongoing efforts to simplify the administrative requirements for Horizon 2020 must be followed through (these measures are addressed in the separate impact assessment of the rules for participation). They will be crucial in reducing barriers to entry, especially for small and medium-sized enterprises and for participants from the new Member States. Thus, these efforts should incorporate new capabilities and ideas, and reduce the concentration of participation and the rigidity of networks. This will have a positive impact on dissemination and valorisation and will also help reverse the decreasing support of a sizeable share of the scientific and innovation community who participated in past programmes and initiatives. The results of simplification need to be monitored closely to ensure that measures taken are effective. A key milestone will be the Horizon 2020 interim evaluation planned for 2017, which will address the key issue of programme implementation. Simplification should be seen to be bearing fruit by then.

- **Partnership and commitment from all actors:** The Commission plays an important role when it comes to managing Horizon 2020 and implementing simplification efforts. But, it is not only the Commission which will determine whether Horizon 2020 will achieve the maximum impacts. Its success will also depend on the research and innovation community itself — on its readiness to master the application and participation procedures; on industry — on its awareness of the opportunities offered by Horizon 2020; and finally, on the national and regional authorities which collaborate with the Commission to construct conducive framework conditions.

- **Programme management:** The various management arrangements proposed for Horizon 2020 must deliver. The Commission has successfully managed programmes and initiatives in the past, but it has never had to manage a programme of such scale and such scope. Externalisation will be scaled up, with all that it entails in terms of locating premises, hiring staff, establishing procedures, etc. Appropriate collaboration arrangements must also be put in place between the different Directorates-General involved in implementing Horizon 2020.

- **Seamless support:** It is one thing to draw up a rich portfolio of flexible funding schemes that could provide seamless support from research to innovation and from idea to market. It is quite another issue to make sure that these instruments work in practice, and that appropriate transfer mechanisms are established between the different Horizon 2020 priorities and between different funding schemes so as to make seamless support a reality.

- **Knowledge triangle coordination:** Horizon 2020 does not encompass the full knowledge triangle of research, innovation and education. Substantial amounts of research and innovation funding are disbursed through the European Structural Funds. Horizon 2020 does not cover education policies beyond the European Institute of Innovation and Technology. Nor does it cover intellectual property rights policy per se. It is, therefore, of crucial importance that appropriate interfaces are established with those Directorates-General, policies, programmes and initiatives that concern knowledge triangle issues outside the scope of Horizon 2020.

- **Broader horizontal policy coordination:** Direct support programmes in the field of research, innovation and the development of researcher skills should be coordinated not only with other knowledge triangle actors, policies, programmes and initiatives but also with sectoral actors, particularly given the focus of Horizon 2020 on the resolution of societal challenges. It is, therefore, of key importance that appropriate collaboration arrangements are established with those Directorates-General, policies, programmes and initiatives dealing with the sectoral policies addressed by Horizon 2020 but also with, for example, industrial policy, competition policy (to facilitate market entry of new players), tax policy (to change incentives and thereby business models and consumption behaviour), etc.

- **Member States:** Critical and emerging technologies cannot be produced through EU-level research and innovation support alone. EU funding and Member State funding have to work in tandem. It is of critical importance that Member States engage in smart fiscal consolidation that ring-fences investments in research, innovation and education and safeguards Europe's long-term innovation capabilities.

- **Programme responsiveness and adaptability:** Horizon 2020 will run over 7 years, a very long period of time in the world of science, technology and innovation. New societal challenges may emerge, and so may new scientific disciplines, thematic priorities, and topics. Content-related flexibility is built into Horizon 2020. But being able to make the correct choices at the most appropriate moments will depend on having the required strategic intelligence at one's fingertips. This means strengthening linkages with the scientific community and society at large, as well as developing a strong internal monitoring and analytical capability.

The Horizon 2020 monitoring system can play a key role in the mitigation of implementation risk. In view of the implementation of Horizon 2020, this is being revised (as explained in the next chapter). The success of Horizon 2020, on the other hand, will have to be judged on the basis of a thorough evaluation. This requires an ambitious and strong Horizon 2020 evaluation system matching the ambition of Horizon 2020 itself. Initiatives being taken in this regard and explained in the next chapter have to be achieved.

6 — Evaluation and monitoring

6.1. Purpose of Horizon 2020 monitoring and evaluation system

To achieve the objectives set out in Chapter 3, it is vital to put in place an appropriate system for policy and programme evaluation and monitoring.

While this system can usefully integrate some elements from the current system for FP7, it needs to undergo a fundamental revision in order to enhance its relevance and impact, given the ambitious policy objectives and structural diversity of the new framework.

The new system will be *strategic*, *comprehensive*, *coherent* and *evidence-based*, providing a strong focus on the assessment of outputs and impacts. It will incorporate radical innovations in the way evidence is gathered and processed, notably more automated data collection mechanisms, an appropriate data archive, external expert advice, dedicated policy research activity, and increased cooperation with Member States and associated states, and it will be *valorised* through appropriate dissemination and reporting activities.

6.2. Outline of key principles and possible indicators

The evaluation and monitoring system will need a clear strategic orientation in order to cover the wide range of activities in a consistent and coherent way. This orientation will be the subject of a dedicated Commission Communication. Key principles of the system will be:

- **Strategic**
  - In preparation for the launch of the new framework, a comprehensive evaluation and monitoring strategy will be developed and agreed by all actors involved. This strategy will ensure appropriate and systematic evaluation coverage of all Horizon 2020 action lines, and will define a detailed timetable for specific evaluation work. The strategy will be updated annually, taking into account new developments in the overall evaluation context.

- **Comprehensive**
  Three well-timed key deliverables are envisaged.
  - A comprehensive interim evaluation of Horizon 2020 and its specific programmes not later than 2017 (3 years into the programme), with a specific focus on the implementation so far, the quality of the research and innovation activities under way, progress towards the challenges and objectives set, and recommendations for possible improvements. This evaluation will also provide valuable inputs to stimulate the debate on the future of EU funding programmes for research and innovation, and is expected to contribute substantially to any forthcoming ex ante impact assessment.
  - A full-scale ex post evaluation will be carried out in 2023 (2 years after the end of the programme), analysing, in depth, the rationale, implementation and impact of the activities. The findings of this evaluation should be taken up, where relevant, in the management of subsequent activities.
  - Annual monitoring of all components under Horizon 2020 — both the interim and ex post evaluations — will be carried out with the assistance of independent external experts, using a broad evidence base. The findings of these evaluations will be rapidly taken into account in the implementation and management of Horizon 2020 or future programmes. They will also be communicated formally to the other institutions and to the stakeholder community at large, in order to provide the opportunity for a broad debate on the issues addressed.

- **Coherent**
  The following components are envisaged to support and complement the overall Horizon 2020 evaluations.

- Each of the thematic or specific components of Horizon 2020 should be submitted to an ex post evaluation, supported by relevant studies and evidence gathering, within 2 years of its completion.
- Specific evaluation studies will be carried out by all services with management and policy responsibilities under Horizon 2020, according to the timetable and objectives defined by the evaluation and monitoring strategy (see the first point in this section).
- Cross-cutting studies will be set out in the evaluation and monitoring strategy, and should shed more light on issues of transversal interest such as the quality of research and innovation performance under Horizon 2020, job creation, growth and the impacts on key technologies or sectors. Also important will be studies on the wider context for research and innovation including the relative positioning of EU research and innovation activities, their global competitiveness and emerging trends.
- The evaluation and monitoring system will also be the basis for carrying out the ex post evaluation of FP7 in 2015 according to the legal requirements.
- Common templates, methodologies and indicators will be adopted, as far as possible, so as to promote comparability and coherence, and to facilitate an aggregated overview.
- Available data will be used to calculate a series of common key indicators. The system of indicators to be developed will link closely to the Horizon 2020 objectives. An indicative outline is given in Table 2. Clear results targets will be set for each indicator — for example, X patent applications, or Y publications in high-impact journals, EUR 1 million funding.

More details are provided in the legislative financial statement of the Horizon 2020 proposal (COM(2011) 809 final, pp. 86–102).

- **Evidence based**
  At the centre of the Horizon 2020 evaluation and monitoring approach will be a powerful data gathering and processing capacity with the following features.

- **Focused on throughput, output and impact:** It will be essential to develop the tools for assessing progress towards objectives, project quality, output and impact of activities, but in a way that does not overburden programme participants: an integrated IT infrastructure and dedicated and automated data collection mechanisms (e.g. online forms and templates for periodic progress reports) will aim to significantly reduce this burden. Furthermore, the comprehensive *ex ante* evaluation of all funding activities should be mirrored by a new system for an independent review of project quality. In addition, the information gathered during and at the end of projects, notably regarding publications and patenting, should be validated and complemented by information on other forms of outputs and deliverables to capture the potential impact of Horizon 2020 activities in a broad sense. This development work should examine the possible use of novel solutions such as unique researcher identifier.
- **Supported by an appropriate data archive:** Experience from recent framework programme evaluations has clearly demonstrated the paramount importance of a comprehensive system for collecting all kinds of timely and relevant data for the evaluation and monitoring process. For FP7, CORDA provides a wide range of relevant data, which are all retrieved from the application, negotiation and reporting processes without any additional burden on the applicant. The principles of this successful approach will be used for the development of a corresponding Horizon 2020 evaluation and monitoring data archive. The main challenges will be the need to systematically integrate, automate, and validate a much broader range of activities under one common IT architecture and the need to integrate additional information on outputs and outcomes (see previous point).
- **Supported by expert advice:** The internal efforts by the respective evaluation functions should be supported by a reference board of independent evaluation experts and users. This reference board should monitor the development and implementation of the

Horizon 2020 evaluation strategy and monitoring, and provide expert advice and strategic guidance on the further development of the system.

– **Supported by a dedicated research activity:** A specific research effort in the field of science of research and innovation policy will be launched to develop innovative new evaluation methods and appropriate IT tools. The key objective of this initiative is to stimulate the development of novel methodologies for the evaluation of research and innovation activities, notably through the use of web based data and services. At the same time, this activity should both deepen and widen the, so far, rather limited expert community in this area.
– **Supported by increased cooperation with Member States and associated states:** While networking across the Commission services involved is essential to ensure an efficient and coherent evaluation and monitoring approach, it is equally important to step up the efforts to connect with actors at national and regional level. Not only will the research and innovation portfolio include a growing number of instruments for which evaluation activities at different levels should be envisaged, but there is also an increasing need to put evaluation work at EU level, and at national or regional level, into mutual context. To this end, a European research and innovation evaluation network will be created, evolving notably from the experiences gained over the last decade with the EU RTD evaluation network. This reorganisation should reflect the enlarged scope of the Horizon 2020 activities and provide the basis for a substantially increased cooperation with Member States and associated states.

- **Valorised through appropriate dissemination and reporting**
  Transparency of the evaluation process is a key element of an overall strategy for full accountability. Building on the positive experiences of recent years, the evaluation and monitoring system will include the following elements in particular.

– The aforementioned key indicators will be analysed in annual Horizon 2020 monitoring reports, which will present key data and indicators on the implementation of Horizon 2020. These reports will essentially draw on the information available through the Horizon 2020 evaluation and monitoring data archive.
– Progress on the implementation of the evaluation and monitoring strategy will also be communicated in an annual Horizon 2020 evaluation report, which will present the key findings from evaluation activities recently completed, the key features of the ongoing evaluation studies, and the planning for evaluation work in the near future.
– A dedicated Horizon 2020 evaluation and monitoring website will present all relevant material and should develop into an active tool to stimulate the exchange on evaluation activities for research and innovation programmes across Europe.

Table 2: **Objectives and Indicators of Horizon 2020**

OBJECTIVE	Indicator(s)
Strengthen Europe's science base	*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 *Future and Emerging Technologies:* - 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 *European research infrastructures:* - Research infrastructures which are made accessible to all researchers in Europe and beyond through EU support
Boost Europe's industrial leadership and competitiveness	*Leadership in enabling and industrial technologies:* - Patent applications obtained in the different enabling and industrial technologies *Access to risk finance:* - Total investments mobilised 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)
Increase the contribution of research and innovation to the resolution of key societal challenges	- Publications in peer-reviewed high impact journals in the area of the different Societal Challenges - Patent applications in the area of the different Societal Challenges - Number of EU pieces of legislation referring to activities supported in the area of the different Societal Challenges
Provide customer-driven scientific and technical support to Union policies	- Number of occurrences of tangible specific impacts on European policies resulting from technical and scientific policy support provided by the Joint Research Centre - Number of peer reviewed publications
Help to better integrate the knowledge triangle	- Organisations from universities, business and research integrated in KICs - Collaboration inside the knowledge triangle leading to the development of innovative products and processes

Annexes

Annex 1: Past achievements and lessons learned

This annex aims to provide an overview of the outputs, effects and impacts achieved by the Framework Programmes for research and technological development and demonstration activities (FP), the Competitiveness and Innovation Programme (CIP), and the European Institute of Technology and Innovation (EIT). As required by the Commission's Impact Assessment Guidelines (EC, 2009b), past FP achievements were discussed at length in the April 2005 *ex ante* impact assessment accompanying the proposal on FP7. In order to avoid duplication, this annex focuses, as far as the FP is concerned, in the first place, on evidence produced since that date. For this reason, the evidence following pertains to FP6 and FP7 in particular.

Summary of past achievements and lessons learned

The different programmes integrated into the common strategic framework for research and innovation — the FP, the CIP and EIT — have achieved large impacts in the course of their history.

FP achievements

The FP has involved large numbers of top (A-team) EU and extra-EU researchers in thousands of first-rate, mixed (firms, universities, research institutes), cross-border projects carrying out excellent, often interdisciplinary, collaborative research on a very wide range of topics. In the absence of EU funding, these projects would not have been carried out, or would have been postponed or scaled down in financial terms, in terms of scope and ambition, or in terms of the number of partners involved.

The FP has facilitated the training and pan-European/extra-European mobility of researchers, enhanced the quality of doctoral training (including through industrial doctorates), added to the research capabilities of participating institutions, and formalised and oriented the R & D and innovation processes of, in particular, small organisations (e.g. SMEs), young organisations (e.g. start-ups), and organisations from new Member States and candidate countries.

The FP has produced new knowledge embodied in large numbers of influential (because highly-cited) (co-)publications and enhanced the development of new products and processes; the development and use of new tools and techniques; the design and testing of models and simulations; the production of prototypes, demonstrators, and pilots; and other forms of technological development.

The FP has generated large numbers of patents and enabled participants to increase their turnover 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. In addition, the results of FP direct and indirect actions have supported EU-level policy formulation.

The FP's positive impacts on innovation have translated, down the line, into large-scale positive macro-economic, social and environmental impacts.

The FP has produced so-called structuring effects: durable changes in the EU research and innovation landscape. If it were not for the FP, the European Research Council, promoting excellence across Europe, would not have been created; the EU would then have been left with a landscape of compartmentalised national research councils, but would have had no funding mechanism to promote EU-wide competition for funds and to encourage higher scientific quality in frontier research. As a result of the Marie Curie Actions, the EU has created the right framework for researchers' careers and the free movement of knowledge. The EU leads in the creation and use of research infrastructures of pan-European importance: as a result of EU leadership, for the first time, a pan-European strategy on research infrastructures (the so-called ESFRI roadmap) has been developed and is now being implemented. Collaborative research projects, international cooperation actions, mobility actions, and research infrastructure actions have generated durable, cross-sectoral, interdisciplinary research and innovation networks across Europe as well as with the world's most dynamic and fastest growing research nations that have survived after the end of EU funding. European Technology Platforms and ERA-NETs have served as useful focusing devices that have helped stakeholders identify and explain their R & D needs jointly, easing the process of developing mutually supportive policies at EU and Member State levels. Joint technology initiatives have focused and aligned key actors in their respective areas, serving as a support to develop coherent sectorial strategies. Article 185 and joint programming initiatives have achieved a better coordination of R & D in Europe and supported a more coherent use of resources.

CIP achievements

According to a recent final evaluation of the EIP component of the CIP, the programme is performing well and on track to achieve the levels of activity anticipated in the CIP decision and *ex ante* impact assessment. Surveys carried out under the evaluation have demonstrated the utility of the programme (it directly meets identified needs) and its European added value. The evaluation found that existing financial instruments are supporting a substantial number of SMEs and administered efficiently, and that most innovation-related actions are seen as well-focused and appropriate. The final evaluation issued several recommendations, mostly aimed at expanding the existing activities launched within the current EIP and making them more comprehensive and consistent. The eco-innovation funding scheme for first application and market replication projects within the EIP helped a number of enterprises to bring their innovative goods to the market.

The ICT policy support programme component of CIP has been able to bring Member States together to test deployment of innovative ICT applications at real-scale in several important policy areas. These actions aimed at stimulating demand and facilitating the formation of markets in areas with high untapped potential, such as cross-border e-health services. They also helped to reduce fragmentation of markets for innovative ICT products and services, slow consensus and standardisation processes, lack of interoperability, diverging legislation and national practices. However, it is still too early to identify whether this potential is being realised as most pilots were launched in 2008 or later, and most are still grappling with midterm implementation. The ICT-PSP is complimentary to the initiatives of FP7, especially in supporting interoperability and attracting a broader constituency (i.e. public authorities) to facilitate the uptake of technologies (Eureval, 2009; Pogorel et al., 2009).

EIT achievements

The main achievements of the EIT since the establishment of the EIT headquarters in April 2010 have been primarily in setting up its own structure and the development of each Knowledge and Innovation Community (KIC) as a single legal entity led by a Chief Executive Officer. The EIT also set up the EIT Foundation in September 2010 in the Netherlands as a new, flexible financing tool to leverage philanthropic funds in support of educational and entrepreneurial activities bringing the EIT and its KICs closer to European society.

While European research and innovation programmes have been successful, there are important lessons to be learned from the past, from stakeholder feedback, and from analytical studies. Research, innovation and education should be addressed in a more coordinated manner and in coherence with other policies and research results better disseminated and valorised into new products, processes and services. The intervention logic of EU support programmes should be developed in a more focused, concrete, detailed and transparent manner. Programme access should be improved and start-up, SME, industrial, EU-12 and extra-EU participation increased. Monitoring and evaluation need to be strengthened (for details, see Section 3).

Detailed evidence on past achievements

The FP achieves a vast reach

Through thousands of contracts, the FP reaches tens of thousands of participants from a variety of sectors, from a large number of EU and non-EU countries, and from a wide range of disciplines.

The case of collaborative research is illustrative. Collaborative research constitutes the largest component of the framework programme. It accounted for 70 % of the budget under FP6 and

Table 3: The changing features of FP shared-cost research actions

Indicators	FP2-EU-12	FP3-EU-15	FP4-EU-15	FP5-EU-15	FP6-EU-25	FP7-EU-27
	1987-1991	1990-1994	1994-1998	1998-2002	2002-2006	2007-2013
	Definitive data	Definitive data	Definitive data	Definitive data	Definitive data	Partial data*
No. of projects	2779	3292	2949	6709	3110	2455
No. of participations (000)	13	18	21	41	40	25
Average no. of participations per project	4,7	5,6	7	6,2	13	10
Average no. of different Member States per project	3	3,5	4,2	3,7	6	6
Average EU funding per project (€000)	1202	1218	1160	1405	3928	4069
Average EU funding per participation (€000)	256	218	165	200	283	378

Source: Directorate-General for Research and Innovation.
* Partial FP7 data (to 1.2011).

accounts for 64 % of the budget under FP7. A statistical analysis performed on shared-cost action participation data (7) across FPs shows that the FP funds large numbers of projects bringing together different types of participants from all Member States as well as from other countries.

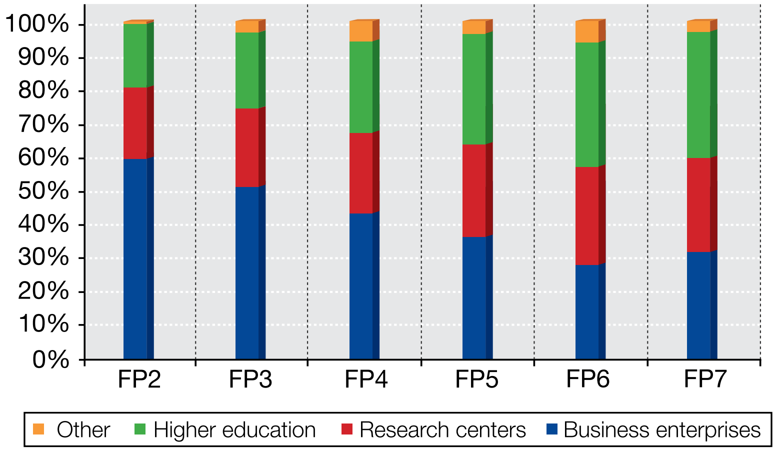
- **The FP funds thousands of research projects and participations with critical mass:** From FP2 to FP5, the growth in the collaborative research budget was accompanied by increases in the number of collaborative research projects (from 2 779 in FP2 to 6 709 in FP5) and participations (from 13 000 to 41 000). As from FP6, more emphasis was put on achieving a 'critical mass' of resources within a project: fewer projects were funded but they were of a greater size than before. The average number of participations per project doubled (from 6.2 to 13) and the average Commission funding per project increased by 278 %, from EUR 1.4 million to EUR 3.9 million. The average EU funding per participation also increased from EUR 200 000 to EUR 283 000. FP7 appears to maintain this trend towards larger projects with higher funding per project and per participation (Table 3).

- **FP research funding and participations are allocated in a balanced manner to different types of research actors:** Available shared-cost action data show an increasingly balanced allocation of funding and participations to the different types of research actors: business enterprises, research centres, and higher education institutions. Business enterprises initially accounted for the largest share of funding and participations. Research centres and higher education institutions gradually increased their shares over time. FP7 appears to have stopped, and even reversed, in terms of both, funding and participations, the decline in business enterprise participation (Figures A1.1 and A1.2).

- **FP collaborative research actions involve a significant number of SMEs:** SMEs accounted for 19.1 % of FP7 shared-cost action participations so far and 15.8 % of FP7 shared-cost funding

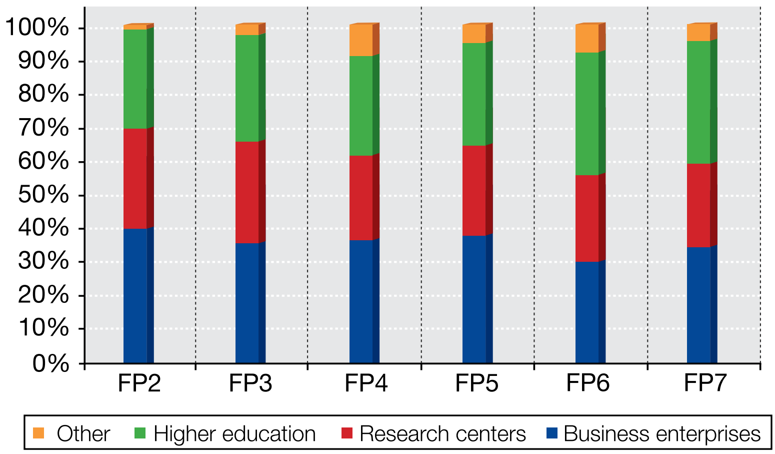
7. The statistical analysis was performed on the framework programmes participation data extracted from the central FP contract management database, CORDA. The shared-cost, collaborative-research actions filter was applied, which implies that, in FP6, only Integrated Projects, STREPs and Networks of Excellence data were considered. The scope of data varies from one FP to another, as the FP instruments and rules for participation evolved and the labels attached in the databases to FP participants also changed. This makes the data difficult to analyse, and the comparison required certain regrouping of data. Moreover, the incomplete data on participants' SME status is a major drawback of FP databases. This situation improved for FP7 reporting.

Figure A1.1: **How is FP funding shared between the main research actors? (% of FP funding received by type of participant)**



Source: Directorate-General for Research and Innovation.
(*) Partial FP7 data (to 1.2011).

Figure A1.2: **How is FP participation shared between the main research actors? (% of FP participations by type of participant)**



Source: Directorate-General for Research and Innovation.
(*) Partial FP7 data (to 1.2011).

disbursed so far (only Member States). Among 'private for profit' participants (mainly business enterprises), SMEs accounted for 49.5 % of participants and 45.1 % of funding. For shared-cost actions, the 15 % SME participation target appears to be achieved.

The FP succeeds in attracting and supporting highly performing SMEs. Some 34 of the 500 fastest growing enterprises in Europe in the year 2010 had participated in the FP, almost all of them several times.

- **The FP brings together participants from a large number of countries: EU Member States, associated countries and third countries** — no less than 243 countries participated in FP6 including 27 EU Member States, 5 associated countries, 3 candidate countries and 108 third countries

Table 4: **FP6 and FP7 participation and funding by country**

	Countries	FP6				FP7*			
		Participations		FP funding		Participations		FP funding	
		No	%	mln €	%	No	%	mln €	%
Member States	AT - Austria	1.208	2,68%	323	2,65%	737	2,6%	275	2,7%
	BE - Belgium	1.645	3,66%	470	3,84%	1.157	4,1%	417	4,2%
	BG - Bulgaria	187	0,42%	23	0,19%	127	0,5%	17	0,2%
	CY - Cyprus	102	0,23%	15	0,12%	68	0,2%	16	0,2%
	CZ - Czech Republic	582	1,29%	91	0,75%	306	1,1%	63	0,6%
	DE - Germany	7.089	15,76%	2.338	19,14%	4.450	15,9%	1.852	18,5%
	DK - Denmark	1.096	2,44%	303	2,48%	577	2,1%	239	2,4%
	EE - Estonia	146	0,32%	21	0,17%	87	0,3%	18	0,2%
	ES - Spain	2.915	6,48%	716	5,86%	865	3,1%	284	2,8%
	FI - Finland	902	2,00%	264	2,16%	1.897	6,8%	654	6,5%
	FR - France	5.007	11,13%	1.572	12,87%	680	2,4%	257	2,6%
	EL - Greece	1.434	3,19%	322	2,64%	2.856	10,2%	1.096	11,0%
	HU - Hungary	594	1,32%	99	0,81%	282	1,0%	59	0,6%
	IE - Ireland	447	0,99%	119	0,98%	321	1,1%	121	1,2%
	IT - Italy	4.344	9,66%	1.139	9,33%	2.824	10,1%	932	9,3%
	LT - Lithuania	131	0,29%	15	0,13%	74	0,3%	12	0,1%
	LU - Luxembourg	73	0,16%	16	0,13%	31	0,1%	10	0,1%
	LV - Latvia	89	0,20%	12	0,10%	33	0,1%	6	0,1%
	MT - Malta	37	0,08%	5	0,04%	25	0,1%	4	0,0%
	NL - Netherlands	2.562	5,69%	827	6,77%	1.659	5,9%	673	6,7%
	PL - Poland	944	2,10%	141	1,16%	465	1,7%	108	1,1%
	PT - Portugal	683	1,52%	125	1,03%	429	1,5%	116	1,2%
	RO - Romania	237	0,53%	28	0,23%	220	0,8%	38	0,4%
	SE - Sweden	1.692	3,76%	533	4,37%	1.062	3,8%	415	4,2%
	SI - Slovenia	310	0,69%	54	0,45%	197	0,7%	44	0,4%
	SK - Slovakia	155	0,34%	21	0,17%	92	0,3%	19	0,2%
	UK - United Kingdom	5.146	11,44%	1.583	12,95%	3.130	11,2%	1.255	12,6%
	JRC	148	0,33%	29	0,24%	84	0,3%	26	0,3%
	Total Member States	**39.757**	**88,37%**	**11.176**	**91,49%**	**24.735**	**88,2%**	**9.027**	**90,4%**
Candidate Countries	HR - Croatia	63	0,14%	8	0,07%	51	0,2%	11	0,1%
	IS - Iceland	64	0,14%	18	0,15%	30	0,1%	11	0,1%
	MK - Former Yugoslav Republic of Macedonia	33	0,07%	3	0,02%	20	0,1%	3	0,0%
	TR - Turkey	194	0,43%	31	0,25%	129	0,5%	27	0,3%
	Total Candidate Countries	**354**	**0,79%**	**60**	**0,49%**	**230**	**0,8%**	**53**	**0,5%**
Associated countries	CH - Switzerland	1.380	3,07%	336	2,75%	1.023	3,6%	404	4,0%
	IL - Israel	493	1,10%	147	1,20%	335	1,2%	135	1,4%
	NO - Norway	770	1,71%	211	1,73%	439	1,6%	172	1,7%
	Total Associated Countries	**2.648**	**5,89%**	**695**	**5,69%**	**1.863**	**6,6%**	**723**	**7,2%**
Third Countries	US - United States	113	0,25%	11	0,09%	141	0,5%	19	0,2%
	AU - Australia	58	0,13%	3	0,02%	62	0,2%	2	0,0%
	CA - Canada	66	0,15%	2	0,01%	59	0,2%	1	0,0%
	JP - Japan	16	0,04%	1	0,00%	20	0,1%	1	0,0%
	CN - China	224	0,50%	28	0,23%	109	0,4%	15	0,1%
	IN - India	66	0,15%	9	0,08%	83	0,3%	18	0,2%
	BR - Brazil	92	0,20%	12	0,09%	56	0,2%	11	0,1%
	RU - Russian Federation	263	0,58%	39	0,32%	151	0,5%	28	0,3%
	Rest of the world	1.186	2,64%	153	1,25%	548	2,0%	91	0,9%
	Total	**44.991**		**12.216**		**28.057**		**9.989**	

Source: Directorate-General for Research and Innovation.
(*) Partial FP7 data (to 1.2011).

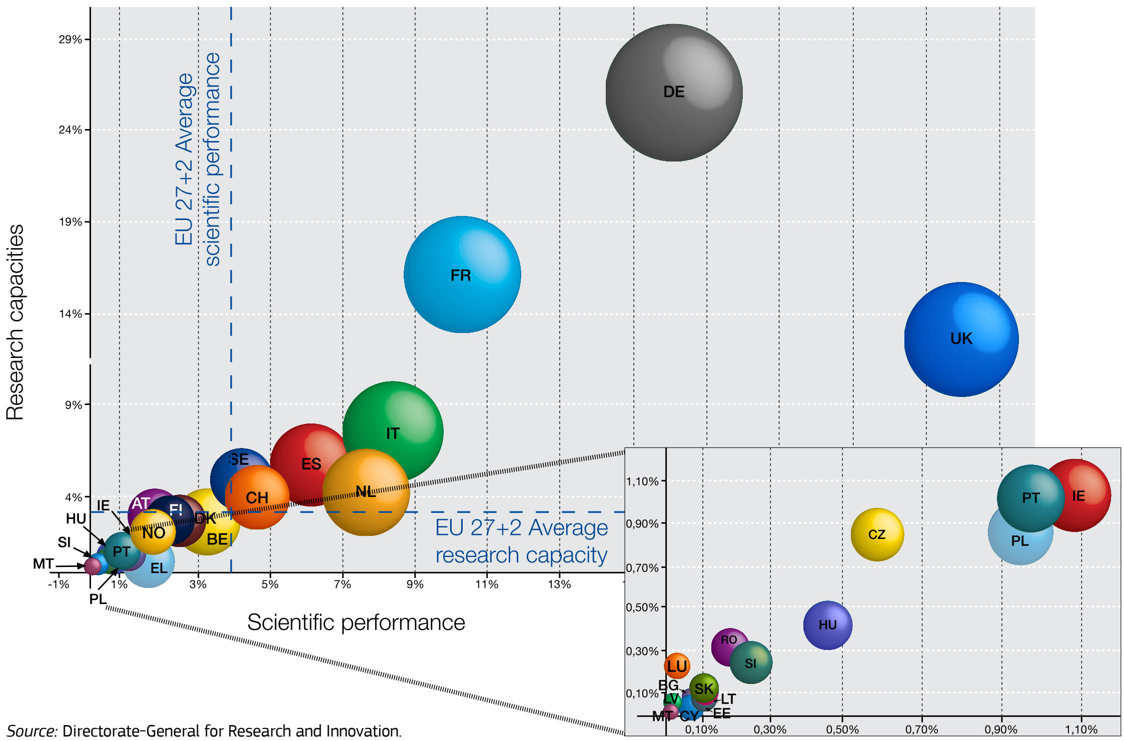
from all continents. After the Member States and associated countries, the so-called BRIC countries (Brazil, Russia, India, China) accounted for most FP participations and funding (Table 4).

- **The FP brings together participants from a large number of regions:** FP6 funding reached 256 of the 271 EU-27 Member State regions (NUTS 2 level), from Crete and Cyprus in the South to Lapland (Finland) in the north and from the Algarve (Portugal) to the Black Sea (Romania).

- **The extent of involvement in the FP of individual EU Member States, associated countries, and EU regions is in line with their economic and research capabilities:** FP collaborative research funding is awarded on the basis of scientific excellence, not nationality; large economies with large research capabilities like Germany, France, Italy and the United Kingdom therefore account for the highest share of both FP funding and participations (Table 4, Figure A1.3). The opposite is true for smaller and new Member States, which do not have the research capabilities to absorb large amounts of FP funding. The statistical analysis shows that there is a very strong correlation (0.98) between the magnitude of FP funding received by a Member State and the size of its economy.

  The same pattern is replicated at regional level: FP participations and funding are concentrated in regions where research activities are concentrated. The top regional recipients of FP funding are the well-known European centres of scientific excellence and innovation performance, including northern Italy, Bavaria, Oxfordshire, Rhône-Alpes and capital regions such as London, Madrid and Île-de-France (Figure A1.4).

Figure A1.3: **Involvement in FP7 is aligned with a country's scientific performance and research capabilities**

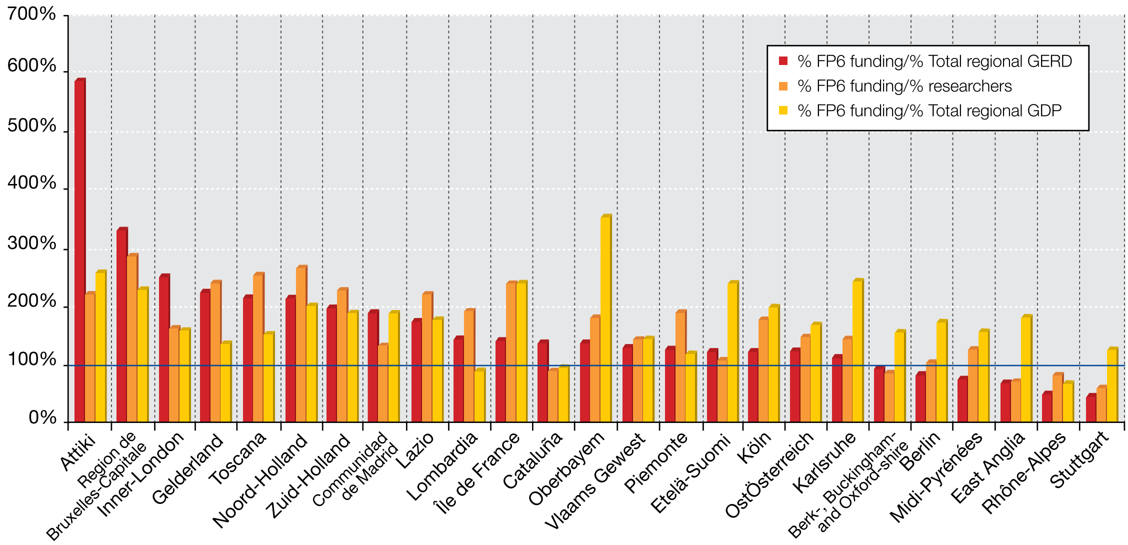


Source: Directorate-General for Research and Innovation.
Data: Eurostat, *Science Metrix-Scopus* (Elsevier).
NB: Research capacities = share of EU-27, Norway and Switzerland GERD; Scientific performance = share of EU-27, Norway and Switzerland highly cited publications; the size of the bubble is proportional to FP7 funding received.

- **Small and new EU Member States and their regions participate more intensely and benefit more from the FP than their research and economic capabilities and scientific and technological performance would suggest:** When ranking Member States in terms of their share of FP participation or funding divided by their share of EU GDP, European researchers or GERD, smaller Member States tend to receive more funding and account for more participation than their economic performance and research capabilities could suggest (Figures A1.5 and A1.6).

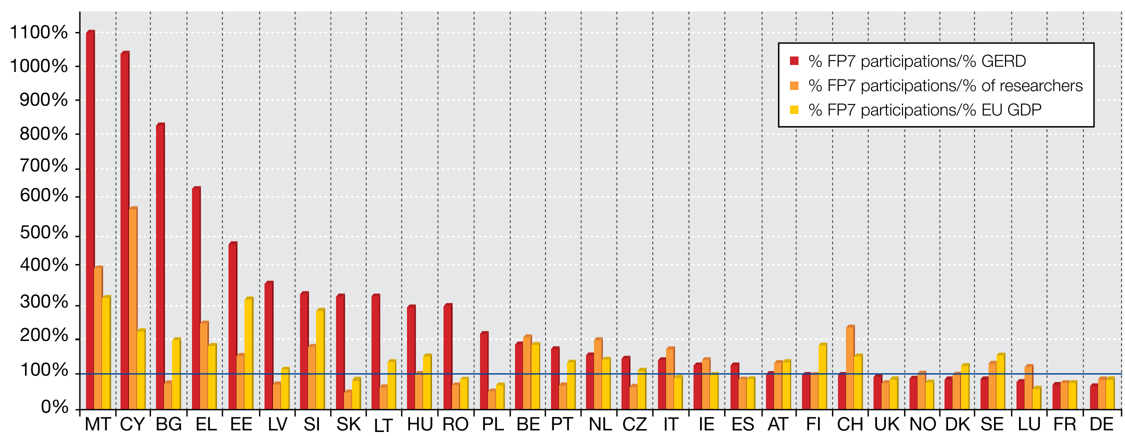
At regional level as well, peripheral and less research-intensive regions obtain much more FP6 funding per euro of research investment (GERD) than more research-intensive regions. This is particularly true for EU-10 regions, which obtain up to five times more than their research investment would suggest (Figure A1.7). In conclusion, it could be put that FP

Figure A1.4: **Top 25 regional recipients of FP6 funding**



Source: Directorate-General for Research and Innovation, data for EU-27.

Figure A1.5: **New Member States participate more intensively in FP7**



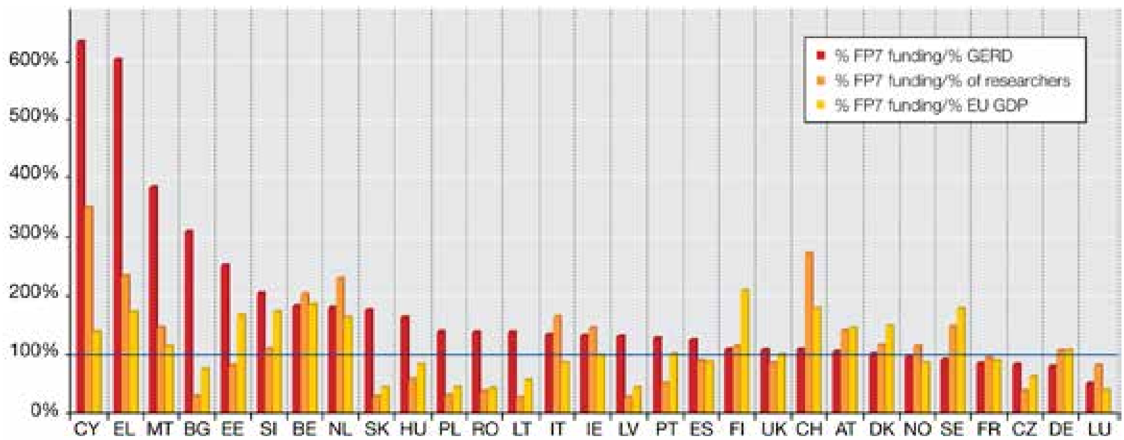
Source: Directorate-General for Research and Innovation, data for EU-27, Norway and Switzerland.

is an important alternative source of funding for less-favoured regions and contributes to filling in the investment gap.

New Member States also participate more intensely in the FP and receive more FP funding than their scientific (share of top 10 % most cited publications) or technological performance (share of PCT (Patent Cooperation Treaty) patents) would suggest (Figures A1.8 and A1.9).

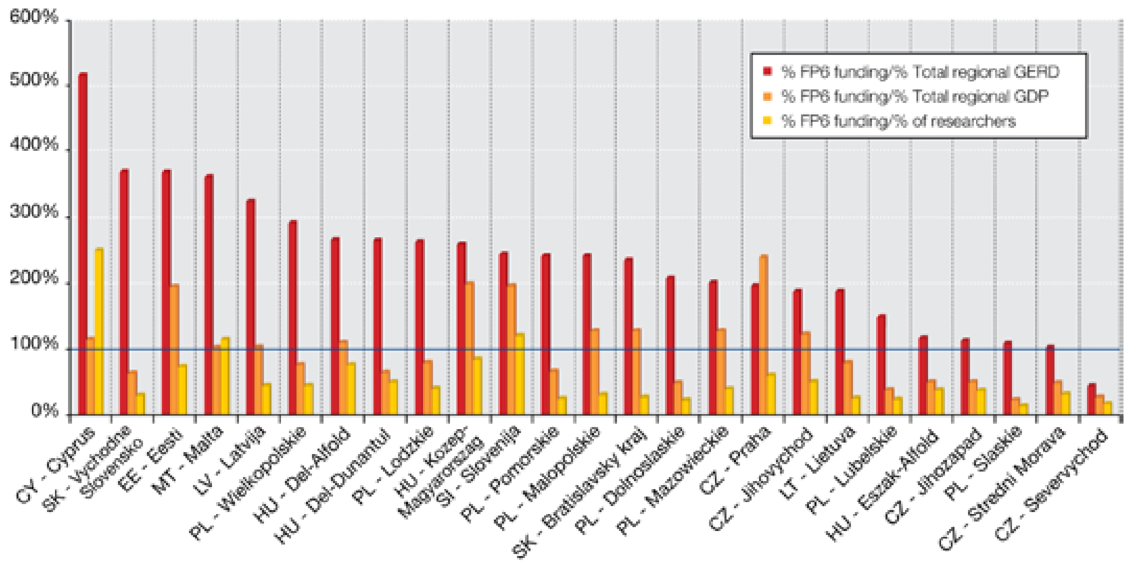
- **The benefits from FP participation go beyond FP funding received: a Member State obtains, on average, EUR 29 of net knowledge return from every EUR 1 invested in the FP.** Participating in an FP collaborative research project offers access to EU-wide knowledge exchange networks. In other words, a single project participant benefits from and accesses the funding received by all project participants combined. An analysis of national knowledge returns from the FP, which takes

Figure A1.6: **Smaller Member States benefit more from FP7 funding in relative terms**



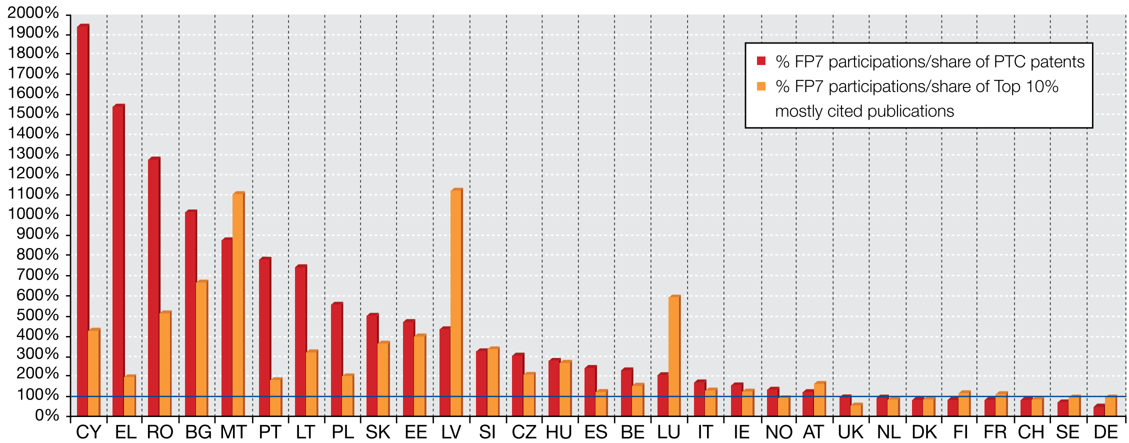
Source: Directorate-General for Research and Innovation, data for EU-27, Norway and Switzerland.

Figure A1.7: **EU-10 regions benefit more from FP funding in relative terms**



Source: Directorate-General for Research and Innovation, data for EU-27.

Figure A1.8: **New Member States participate more intensely in FP7 than their R & D output would suggest**



Source: Directorate-General for Research and Innovation, data for EU-27, Norway and Switzerland.

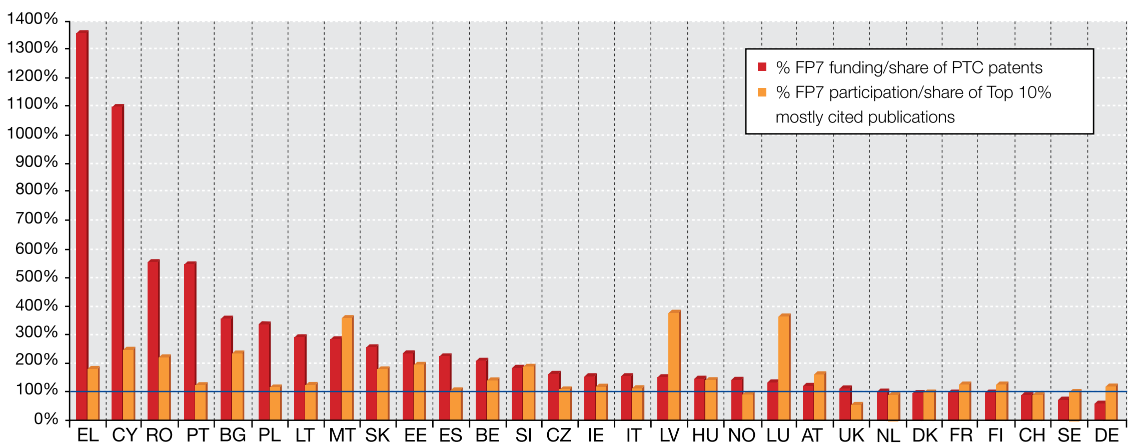
account of the collaborative research network multiplier, shows that all countries enjoyed net positive knowledge returns under FP6. The average return was EUR 29 per EUR 1 invested for the EU-27, Norway and Switzerland (Figure A1.10). This represents an increase of about EUR 8 compared to FP5.

The size of these returns tends to be inversely related to a country's number of FP participations. Countries with a smaller number of participations (smaller and new Member States) benefit from higher net knowledge returns than countries with a larger number of FP participations (larger EU economies). This is probably linked to the fact that smaller numbers of FP participations translate into a pattern of widely dispersed single participations per project, while a larger number of FP participations translates into a pattern where two or three participants from a country are regularly present in a project.

The FP involves top (A-Team) *researchers and organisations in high-quality research*

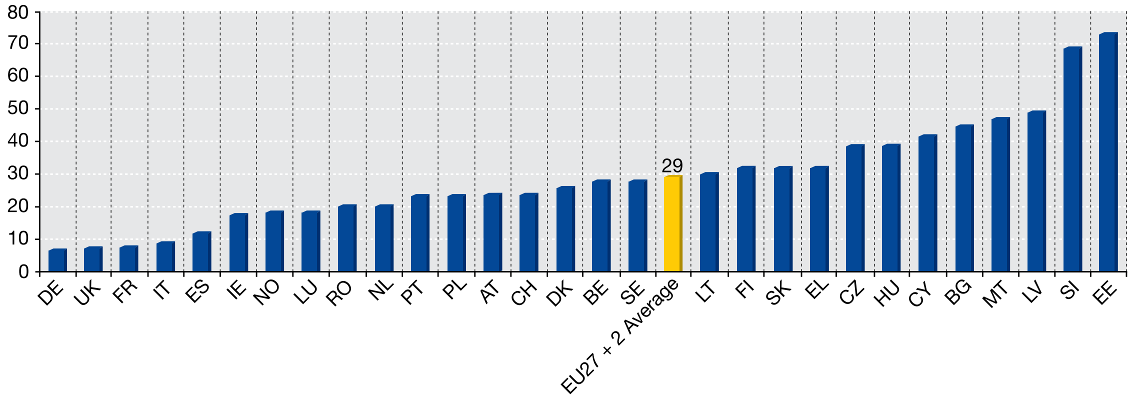
The FP6 *ex post* evaluation (Rietschel et al., 2009) concluded that FP6 involved top-quality researchers

Figure A1.9: **New and smaller Member States benefit more from FP7 than their R & D output would suggest**



Source: Directorate-General for Research and Innovation, data for EU-27, Norway and Switzerland.

Figure A1.10: **Net knowledge return per EUR 1 invested in the FP6**



Source: Directorate-General for Research and Innovation.
NB: (Value of shared-cost contracts in which each country participating (no double counting))/Contribution to FP shared-cost actions budget) — 1); EU-27 + 2 (NO and CH) contribution to FP6 shared-cost actions budget calculated on the basis of the share of their GDP in the EU-27, Norway and Switzerland GDP.

in first-rate projects performing high-quality research. This conclusion was based on the following.

- **An FP-wide bibliometric study:** This study demonstrated that the publication and citation performance of FP project 'lead scientists' is better than that of their non-FP peers (EPEC, 2009).

- **Thematic bibliometric evidence:** An *ex post* impact assessment of the 'Global Change and Ecosystems' sub-priority found, based on peer review and bibliometric indicators that the work was of high scientific quality (EPEC, 2008).

- **The FP5 and FP6 Innovation impact study:** This study found that, compared with the average company in their sector, FP industrial participants are more R & D-intensive, more innovative, better networked and more focused on international markets, and file more patents (Polt et al., 2008).

- **An FP6-wide participation survey:** This study found that participants with high and very high R & D capabilities represented around 80 % of all FP6 survey respondents. Under FP5, the share was 60 % (IDEA Consult, 2009c).

- **Self-assessments submitted to the FP6 Expert Group:** Twenty-four Commission research managers provided self-assessments to the FP6 *ex post* evaluation Expert Group. Eight said independent reviews had confirmed that nearly all the research in their portfolio was of international standard. Another seven said that at least two thirds was of international standard.

- **The pan-European perception of the quality of FP-funded research:** In many countries, the receipt of FP funding is seen as a quality indicator for the scientists, research groups and organisations involved. For this reason, some research councils actively support EU applications while some universities provide matching funding.

- **The extra-European perception of the quality of FP-funded research:** Third-country researchers have a positive image of the FPs in general and FP6 in particular. They associate the programme with top-class research and believe that the FP provides better career references for participants, is better in mobilising top-class researchers and institutes, and provides better funding opportunities than other similar (competing) programmes.

The FP Interim evaluation (Annerberg et al., 2010) concluded that excellence seemed to have been at the heart of the bulk of FP7-funded projects and reaffirmed the finding of the FP6 *ex post* evaluation that EU funding is not just for the B-team, but attracts A-team members. This conclusion was based on the following.

- **An analysis of FP7 top funding recipients:** The FP7 interim evaluation concluded that 'there can be little doubt that FP7 attracts the top EU researchers from universities and RTOs' since 'the list of organisations that have obtained the largest amounts of funding from FP7 can be read as a *Who's Who* of European research quality'.

- **An analysis of FP7 collaborative research proposal evaluation scores:** FP proposals are peer-reviewed and scored according to three criteria: scientific excellence, project management quality, and potential impact. The mean score for 'scientific quality' was 4.4 out of 5 (minimum 4) and the mean sum for the three criteria was 13.1 out of 15, far above the minimum of 10 specified in the programme rules and, according to the evaluation expert panel, an objective measure of average proposal quality.

- **An analysis of ERC proposal evaluation scores:** The FP7 interim evaluation concluded that the ERC is attracting applications of high-quality as some 56 % of the total number of applications was evaluated as above the threshold set by the evaluation criteria.

- **Self-assessments submitted to the FP7 Expert Group:** Seven out of 10 self-assessments submitted to the evaluation expert panel said that 'nearly all' or 'a majority' of the research funded was world-leading. The other self-assessments said there was not yet enough information to judge.

The quality of FP participants is also demonstrated by an analysis of FP participation data.

- **The FP supports Europe's industrial R & D champions:** All FP6 and FP7 shared-cost action top industrial participants (in terms of funding, in terms of participations) are European companies figuring in the ranking of the 'Top 1 000 Global R & D Investing Firms' ([8]). The top FP6 industrial participant, for example, was Siemens AG (EUR 46.4 million, 150 participations) while the top FP7 industrial participant so far is SAP AG (EUR 53 million, 55 participations).

- **The FP funds Europe's most excellent universities:** About half of the 50 FP6 shared-cost action top university participants rank among the world's best 100 universities while 94 % rank among the world's best 400 universities (Academic Ranking of World Universities, 2010). The top 100 European universities in the 2008 Leiden ranking received about half of the FP7 funding disbursed at that time to European higher education institutions.

- **The FP provides support to Europe's leading public research centres:** Leading European public research centres such as the Max-Planck-Gesellschaft, the Fraunhofer-Gesellschaft, the CNRS (Le Centre national de la recherche scientifique) and the Commissariat à l'énergie atomique are top FP participants occupying key positions in FP projects and networks. Under FP6, for example, these four institutes accounted for EUR 562.9 million of funding and 1 244 participations.

- **The FP connects Europe with global centres of excellence:** Eight of the world's top 10 non-European universities (Academic Ranking of World Universities, 2010) participated in FP6 and FP7-funded collaborative research: MIT, the California Institute of Technology, and the Universities of Harvard, Berkeley, Princeton, Stanford, Columbia and Chicago. Moreover, in both FP6 and FP7, one could find other world centres of excellence participating such as the Universities of Tokyo and Kyoto, Universities of Toronto, British Columbia and Melbourne, as well as the Australian National University.

Other evidence concurs.

- According to a Dutch FP impact study (Technopolis, 2009), 'bibliometric research and over 100 interviews held in the Netherlands, confirmed that the European research programmes produce high-quality research and attract the best European researchers'.

8. Of the 34 European companies in the Top 100 R & D investing companies, 31 received FP funding under FP6 (http://webarchive.nationalarchives.gov.uk/20101208170217/http://www.innovation.gov.uk/rd_scoreboard/downloads/2010_RD_Scoreboard_data.pdf).

- According to an EC-commissioned study on ICT research performance in FP (Bocconi University, 2010), 'the Directorate-General for the Information Society and Media projects have been highly effective in attracting top-quality researchers and research teams from the research fields relevant for the ICT area'.

- As demonstrated by a study analysing participation of top European universities (selected with the Leiden crown indicator) in the FP6, they had a key role in terms of participation and funding, with a leading role in the coordination of projects (JRC-IPTS, 2009).

FP research is often helpfully interdisciplinary

- There is substantial evidence that interdisciplinary research is more productive than mono-disciplinary research. In this respect, the FP7 interim evaluation (Annerberg et al., 2010) concluded that the FP promotes cross-disciplinary research in an implicit and generic way through work programmes and calls for proposals that target certain problems, challenges or application areas. Virtually all Commission self-assessments submitted to the evaluation expert panel gave scores of 5 or 6 out of 6 for cross-disciplinarity.

- An EC-commissioned evaluation of FP6 environmental research (EPEC, 2008) concluded that several projects addressed new issues and initiated new approaches, in particular research with a strong interdisciplinary component.

Through the FP, large numbers of scientists are trained

- Training is the core preoccupation of the FP's **Marie Curie Actions**, which promote cross-border, cross-sectoral and cross-disciplinary researcher mobility, as well as skills and career development.

– The FP6 *ex post* evaluation (Rietschel et al., 2009) noted that FP human resource actions are almost universally judged to be a major success. FP6 human resources and mobility schemes involved 8 000 organisations and supported some 12 500 fellows.

– The FP7 interim evaluation (Annerberg et al., 2010) noted that the specific programme 'People' is making a valuable contribution to the development of researcher human capital and that 'the Marie Curie Actions, through their bottom-up approach, have promoted excellence and have had a pronounced structuring effect on the research landscape'. In the period 2007–10, 38 calls were launched and concluded in the 'People' programme resulting in nearly 5 500 projects retained for funding. During that period, over 6 400 researchers benefited from individual fellowships and grants to enhance their career prospects. Nearly 400 ITN (Initial Training Networks) and IAPP (Industry-Academia Partnerships and Pathways) schemes were selected for funding providing training and knowledge transfer to more than 6 500 researchers.

– The German Federal Ministry of Education and Research noted that the FP offers good opportunities for supporting upcoming scientists. Young scientists become involved in international research networks and have the opportunity to perform research at foreign institutions within the framework of mobility programmes. In particular, universities and non-university research institutions emphasise the opportunities for supporting young talent through participation in the mobility programmes (Federal Ministry of Education and Research, 2009).

- There is a training element in **European Research Council** advanced grants, with preliminary analysis of the financial reports revealing that advanced grant teams typically consist of two doctoral students and two postdoctoral researchers in addition to the principal investigator (Annerberg et al., 2010).

Table 5: **Status of users at research infrastructures during FP6**

Researcher status	Total	%
Experienced researchers	12 804	49
Post-doctoral researchers	4 633	18
Post-graduate	7 050	27
Undergraduate	1 275	5
Technicians	303	1
Total	26 065	100

- Training is also provided through the FP's **research infrastructure** actions, which facilitate access to unique and expensive infrastructures of European importance. Nine out of 10 researchers say that without FP funding they would not have been able to access vital research facilities, which is often a precondition for successful frontier research. Under FP6, about half of the 26 000 users who benefited from access were young researchers (undergraduate, postgraduate and postdoctoral). These highly trained personnel form an invaluable human capital resource for serving current and future industrial needs (Table 5).

- Large numbers of scientists have been trained through FP-funded **collaborative research**.

– According to an EC-commissioned evaluation of the FP5 'Growth' programme, projects had generated, or were expected to generate, 2 152 doctorates (Ramboll Management and Matrix Knowledge Group, 2008).

> The CASCADE Network of Excellence (FP6) — a highly multidisciplinary network dealing with chemical contaminants — developed an extensive training featuring a wide array of scientific disciplines, including risk assessment, toxicology, biochemistry, molecular biology, mouse genetics, *in silico* and *in vitro* methodologies that led to the establishment of an international postdoctoral programme (CASCADE-FELLOWS).

– According to a survey among FP5-7 project coordinators working in the research theme 'Food, Agriculture and Fisheries and Biotechnology', almost 80 % of projects trained at least one PhD student and 73 % at least one postdoctoral researcher. Some 18 % of projects trained more than 10 PhDs, which provides evidence of the impact of the FP on the training of young researchers. Significant efforts were also made to train other personnel: over 50 % of projects trained graduate, technical and administrative personnel (EC, 2011h).

– According to an Austrian FP impact study (Technopolis, 2010a), 'it is important to note that training of young researchers not only occurs in the human resources-oriented measures (the "People" programme and ERC Starting Grant) but also in the "traditional" cooperative FP projects'.

– According to an Irish evaluation of FP6, each project produced, on average, 2.3 newly trained/qualified personnel (Forfás, 2009).

The FP improves participants' R & D and innovation capabilities

- The FP7 interim evaluation (Annerberg et al., 2010), referring to a UK evaluation of the FP identifying important participant capability impacts (see following), considered it 'reasonable to infer that similar outcomes will have occurred elsewhere'.

- A study of FP6 behavioural additionality (IDEA Consult, 2009b) found that FP funding increased FP participant organisations' ability to network with universities, public research institutes and firms; that FP project management experience was already, or would be, used in other R & D and innovation projects within the organisation; and that FP funding helped to formalise the R & D and innovation processes, in particular for very small and young organisations and for organisations coming from candidate countries.

- A study of the impact of FP6 in new Member States (COWI, 2009) found that FP6 'had an important impact on research organisations' interests and capacity in networking and … inspired a networking approach to the management and implementation of research projects with more focus on cooperation, formation of consortia, multidisciplinarity, communication and management skills'. It also produced 'an increase in skills and research capabilities of its key research staff' and resulted in the 'development of administrative capacity/competence to handle international project management processes'.

- An FP6-wide participant survey (IDEA Consult, 2009c) concluded: 'The learning effects of participating in a project under FP6 appear to be high for individual organisations. Much of the experience gained, both technological and managerial, can and will be used again in future R & D projects'.

- A survey among the FP6 IST programme participants (WING, 2009) found that more than 80 % of participants consider that EU projects have enabled them to significantly extend their knowledge base and RTD capability, develop new skills and competence and explore new technology paths that they would have not addressed otherwise. The same share of participants highlighted the important impact of their FP participation on networking and the building of new long-term strategic partnerships allowing them to gain access to complementary expertise.

- The same survey-based study (WING, 2009) showed that around 75 % of industrial participants found that their participation has helped improve their innovation capacity and explore new opportunities, including the successful reuse of knowledge developed within projects in another context (WING 2009).

- An Irish evaluation of FP6 participation (Forfás, 2009) found that 'the primary benefits came in the form of improved relationships and networks, increased knowledge and capabilities (both scientific and technological), and enhanced reputation and image'.

- A Spanish evaluation of FP6 participation (Zabala Innovation Consulting SA, 2010) found that 'for 52 % of the surveyed researchers, participation in the FP6 contributed to strengthening their research teams, above all due to the scientific excellence offered by the acquisition of capabilities and abilities during the project'.

- A Swedish longitudinal evaluation of FP participation (VINNOVA, 2008) found that 'FP money has been one of the factors enabling the [automotive] industry in general, and Volvo AB in particular, to maintain the high level of technological capabilities that have so far protected vehicles design and production activities in Sweden, which from a scale logic are anomalous'. It noted that 'the survey confirmed the earlier finding that capacity building was an important aspect of the FP projects and also showed more clearly that participants were involved because of the opportunities for technical learning offered'.

- A UK evaluation of FP6 and FP7 found that the FP has a large impact on the nature and extent of UK researchers' international relationships and networks, as well as on their knowledge base and scientific capabilities. Other notable outcomes include increased scientific reputation, an improved ability to attract and retain world-class researchers and a positive impact on researcher careers. Lastly, FP has a positive impact on the attitudes, outlook and connectedness of individual researchers, as well as serving as a training ground for project management and administration.

The FP produces large numbers of high-quality, often collaborative scientific outputs

- According to an EC-commissioned evaluation of the FP5 'Growth' programme (Ramboll Management and Matrix Knowledge Group, 2008), projects had generated, or were expected to generate, 18 974 publications.

- According to an EC-commissioned study on FP6 network effects (AVEDAS et al., 2009), the number of publications produced between one year after the starting month of the project and the end of 2007 by the principal investigators of 2003–05 FP6 projects (n = 1.312) amounted to 32 466.

- According to the same study, FP6 projects produced increased co-publication activity between project partners (i.e. two partners from the same FP6 project published one or more articles together after having participated together in FP6). Publications from FP6 principal investigators, either with or without other FP6 partners, had a 50 % higher impact than the world average. Co-publications by collaborating FP6 partners had significantly higher impact (around twice the world average) than publications in which FP6 partners did not co-publish.

- According to an EC-commissioned evaluation of FP6 environmental research (EPEC, 2008), EU environmental research is leading in several environmental research areas. According to peer-reviewers, the scientific and technological impact of EU environmental research is particularly high for projects in three areas: climate change (4.6/5), water and soils (4.5/5), and natural hazards (4.4/5). According to a bibliometric analysis, three areas of EU environmental research can be distinguished for their higher impact factor: climate change, water and soils, and biodiversity and ecosystems. Climate change in particular is the area in the sub-priority 'Global change and ecosystems' that receives the highest ranking in almost all types of impact, especially as regards scientific impacts. All projects in the 'Climate change' area are unanimously qualified as being of high scientific quality, producing 'excellent new science'.

- According to a German evaluation of FP6 (Federal Ministry of Education and Research, 2009), scientific personnel participating in FP6 stated that a substantial part of their publications was due to their participation in the FP.

- According to an Irish evaluation of FP6 (Forfás, 2009), each project produced, on average, 12.7 publications (of which 5.3 were in refereed journals and books) and 5.2 conferences, seminars or workshops.

- Bibliometric analyses of FP6 projects (EPEC, 2009) indicate a high productivity of papers in high-quality journals by FP-funded scientists working in the research theme 'Food, Agriculture and Fisheries and Biotechnology'. For FP6 Food, coordinators were found to perform better than non-FP- funded peers.

- The results of survey performed by the Directorate-General for Research and Innovation among FP5 to FP7 coordinators showed that the EU-funded research theme 'Food, Agriculture and Fisheries and Biotechnology' produced on average 4.4 publications per project. Some projects have produced particularly high numbers of publications in peer-reviewed journals (e.g. 400 publications by the fishery projects SEAFOODplus and IMAQUANIM; 120 publications by the agriculture FP6 project EU-SOL).

- An analysis undertaken by the EC showed that around 50 % of all FP6 projects in the domain of ICT produced at least one scientific article included in a high-impact journal (ISI Web of Science — ISI WoS) database and that 82 % of projects produced at least one other publication outside the WoS database. For FP7-ICT, the share of projects reporting at least one scientific article in the ISI WoS database was 32 % (at the end of the first 2 years of the programme), and 71 % of projects under FP7-ICT produced at least one other publication outside of the ISI WoS database.

The FP produces numerous technological outputs and innovations

- For firms, FP collaborative research projects are more than self-financed collaborative research projects focused on risky, complex and long-term exploration rather than on short-term exploitation: firms participate in the FP mainly to achieve knowledge and technology-related objectives, and less to achieve direct commercialisation-related objectives. In addition, FP projects are not, and should not be, assessed as stand-alone R & D activities; they form part of a wider portfolio of R & D projects.

- Notwithstanding the above, the FP has a significant positive impact on innovation and competitiveness: FP-funded research produces large numbers of patents, innovations and micro-economic benefits (Figures A1.11 and A1.12).

- An EC-commissioned evaluation of the FP5 'Growth' programme (Ramboll Management and Matrix Knowledge Group, 2008) found that — although exploitation was not the primary objective — exploitation objectives were achieved in 54 % of the projects; projects had generated or were expected to generate:
  - the creation of 248 spin-off companies;
  - 3 724 prototypes, demonstrators, pilots;
  - some EUR 7.2 billion additional sales;
  - EUR 891 million in cost reduction;
  - 1 077 patent applications;
  - 204 registered designs and other forms of IPR protection;
  - the safeguarding of 37 588 jobs and 8 038 new jobs;
  - 310 inputs into technical standards.

- According to an EC-commissioned study on FP6 behavioural additionality (IDEA Consult, 2009b), projects would have led to a smaller range of potential applications and a smaller number of marketable products if continued without FP6 funding.

- According to an EC-commissioned study on FP6 network effects, FP6 resulted in increased competitiveness of the European Research Area because of, inter alia, the development of new and improved research methods and techniques and more commercial or industry-based approaches in the research. The same study found the following answers to the question 'What outcomes has the FP6 led to that your organisation would not have achieved if it had not been involved in FP6?': 'New or improved commercial products, services': about 2.8 out of 5; 'Patents, intellectual property': about 2.9 out of 5.

- According to an FP6-wide survey (IDEA Consult, 2009c), industrial organisations clearly expected commercial returns. Almost half of them (47 %) stated they were likely to very likely, and 60 % of this group expected these returns within 2 years (90 % within 5 years).

- According to the FP5 and FP6 Innovation impact study, a great majority of FP participants reported at least one form of commercialisable output (new or improved processes, products, services, standards) stemming from their FP project and a large number even recorded more than one such output; an econometric analysis showed that the FP produces output additionality — a positive impact on the innovative sales of firms participating in the FP; and small and medium-sized enterprises indicated the most positive results in terms of innovation in FP projects.

- According to a Finnish evaluation of FP6 (TEKES, 2008), 'commercialisable output is not the core objective of the FPs but EU collaboration nonetheless contributes significantly to the creation of innovation'.

- According to a German evaluation of FP6 (Federal Ministry of Education and Research, 2009), scientific personnel participating in FP6 stated that a substantial part of their patent applications was due to their participation in the FP. Large, export-oriented companies as well as companies in the field of cutting-edge technology and the knowledge-intensive service sector were more likely to take part in FP6 than in federal or *Länder* programmes because, among other reasons, participation tended to have a positive effect both with regard to the extent of their own R & D activities and the commercial success of innovations.

- According to an Irish evaluation of FP6 (Forfás, 2009), each project produced, on average, 0.1 patent applications, 0.4 new or significantly improved commercial product or services, and 0.4 new or significantly improved scientific or industrial processes.

- A Swedish long-term evaluation of the FP (VINNOVA, 2008) found significant impacts on the ability to compete in vehicles and in electronics (especially telecommunications); in ICT, FP participation in European and global standardisation had been a key factor in building the Swedish telecommunications industry's position in mobile telephony, while in vehicles, the FP had, together with complementary national programmes, been instrumental in supporting the Swedish industry's technical specialisations, especially in safety and combustion.

- According to a Swiss evaluation of FP5 and FP6 (State Secretariat for Education and Research, 2009), participation generated both knowledge and jobs.

- According to a UK evaluation of the FP (Technopolis, 2010c), a majority of UK business participants stated that their involvement in the FP had yielded important commercial benefits; in terms of immediate project outputs, a significant proportion of business respondents reported having made or gained access to new or significantly improved tools or methodologies and in a large minority of cases, firms reported the creation of formal elements of intellectual property; beyond these immediate project results, around 20 % of businesses stated that their participation had made significant contributions to the development of new products and processes and in around 10 % of cases, organisations reported increased income and market share; lastly, company interviews suggested that FP participation had made a significant contribution to the competitiveness of leading players in several niche technology markets, from inkjets to photonics.

- An econometric analysis of Round 3 Community Innovation Survey micro-data covering 18 European countries carried out by the Joint Research Centre's (JRC) Institute for Prospective Technological Studies (IPTS) found that the FP has a positive impact on incremental innovation (new to the firm) and, even more, on radical innovation (new to the market). The FP fosters collaboration and has a positive impact on R & D intensity via collaboration and directly. The higher the R & D intensity, the more incremental and radical innovation.

- An analysis of 2006 Community Innovation Survey micro-data confirmed the above results by showing that FP participants collaborate more, patent more, and are more innovative than non-participants.

- The EC-commissioned analysis of prospects for research and innovation in the theme 'Food, Agriculture, Fisheries and Biotechnologies' (report from independent experts to the European Commission, 2011a) concluded that scientific productivity in some FP6 'Food' research projects was combined with strong technological outputs (patents and innovation, in particular in biotechnology and food projects) and/or with attention to policy needs (in the remaining areas of research). This suggests a cross-fertilisation between science, technology and policy development that has contributed to excellence.

- The results of survey performed by the Directorate-General for Research and Innovation among FP5 to FP7 coordinators (Coordinator Survey, 2010) showed that the EU-funded research in the theme 'Food, Agriculture and Fisheries and Biotechnology' produced, on average, 0.5 patent and 0.69 new innovative products per project funded.

- The EC-commissioned analysis of impact of FP agricultural and forestry research (Report from independent experts to the European Commission, 2011b), concluded that a significant proportion of projects had developed more 'technological' than 'scientific' results, the average of technological invention being four per project in FP6. Where the nature of the research allowed, projects successfully delivered on patents and new products. For example, in the area of plant health research, nearly 15 % of projects led to patent applications and 30 % to commercial products, models and processes.

- An analysis of random sample of projects funded by the 'Security' theme in FP7 showed that they produced 0.51 patents or other forms of intellectual property per project.

- Evidence from the Community Innovation Surveys shows that 340 firms in the food and beverage manufacturing sector that have introduced a new product, or new process, have received funds from FP5 and FP6 programmes; this suggests a significant role for FP funding in improving the innovation performance of firms.

EU research and innovation programmes support European and national policies

- According to an EC-commissioned evaluation of the FP5 'Growth' programme (Ramboll Management and Matrix Knowledge Group, 2008), projects had generated or were expected to generate 423 inputs into EU legislative texts.

- According to an EC-commissioned evaluation of FP6 environmental research (EPEC, 2008), EU environmental research contributes to the knowledge base and development of methods and tools for environment-related policy. The study found that:

– at the international level, EU research related to climate change contributed to the International Panel on Climate Change (IPCC), either directly, through individual researchers involved in the IPCC review, or through references to EU-funded projects in IPCC reports;

– in the domain of environment and health, there were strong links with EU policy priorities, most notably with the implementation of the Environment and Health Action Plan 2004–10 as well as with the implementation of European directives;

– all natural hazards projects contributed to some extent to regional, national and European policies in the field of natural hazards, guidelines and standards;

– water and soil projects played a large role in the formulation and implementation of the Water Framework Directive;

– Earth observation projects had direct impacts on policymaking through the use of their outcomes by stakeholders such as the IPCC and WMO.

- According to an Irish evaluation of FP6 (Forfás, 2009), each project accounted for, on average, 0.4 new or significantly improved regulation or policy.

- Research in the field of security contributed to the development of EU policies in domains such as EU internal security, EU disaster response capacity, the EU chemical, biological, radiological and nuclear (CBRN), and explosives action plans, critical infrastructure protection, health security and also violent radicalisation, privacy and data protection. Since 2007, a total number of 20 Council and Commission policy documents reflect the use of security research resulting data (Table 6).

- According to a survey among FP5–7 coordinators working in the research theme 'Food, Agriculture and Fisheries and Biotechnology' (Coordinator Survey, 2010), more than 60 % of FP projects have provided inputs to European policies, 56 % to national policies, and 25 % to international agreements.

- The analysis of the EUR-Lex database demonstrates that 73 separate FP projects in the research theme 'Food, Agriculture and Fisheries and Biotechnology' were quoted 103 times by different EU-produced documents. The average new decision support tool/policy recommendations per project is estimated to respectively 2, 1.7, 1 and 0.8 per project in the field of fisheries and aquaculture, agriculture, food and biotechnologies (EC, 2011h).

- The analysis of FP5 to FP7-funded research (Report from independent experts to the European Commission, 2011b) in plant and animal health has had a great impact on the further development of legislative measures governing disease surveillance, control and eradication, animal welfare and use of wastes. New methods were also developed, which became, initially, European and, later, international standards. Results from the animal health projects have had a great influence on the work of the World Organisation for Animal Health (OIE), for example in developing international standards for disease control, animal welfare and trade, recognised by the World Trade Organisation (WTO).

- The analysis of FP5 to FP7-funded research (Report from independent experts to the European Commission, 2011c) in the fisheries and aquaculture areas has had significant impact on the formulation and implementation of the common fisheries policy, in particular with regards to developing the scientific basis of fisheries management, monitoring of stocks, environmental requirements and developing sustainable aquaculture with an increased involvement of research institutes from Mediterranean partner countries, new Member States and candidate countries.

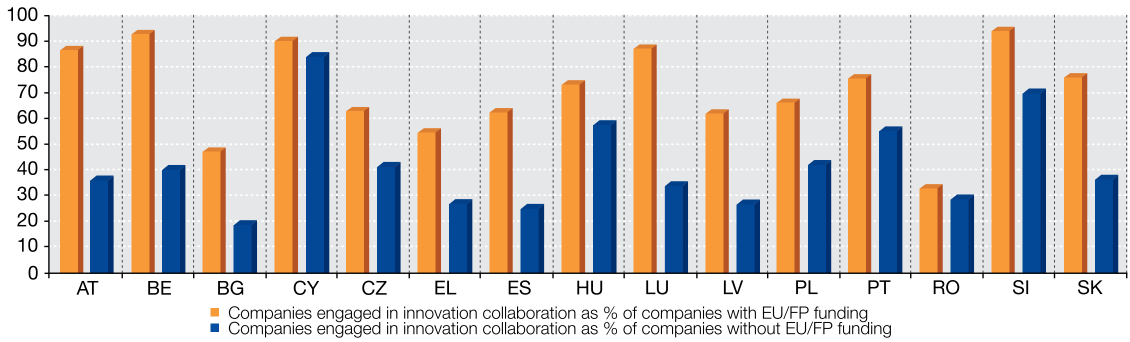
The FP produces structuring effects: durable changes in the European RTDI lanscape

- **Through the FP, the European Research Council, which promotes excellence across Europe, was created.**

– The European Research Council (ERC) would not have been created without an EU initiative. The EU would then have been left with a landscape of compartmentalised national research councils, but would have had no funding mechanism to promote EU-wide competition for funds and to encourage higher scientific quality in frontier research.

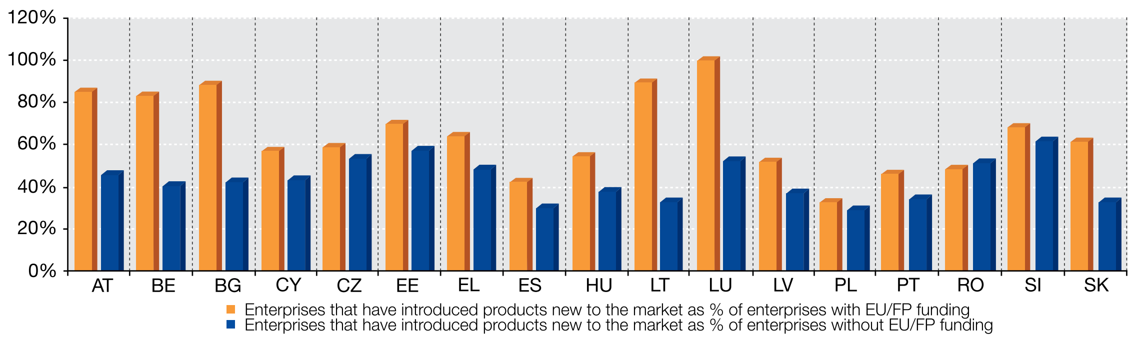
– The FP7 interim evaluation (Annerberg et al., 2010) noted that there is evidence suggesting that a level of compatibility (even calibration) has developed between the ERC and national research councils as the latter increasingly 'accept' the ERC evaluation results as a basis for awarding grants to highly-rated researchers who fail to be funded by the ERC. The ERC suggests that national research councils or agencies are adopting similar funding schemes to the ERC model, and ERC grantees are often offered improved conditions by their host institutions, while ERC applicants are offered national funding.

Figure A1.11: **FP participants collaborate more than non-participants**



Source: Eurostat.
NB: Data concern the manufacturing sector.

Figure A1.12: **FP participants are more innovative than non-participants**



Source: Eurostat.
NB: Data concern the manufacturing sector.

- **As a result of the FP, the EU leads in the creation and use of research infrastructures of pan-European importance.**

– As a result of EU leadership, for the first time, a pan-European strategy on research infrastructures (the so-called ESFRI roadmap) has been developed and is now being implemented. No fewer than 10 next-generation European infrastructures (e.g. IAGOS (In-service Aircraft for a Global Observing System), ESS (European Spallation Source) and SHARE (Survey of Health, Ageing and Retirement in Europe)) are currently being built by groups of Member States and these facilities would not have seen the light of day if it were not for EU action. In addition, without EU funding measures to facilitate access to unique and expensive infrastructures, 9 out of 10 researchers say that they would not have been able to access vital research facilities, which is often a precondition for successful frontier research. For example:
  - the IA-SFS project has created the largest network of free electron lasers and synchrotrons in the world, serving several thousand European scientists and allowing a wide range of applications;
  - the European Grid Infrastructure gives European researchers access to the aggregated processing power of 200 000 computers in the world's largest distributed computing infrastructure ever built, with over 290 sites in more than 50 countries.

– The Global Monitoring for Environment and Security (GMES) provide the EU with independent data and products that assist in emergencies, support crisis response and allow benefits from 'global' economies of scale (i.e. the 'Urban Atlas' service developed in GMES, allowed a tenfold reduction of mapping costs of urban areas).

- **As a result of FP mobility and career actions, a framework for training and career development of researchers and free movement of knowledge is being created.**

– The Marie Curie Actions set standards for innovative research training, provide the right skills for researchers to match market needs and promote attractive career development for researchers from all nationalities at all levels of their career.

– The Marie Curie Actions set standards of attractive employment conditions, open recruitments for all EU researchers, and aligns national fellowship programmes to the principles of the European Researchers Charter and Code of Conduct for the Recruitment of Researchers through the co-funding mechanism.

- **The FP makes it easier for private companies to develop and implement joint strategic research agendas, which help boost their competitiveness and stimulate smart, sustainable and inclusive growth.**

– An important achievement of the FP has been to establish instruments and mechanisms (e.g. European Technology Platforms (ETPs), Joint Technology Initiatives (JTIs)) that facilitate the joint development and implementation of

Table 6: Impact of FP7 security research as addressed in EU policy documents

	03/2011	2010	2009	2008	2007	
Commission Communications	1	3	2	2		**8**
Commission other policy docs	1		2			**3**
Council conclusions/ declarations			1	2	1	**4**
Council policy docs other		3	1	1		**5**
	2	**6**	**6**	**5**	**1**	**20**

Source: Secretary-General VISTA programme and the Council Secretariat.

strategic research agendas by the private sector and for public-private partnership. These strategic research agendas have played a key role in boosting the competitiveness of the sectors involved.

– The FP6 *ex post* evaluation (Rietschel et al., 2009) noted that initiatives such as ETPs were clearly useful and successful: these transnational focusing devices and smaller-scale efforts at policy coordination helped stakeholders identify and explain their needs jointly, eased the process of developing mutually supportive policies at European and Member State levels, and were likely to lead to changes in funding patterns.

– The FP7 interim evaluation (Annerberg et al., 2010) noted that JTIs have focused and aligned key actors in their respective areas, serving as a support to develop coherent sectorial strategies. In the case of the ARTEMIS and ENIAC joint undertakings, these aligning processes have involved new actors, including SMEs that have previously not taken part in strategic discussions at European level.

- **The FP helps bring together compartmentalised national research funding across borders so as to achieve the scale needed to tackle important societal challenges.**

– One of the pioneering achievements of the FP has been to establish instruments and mechanisms (e.g. ERA-NET, Article 185) for the joint programming of Member State research. This has led to a new approach to research funding involving countries pooling and coordinating their own national funds across borders.

– The FP6 *ex post* evaluation (Rietschel et al., 2009) noted that initiatives such as ERA-NETs were clearly useful and successful: these transnational focusing devices and smaller-scale efforts at policy coordination helped stakeholders identify and explain their needs jointly, eased the process of developing mutually supportive policies at European and Member State levels, and were likely to lead to changes in funding patterns.

– According to the same FP6 *ex post* evaluation, ERA-NETs considerably changed the views of policymakers and implementers. ERA-NETs enabled RTD funders to appreciate the value of cooperating and coordinating research activities and to change their practices. ERA-NETs enabled cooperative priority setting by sharing strategic intelligence. ERA-NETs encouraged the synchronisation of national research programmes. Small countries like Norway found that ERA-NETs enabled them to fill gaps in the national research portfolio and increased the exposure of national research performers to competition. Many of the ERA-NETs made good progress toward issuing joint calls and added value to the European RTD funding portfolio. In some cases, joint calls involved large amounts of money and, in a handful of areas, the common programming which resulted was in areas of national significance, producing quite large calls, for example EUR 35 million and EUR 15 million in the Plant Genomics Network.

– An evaluation of ERA-NET Plus — which facilitates joint calls through topping up the joint national funding with FP7 funds (33 % of the joint call) — found that it is contributing to the pooling national resources, succeeding in bringing together efforts to meet joint challenges, and acting in some cases as a bridging mechanism (Annerberg et al., 2010).

– An interim evaluation of the Ambient Assisted Living (AAL) Article 185 initiative concluded that it made progress towards its objectives and that its overall direction was positive. The evaluation report added that it was a remarkable achievement that, in just a few years, the countries supporting the AAL programme engaged in such close cooperation. It was strong evidence of their interest that they increased their financial contributions significantly beyond the minimum required. AAL also achieved a high level of SME participation at about 40 % compared with less than 20 % in the first call of the FP7 ICT & Ageing programme (Annerberg et al., 2010).

- **FP-funded collaborative research produces cross-border, cross-sectoral, interdisciplinary networks that are durable, well-structured,**

and well-integrated into global innovation networks.

- ***The FP produces large numbers of cross-border links and networks.***
  - JRC-IPTS (2011) argues that the 'FPs have been pivotal for transforming informal nation-based networks of research collaborations within epistemic communities of academics and industrial researchers into formal collaboration arrangements between organisations at European level. The networks formed by the organisations have become almost as important an outcome of FPs as the scientific and technological results of research projects conducted by them'.
  - Protogerou et al. (2010) found that ICT collaborative research funded under FP4, FP5 and FP6 had produced complex networks and that the introduction of new instruments in FP6 had considerably increased interconnectivity compared with the previous FPs, thus contributing to the implementation of the European Research Area initiative.
  - An analysis of FP participation data shows that under FP6, the number of transnational collaborative links reached 400 000 (Figure A1.13), more than double the number of links created under FP5. This increase of connections in FP6 is due to a changing dynamic at the project level: the average number of participants per project doubled from FP5 to FP6 and the average number of Member States per project increased from 3.7 to 6 (Table 3). After 4 years of FP7, the number of collaborative links almost reached that of FP5, namely 154 000. However, it seems that at the end of FP7, less collaborative links will have been created than under FP6, as the projects, on average, engage less participation.

- ***The networks created by the FP are well structured.***
  - JRC-IPTS (2011) shows that, **over time**, FP collaborative research networks have increased in size and created a highly dense and integrated structure. Well-connected organisations (mainly higher education organisations and research centres) are situated at the core of this structure, which not only participate in a large number of projects but are also directly linked with a large number of other core organisations and local partners. These key FP players come from across the EU and associated countries but the majority are from France, Germany, Italy, the Netherlands and the United Kingdom (Figure A1.14).
  - The same study shows that this group of key players, which participate in most projects and create most collaborative links, has not been renewed since FP2 (Table 7).
  - Protogerou et al. (2010) found that ICT collaborative research funded under FP4, FP5 and FP6 had produced complex networks structured around a core of organisations, mainly universities and research institutes assuming a very influential role over time.
  - The FP6 *ex post* evaluation (Rietschel et al., 2009) found that, in the area of IST, FP-funded projects had produced networks involving key 'hubs' (e.g. the Fraunhofer institutes) connected to large numbers of participants.
  - An EC-commissioned FP6-wide study of FP6 network effects (AVEDAS et al., 2009) found that there was a high degree of organisational embeddedness and network stability in the FP. In each of the five FP6 thematic areas, there was a small number of close-knit organisations in the core that dominated the network (i.e. they were highly connected to one another through several projects, while the remaining organisations were in the network periphery and connected to the core but not connected to one another). The actors in the core — the central actors coordinating the projects — were primarily large national research associations (e.g. Fraunhofer-Gesellschaft, CNRS, INSERM (l'Institut national de la santé et de la recherche médicale)) and universities in all thematic areas except in IST where industry was also a central actor.

- ***The networks created by the FP are durable.***
  - According to an EC-commissioned FP6-wide survey (IDEA Consult, 2009c), 56 % of respondents had already participated in FP5. In addition, 86 % of respondents said they would continue to collaborate with other

members on new activities after the network funding had been discontinued, demonstrating the value placed on the relationships that had been built.
- In the same vein, a study by JRC-IPTS (2011) shows that the share of organisations 'returning' to the FP increases from one FP to another reaching 50 % in FP6 (Table 7). This points to a perfect balance between network stability and renewal.

– ***The networks created by the FP are well integrated into global innovation networks.***
  - In the area of IST, the FP6 *ex post* evaluation (Rietschel et al., 2009) found that there was a strong overlap between FP networks and patenting and ICT business networks pointing to the fact that the FP is well integrated into global innovation networks.

- **FP mobility actions promote the same kinds of durable cross-border, cross-sectoral, interdisciplinary networks.**

  – The FP6 *ex post* evaluation (Rietschel et al., 2009) noted that by establishing working relations across Europe's knowledge infrastructure, Marie Curie Actions have been a major driver towards the ERA and also provided opportunities for European researchers to build long-term relationships with colleagues outside Europe.

  – According to the survey launched among Marie Curie fellows in FP6 (The Evaluation partnership, 2010), 90 % of them considered that the grant helped them to make significant new professional contacts and 70 % of them intended to maintain these links.

- **The FP structurally increases the attractiveness of Europe as a place to carry out research.**

– The FP7 interim evaluation (Annerberg et al., 2010) noted that the specific programme 'People' has been an important instrument in making Europe attractive to the best researchers and to implement the EU's career development policy.

– It also noted that, according to an analysis by the ERC Executive Agency, a significant share of all applicants had been working in the United States, indicating that the programme is having an effect on attracting top researchers back to Europe.

- **Indirectly and directly, the FP influences the design of Member State research policies, especially in the EU-12.**

– Marie Curie Actions set a valuable benchmark for the working conditions and employment standards of EU researchers with active participation in the European partnership for researchers and the Code of Conduct for the recruitment of researchers, promoting mobility and better careers for researchers in Europe.

– The Open Method of Coordination (OMC), including exercises such as policy mix peer reviews, helped Member States devote more effort to the Barcelona goals.

– The 'Science in Society' programme had some remarkable structuring effects on ERA in the field of participatory technology assessment, capacity-building of civil society organisations, and promoting open science in academic journals.

– According to an EC-commissioned study on the impact of FP6 on the EU-12 (COWI, 2009):
  - several new Member States (especially Lithuania, Poland and Romania) have been inspired by the FP to take a more networked approach to funding, moving from single-beneficiary to multi-beneficiary projects;
  - in several new Member States (e.g. Lithuania and Romania, and, to lesser extent, the Czech Republic, Poland and Slovenia), FP6 priorities have effectively substituted 'national' priorities;
  - in some of the new Member States (Lithuania, Poland and Romania), FP6 has been a vehicle for a transformation and reorientation of the research policy planning where the programmatic qualities of the FP6 have been used; these qualities include: (i) the strategic and 'applied' approach to research with priority areas; (ii) the planning horizon

(e.g. adopting a 2007–13 time horizon); (iii) the evaluation procedure for national research proposals.

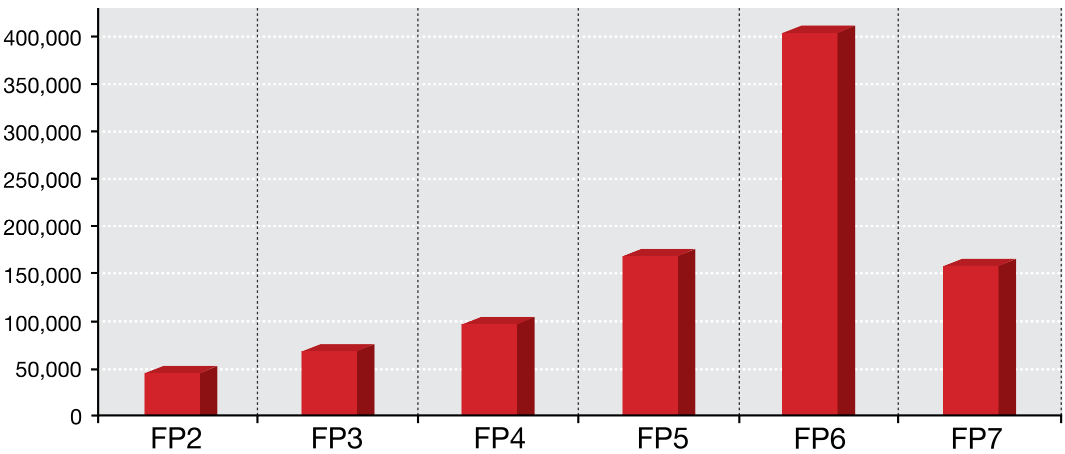
- to stimulate an international reorientation of national research, some countries (Lithuania, Poland and Romania) reward submission of FP6 proposals in national research evaluation procedures, using a standardised 'uplift' (e.g. in Romania, where an FP6 submitted proposal automatically receives a 5 point bonus — out of 100 points).

The EU research and innovation programmes produce large macroeconomic impacts

Studies show that EU funding produces large macroeconomic impacts.

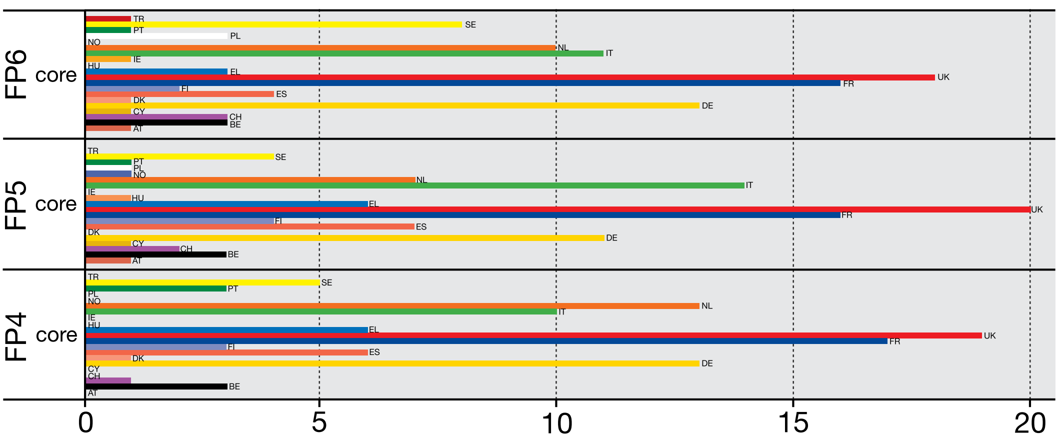
- See Annex 5: An extensive body of academic economics literature has demonstrated that R & D produces large-scale macroeconomic effects.
- The FP7 *ex ante* impact assessment identified large-scale FP macroeconomic effects:

Figure A1.13: **Collaborative links (national and international) established through FP-funded shared-cost actions**



Source: Directorate-General for Research and Innovation.
(*) Partial FP7 data (to 1.2011).

Figure A1.14: **FP core organisations: distribution by countries and FP (%)**



Source: JRC IPTS (2011).

– EUR 1 of FP funding leads to an increase in industry added value of between EUR 7 and EUR 14;

– Member States' own evaluations also demonstrate the high impact of the FP: the FP's annual contribution to, for example, UK industrial output exceeds GBP 3 billion;

– using the NEMESIS econometric model, the long-term FP7 macroeconomic impact was estimated at an extra 0.96 % of GDP, an extra 1.57 % of exports, and a reduction by 0.88 % of imports.

- The potential value added generated by eco-innovation pilot and market replication projects under CIP could be calculated in some EUR 3.4 million per EUR 1 million invested (Directorate-General for the Environment, Varma, 2007).

- Each EUR 1 of EU budget invested in the CIP venture capital facility has mobilised EUR 6.8 of other private or public funds (EC, 2011g).

The FP produces large social impacts

Studies show that EU funding produces large employment and other social impacts.

- See Annex 5: An extensive body of academic economics literature has demonstrated that R & D generates large employment effects.

- Using 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 in the field of research.

- **Survey** evidence supports the aforementioned modelling results on employment.

– 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 (Ramboll Management and Matrix Knowledge Group, 2008).

– According to a survey among FP5 to FP7 project coordinators working in the research theme 'Food, Agriculture and Fisheries, and Biotechnology', close to 5 % of all projects resulted directly in the creation of a new company. Some 82 % of all projects created jobs for the duration of the project and 35 % of all projects created new jobs after the end of the project; 38 % of all projects created at least one permanent S&T job.

– According to a Dutch FP impact study (Technopolis, 2009), 'the [FP's] impact on the human research capital in the Netherlands is considerable, with approximately 1 200 researchers in the public sector alone funded by the FPs annually. For many research groups this is an important factor to guarantee the continuity of the group'.

– According to an Irish evaluation of FP6 (Forfás, 2009), 80 % of participating organisations or research groups improved their ability to attract staff or increased employment (low impact: 27 %, medium impact: 42 %, high impact: 11 %).

– A Spanish evaluation of FP6 participation (Zabala Innovation Consulting SA, 2010) found that, with regard to the creation of university posts, the FP

Table 7: **Distribution of returning actors and new entrants within the 100 core organisations (%)**

	FP1		FP2		FP3		FP4		FP5		FP6	
	Core	All	Core	All	Core	All	Core	All	Core	All	Core	All
Old Boys	0	0	87	23.3	100	36.9	100	26.5	100	34.6	100	49.4
New Entrants	100	100	13	76.7	0	63.1	0	73.5	0	65.4	0	50.6

Source: JRC-IPTS (2011).

performed better than national or regional programmes according to 38.89 % of respondents and equally well according to 50 % of respondents. With regard to the creation of public research organisation posts, the FP performed better than national or regional programmes according to 8.33 % of respondents and equally well according to 75 % of respondents.

– A Swedish evaluation of the FP (VINNOVA, 2008) found that industrial FP participants' R & D activities and employment in the technology of the project tended to grow afterwards.

– According to a Swiss evaluation of FP5 and FP6 (Interface Institut für Politikstudien and Fraunhofer-Institut für System- und Innovationsforschung, 2005), 'rough estimates suggest that at least around 950 temporary and permanent positions are created as a direct result of the framework programme'.

– A Swiss evaluation of FP6 (State Secretariat for Education and Research, 2009) stated that 'while certain significant benefits of Switzerland's participation in FPs are not measurable, there is no doubt that FPs have various impacts in social (welfare, security, equality, education …) … employment … areas …, even if it is not known to what extent or in what way, precisely'.

– According to a UK evaluation of the FP (Technopolis, 2010c), respondents reporting a positive benefit to cost ratio of FP participation pointed to the additional employment and training opportunities created, particularly in relation to attracting and funding high-quality scientists and motivated early-stage researchers.

- Through Marie Curie Actions, the FP set a valuable benchmark for the working conditions and employment standards of EU researchers (Annerberg et al., 2010).

- The FP produces indirect social benefits through relevant natural sciences research.

– According to an FP6-wide participation survey (IDEA Consult, 2009c), all thematic priorities contribute substantially to a better quality of life while life sciences, genomics and biotechnology for health, nanotechnologies and nanosciences, knowledge-based multifunctional materials and new production processes and devices, and food quality and safety contribute to better healthcare.

– According to a Dutch FP impact study (Technopolis, 2009), 'societal impact is demonstrated in domains with a strong societal mission such as health, sustainability and food safety'.

- The FP also produces indirect social benefits through social sciences research on relevant issues.

– An evaluation of FP5 and FP6 social and environmental effects (EC, 2005a) lists research on the following socially relevant issues:
  - human rights (increasing equality of opportunity and entitlement, including among genders; ensuring that ethical issues are appropriately and effectively addressed; ensuring compatibility with the EU's Charter of Fundamental Rights);
  - social cohesion (reducing social exclusion; reducing risks of poverty);
  - economic cohesion (reducing disparities of income for particular sectors, groups of consumers, citizens, workers);
  - employment (increasing employment opportunities — job creation, enterprise creation; increasing quality of employment and of the working environment);
  - human capital formation (improving educational achievements in the population; increasing training and lifelong learning opportunities; increasing skills and learning capability/flexibility, both within and outside the research community);
  - public health and safety (improving the health of the population; reducing safety risks; improving nutrition, food quality and safety);
  - social protection and social services (improving accessibility to health services; improving long-term sustainability of health services);

- liveable communities (improving quality of housing, infrastructures, services and the living environment in general);
- culture (preserving cultural diversity while increasing integration; preserving and exploiting cultural heritage);
- consumer interests (improving consumer information and choice; reducing consumers' risks);
- security (preventing crime and increasing protection against terrorism; improving the protection of networks and infrastructures; increasing the interoperability of integrated systems and services);
- governance (increasing participation and social capital formation through increased accountability, democracy, citizens and stakeholders' empowerment, active citizenry);
- international cooperation — promoting cooperation among Member States to reduce inequalities, achieve convergence and enhance social cohesion; promoting socioeconomic conditions (e.g. welfare, quality of life) in non-EU countries;
- role of SMEs — increasing and enhancing the potential contribution of SMEs towards job creation, social cohesion, regional development, etc. (through the improvement of their technological capabilities and their increased involvement in research networks).

The FP produces large environmental impacts

The clearest environmental impacts are produced by FP-funded environmental research.

- According to an EC-commissioned evaluation of FP6 environmental research (EPEC, 2008), for example, EU environmental research contributed to the knowledge base and development of methods and tools for environment-related policy. The study found that:

  – at the international level, EU research related to climate change contributed to the International Panel on Climate Change (IPCC), either directly, through individual researchers involved in the IPCC review, or through references to EU-funded projects in IPCC reports;

  – in the domain of environment and health, there were strong links with EU policy priorities, most notably with the implementation of the Environment and Health Action Plan 2004–10 as well as with the implementation of European directives;

  – all natural hazards projects contributed to some extent to regional, national and European policies in the field of natural hazards, guidelines and standards;

  – water and soil projects played a large role in the formulation and implementation of the Water Framework Directive;

  – Earth observation projects had direct impacts on policymaking through the use of their outcomes by stakeholders such as the IPCC and WMO.
    - Environmental challenges are global and need to be tackled together with international partners at European and global levels. Environmental research requires harmonised sets of data produced through satellite monitoring. The scale of the investment needed and the need for full European/international coverage and for open data access requires EU-level action. The FP7 environmental research priority allocated substantial resources to the development of the Global Earth Observation System of Systems (GEOSS) promoting the rapid expansion of full, open access to space and ground-based, water and airborne data and observations. GEOSS is maintained by the 85 member governments and the 61 participating organisations of the Global Earth Observation (GEO) on the basis of a 10-year implementation plan (2005–15). Inspired by the data-sharing principles developed by the Global Earth Observation (GEO) initiative, agencies involved in Earth observation are making their data much more easily accessible, free of charge. The international character of GEOSS enables the participants to benefit from both know-how and data from other regions of the world. This represents a clear improvement of the general situation deplored by the EEA (2010c) of limitation in the transnational use of infrastructures

funded at national levels. Funded projects under the Global Earth Observation initiative (FP7) play a key role in the development of GEOSS. FP7 examples include: EBONE aimed at building a biodiversity observation system, EuroGEOSS implementing a brokering service for accessing data, and ImpactMIN aimed at developing monitoring impacts of mining operations using Earth observations.

Yet, other kinds of FP-funded research also produce clear environmental impacts.

- According to an evaluation of FP3 and FP4 **Brite-Euram** projects, for example, just over one third of industrial participants reported that their project had had at least one environmental impact within their organisation, and the vast majority of these (97 %) were positive: 39 % cited savings in materials; 32 % cited energy savings; and 32 % cited reductions in the release of dangerous products.

- According to an EC-commissioned evaluation of the FP5 'Growth' programme (Deloitte, 2006) — which covered key actions such as 'Innovative products, processes and organisation', 'Sustainable mobility and intermodality', 'Land transport and marine technologies' and 'New perspectives for aeronautics', and generic activities such as 'New materials and their production and transformation (including steel)' and 'Measurement and testing' — the average environmental impact per project was substantial reaching 6.08 % in terms of the expected reduction of waste and 4.06 % in terms of the expected energy saving.

- According to an evaluation of a subset of FP5 'Growth' programme projects (Ramboll Management and Matrix Knowledge Group, 2008), nearly 25 % of all evaluated projects anticipated medium-high or high benefit with regard to the reduction or prevention of emissions, while about 20 % anticipated medium-high or high benefit with regard to saving natural resources.

- According to an evaluation of FP5 and FP6 social and environmental impacts (EC, 2005a), important projects were, for example, **ExternE** (Externalities of Energy) and **ExternE-Transport**, **RECORDIT** (Real Cost Reduction of Door-to-Door Intermodal Transport), and **ECOSIT** (External Costs of Industrial Technologies) that produced results that fed directly into policy formulation in the energy and transport sectors (e.g. the recent revision of the Eurovignette Directive). Similarly, the **DYN-GEM-E3** project was instrumental in energy taxation reforms through 'the macroeconomic evaluation of energy tax policies within the EU'. The **POLES** model, also developed with EU energy research funding, was used to define the future CO2 emission baseline in the context of post-Kyoto targets.

- According to an FP6-wide participation survey (IDEA Consult, 2009c), the thematic priorities 'Sustainable development, global change and ecosystems' and 'Nanotechnologies and nanosciences' etc. contributed to the sustainable use or production of energy, while the thematic priorities 'Sustainable development, global change and ecosystems', 'Nanotechnologies and nanosciences', 'Aeronautics and space', and 'Food quality and safety' contributed to the environment.

According to a survey conducted among FP5, FP6 and FP7 project coordinators working in the research theme 'Food, Agriculture and Fisheries, and Biotechnology', 49 % of all projects produced positive environmental impacts. Some 18 % of all project coordinators stated that their project contributed to the reduction of greenhouse gas emissions, while 41 % of all project coordinators stated that their project contributed to resource efficiency. Indirect environmental benefits were produced through FP research on how to improve the use of production inputs and increase resource use efficiency (e.g. water, which was targeted specifically in FP7); on how to reduce the reliance on pesticides and animal health products; on how to improve and make safer the use of animal waste to reduce environmental pollution; on GMO management strategies, models and containment systems, ensuring environment protection, food safety; on how to extend the use of renewable forest resources; on the long-term sustainability and productivity of forest ecosystems considering carbon sequestration, the water cycle, climate change; on how to reduce the loss of biodiversity in agriculture and forestry. National evaluations of the FP arrive at the following similar conclusions.

- According to an Irish evaluation of the FP (Forfás, 2009), 50 % of all projects made a contribution to 'improved environmental preservation or protection'.

- A Swedish evaluation of the FP (VINNOVA, 2008) found that 'framework programmes have positive effects on the behaviour of the research community, competitivity, jobs, regulation and the environment'.

- According to a Swiss evaluation of the FP (State Secretariat for Education and Research, 2009), 'no fewer than 70 projects from the FP5 environment programme were explicitly referred to in European Commission position papers. The EU Directive on greenhouse gas emission allowance trading was also based on findings from FPs'. The evaluation also stated that 'while certain significant benefits of Switzerland's participation in FPs are not measurable, there is no doubt that FPs have various impacts in ... environmental (energy, pollution, natural disasters ...) ... areas ..., even if it is not known to what extent or in what way, precisely'.

- According to respondents to a UK evaluation of the FP (Technopolis, 2010c), FP activities strengthened previously weak UK capabilities in a number of environmentally relevant research areas: 'The FP6 Marie Curie Research Training Networks (RTN) has allowed us FINALLY to tackle an important research area (breeding of a novel fodder legume with tannins for animal nutrition, health and greenhouse gas emissions). An FP7 Marie Curie IEF (Intra-European Fellowship) is similarly enabling us to get involved in a willow breeding programme for the benefit of animals and the environment'. The FP5 **STAIRRS** and the FP6 **SILENCE** projects also directly informed the Environmental Noise Directive and railway TSI (Technical Specification for Interoperability) processes.

Success stories

- FP-funded collaborative research leads to technological breakthroughs. In 2004, European engineers receiving collaborative research support were able to develop the first chip in the world to go below the 45 nm limit. The momentum generated by the **NANOCMOS** and subsequent projects put EU industry in pole position, opening the door to a wide range of innovations in products and services ranging from communications to embedded electronics where Europe holds a large share of the global market (40 % of total market worth more than EUR 100 billion per year).

- FP-funded collaborative research reduces risk and enables the achievement of pan-European standards. Standards and technologies developed by FP-funded researchers are today found in over 600 million 3G mobile phones, generating more than EUR 250 billion of revenues every year to EU companies in products and services.

- FP-funded collaborative research facilitates the growth of innovative SMEs. In 2006, two small research-based companies from Sweden and Belgium, BioInvent and Thrombogenics, received, together with academic and clinical partners, a EUR 1.9 million grant to form the project **ANGIOSTOP**. The firms have since developed an innovative form of treatment for cancer. In 2009, the companies secured a EUR 50 million investment from global pharmaceutical giant Roche, with the possibility of increasing this amount to EUR 450 million.

- EU funding leverages private investment. In the case of **RSFF**, the volume of loans is 12 times the EU contribution, and the additional leveraged investment in research, development and innovation is 30 times the EU contribution.

- As a result of targeted JRC research costing about EUR 1 million, the cost of tests for BSE were reduced and the direct EC subsidy per test could be scaled back from EUR 20 to EUR 7 resulting in cumulative savings for the Community budget over the period 2002–06 of about EUR 250 million.

- JRC research enabled the launching of the GI2000 initiative and the 2007 INSPIRE Directive establishing an infrastructure for spatial information in Europe. The estimated EU, national and regional investments for INSPIRE are of the order of EUR 100 million, whereas annual benefits of the full implementation of the directive are estimated at EUR 8–12 billion.

- The aim of the **SLIC** project was to develop and commercialise a compact device (lab-on-a-chip) for the extraction, identification and analysis of microRNAs, which affect gene regulation. As a result of the international, collaborative framework of the European project, it was possible to recruit an interdisciplinary team with highly specialised skills, not all of which could be found in a single country. With the technology developed in the SLIC project, the time required for microRNA analysis has been reduced from a day to a quarter of an hour. This is associated with a considerable reduction in the costs of these procedures, which are now widely practised. This innovation entails significant benefits not only in economic terms (the Swiss start-up project coordinator, Ayanda Biosystems, has been approached by the leading companies in the sector), but also for science and health (more rapid and less costly diagnostics).

- Secure communication is an essential requirement for companies, public institutions and citizens. Encryption systems currently used are rendered vulnerable in particular by the continuing growth in computing power. Quantum cryptography, based on the quantum properties of light, ensures communication channels which are demonstrably inviolable. In 2008, the **SECOQC** project enabled the deployment of a telecommunication network based on quantum cryptography — a world first. No European group had expertise in all the technologies that were needed to establish a network of this kind. To succeed, the SECOQC project had to draw on the skills of 40 participants from 11 different countries. The demonstration of the feasibility of an inviolable communication network heralded the birth of a new market. The SECOQC project also led certain partners to jointly develop the first international standards in this new industry.

- The aim of the **CASOPT** project is to produce a paradigm change in the design of complex electromagnetically-driven industrial products. State-of-the-art simulation-based design is to be replaced by optimisation-based design. This new approach is the key to achieving the goals of miniaturisation, reductions in the quantity of materials required and costs, and improvements in the energy efficiency of products. The research consortium brings together partners from industry and academia in a project based on knowledge transfer. As the CASOPT project is highly multidisciplinary, it was necessary to assemble a team of world-class experts in numerical analysis, simulation, optimisation, geometric design and parallel computing. The realisation of this project essentially relies on existing site competencies and knowledge transfer among the partners, with support from additionally recruited experts. Synergies arise between the experience of private-sector and university institutions, and also between experienced researchers and others who are younger and highly motivated. This offers them a unique opportunity to carry out research within a network, and also to develop other research ideas and projects. In the short term, the results of the project will be used in the design of power transmission and distribution systems. The CASOPT project will make it possible to push the performance of products beyond current limits without adversely affecting their reliability or robustness. In addition, highly skilled young students, PhD students or postdoctoral researchers participating in this type of project can be recruited by industrial partners. In the long term, the project could have a decisive impact on the evolution of industrial design concepts for many different sectors, but also for SMEs, whose product range is also covered.

- FP collaborative research is often pioneering in its domain. The FP project on the **Yeast genome** was the first international grant in genomics. Its aim was to reveal the first full set of genes of a eukaryotic genome and in a broader sense, identify basic biological mechanisms common to all living organisms, including man. This 7-year research project involved an international effort of 641 scientists in Canada, Europe, Japan and the United

States sequencing a total of 12.3 million of DNA base pairs covering the 16 nuclear chromosomes. Europe was not only at the centre of this large research venture, but also provided much of the sustained funding required to ensure the success of this pioneering task. A total of 92 European laboratories and over 400 European scientists have participated in this network. By the end of 2010, this project has generated more than 500 scientific articles reporting yeast DNA sequences and a total of 2 849 patents registered. With the discovery that the yeast genome is similar to that of man, very interesting prospects have opened up for the future understanding of certain diseases — such as cancers and genetic diseases.

- Oil is rapidly becoming scarce and its use for transport purposes is responsible for a quarter of greenhouse gas emissions. It is important to develop clean and commercially viable alternatives to the combustion engine. Electric vehicles are widely seen as the most credible alternative to fossil fuel-based road transport. For Europe, it is of critical importance to develop an early technological and competitive lead in this rapidly developing market. Against this background, the objective of the **European Green Cars Initiative** is to support R & D on technologies and infrastructures that are essential to achieve breakthroughs in the use of renewable and non-polluting energy sources, safety and traffic fluidity. The European Green Cars Initiative is one of the three Public-Private Partnerships (PPP) of the European Economic Recovery Plan announced by the President of the European Commission on 26 November 2008. Beyond providing loans through the European Investment Bank, the PPP European Green Cars Initiative is making available a total of one billion EUR for R & D through joint funding programmes of the European Commission, industry and the Member States. These financial support measures will be supplemented by demand-side measures, involving regulatory action by Member States and the EU, such as the reduction of car registration taxes on low CO2 cars to stimulate new car purchases. The reason for an initiative at EU level is that a critical mass of combined expertise and effort is needed from all Member States and relevant industrial sectors to overcome the market and systemic failures associated with the introduction of new basic technologies. To avoid fragmentation reflected in research duplication and gaps, and to arrive at robust industry standards, a frequent exchange of information is needed between sectors and levels of government that do not normally interact on a regular basis. Investing in the production of equipment, components and electric systems is attractive only when everyone is on board. Since its launch merely 2 years ago, the European Green Cars Initiative has already brought closer the introduction of green vehicles on Europe's roads. The initiative instigated 51 research projects on technologies and standards needed to make electric vehicles feasible and commercially attractive. Advances have already been made in fields contributing to batteries that charge faster and have a longer driving range, and new vehicle models.

- The objective of the **NAD** project was to develop nanoparticles for Alzheimer's disease diagnosis and therapy. The rationale for the project was the fact that about 24 million people worldwide are affected by dementia and that the number of new cases per year reaches almost 5 million. In Europe, there are 5 million cases of dementia, 3 million of which are classified as Alzheimer's disease. NAD involved 19 partners from 13 different European countries. The critical mass needed to develop treatments of Alzheimer's disease is greater than that which can be found at individual Member State level and it was as a result of the internationally collaborative nature of this EU-funded research project that it was possible to bring together a comprehensive range of cutting-edge European expertise from several multidisciplinary key areas: chemistry, physics, biochemistry, molecular biology, cell biology, pharmacology, biophysics, computational biology, nanotechnology, neurology, anatomy and toxicology. If successful, NAD will produce nanoparticles able to cross the blood-brain barrier and reach the brain (site of the disease). Molecules able to selectively recognise (diagnosis) and destroy (therapy) toxic peptides characteristically accumulated in the brain of diseased patients will be identified and attached to the nanoparticles.

- The objective of the **EDCTP** (European and Developing Countries Clinical Trial Partnership) Article 185 Initiative was to accelerate the development of new clinical interventions to fight HIV/AIDS, malaria and tuberculosis in developing countries. The background to the project was that worldwide over 30 million people are living with HIV and close to 3 million people become infected each year. In addition, each year, there are close to 250 million cases of malaria worldwide (and close to 900 000 deaths) as well as 9 million cases of tuberculosis. EDCTP involves the European Commission, 16 European countries (14 Member States and 2 associated countries), industry, private charities such as the Bill & Melinda Gates Foundation, and 29 sub-Saharan African countries. The conceptualisation and implementation of this project required a level of coordination of a wide range of funding sources that could only be achieved at EU level. EDCTP has so far supported 54 clinical trials on new treatments and vaccines for HIV, malaria and tuberculosis and the training of 158 medical researchers. The US Food and Drug Administration has approved an antiretroviral formulation for HIV-infected children in Africa, which was tested through an EDCTP project. The first African Networks of Excellence for clinical trials in central Africa have been established and there are now national ethics committees in many African countries as a result of the EDCTP.

- The **PEPPOL** (Pan-European Public Procurement Online) pilot project, funded by ICT-PSP, is creating a standards-based IT transport infrastructure which enables cross-border, interoperable public eProcurement with standardised electronic document formats. In results, it is easier for companies to bid for public sector contracts anywhere in the EU in a simpler and more efficient way. Twelve Member States or associated countries are currently involved in the pilot.

- The innovative ICTs are used to help people receiving medical assistance anywhere in the EU. The ICT-PSP market demonstration project **epSOS** is building a service infrastructure demonstrating cross-border interoperability between electronic health record systems in Europe. The medical services are becoming more accessible throughout Europe as a result of removing linguistic, administrative and technical barriers: 23 Member States or associated countries are currently involved in this pilot project.

Detailed evidence on lessons learned

While European research and innovation programmes have been successful, there are important lessons to be learned from the past, from stakeholder feedback, and from analytical studies. Research, innovation and education should be addressed in a more coordinated manner and coherent with other policies and research results better disseminated and valorised into new products, processes and services. The intervention logic of EU support programmes should be developed in a more focused, concrete, detailed and transparent manner. Programme access should be improved and start-up, SME, industrial, EU-12 and extra-EU participation increased. Monitoring and evaluation need to be strengthened.

The need for improved horizontal and vertical policy coordination

A number of FP *ex post* evaluations have noted that the coordination between, on the one hand, the FP and other EU policies and, on the other hand, the FP and Member State research activities could be improved.

With regard to horizontal policy coordination in the narrow sense, the FP7 interim evaluation (Annerberg et al., 2010) noted that a strategic shift is needed to establish stronger and better connections between research, innovation and education (the so-called knowledge triangle). As for broader horizontal policy coordination, the FP6 *ex post* evaluation (Rietschel et al., 2009, pp. 58–59) called for a clearer division of labour between the FP and the cohesion funds. It also stated that other EU policies such as transportation and energy would benefit from a more coordinated interface between FP research activities and regulatory and demand-side policies.

The need for horizontal policy coordination is confirmed by the conclusions of the OECD's work on the most appropriate system of innovation governance.

The OECD (2005a), for example, mentions the need to develop 'a strategic, horizontal approach', which 'should include and develop the innovation policy potential in other ministerial domains and ensure a coordinated division of labour between them'. And the OECD (2010b) concludes that 'given the increasingly central role of innovation in delivering a wide range of economic and social objectives, a whole-of-government approach to policies for innovation is needed'.

With regard to vertical policy coordination, the FP6 *ex post* evaluation noted that, given its small size compared to Member State expenditure, the FP should not try to substitute for Member State R & D policies but should use its added value in a more strategic way and set an attractive and accepted European agenda. In the same vein, European research policy expert Erik Arnold (2009, p. 28) concluded that the division of labour between the EU and national levels should be further refined and more explicitly defined, in particular in view of the introduction of the likes of the European Research Council and the Joint Technology Initiatives.

The need for vertical policy coordination is confirmed by the results of OECD work on the optimal system of innovation governance. The OECD (2010b), for example, calls for 'coherence and complementarities between the local, regional, national and international levels'.

The need for focus and more robust intervention logic

A number of FP *ex post* evaluations (Rietschel et al. (2009) v European Court of Auditors (2007), paragraph IV) have noted that the programme's design could be improved. The view held 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.

With regard to the FP's objectives, the FP6 *ex post* evaluation (Rietschel et al., 2009, p. vii) as well as expert evidence (Arnold, 2005, p. 29) noted that there were too many — addressing almost all S&T and socioeconomic challenges — and that they were too abstract and vague and therefore untestable, complicating *ex post* evaluation. A recent European Parliament ITRE Committee report (2011, paragraph 9) noted in the same vein that 'an ever-growing number of objectives and themes covered and diversification of instruments has widened the scope of FP7 and reduced its capacity to serve a specific European objective'.

In addition, no explicit links are made between higher-level objectives and lower-level concrete technical goals (EC, 2005b, p. 19; Arnold, 2009, p. 2). Meanwhile, instruments are not designed explicitly to achieve particular objectives: challenges are defined so as to match existing instruments, not the other way around (Stampfer, 2008, p. 13). The result is 'catch all' instruments trying to tackle all problems and to satisfy all types of stakeholders. That is why the European Court of Auditors has called for a system which addresses a single objective in each instrument (European Court of Auditors, 2009, paragraph 57).

The importance of focus and a proper hierarchy of objectives (combined with appropriate monitoring) is confirmed by recent OECD work. The OECD (2010b), for example, argues in favour of 'a more strategic focus on the role of policies for innovation in delivering stronger, cleaner and fairer growth'. The OECD (2005a) notes that 'third-generation innovation policy cannot be properly implemented without precise targets and intelligent follow-up. Governments should increase their capacity to develop actions plans based on horizontal, strategic approaches and translate these into concrete measures to be taken by each ministry or agency. This will enhance vertical coherence, with monitoring and indicator systems ensuring sound reporting of empirical facts to the strategic apex'.

The need to lower the barriers to participation

All FP *ex post* evaluations — see, for example, the chapters on participation in the FP6 *ex post* (Rietschel et al., 2009) and FP7 interim evaluations (Annerberg et al., 2010) — 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 for first-time, start-up, SMEs and EU-12 applicants in particular.

The need to increase the production, dissemination and valorisation of project outputs

Participants' main reasons for getting involved in the FP relate to networking and the creation of new knowledge (Arnold, 2009, p. 2). FP research is also more of a long-term, exploratory, technologically complex nature (Polt et al., 2008). The FP should not, therefore, be expected to produce new, immediately commercialisable products and processes.

Nevertheless, FP evaluations conclude that more attention should be paid to the production of project outputs and to their dissemination and economic valorisation, in particular since the FP is supposed to support Europe's competitiveness. What is highlighted is 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 (Rietschel et al., 2009, pp. 26 and 37; Annerberg et al., 2010, 62 ff.). In the same vein, the FP7 interim evaluation observes a lack of clarity on how the FP incorporates innovation (as opposed to 'pure' research).

In this respect, the OECD (2010b) argues that 'the creation, diffusion and application of knowledge are essential to the ability of firms and countries to innovate and thrive in an increasingly competitive global economy'.

The need to strengthen monitoring and evaluation

The main problem affecting the FP monitoring and evaluation system relates to the aforementioned lack of focused objectives and robust intervention logic. The evaluation process aims to link evidence emerging from project implementation with the strategic and specific objectives set for the programme. As the European Court of Auditors (2007) observed, if this connection is difficult to make, an assessment exercise becomes extremely complicated. However, the FP evaluation and monitoring system suffers from other problems as well.

The importance of a proper monitoring and evaluation system is emphasised by the OECD. The OECD (2005a), for example, recommends 'improving evaluation and learning': 'In general, governments should create a solid basis for evaluation and learning and make them part of the policymaking process. This includes evaluation of broader reforms, as knowledge about their impact on innovation is useful for feedback and policy formulation. A more holistic approach to evaluation and learning can enhance feedback in the governance system and lead to more effective policy'. The OECD (2010b), on the other hand, also argues that 'evaluation is essential to enhance the effectiveness and efficiency of policies to foster innovation and deliver social welfare. Improved means of evaluation are needed to capture the broadening of innovation, along with better feedback of evaluation into the policymaking process. This also calls for improved measurement of innovation, including its outcomes and impacts'.

Annex 2: The need for public intervention and European added value

Public intervention in research and innovation is justified by market and systemic failures

- The right balance between public and private investment should be struck on the basis of a careful assessment of the presence of market and/or systemic failures that government should address.
- Research is seriously affected by **market failures**: as a result of such failures, there is significant private sector underinvestment in research and a solid basis for public support.

– A first market failure concerns **risk and uncertainty**. At the start of a research project, it is not at all sure that the research efforts undertaken will actually result in new knowledge and innovation. The challenge of risk and uncertainty is exacerbated by the fact that the cost of R & D is rising, because it becomes more expensive to carry out research and because the life cycle of products is shortening dramatically (for more on the costs of research, see Box 11). Levels of risk and uncertainty are especially high when developing the breakthrough technologies required by new techno-economic paradigms, in other words when engaging in radical rather than incremental

Box 11: **Striking results of a recent EU survey on cost of research**

A recent EU survey on 'costs of research' was conducted among 200 R & D-intensive private companies and public research organisations equalling over 115 100 R & D employees (or 112 520 full-time equivalents (FTE)) in Europe's ICT, pharmaceutical, chemical, and automotive sectors. The results of the survey methodology have been cross-checked in 37 in-depth case studies entailing over 50 personal interviews with R & D managers.

The surveyed companies unanimously judge R & D labour costs to be by far the largest cost component of undertaking R & D (50 %), followed by capital costs (such as ICT, machines and infrastructures at 17 %) and purchased R & D (14 %). Although relocation intensities differ per sector, surveyed companies strikingly agree that relocating abroad is not an important action to reduce R & D costs; it is part of a larger strategic decision to be closer to a particular market in order to adapt products to local demand and tap into local (R & D) expertise.

The R & D labour cost is not only the largest cost component of R & D, it is also the cost factor most difficult to contain as it is governed by global demand and globally comparable wages. As one manager put it, 'one has to pay the salaries and one has to provide the infrastructure and equipment, otherwise it is impossible to attract excellent researchers in our industry', a trend most likely to continue in the future.

The activities considered by the surveyed companies to be most important in bringing down the cost of research, are:

- aligning R & D with business strategies;
- joining collaborative R & D projects; and
- technological efficiency of the R & D process.

The activities considered by the surveyed companies to be most influential in driving up the cost of research, are:

- complexity of the R & D process;
- environmental legislation; and
- regulation of product markets.

To the question whether the cost of research has increased in the past 5 years, surveyed firms reported an increase of 47 % in R & D expenditures or total R & D costs over the last 5 years. 87 % of companies reported that this growth was primarily based on an increase of the volume of R & D, while 13 % said that it was due to rising prices.

To the question whether the cost of research will continue to increase in the next 5 years, the companies reported to expect an increase of 30 % on average. Given that the major cost component is R & D labour, costs of research in the longer term (20 years) are unlikely to fall in relative terms.

Source: COST (2011).

innovation. A related point is that market prices do not take full account of negative externalities (e.g. polluting activities). As long as markets do not punish environmentally harmful impacts or reward environmental improvements, competition between environmental and non-environmental innovation is distorted and a socially suboptimal amount of investment occurs.

– Companies may be reluctant to invest in research out of fear that the new products they may come up with may make the products they are currently deriving substantial profits from **obsolete**. Such rigidity, such path dependency, prevents investment in radical innovations that can revolutionise markets and produce huge social benefits.

– Another market failure results from the fact that, even if the research initiative gives rise to new knowledge and innovation, it is not at all sure that the researcher or company that has undertaken the research efforts will be able to exclusively **appropriate** all the benefits deriving from it.

– The appropriation problem is exacerbated in the case of public goods and paradigm shifts.
  - Companies are reluctant to invest in research on **public goods**. Examples of public goods are clean air, clean drinking water, health, etc. The social benefits of research on public goods exceed the possible private gains to be derived from it, which leads to private under-investment in research. A good example in this respect is the fact that private pharmaceutical companies carry out comparatively little research on the development of vaccines for diseases such as malaria, tuberculosis, and African strains of HIV. Another good example concerns eco-innovation, which produces positive externalities in the form of positive environmental effects for which the eco-innovator is not fully 'rewarded'.
  - Companies are also reluctant to invest in research for which, as yet, there is no immediate pay-off either because no such market exists or a market exists but is not yet fully developed. This is often the case for **paradigm-shifting** breakthrough technologies (e.g. environmental technologies, hydrogen, nuclear fusion, etc.). In such cases, public support is essential not only to support research but also to 'make' a market through public procurement, the provision of incentives to consumers, investment in accompanying infrastructure, etc.

- The need for public support for research also derives from the system nature of innovation, and from the importance to invest in human capital and networks to ensure the absorption of knowledge.

– The innovation systems literature argues that what matters for an economy's innovation performance are the **linkages** and flows of information between the different actors in the innovation system. These linkages and flows are often suboptimal and government can play a role in strengthening them.

– As argued above, the dissemination, valorisation and economy-wide **market take-up** of new technologies is an issue of a systemic nature. For example, electric cars will not be used on a large scale if electric vehicle refuelling points are not widely available. The public sector often has to take the lead in addressing such systemic obstacles to technology uptake. Another good example concerns eco-innovation, which does not concern a single sector in conventional terms but a range of technologies, products, services, business models, and potential target markets. This makes it more difficult for potential investors to evaluate funding opportunities and assess risks than if all investment opportunities were built around a common technology platform. This is especially the case in sub-sectors, such as those not related to energy, which are less known or considered immature and therefore riskier.

Public intervention in research and innovation produces clear benefits

Public research generates direct economic benefits

- It is a source of useful new information and knowledge (Martin et al., 1996, p. vii; CaSE, 2009).

- It creates new instrumentation and methodologies (Martin et al., 1996, p. vii).

- Those engaged in basic research develop skills which yield economic benefits when individuals move from basic research carrying codified and tacit knowledge (Martin et al., 1996, p. vii). Highly skilled scientists and engineers are one of the most predictable and rapid outputs of the research base and one that is highly prized by industry. They carry with them tacit knowledge — skills and experience — which, in turn, creates impacts in public or private research and is highly valued in other sectors too (CaSE, 2009). Alongside new knowledge, universities working at the research frontier have a second core 'product', namely highly trained people, an essential resource for UK companies and foreign companies investing in the United Kingdom. Both outputs are essential for sustaining and improving the country's economic performance (RCUK, 2010).

- Through participation in basic research, access is granted to networks of experts and information (Martin et al., 1996, p. vii).

- Those trained in basic research may be good at solving complex technological problems (Martin et al., 1996, p. vii).

- And, finally, on the basis of basic research, spin-off companies are created (Martin et al., 1996, p. vii). From 2003 to 2007, 31 university spin-outs were floated on stock exchanges with an IPO value of GBP 1.5 billion and 10 spin-outs were bought for a total of GBP 1.9 billion (CaSE, 2010). Universities also encourage innovation by smaller local businesses and, through incubators and science parks, the emergence of new companies (RCUK, 2010). University research has led to the development of many innovations that have been commercialised either through licensing to private companies or the formation of new start-up companies. This 'technology transfer' activity has been particularly intense in the United States since the Bayh-Dole Act in 1980. This piece of legislation not only gave universities the right to patent new discoveries but also mandated them to license inventions made with federally sponsored research to the private sector. Now, nearly all US research universities have a technology licensing office and explicit intellectual property policies and royalty-sharing arrangements for their scientists. Between 1991 and 2000, the number of licences on university inventions in the United States increased from 1 278 to 4 362, and licensing income rose from USD 186 million to USD 1.3 billion. Licensing and start-ups based on university innovations are increasing in Europe too, with the United Kingdom taking the lead (RCUK, 2010).

Public research increases the pay-off to private R & D and supports innovation

- US research estimates that a 10 % increase in university R & D increases corporate patenting by between 1 % and 4 % (Jaffe, 1989; Jaffe and Trajtenberg, 2002) (quoted in RCUK, 2010).

- Some 15 % of new products and 11 % of new processes would have been developed with a substantial delay in the absence of academic research (Mansfield, 1998).

- Approximately 20 % of private sector innovations are partially based on public sector research (Tijssen, 2002).

- Cohen, Nelson and Walsh (2002) evaluated (in the US manufacturing sector) the influence of public (i.e. university and government R & D laboratory) research on industrial R & D, the role that public research plays in industrial R & D, and the pathways through which that effect is exercised. They found that public research is critical to industrial R & D in a small number of industries and, importantly, affects industrial R & D across much of the manufacturing sector. Overall, public research proposes new R & D projects and contributes to the completion of existing projects in roughly equal measures. Key channels through which university research impacts industrial R & D include published papers and reports, public conferences and meetings, informal information exchange, and consulting.

- A stochastic frontier analysis by the European Commission's Directorate-General for Economic and Financial Affairs found significant positive effects on the number of patents and business patents per million inhabitants for a number of independent variables related to public intervention: the public R & D stock, international research cooperation and international researcher mobility (through which access is provided to the stock of foreign R & D), and the share of R & D invested in basic research (Mandl et al., 2008).

High-quality public research attracts private R & D

- Belderbos et al. (2009) found that by controlling for a wide range of host country factors, the number of relevant ISI publications by scientists based in the host country has a substantial positive impact on the propensity to conduct foreign R & D. The effect of academic research is significantly larger for firms with a stronger science orientation in R & D — as indicated by citations to scientific literature in prior patents.

- Doh et al. (eds) found that US multinational corporations' R & D location decisions, and the relative levels of R & D investment in a given country location, are mostly influenced by broad, macroeconomic and development factors. Scientific output and, to a lesser extent, institutional quality, appropriability regimes, and telecommunications infrastructures, also influence R & D location, while the presence of existing MNC investment is not found to influence R & D investment.

- Dosi, Llerena and Sylos Labini (2009) presented cross-country comparisons revealing that industry-financed R & D is positively associated with both the per capita number of highly cited researchers and expenditure on higher education R & D. This also held within sectors: in a number of industrial sectors, R & D intensity was positively correlated with the quality of academic research in selected related fields, and those countries with the highest per capita number of highly cited scientists in relevant fields displayed the highest R & D intensities.

- Guimón (2008) found that the empirical evidence available suggests that, among the factors related to the host country, the main location drivers for R & D-intensive foreign direct investment are the availability of world-class research infrastructure and skilled labour as well as the dynamism of the national innovation system, that is, the degree of interaction and collaboration among different firms and other 'knowledge producing and diffusing organisations' (universities and research centres, consultants, industrial associations, etc.).

- Abramovsky, Harrison and Simpson (2007) (quoted in RCUK, 2010) investigated the relationship between the location of private sector R & D laboratories and university research departments in Great Britain. They combined establishment-level data on R & D activity with information on levels and changes in research quality. The strongest evidence for co-location was found for pharmaceuticals R & D but also for other sectors evidence for co-location was found. There is evidence that private sector R & D laboratories in the United Kingdom are disproportionately clustered around highly rated university research departments. This phenomenon is not driven just by university spin-outs: in some industries, foreign-owned companies are choosing to locate in close proximity to high-quality research. This implies that multinational companies may be sourcing cutting-edge technologies from universities in the United Kingdom. The results of this study show that R & D facilities 'cluster' near university departments, particularly in the pharmaceuticals and chemicals sectors. A postcode area (e.g. 'OX' for Oxford) with a chemistry department rated 5 or 5* by the 2001 RAE (Research Assessment Exercise) is likely to have around twice as many pharmaceutical R & D laboratories and around three times as many foreign-owned pharmaceutical R & D laboratories compared with a postcode area with no 5 or 5* rated chemistry departments.

- Research also finds evidence that foreign-owned laboratories in the machinery and aerospace sectors are likely to be located near to materials science and electrical engineering departments rated 4 or below by the RAE (Abramovsky and Simpson, 2008) (quoted in RCUK, 2010). This suggests that companies also benefit from proximity to more applied, commercially-oriented research activity.

- A recent study analyses the relationship between the number of patenting manufacturing firms and the quantity and quality of relevant university research across UK postcode areas (Helmers and Rogers, 2010) (quoted in RCUK, 2010). It finds that different measures of research 'power' and 'quality' positively affect the patenting of small firms within the same postcode area. This indicates that small firms benefit from localised university-industry knowledge transfer.

- A further study of research and local development examines the impact of university business incubators on innovation by firms close by (Helmers, 2010) (quoted in RCUK, 2010). Standard business incubators provide start-up companies with a range of support measures, including physical space within the incubator building, training and coaching, business contacts, access to finance, etc. University incubators have an additional advantage in that they can draw on the resources available at the university, including academic support, access to research facilities, as well as easy access to the student pool to recruit employees. The study finds that the recent wave of establishment of new university business incubators in the United Kingdom has generated local externalities by increasing the patenting propensity of incumbent firms located geographically close to the new university business incubators. Incumbent firms react to the entry of new firms within the same sector by increasing their propensity to patent by 2–6 %. The effect is stronger the closer the entrant is geographically located to an incumbent — the strongest impact occurs within a radius of 5–15 km. Beyond 100 km, entry has no economically significant effect on incumbent patenting.

- Recent research on knowledge spillovers from university innovation in the United States confirms that, for companies to use publicly funded research most effectively, geographical location has a significant contribution (Belenzon and Schankerman, 2010) (quoted in RCUK, 2010). Analysing patent citations both to university patents and scientific publications, the study finds that knowledge spillovers are strongly localised, sensitive to distances of up to 15 miles. Companies located in the same state as the cited university are substantially more likely to cite one of the university patents than a company located outside the state.

Public subsidies for private research increase the total amount of research expenditure (input additionality, crowding-in effect, leverage effect)

- Most recent studies find positive effects of R & D subsidies on R & D investment (Czarnitzki, 2011).

- EUR 1 of public funding for R & D (including defence) leads to additional business R & D of EUR 0.70–0.93 when allocated to business (Guellec and van Pottelsberghe, 2000; EC, 2004).

- A 10 % increase in university research increases private R & D by 7 % (Jaffe, 1989; Jaffe and Trajtenberg, 2002) (quoted in RCUK, 2010).

- A 1 % increase in public basic pharmaceutical research leads to a 1.7 % increase in industry R & D after 8 years. And a 1 % increase in public clinical research leads to a 0.4 % increase in industry R & D after 3 years (Toole, 2007) (quoted in CaSE, 2010).

- This additional research expenditure does not just translate into higher researcher wages; it generates additional research (Aerts, 2008; Lokhsin and Mohnen, 2008).

The crowding-in or leverage effect of public subsidies for private research is larger in the case of more productive collaborative research

- The crowding-in/leverage effect of public funding is larger for industry-science collaborative research than for pure industrial research (Czarnitzki, 2011).

- Industry-science collaborative research projects produce larger spillover effects than pure industrial research projects (Czarnitzki, 2011).

Public subsidies for private research increase the total amount of innovation (output additionality)

- Subsidised private R & D leads to more innovation output. It has a positive impact on patents and new product sales (Czarnitzki, 2011).

The added value of EU-level support for research and innovation is undisputed

All FP *ex post* evaluations agree that EU-level support in the field of research and innovation is marked by European added value. As a result of EU initiatives in fields such as frontier research (ERC), research infrastructures (ESFRI), the coordination of research funding (JTIs, joint programming), and research training and career development (Marie Curie Actions), the European R & D landscape is radically changing for the better. In addition, the EU supports actions like cross-border collaborative research, cross-border research mobility and cross-border access to research infrastructures that are most efficiently organised at EU level, that are of strategic importance, and for which no alternatives exist

The literature is unanimous

The European added value of EU intervention in the field of research and innovation is undisputed.

- The FP7 interim evaluation (Annerberg et al., 2010) concluded that 'FP7 is assessed to fill in important gaps between national research activities, thus gaining critical mass in many areas and ensuring added value, as the assessments suggest that the FP7 activities are not likely to have been implemented without EU-level funding'.

- The FP6 *ex post* evaluation (Rietschel et al., 2009) concluded that 'the activities under FP6 … generated European added value' and that 'FP6 was a powerful mechanism for catalysing RTD in Europe that could only be realised through action at the European level', and '[could] find no evidence that plausible alternative approaches would have been more successful in the same timeframe, acknowledging the ambition, scale and importance of FP6'.

- The Five-Year Assessment 1999–2003 (EC, 2005) concluded that all evidence seen by it 'whether at Community or Member State level, consistently emphasised the significant additionality and European added value for the framework programmes'.

- European S&T expert Erik Arnold (2009) states the widely held consensus view that '[FP] projects were mostly "additional" in the sense that they would not have been conducted without European funding', that 'their role was therefore quite distinct from nationally funded projects', and that 'FP6 provided opportunities for extended international and cross-sectoral networking, for projects of a greater scale (particularly financial scale), and for projects of a greater technical and scientific complexity — opportunities which would have been severely limited without the funds it made available'.

As a result of EU initiatives, the European R & D landscape is radically changing for the better.

- **The EU created the European Research Council, which promotes excellence across Europe**

– The European Research Council would not have been created without an EU initiative. The EU would then have been left with a landscape of compartmentalised national research councils, but would have had no funding mechanism to promote EU-wide competition for funds and to encourage higher scientific quality in frontier research.

- **The EU leads in the creation and use of research infrastructures of pan-European importance**

– As a result of EU leadership, for the first time, a pan-European strategy on research infrastructures (the so-called ESFRI roadmap) has been developed and is now being implemented. No less than 10 next-generation European infrastructures (e.g. IAGOS (In-service Aircraft for a Global Observing System), ESS (European Spallation Source) and SHARE (Survey of Health, Ageing and Retirement in Europe)) are currently being built by groups of Member States and these facilities would not have seen the light of day if it were not for EU action. In addition, without EU funding measures to facilitate access to unique and expensive infrastructures, 9 out of 10 researchers say that they would not have been able to access vital research facilities, which is often a precondition for successful frontier research. For example:

- the IA-SFS project has created the largest network of free electron lasers and synchrotrons in the world, serving several thousand European scientists and allowing a wide range of applications;
- the European Grid Infrastructure gives European researchers access to the aggregated processing power of 200 000 computers in the world's largest distributed computing infrastructure ever built, with over 290 sites in more than 50 countries, utilised by 13 000 researchers.

- **The EU makes it easier for private companies to develop and implement joint strategic research agendas, which help boost their competitiveness and stimulate smart, sustainable and inclusive growth**

– An important achievement of the framework programme has been to establish instruments and mechanisms (e.g. European Technology Platforms, Joint Technology Initiatives) that facilitate the joint development and implementation of strategic research agendas by the private sector and for public-private partnership. These strategic research agendas have played a key role in boosting the competitiveness of the sectors involved. For example:
  - the Innovative Medicines Initiative is helping to make Europe the most attractive place for pharmaceutical R & D, thereby enhancing access to innovative medicines for patients; it does so by providing new tools and methodologies to remove major bottlenecks in drug development;
  - the Clean Sky Joint Technology Initiative is bringing significant step changes regarding the environmental impact of aviation. Clean Sky will speed up technological breakthroughs and shorten the time to market for new and cleaner solutions tested on full-scale demonstrators. It will thus contribute significantly to reducing the environmental footprint of aviation (i.e. emissions and noise reduction but also green life cycle) for future generations.

- **The EU helps bring together compartmentalised national research funding across borders so as to achieve the scale needed to tackle important societal challenges**

– One of the pioneering achievements of the FP has been to establish instruments and mechanisms (e.g. ERA-NET, Article 185 initiatives) for the joint programming of Member State research. This has led to a new approach to research funding involving countries pooling and coordinating their own national funds across borders. For example:
  - a pilot joint programming action has brought together 23 Member States and associated countries to jointly develop and fund a strategic research agenda for tackling neurodegenerative diseases and Alzheimer's disease;
  - EURAMET is an action aimed at coordinating metrology research across Europe. Involving 22 National Metrology Institutes, it pools 44 % of overall metrology resources in one initiative, reducing duplication of research and encouraging the more efficient use of resources.

The EU most efficiently organises cross-border research and mobility actions that are of systemic and strategic importance and for which no alternatives exist.

- **EU cross-border research, innovation and mobility actions are of systemic importance**

– **Cross-border collaborative research and innovation collaboration actions** are of key importance since they underpin the 'open innovation' paradigm.
  - Cross-border collaborative research and innovation collaboration actions enable the achievement of the **critical mass** required for breakthroughs when research activities are of such a scale and complexity that no single Member State can provide the necessary

financial or personnel resources; for example, when a large research capacity is needed and resources must be pooled to be effective or when there is a strong requirement for complementary or comparative knowledge and skills (e.g. in highly interdisciplinary fields). Telling examples are rare diseases research, space research, ICT, etc. For example, when researching rare diseases, the FP helps bring together the necessary critical mass of patients, expertise, and facilities. There are at least 6 000 to 7 000 rare diseases, which, taken together, affect some 20 million European citizens. However, research at national level is often hampered by a thin distribution of patients, few specialised research groups, and a lack of standardisation of available data and material collections.

- Cross-border collaborative research and innovation collaboration actions enable research addressing **pan-European policy challenges**. Public policy challenges have become increasingly international (e.g. environment, health, food safety, climate change, security) and their resolution has become increasingly dependent on the establishment of a common scientific base. Moreover, research can lead to the establishment of harmonised laws and standards. Given the shared interest and the scale on which these issues arise, such research activities are best organised in a cross-border collaborative manner.
- Cross-border collaborative research and innovation collaboration actions reduce risk and enable the achievement of **pan-European standards**. Working in transnational consortia helps firms to lower research risks, thus enabling certain research to take place. Involving key EU industry players helps reduce commercial risks, by ensuring that research results and solutions are applicable across Europe and beyond, enabling the development of EU and worldwide standards and interoperable solutions, and offering the potential for exploitation in a market of 500 million people. The FP supports the kind of pan-European research collaboration required to speedily produce industrial standards that can set the tone and be adopted at the global level. ICT research and innovation, for example, is increasingly organised around new kinds of collaboration involving common, open technology platforms with high spillover and leverage effects. They allow a much wider range of stakeholders to profit from new developments and further innovate. Federating and partnering at EU level helps ensure that research results and solutions are applicable across Europe and beyond. It enables consensus-building, interoperable solutions and the development of EU and worldwide standards. EU research also provides an important umbrella to facilitate globally interoperable ICT systems, global consensus and standards. Direct EU-level actions also support pre-normative research in support of standardisation, harmonisation and development of reference materials and methods. Without the FP, Europe would not have been at the origin of the global standard for 2G and 3G mobile communications.
- Cross-border collaborative research and innovation collaboration actions enable the rapid and wide **dissemination** of research results (to users, industries, firms (SMEs in particular), citizens, etc.) leading to better exploitation of research and making a larger impact than would be possible only at Member State level.
- **Growing innovative SMEs**: Innovative SMEs, for example in the field of ICT and services, play a vital role in generating new ideas and transforming these into business assets. They are agile, able to focus their research and innovation efforts and take fast technical and business decisions. SME involvement in research and innovation at EU level improves their partnerships and alliances with other companies and research laboratories across Europe. This enables innovative SMEs to develop new products and services beyond their in-house and national capabilities, and allows them to grow and enter new international markets.
- **Leveraging private investment**: Through EU research schemes such as collaborative research, joint technology initiatives

(ARTEMIS, Clean Sky, ENIAC, FCH, IMI), and joint programming initiatives (e.g. EDCTP, AAL, Eurostars, EMRP), private companies can collaborate with foreign partners on a scale not possible at national level, in projects tested for excellence and potential market impact, which induces them to invest more of their own funds than they would under national funding schemes. In the field of key enabling technologies (KETs), for example, a common European strategy with coordination mechanisms creates synergies and economies of scale that lead to improved industrial exploitation of KETs in the EU.

- **Marie Curie Actions cross-border and cross-sector researcher mobility and training actions** are of key importance as they can increase the quantity and quality of the EU's research knowledge base by attracting young people into research, attracting top researchers to Europe and ensuring excellent training to the coming generations of European researchers; have a pronounced structuring effect on the European Research Area by setting standards for innovative research training, promoting attractive career development for researchers from all nationalities at all levels of their career, setting standards of attractive employment conditions and open recruitment for all EU researchers, spreading the good practices of the European Researchers Charter and Code of Conduct for the recruitment of researchers, and leveraging additional financing and aligning national resources through the co-funding mechanism of fellowship programmes; strengthen innovation by exposing researchers to an industrial environment at an early stage in their career, promoting long-term cooperation between academia and industry, and ensuring participation of a broad spectrum of small and large enterprises in the training and career development of researchers.

– **Cross-border innovation support actions** — comprising innovation 'policy intelligence' (gathering and processing analytical data for better policymaking in innovation cannot be achieved without the EU dimension and the cross-country comparisons) and innovation 'policy learning' (important added value comes from bringing together knowledge and experience from different contexts, supporting cross-country comparisons of innovation policy tools and experiences and the opportunity to identify, promote and test best practice from over the widest possible area) — contributes to better policies and tools for supporting businesses in bringing innovation to the market. The ICT-PSP component of CIP has been able to bring Member States together to test the deployment of innovative ICT applications at real-scale. These actions aim at stimulating demand and facilitating formation of markets in areas with high untapped potential such as cross-border e-health services. Cross-border innovation support actions also comprise EU-level venture capital support. High-tech start-ups require venture capital. Venture capital markets can only function well at European scale, however, and improvement requires European action. It is only possible at European level to achieve the necessary scale and the strong participation of private investors that are the hallmarks of a self-sustaining venture capital market. Many successful companies such as Skype, WaveLight AG, Fimasys, etc. would not exist today without the funding and guidance provided during their early stages by venture capitalists supported by the CIP-EIP. Specialised innovation support, access to venture capital or benchmarking innovation management performance against competitors would be best provided through an 'internal market for innovation support'.

- **EU cross-border research, innovation and mobility actions are of strategic importance to participants**

– A study on ICT under FP4 and FP5 (Databank Consulting et al., 2004) found that FP collaborative research funded mainly two types of R & D projects: (i) 'Core' projects: highly interesting, necessary and strategically important projects that occur in the core technology areas of the respondents (58 % of projects); (ii) 'Complex/risky' projects: long-term, technically complex, and risky from commercial and technical point of view (26 % of projects) — 40 % of industry participants in FP6 IST projects reported their research in the ICT programmes being of high to very high commercial risk.

- A study on Marie Curie Actions under FP4 and FP5 (Van de Sande et al., 2005) found that participating in such actions was perceived as having an important impact (score of up to 90 %) on issues central to career development like the development of research skills, the accumulation of international experience, the development of transnational research networks, etc.

- An Austrian study on FP4 (Joanneum Research et al., 2001) found that most FP projects were seen as of strategic importance: 37.7 % of EU projects were seen as of central importance and 53.7 % of EU projects supported other innovation activities. FP projects were closer to the scientific/technological core concentration of the company, more involved, and more application-oriented than nationally funded projects and, against this backdrop, FP projects gained a specific strategic significance for companies.

- A Danish study on FP4 (Danish Institute for Studies in Research and Research Policy, 2000) found that more than 90 % of participants participated in projects with a research content close to the core of the workplace. Close to 75 % of participants indicated that the projects were part of the long-term strategic R & D.

- A Finnish study on FP4 (Luukkonen and Hälikkä, 2000) found that most FP projects were either of strategic/central importance or of potential future importance/supporting other research activities. For large companies, for example, the shares were over 20 % and over 55 % respectively, while for SMEs, the shares were 40 % and over 40 % respectively.

- An Irish study on FP4 (Forfás, 2001) found that, generally speaking, the projects undertaken by Irish participants were complex, exciting, long-term projects in core technologies which most organisations considered of strategic importance and high relevance to their organisations.

- A survey covering the whole of FP5 (ATLANTIS Research Organisation et al., 2004) found that most FP5 projects were seen as strategically important projects in core technology areas for the organisations concerned. Typically, they were tightly linked either conceptually or more pragmatically with other in-house projects but were only feasible when undertaken in collaboration with others. Projects were generally of a high scientific and technical complexity and skewed towards the longer-term end of the spectrum. Work of an applied R & D nature nevertheless still predominated over more basic research, especially for industrial participants.

- A Finnish study on FP5 (Uotila et al., 2004) found that FP-funded projects were either of high current or of future strategic importance. For large companies, for example, the shares exceed 20 % and 55 % respectively, while for SMEs, the shares exceeded 20 % and 65 % respectively.

- A Norwegian study on FP5 (NIFU, STEP and Technopolis, 2004) found that EU-funding seemed to stimulate businesses to get involved in more risky research than otherwise, which could widen their technological horizons and opportunities.

- The Innovation impact study on FP5 and FP6 (Polt et al., 2008) found that, compared to collaborative research projects funded exclusively via internal R & D budgets, FP projects were, on average, characterised by lower commercial risk, longer-term R & D horizon, more interest in 'peripheral' technologies outside the core technologies of participants, and a focus on exploration (rather than exploitation) strategies.

- A survey covering the whole of FP6 (IDEA Consult, 2009) found that 'FP-funded projects are incomparable with national/regional funded projects, as their objectives and characteristics are very different' (p. 24) and that 'the average research project funded under FP6 [concerns] long-term, strategically highly important, technically highly complex R & D in a core technological area of the organisation … It is tightly linked with other in-house projects but mainly considered only feasible with external collaborators' (p. 20).

– A German study on FP6 (Federal Ministry of Education and Research, 2009) found that large, export-oriented companies as well as companies in the field of cutting-edge technology and the knowledge-intensive service sector were more likely to take part in FP6 than in federal or *Länder* programmes. They concluded that the European and international focus of the FPs was particularly attractive for companies in sunrise sectors.

- **Without the EU programmes, most of these strategically important research and innovation actions would simply not take place or be far less ambitious**

– Interview-based evidence indicates that in the absence of CIP funding, eco-innovation projects would not have benefited from cross-border cooperation and learning and the resulting EU-wide market scope. Most beneficiaries indicated that they would not have moved forward with the development of the technology or, had they done so, it would have been on a much smaller scale focusing on the needs and characteristics of the national or regional markets.

– As Table 8 shows, the FP achieves very high levels of overall 'project additionality': without FP funding, the great majority of FP projects would not have been carried out at all (hypothetical case). This is a first key finding that is highly robust: it is a finding valid across a series of FPs and across a range of different actions; it is a finding resulting from Commission-commissioned evaluation studies as well as nationally commissioned evaluation studies; and it is a finding confirmed through control groups: the great majority of rejected FP proposals never got implemented (experimental case).

– A second key finding is that the levels of overall 'project additionality' achieved by the FP are much higher than those achieved by most European and non-European national R & D funding schemes (compare Tables 8 and 9). It seems that there are far fewer substitutes for EU funding than there are for national schemes.

– A third key finding is that the FP achieves very high levels of 'behavioural additionality': the great majority of those projects that would have been carried out in the absence of EU funding would have changed dramatically, undermining their strategic importance: they would have been carried out on a smaller scale (with less money, with fewer partners), with a reduced scope (less ambitious), and at a later stage or over a longer period of time.

– A fourth key finding is that the levels of 'behavioural additionality' achieved by the FP are much higher than those achieved by most European and non-European national R & D schemes.

– A fifth key finding is that the FP achieves very high levels of 'project' and 'behavioural' additionality not only overall but also and particularly for strategic projects. This is, once more, a finding that is highly robust: it is a finding valid across a series of FPs resulting from Commission-commissioned evaluation studies as well as nationally commissioned evaluation studies and it is a finding confirmed through control groups:
  - a study on ICT under FP4 and FP5 found high levels of project additionality for the FP overall (Table 9) as well as for strategically important projects (Databank Consulting et al., 2004);
  - a Finnish study on FP4 (Luukkonen and Hälikkä, 2000), found high levels of additionality for the FP overall (Table 9) as well as for strategic projects;
  - a survey covering the whole of FP5 (ATLANTIS Research Organisation et al., 2004) found high levels of additionality for the FP overall (Table 9) as well as for strategic projects (Table 10);
  - a survey covering the whole of FP6 (IDEA Consult, 2009) found high levels of additionality for the FP overall (Table 9) as well as for strategic projects (Table 11);
  - according to a survey among participants in FP5/FP6 ICT projects (WING, 2009), the evolution from FP5 to FP6 saw larger

enterprises and SMEs shifting their focus towards longer-term research of high strategic importance in what they considered their core R & D area: this trend continued into FP7 and saw further increases in the strategic importance of FP7 ICT research for all stakeholder groups, whereby 70 % of all surveyed participants deemed the programme of high to very high strategic importance for their own organisation (Technopolis, 2010c).

Table 8: **Additionality of the FP (FP4-5) in the field of ICT**

		Additionality	
		Project possible only with EU funding	Project potentially able to find other funding
All projects	High strategic imp	55%	19%
	Low strategic imp	18%	7%
Core projects	High strategic imp	61%	22%
	Low strategic imp	9%	1%
Complex-risky projects	High strategic imp	45%	12%
	Low strategic imp	20%	10%

Source: Databank Consulting et al., 2004

Table 9: **Additionality of FP4 overall**

			Additionality		
			High	Low	None
Firms	Strategic value	Of central importance	42	53	5
		Of potential future importance	49	49	2
		Of marginal importance	49	49	2
Non-firms	Strategic value	Of central importance	45	49	6
		Of potential future importance	58	39	3
		Of marginal importance	67	30	3

Source: Luukkonen and Hälikkä, 2000

Table 10: **Additionality of FP5 overall**

			High	Low	None
	Pure Additionality	Behavioural Additionality	No Additionality	Negative Additionality	Total
High Strategic Importance	38.7%	30.6%	3.8%	0.9%	74.0%
Moderate Strategic Importance	13.6%	4.6%	1.1%	0.1%	19.4%
Low Strategic Importance	4.9%	1.3%	0.3%	0.1%	6.6%
Total	57.2%	36.5%	5.2%	1.1%	100.0%

Source: ATLANTIS Research Organisation et al., 2004

Table 11: **Additionality of FP6 overall compared to FP5**

	Low to very low strategic importance	Medium strategic importance	High to very high strategic importance	Weighted average
	FP5 additionality and strategic importance			
No additionality	14%	5%	5.5%	6%
Behavioural add.	14%	25%	42.5%	37%
Pure additionality	72%	70%	52%	57%
Total	7%	20%	73%	100%
	FP6 additionality and strategic importance (experimental group)			
No additionality	0%	4%	5%	4%
Behavioural add.	27%	37%	42%	39%
Pure additionality	73%	59%	53%	57%
Total	11%	27%	62%	100%
	FP6 additionality and strategic importance (control group)			
No additionality	7%	4%	7%	6%
Behavioural add.	21%	29%	38%	33%
Pure additionality	72%	68%	55%	61%
Total	14%	28%	58%	100%

Source: IDEA Consult, 2009

Table 12: Evaluations of the FP

FP	Study owner – Scope of the Evaluation	Full Project Additionality (Share of respondents who did (failed applicants) or would (participants) abandon the project in the absence of FP funding	Partial Project Additionality (Share of respondents who did (failed applicants) or would (participants) change the nature of the project in the absence of EU funding) (*: share of total respondents; **: share of respondents who did (failed applicants) or would (participants) not abandon the project)				Reference
			Scale additionality (Share of respondents who did (failed applicants) or would (participants) reduce the scale of the project in the absence of FP funding)	Acceleration additionality (Share of respondents who did (failed applicants) or would (participants) postpone or increase the duration of the project in the absence of FP funding)	Scope additionality (Share of respondents who did (failed applicants) or would (participants) reduce the scope or objectives of the project in the absence of FP funding)	Networking Additionality (Share of respondents who did (failed applicants) or would (participants) reduce the number of (international) partners in the absence of FP funding)	
FP3&4	EC – BriteEuram	45% large companies would 51% SMEs would	44% large companies would* 22% SMEs would*		90% would*		European Commission (2002)
FP4&5	EC – IST	73% would					Databank Consulting et al. (2004)
FP4&5	EC – Marie Curie	69% would (Cat 20) 53% would (Cat 30) 70% would (Cat 40)					Van de Sande et al. (2005)
FP4	National – Austria	70.1% would	86% would**				Joanneum Research et al. (2001)
			40% would**		52% would**	40% would**	

FP4	National – Denmark	70% would	60% would*	50% would*			Danish Institute for Studies in Research and Research Policy (2000)
FP4	National – Finland	54% would	22% would*	19% would*	17% would*		Luukkonen and Hälikkä (2000)
FP4	National – Ireland	82% would	>70% would**	Almost 40% would**	Almost 80% would**	Almost 40% would**	Forfas (2001)
FP4&5	National – UK	70% would	17% would*				DTI - Office of Science and Technology (2004)
				59% would**	90% would**	64% would**	
FP5	EC – All	57% would 84% did	36% would* 16% did*				ATLANTIS Research Organisation et al. (2004)
			76% would** >40% did**	33% would** >50% did**	43% would** 6% did**	70% would** 43% did**	
FP5	EC – Growth	69.6% would				20.9% would*	Matrix Insight Ltd. (2008)
FP5&6	EC – SME	55% would		45% would*	45% would*		European Commission (2007)
FP5	EC – Research Infrastructure Access	88% would					European Commission (2003)
FP5	National – Finland	70% would	40% would*	36% would*	14% would*		Uotila et al. (2004)
FP5	National – Norway	Almost 95% would	>90% would*	>80% would*	47% would**	<80% would**	NIFU, STEP and Technopolis (2004)
FP5&6	National – Switzerland	75% would 70% did					Interface Institut für Politikstudien and Fraunhofer-Institut für System- und Innovationsforschung (ISI) (2005)
FP6	EC – All	66% did 57% would	29% did* 38% would*				IDEA Consult (2009)
			76% did** 83% would**	60%/57% (start/ duration) did** 44%/46% (start/ duration) would**	71% did** 78% would**	69% did** 80% would**	

FP	Study owner – Scope of the Evaluation	Full Project Additionality (Share of respondents who did (failed applicants) or would (participants) abandon the project in the absence of FP funding	Partial Project Additionality (Share of respondents who did (failed applicants) or would (participants) change the nature of the project in the absence of EU funding) (*: share of total respondents; **: share of respondents who did (failed applicants) or would (participants) not abandon the project)				Reference
			Scale additionality (Share of respondents who did (failed applicants) or would (participants) reduce the scale of the project in the absence of FP funding)	Acceleration additionality (Share of respondents who did (failed applicants) or would (participants) postpone or increase the duration of the project in the absence of FP funding)	Scope additionality (Share of respondents who did (failed applicants) or would (participants) reduce the scope or objectives of the project in the absence of FP funding)	Networking Additionality (Share of respondents who did (failed applicants) or would (participants) reduce the number of (international) partners in the absence of FP funding)	
FP6	EC -All	59% did (control group I) 63% did (control group II) 57% would	35% did (control group I)* 33% did (control group II)* 39% would*				IDEA Consult (2009)
FP6	National – Finland	80% would	53% would*	39% would*	40% would*		TEKES (2008)
FP6	National – Ireland	56% did					Forfas (2009)
FP6	National – Spain	74% would	23% would*				Zabala Innovation Consulting SA (2010)

Note: Sum of answers "important" and "very important, I would not have gone abroad otherwise" for question on importance of Marie Curie for stimulating mobility.

Table 13: Evaluation of national R & D support schemes

Study owner – Scope of the Evaluation	Full Project Additionality (Share of respondents who did (failed applicants) or would (participants) abandon the project in the absence of national funding	Partial Project Additionality (Share of respondents who did (failed applicants) or would (participants) change the nature of the project in the absence of EU funding) (*: share of total respondents; **: share of respondents who did (failed applicants) or would (participants) not abandon the project)				Reference
		Scale additionality (Share of respondents who did (failed applicants) or would (participants) reduce the scale of the project in the absence of national funding)	Acceleration additionality (Share of respondents who did (failed applicants) or would (participants) postpone or increase the duration of the project in the absence of national funding)	Scope additionality (Share of respondents who did (failed applicants) or would (participants) reduce the scope or objectives of the project in the absence of national funding)	Networking Additionality (Share of respondents who did (failed applicants) or would (participants) reduce the number of (international) partners in the absence of national funding)	
Austria - FFF	28% would 31% did	57% would* 47% did*				Falk (2004); Joanneum Research, WIFO and KOF (2004); OECD (2006)
		74% would** 60% did**	Postpone: 32% would** 43% did** Lengthen: 51% would** 61% did**	49% would** 40% did**		
Flanders - IWT	29% would	46% would*				Georghiou et al. (2004); OECD (2006)
Flanders - IWT	41% would 43% did	48% would* 25% did*				Steurs et al. (2006)
Australia – R&D Start Programme	37% would	90% would**	100% would**		59% would**	OECD (2006)

Study owner – Scope of the Evaluation	Full Project Additionality (Share of respondents who did (failed applicants) or would (participants) abandon the project in the absence of national funding	Partial Project Additionality (Share of respondents who did (failed applicants) or would (participants) change the nature of the project in the absence of EU funding) (*: share of total respondents; **: share of respondents who did (failed applicants) or would (participants) not abandon the project)				Reference
		Scale additionality (Share of respondents who did (failed applicants) or would (participants) reduce the scale of the project in the absence of national funding)	Acceleration additionality (Share of respondents who did (failed applicants) or would (participants) postpone or increase the duration of the project in the absence of national funding)	Scope additionality (Share of respondents who did (failed applicants) or would (participants) reduce the scope or objectives of the project in the absence of national funding)	Networking Additionality (Share of respondents who did (failed applicants) or would (participants) reduce the number of (international) partners in the absence of national funding)	
Finland – TEKES funding	20% would	46% would*		>60% pursued R&D not connected to the short-term needs of business operations >70% realised riskier and more profitable research		OECD (2006)
Norway – Innovation Norway funding	53% would	16% would have reduced scale or postponed*				OECD (2006)
US - ATP	93% would			82% of projects more ambitious than other R&D projects 70% of projects more technically difficult than other R&D projects		OECD (2006)

Annex 3: EU S&T performance and investment

The global S&T landscape is changing

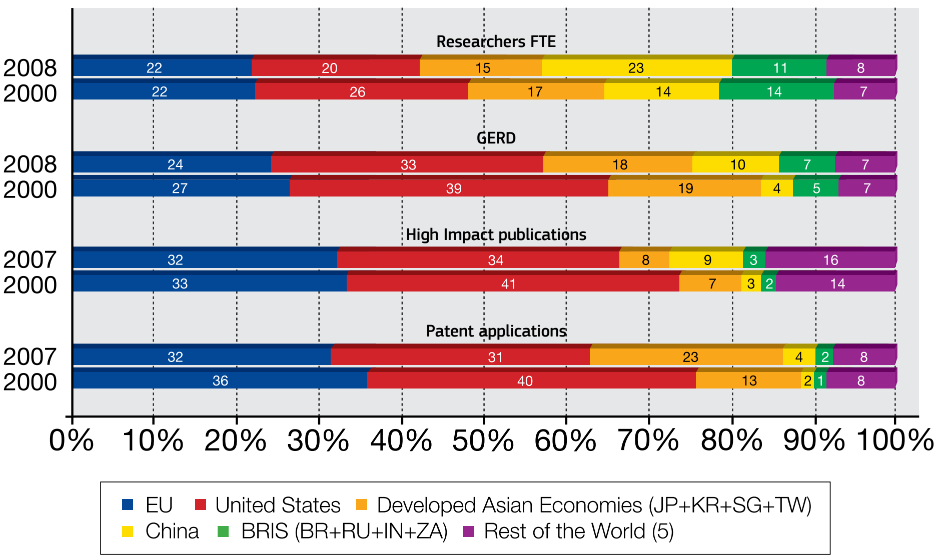
The last decade has already seen a shifting centre of gravity of scientific and economic activity towards Asia (Figure A3.1). If one considers the five Asian countries (China, Japan, Singapore, South Korea and Taiwan) for the latest year:

- 38 % of researchers worldwide came from these countries in 2008 compared with 30 % in 2000; over the same period, the EU's share fell from 22.4 % to 21.7 %;
- these countries represented 29 % of global R & D in 2008 compared with 22 % in 2000; over the same period, the EU's share fell from 27 % to 24 %;
- the Asian-5 accounted for 15 % of all high-impact scientific publications in 2007, up from 10 % in 2000; over the same period, the EU's share dropped from 33.2 % to 32.4 %;
- the Asian-5 applied for 28 % of all (PCT) patents in 2007, twice their share in 2000; the EU, meanwhile, saw its share decline from 36 % to 32 %.

If current trends continue over the next three decades, the emerging economies could be as important economically and scientifically as the advanced economies. Under conservative assumptions for growth and for R & D spending (9), the emerging economies could be investing the same volume of

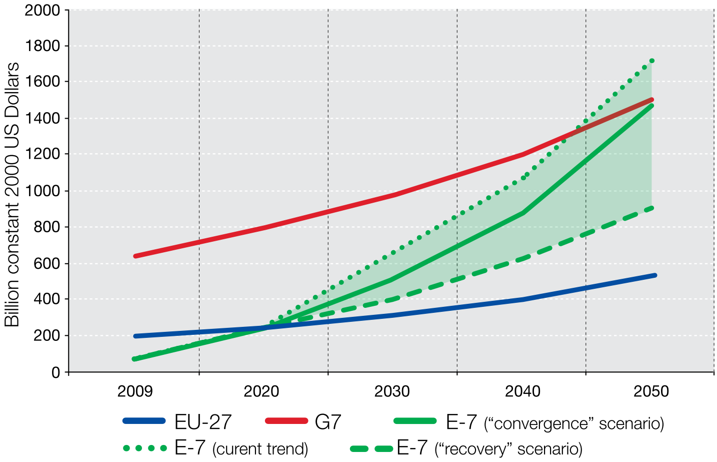
9. These estimates are based on GDP growth forecasts made by the HSBC (*The World in 2050 — Quantifying the Shift in the Global Economy*, HSBC, January 2011). They assume that G7 R & D spending evolves based on the trend observed during the period 1996–2007. For E7, they assume that R & D expenditure evolves according to the 1996–2007 trend until a country reaches an R & D intensity of 3 %, and then after this the annual R & D intensity growth for that country is limited to 1 %.

Figure A3.1: **Participation in global R & D — share (%)**



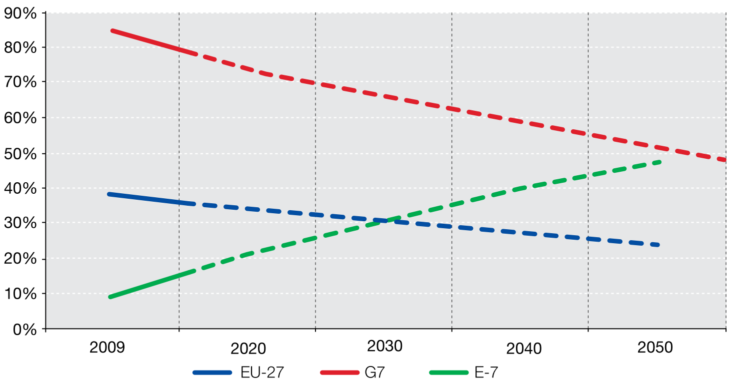
Source: Directorate-General for Research and Innovation, Innovation Union Competitiveness Report 2011.
Data: Eurostat, the OECD, Unesco, *Science Metrix-Scopus* (Elsevier).
(1) Elements of estimation were involved in the compilation of the data.
(2) GERD: shares were calculated from values in current EUR PPS.
(3) (a) top10 % most cited publications — fractional counting method; (b) ASIAN-5 does not include Singapore and Taiwan.
(4) Patent applications under the PCT (Patent Cooperation Treaty) at international phase, designating the European Patent Office.
(5) The coverage of the Rest of the world is not uniform for all indicators.

Figure A3.2: **Long-term trends in R & D spending**



Source: Directorate-General for Research and Innovation.
Data: HSBC estimates of GDP growth, the OECD, World Bank.
NB: (i) The G7 is the group of seven industrialised nations: Canada, France, Germany, Italy, Japan, United Kingdom and the United States; the E7 is a group of rapidly emerging economies: Brazil, China, India, Indonesia, Mexico, Russia and Turkey; (ii) the three scenarios are: (a) the Current trend scenario, the projections are based on the trend observed during the period 1996–2007 (the maximum R & D intensity for each country is limited to 5 %); (b) the Convergence scenario assumes that R & D expenditures for all countries will continue along the current trend but, for E7 countries once an R & D intensity of 3 % is reached, the annual R & D intensity growth for that country is limited to 1 %); (c) the Recovery scenario assumes that G7 countries will — by 2020 — spend at least 3 % of GDP o research (political commitment) and will continue to increase their investments. After 2020, it is assumed that the annual growth rate of R & D intensity in G7 will be the average annual growth rate during the period 1990–2020.

Figure A3.3: **Long-term trends in world shares of PCT patents**



Source: Directorate-General for Research and Innovation.
Data: OECD patent database.
NB: The graph is based on the assumption that R & D spending in the E7 and the G7 will evolve in line with the Convergence scenario in Figure A3.2. It assumes a gradually increasing propensity to patent (patent/business R & D ratio) for the E7 countries and a stable propensity for the G7. Data are for patent applications filed under the PCT, at international phase, designating the European Patent Office (the PCT is a system facilitating the worldwide filing of patent applications).

R & D as the G7 countries by 2050 (Figure A3.2), and by 2020, they could already be investing more than the EU. This expansion of R & D spending by the emerging countries should inevitably lead to their producing more patents in the coming decades.

As seen in Figure A3.3, whereas the G7 currently account for 85 % of PCT patent applications compared with only 8 % for the E7 countries, by 2050 the G7 share could have diminished to 50 %, with the E7 countries at nearly the same level (46 %).

Europe needs research and innovation to recover from the economic crisis, and to boost growth and jobs, but the context for investment is difficult

In this competitive global setting, Europe needs to set itself on a path towards a strong recovery from the economic crisis. But this will not be easy. Following the crisis, R & D investment has slowed. For the EU as a whole, the decrease in nominal R & D expenditure was about EUR 3 billion (– 1.32 %, from EUR 239.7 billion in 2008 to EUR 236.8 billion in 2009).

The total government R & D budget for EU-27 increased in 2009 (to EUR 88.6 billion, from EUR 86.2 billion in 2008 [10]). In the medium term, the need for fiscal consolidation may place further pressure on the ability of some European governments to maintain their investment in R & D. Business investment in R & D was more affected than public investment in 2009. In EU's business sector, R & D expenditure decreased by – 3.07 % that year in nominal terms.

The EU is still lagging behind in terms of the percentage of its GDP invested in R & D. In 2008, EU R & D intensity was 1.92, compared with 2.77 for the United States and 3.44 for Japan. The 2009 figure shows an increase (2.01), but this is largely due to falling GDP.

Private R & D in Europe has largely stagnated at around 1.2 % of GDP over the last decade, whereas business R & D intensity grew rapidly in Japan (from 2.2 % to 2.7 %) and South Korea (from 1.7 % to 2.5 %) over the same period, and more than doubled in China (from 0.5 % to 1.1 %).

While many fast growing firms are created as SMEs, their R & D intensity is lower in Europe (0.25 in 2007) than it is for the United States (0.30) and South Korea (0.56). This lack of investment is in turn reflected in the smaller role played by 'young leading innovators' or 'Yollies' — R & D intensive firms which rapidly grow into world leaders due to substantial R & D efforts [11].

10. Source: Eurostat — Government Budget Appropriations or Outlays on R & D.
11. Veugelers, R., Cincera, M., *Bruegel Policy Brief*, August 2010.

And Europe's competitiveness and innovative performance are weak

In Europe, total factor productivity stagnated in the last decade compared with around a 7 % increase since 2000 in the United States and Japan [12]. Various studies have pointed to the need to improve the productivity of the service sector by increasing R & D in services [13].

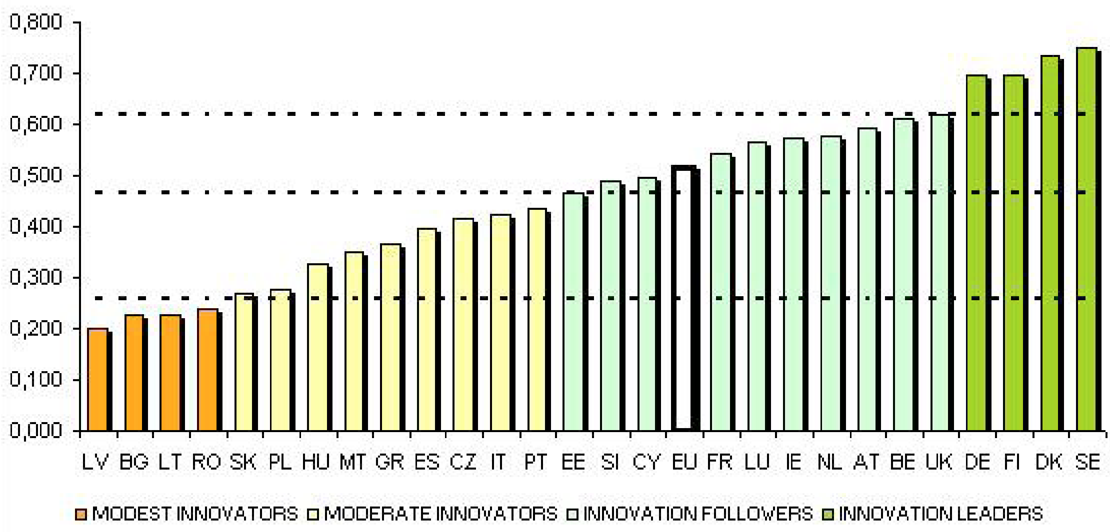
While analyses show that growth in trade in manufacturing is largely driven by high-technology industries [14], the EU's performance in high technology is far from strong. The share of high-tech and medium-high-tech products in EU exports is lower than that of its main trading partners — 47 % in 2008, compared with 60 % for the United States, 71 % for South Korea, and 75 % for Japan [15]. Taking a broader view, the overall innovation performance gap has broadened with the United States and Japan, while emerging countries are catching up [16].

One of the weaknesses of Europe's innovation system is the poor links between public and private research actors, which lower its capacity to maximise the use of local knowledge. The EU produces only 36 scientific co-publications per million population which involve public-private collaboration, whereas the United States produces 70, and Japan, 56 [17].

These weak science-industry links, combined with Europe's underinvestment in private R & D have an impact on its capacity to introduce technological innovation. In 2007, the EU produced four PCT patent applications [18] per EUR 1 billion of GDP, slightly below the United States and much lower than Japan and South Korea, which produced eight and seven respectively. In 2009, the economic revenues obtained from the licensing of these patents, which in part relates to their quality and usefulness, amounted

12. Directorate-General for Economic and Financial Affairs, 2010.
13. For example, the report of the CREST OMC 3 % Working Group on promoting the role of R & D in services, 2009.
14. *Science, Technology and Industry Scoreboard 2009*, OECD, p. 86.
15. *European Innovation Scoreboard*, 2010.
16. *European Innovation Scoreboard*, 2010.
17. *European Innovation Scoreboard* 2010, data for 2008.
18. Patent applications under the Patent Cooperation Treaty, at international phase, designating the EPO by country of residence of the inventor (Source: OECD).

Figure A3.4: **Innovation performance of EU Member States**



Source: Directorate-General for Enterprise and Industry, Directorate-General for Research and Innovation, Innovation Union Scoreboard 2010.
NB: Average performance is measured using a composite indicator building on data for 24 indicators going from a lowest possible performance of 0 to a maximum possible performance of 1. Average performance in 2010 reflects performance in 2008/09 due to a lag in data availability. The performance of Innovation leaders is 20 % or more above that of the EU-27; of Innovation followers, it is less than 20 % above but more than 10 % below that of the EU-27; of Moderate innovators, it is less than 10 % below but more than 50 % below that of the EU-27; and, for Modest innovators, it is below 50 % that of the EU-27.

to 0.2 % of the total GDP in Europe ([19]). In contrast, these revenues were more than double and triple in Japan and the United States. Moreover, this gap has widened considerably during the past decade.

Globally, the EU is failing to close the innovation performance gap with its main international competitors: Japan and the United States. Although the trends in most EU Member States are promising despite the economic crisis, progress is not fast enough. While the EU still maintains a clear lead over the emerging economies of India and Russia, Brazil is making steady progress, and China is catching up rapidly. Within the EU, Sweden is the most impressive performer followed by Denmark, Finland and Germany. The United Kingdom, Belgium, Austria, Ireland, Luxembourg, France, Cyprus, Slovenia and Estonia, in that order, form the next group (Figure A3.4).

All the innovation leaders have higher than average public-private co-publications per million of population, which points to good linkages between the science base and businesses. All Europe's most innovative countries also excel in the commercialisation of their technological knowledge, as measured by their performance in terms of license and patent revenues from abroad.

Europe also needs to raise scientific quality ...

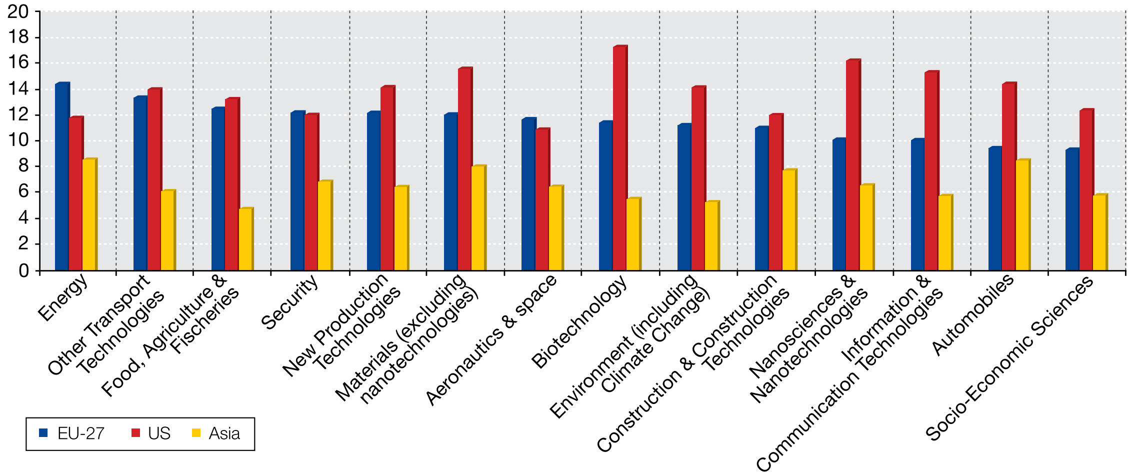
While 15 % of US scientific publications are among the top 10 % most cited publications worldwide, only 11 % of EU publications fall into this category. Meanwhile, China had 7 % of its publications in the top ranking in 2007, compared with just under 5 % in 2000 ([20]).

When it comes to academic institutions, of the 386 most active research universities in the world 45 % are in Europe and 32 % in the United States ([21]). But only 8 of the 76 universities in the world with the highest citation impact are located in the EU; 67 are located in the United States.

19. Source: Eurostat.

20. Source: Science-Metrix, Scopus (Elsevier).
21. According to the latest edition of the Shanghai Ranking.

Figure A3.5: **Percentage of scientific publications in the top 10 % most cited (2000–09)**



Source: Directorate-General for Research and Innovation.
Data: Eurostat, *Science Metrix-Scopus* (Elsevier).

This pattern of the EU falling behind in terms of quality is continued if one looks across different fields. Figure A3.5 shows a number of S&T areas that relate to the fields of the EU FP. It can be seen that in almost all areas, the United States has significantly more publications in the top 10 % most cited than does the EU.

If one looks at scientific impact in key fields in relation to the growth in scientific output in these fields (Figure A3.6), two trends emerge clearly. Firstly, in the areas of health, environment, nanoscience, biotechnology and ICT, Europe's impact falls behind that of the United States (albeit that in the environment field its publication output is growing slightly faster). Secondly, while China is still behind the EU and the United States in these fields in terms of scientific impact and in terms of publication volume, its output is growing at a much faster rate.

... And gain a technological lead over its competitors

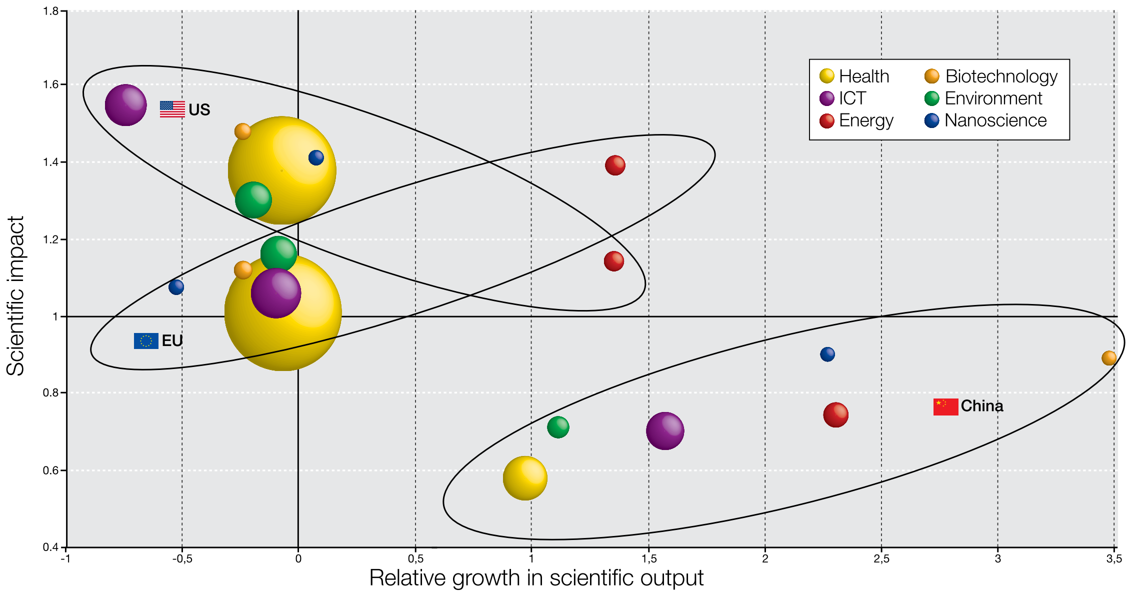
When it comes to the development of new technologies, Europe needs to rise to the challenge of global competition. It is relatively strong in certain more traditional fields such as automobiles, aeronautics, other transport and construction, where it must seek to maintain its large share of global patents (Figure A3.7). However, in a number of technology areas Europe is behind its competitors. This is certainly true for some key enabling technologies: for example, in nanotechnology, the EU has 28 % of world patents compared with 45 % for the United States and 24 % for Asia; in biotechnology, the EU has 30 % versus 48 % for the United States and 19 % for Asia; while in ICT, the EU has 29 % of global patents, the United States 40 % and Asia 30 %. The EU also lags in terms of patents in key areas for the future, notably health, energy, space and security.

If one takes a combined look at Europe's relative performance in both science and technology across various fields (Figure A3.8), one sees that it is ahead of the United States in terms of both science and technology output in the field of aeronautics and space. However, Europe is weaker than the United States in the fields of nanotechnology, biotechnology and ICT, as well as in health and new production technologies.

... While better harnessing its research and innovation to tackle societal challenges

The EU faces serious challenges across a number of key areas, including health, energy and the environment. However, when it comes to science and innovation, Europe's performance in these areas is mixed as the following examples show.

Figure A3.6: **Scientific performance in key fields**



Source: Directorate-General for Research and Innovation.
Data: Eurostat, *Science Metrix-Scopus* (Elsevier).
NB: Scientific impact = average of relative citations computed for 2000–06 publications (with sliding citation time window (N; N + 3)); a value above 1 means a country is cited more often than the world average. Relative growth in scientific output 2005–09 compared with 2000–04; expressed as the absolute difference in percentage points between growth of country X and the world average growth of publications in the field; the size of the bubble is proportional to the volume of publications.

- The EU devotes considerable resources to environmental sciences (in 2008, it invested EUR 5 per capita, compared with just EUR 2 by the United States and Japan) ([22]). The EU also leads the field in patenting related to air and water pollution control, solid and waste management and renewable energies. For these fields combined, the EU holds 35 % of all patents, compared with 22 % for the United States and 20 % for Japan ([23]).

- In health-related research, the United States is the world leader. In terms of public budgets, the United States devoted more than 0.2 % of GDP to such research, while the EU invested 0.05 % ([24]). Companies in the United States invest almost twice as much in health R & D compared with their EU counterparts. As a consequence, the United States leads in patents related to medical technologies, accounting for almost half of all world patents (49 % of PCT patent filings), while the EU's share is only one quarter. When it comes to pharmaceuticals, the United States also leads with a 42 % share of patents worldwide, while the EU has 28 % ([25]).

Figure A3.9 gives an overview of Europe's technological performance across a range of fields compared with that of North America and Asia. Europe's strength in renewable energy and certain environmental technologies can be clearly observed. However, in a number of key areas, either directly related to societal challenges or in certain enabling fields which will underpin future advances, Europe is faced with strong competition.

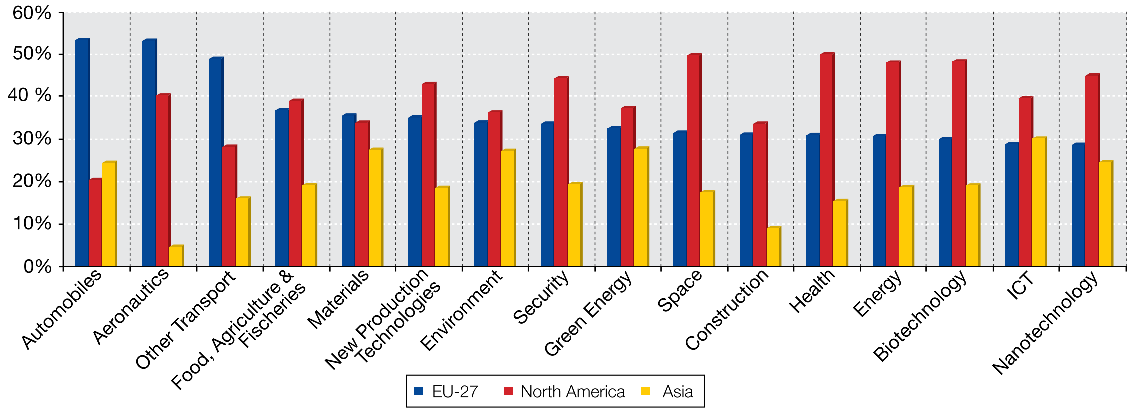
... And investing in R & D in a more coordinated way

'Integrating the research base by overcoming fragmentation in research' is the first recommendation

22. *Science, Technology and Industry Scoreboard 2009*, OECD.
23. *Science, Technology and Industry Scoreboard 2009*, OECD.
24. *OECD, Measuring Innovation: A New Perspective*, 2010.

25. *Science, Technology and Industry Scoreboard 2009*, OECD; data on medical technology and pharmaceutical patents are PCT filings for the period 2004–06.

Figure A3.7: **Patent shares 2000–09 (PCT applications)**



Source: Directorate-General for Research and Innovation.
Data: EPO PATSTAT database (from a study by the Research Division INCENTIM (MSI, Faculty of Business & Economics, KU Leuven), and Università Commerciale Luigi Bocconi, KITeS).

made in the interim evaluation of the seventh framework programme (FP) ([26]). The national fragmentation of public R & D funding is perceived both as a suboptimal use of public funding for R & D and as a factor undermining the S&T performance of Europe.

The EU needs to increase the effectiveness of its investment in research and innovation through greater coordination and collaboration. Transnational collaboration in science is known to produce higher impact results and stimulate excellence. **International co-authorship results, on average, in publications with higher citation rates than purely domestic papers (Figure A3.10).**

Indeed, Europe's scientific impact is higher in those fields where European countries collaborate more:

- the highest share of EU scientific publications involving cross-border European collaboration is found in 'physics and astronomy', 'multidisciplinary sciences' and 'earth and environmental sciences' (Figure A3.11);
- and it is in these disciplines ([27]) where one observes the highest impacts: in the five countries that publish a large part of all EU publications (Germany, France, the United Kingdom, Spain, Italy), publications in these disciplines are more frequently cited than a (world) 'average' publication in the same disciplines ([28]), and these disciplines are systematically among the disciplines with the highest impact scores in France, Germany and the United Kingdom (Figure A3.12). This also holds true in most other EU countries;
- for most countries, 'multidisciplinary sciences' also rank very high in terms of impact, in particular in Germany, France and the United Kingdom, where it ranks first.

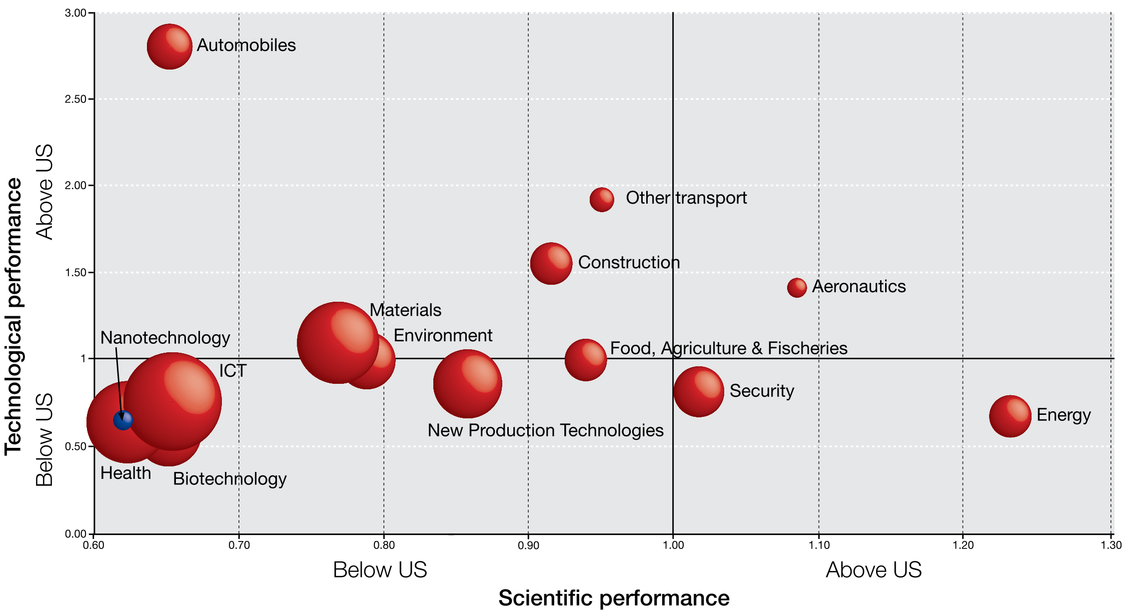
Europe can also make more efficient and effective use of its resources through pooling and sharing them. A good example is that of large-scale research infrastructures, where the sharing of costs and access makes sound economic sense.

- The level of funds required for their construction cannot be provided by a single European State. The total estimated cost of the 51 research

26. (i) For each technology field, the X-axis of the graph shows the global market share of Europe in terms of EPO/PCT patents compared with the market share of Asia (expressed as a logarithm), and the Y-axis shows the market share of Europe compared with the market share of North America (expressed as a logarithm): the size of each bubble is proportional to the number of patents by European inventors in the field; (ii) the broad technology domains are shown in bold; (iii) data relate to the period 2003–05.

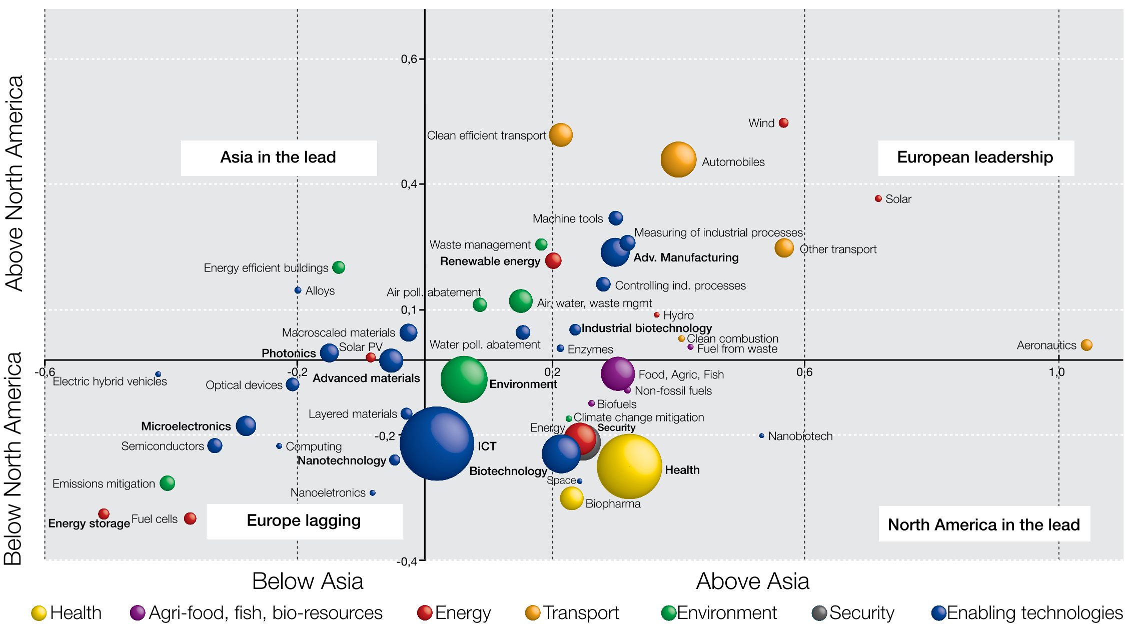
27. Physics, astronomy, earth sciences and environmental sciences.
28. That is, the field-normalised impact scores of these disciplines are above 1 (with the exception of earth sciences and environmental sciences in Italy).

Figure A3.8: **European S&T performance relative to the United States**



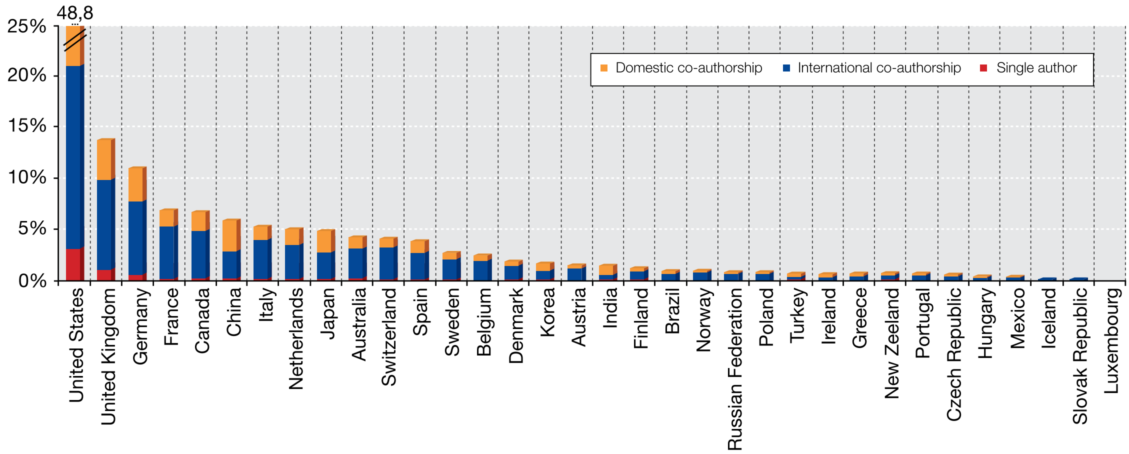
Source: Directorate-General for Research and Innovation.
Data: PCT patents — EPO PATSTAT database (from a study by the Research Division INCENTIM (MSI, Faculty of Business & Economics, KU Leuven), and Università Commerciale Luigi Bocconi, KITeS); scientific publications — *Science Metrix-Scopus* (Elsevier).
NB: (i) Scientific performance is measured in terms of the % of publications in the top 10 % most cited category (2000–06 publications with sliding citation window (N, N + 3)); on the X-axis, the percentage for the EU is divided by that for the United States; (ii) technological performance is measured by the share of global PCT patents for the period 2000–09 (patents filed under the Patent Cooperation Treaty (PCT), at international phase, that designate the EPO); on the Y-axis, the share for the EU is divided by that for the United States; (iii) the size of the bubbles = number of EU-27 patents in the technology field.

Figure A3.9: **Europe's technological performance compared with North America and Asia** ([26])



Source: Directorate-General for Research and Innovation
Data: OECD patent database and specific studies ([27]); Europe covers EU-27, Iceland, Norway and Switzerland; Asia covers Japan, China, South Korea, Singapore and Chinese Taipei.

Figure A3.10: **Highly cited (top 1 %) scientific articles by type of collaboration, 2006–08 (% of highly cited scientific articles worldwide)**



Source: Directorate-General for Research and Innovation.
Data: OECD, *Measuring Innovation: A New Perspective*, 2010.

infrastructures of the European Scientific Forum for Research Infrastructures (ESFRI) Roadmap ([29]) is in the order of 84 % of total annual capital expenditure ([30]) in the EU, or 2.7 times the amount of total 2007–13 Structural Funds earmarked for research infrastructures in the EU.

- In addition, the scientific community that can best make use of one of these facilities is relatively limited in a single country, so that the level of investments for building and operating the facility is incommensurate with the number of domestic users, resulting in a suboptimal exploitation of these investments.

- Indeed, the actual value added of some of these large-scale infrastructures is precisely the pooling of data, the multiplication and diversification of experimental cases and contexts that a single country could not gather alone.

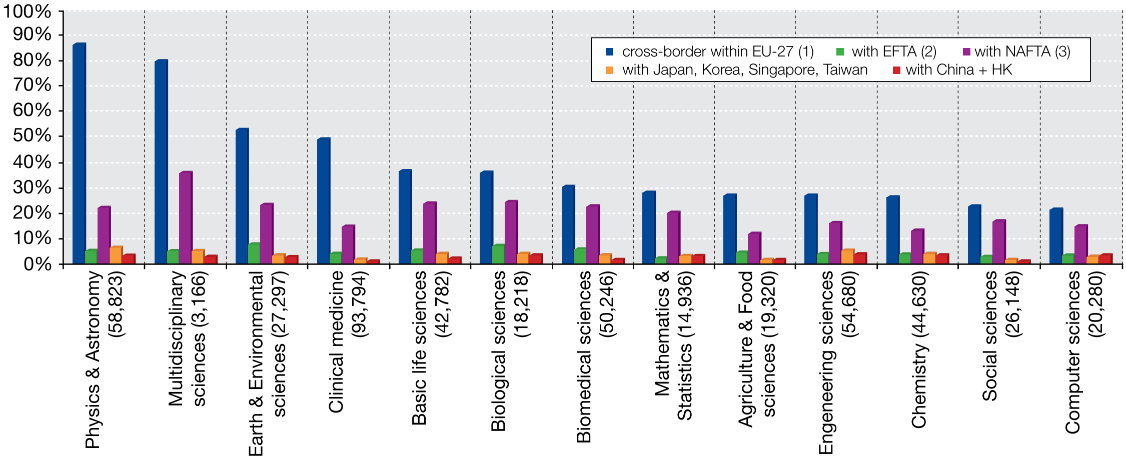
Yet, in spite of these benefits of coordination, a recent review of national R & D programmes in 11 European countries showed that very few of them in Europe are genuinely open, in the sense of allocating funding to foreign-based research performers under conditions which are close to the ones applied to domestic actors ([31]). The prevailing national approaches to R & D collaboration in Europe are to use EU-level instruments (for transnational coordination of research activities) rather than opening national funding sources to foreign-based research actors ([32]).

However, even the transnational coordination of public R & D funding remains limited: only about 11.1 % of public R & D funding in the EU (27 Member States' national R & D budgets plus FP) can be considered as 'coordinated public funding of R & D'. Of this, 7.5 % is attributable to the FP and just 3.6 % to various forms

29. As of early 2011, 10 research infrastructures of the ESFRI Roadmap are in the implementation phase and 41 in the preparatory phase (including three research infrastructures of the European Strategy for Particle Physics, as approved by the CERN Council).
30. 'Capital expenditure on R & D' includes expenditure on fixed assets used in R & D activities such as land and buildings and also expenditure on equipment, research instruments and computer software. The other category of R & D expenditure, 'current cost' includes labour costs and the non-capital purchase of materials and supplies (Frascati Manual).

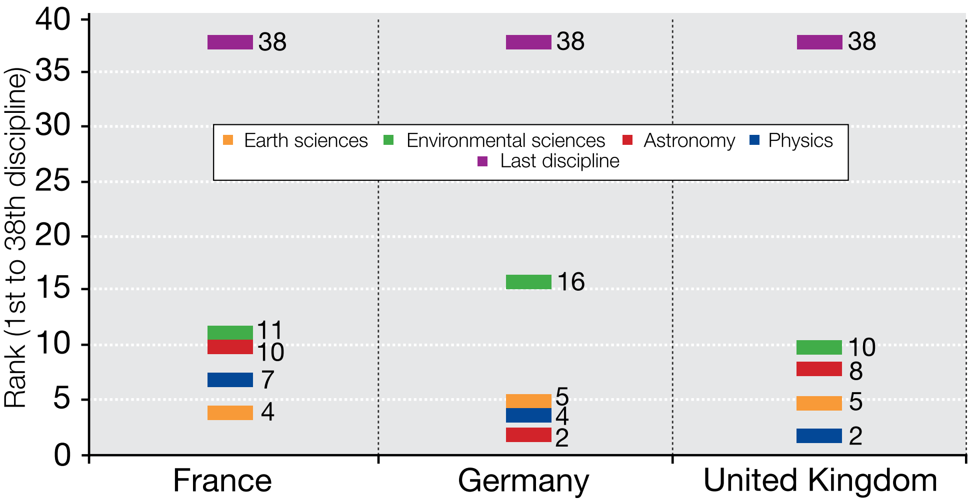
31. The study 'Investments in joint and open R & D programmes and analysis of their economic impact', funded by the Directorate-General for Research and Innovation (forthcoming).
32. Recent reviews of R & D programmes in several European countries found that linking national research programmes to EU priorities under the FP, or planning large infrastructures according to EU directions, and using EU-level instruments such as ERA-NETs, are various ways to encourage international collaboration in R & D: (i) *Monitoring progress towards the ERA*, European Commission, ERAWATCH Network, 2009 (http://cordis.europa.eu/erawatch/index.cfm?fuseaction=reports.home); (ii) national mapping of open R & D programmes in the study 'Investments in joint and open R & D programmes and analysis of their economic impact', funded by the Directorate-General for Research and Innovation (forthcoming).

Figure A3.11: **EU-27 co-publications by main scientific fields, 2006 (% of all EU-27 Publications) (4) (in parenthesis: total number of publications of the field)**



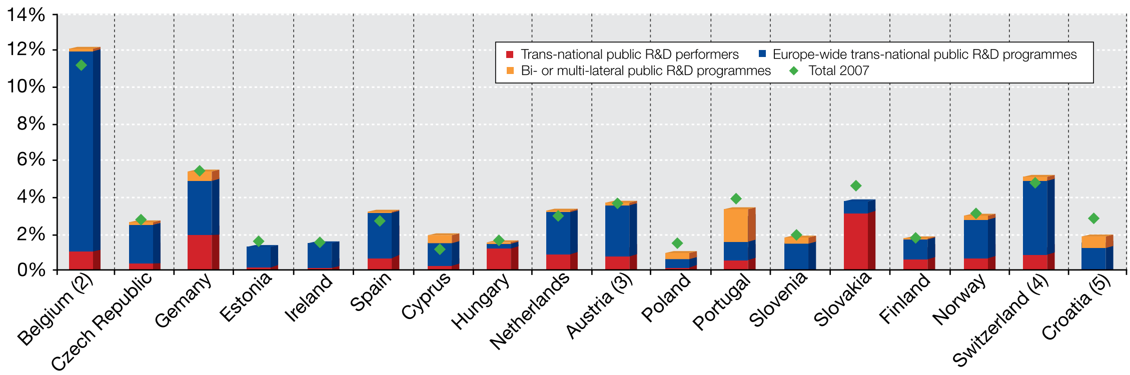
Source: Directorate-General for Research and Innovation.
Data: CWTS-Leiden University/Thomson Reuters, own calculations.
(1) Co-publications involving authors with addresses in at least two Member States.
(2) Publications involving at least one author with an address in the EU-27 and at least one author with an address in Iceland, Liechtenstein, Norway or Switzerland.
(3) Publications involving at least one author with an address in the EU-27 and at least one author with an address in Canada, Mexico or the United States
(4) The four categories are not mutually exclusive as authors based in several world regions may be involved in a given EU-27 publication.

Figure A3.12: **Rank of astronomy, physics, earth and environmental sciences among 38 scientific disciplines (1) according to field normalised impact score, 2005–07**



Source: Directorate-General for Research and Innovation.
Data: CWTS-Leiden University/Thomson Reuters.
NB: The 38 scientific disciplines cover all natural sciences, social sciences and humanities.

Figure A3.13: **National public funding of transnationally coordinated research by category** ([1])
(% of total national GBAORD, 2008)



Source: Directorate-General for Research and Innovation, Innovation Union Competitiveness Report 2011.
Data: Eurostat.
([1]) Experimental data.
([2]) BE: Data of some regional authorities in Belgium are probably not included.
([3]) AT: federal or central government only.
([4]) CH: 2007 value uses 2006 GBAORD as denominator.
([5]) HR: 2007 value uses 2008 GBAORD as denominator.

of coordinated national funding ([33]). Figure A3.13 shows more detail of these latter forms of coordinated national funding, illustrating how much countries devote from their national R & D budgets to transnationally coordinated research. Overall, more than 95 % of national R & D budgets are spent nationally without coordination across countries.

33. This comprises: (i) transnational public R & D performers located in Europe: CERN, EMBL, ESO, ESRF, ILL, JRC (future research infrastructures of the ESFRI Roadmap will belong to this category); (ii) Europe-wide transnational public R & D programmes and agencies: ESA, EMBO, ESF, EUREKA, ERA-NET, ERA-NET+, JTIs (public funding part: ENIAC, ARTEMIS), Article 185 (European and Developing Countries Clinical Trials Partnership, Eurostars and Ambient Assisted Living for the elderly) (the Joint Programming Initiatives belong to this category); (iii) bi- or multilateral public R & D programmes established between Member States' governments and with candidate countries and EFTA countries.

Annex 4: The economic role of science, technology and innovation

Introduction

Europe suffers from a weak recovery from the economic-financial crisis, from weak economic growth over the last decade, from a long-standing gap in living standards with the United States, and from dire future economic prospects.

A key reason for this is Europe's lack of investment in intangibles, in particular research and innovation, which are critical for promoting increases in labour productivity and structural economic growth.

Modern 'growth accounting' literature

- The key role played by research and innovation in structural economic growth is highlighted by the modern 'growth accounting' literature, which integrates the concept of intangible assets.

- There are three kinds of intangible assets: (i) scientific R & D and non-scientific inventive and creative activities (scientific and creative property); (ii) software, computer programs and computerised databases (computerised information); and (iii) firm-specific human capital, organisational capital and brand names (economic competencies) (INNODRIVE, 2009).

- Intangible capital is an essential ingredient for economic growth (Jona-Lasinio et al., 2011). Labour productivity, which, in the long term, is commonly viewed as connected to the living standards of the workforce, is strongly promoted by the accumulation of intangible capital (INNODRIVE, 2009). An econometric analysis shows a positive and significant relation between business investment in intangible capital and overall economic labour productivity growth (Roth and Thum, 2010).

- The OECD estimates indicate that in Member States like Austria, Finland, Sweden, the United Kingdom, and the United States, investment in intangible assets and MFP growth (linked to innovation and improvements in efficiency) together accounted for between two thirds and three quarters of labour productivity growth between 1995 and 2006, thereby making innovation the main driver of growth (OECD, 2010b).

Modern economic theory

- The modern 'growth accounting' literature confirms what modern economic theory has unanimously recognised for quite some time now: that research and innovation are prerequisites for the creation of more and better jobs, for productivity growth and competitiveness, and for the structural economic growth vital for social cohesion and required to sustain Europe's social model.

Macro and microeconomic literature

- This recognition has been based on an extensive body of macro and microeconomic literature that has produced a number of clear conclusions.

- The economic returns to public and private research are high.

– **Total R & D**
  - Empirical work has established robust relationships at the macroeconomic level between investment in innovation and productivity, and firm-level studies have also found positive and significant effects of R & D on productivity growth (OECD, 2010b).
  - A 0.1 percentage point increase in R & D could boost output per capita growth by some 0.3–0.4 % (Bassanini and Scarpetta, 2001).

- Astochastic frontier analysis by the European Commission's Directorate-General for Economic and Financial Affairs found that an economy's R & D intensity has a significant positive effect on the number of patents per million inhabitants of that economy and that R & D investments are characterised by non-decreasing returns to scale (Mandl et al., 2008).
- Following detailed analysis, a team of social scientists has concluded that factors connected with the concept of 'human capital' are responsible for around 70 % of the difference in wealth between regions; three dimensions of human capital are important, one relating to productivity and innovation; human capital is measured by looking at two things: the amount of public and private money being invested in research and technological development (R & D), and the number of patent applications being made in each region (EurActiv.com).

– **Public R & D**
  - The rate of return for publicly funded R & D usually exceeds 30 % (Muldur et al., 2006).
  - Each extra 1 % in public R & D generates an extra 0.17 % in productivity growth (Guellec and van Pottelsberghe de la Potterie, 2001, 2004).
  - Estimates of the impact of UK Research Council spending on the United Kingdom's national output suggest that a cut of GBP 1 billion in annual spending would lead to a fall in GDP of GBP 10 billion (Haskel and Wallis, 2010).
  - The USD 3.8 billion spent by the US government to map the human genome spurred the creation of tens of thousands of jobs and gave rise to an industry that — while slow to deliver medical breakthroughs — now generates about USD 67 billion in annual economic activity. The genome-sequencing project triggered many novel types of economic activity, from the manufacture of sequencing machines and other instruments to the devising of genetic test kits and diagnostic materials used for laboratory experiments. The investment also produced significant economic returns in the form of tax revenues and personal income. The USD 3.8 billion, along with subsequent capital provided by the government and the private sector, has generated a total return of roughly USD 49 billion in direct and indirect federal tax revenues over the last two decades or so. Over the same period, those initial investments also helped to drive USD 796 billion in direct and indirect economic output and generate USD 244 billion in total personal income. In 2003, for example, the National Institutes of Health and Department of Energy together invested USD 437 million in the Human Genome Project. That directly led to USD 552.9 million in economic activity, the creation of 5 025 jobs and USD 51 million in federal tax revenue. When the ripple effect is included, the impact was greater: USD 1.65 billion of economic output, 12 422 jobs created, and USD 125.5 million in federal tax revenue (Wall Street Journal).
  - Spending by the National Institute of Health directly and indirectly supported nearly 488 000 jobs and produced USD 68 billion in new economic activity in 2010 (Wall Street Journal).
  - According to UK research, a GBP 1 investment in public/charitable cardiovascular disease (CVD) research produced a stream of benefits thereafter that is equivalent in value to earning GBP 0.39 per year in perpetuity. The total rate of return for mental health research is 37 % (HERG Brunel University et al., 2008).

– **Private R & D**
  - Firms' returns on their own investment in research usually range from 20 % to 30 % (Muldur et al., 2006).
  - Societal returns on firms' investment in research usually range from 30 % to 40 % (Muldur et al., 2006).
  - Each extra 1 % in business R & D generates an extra 0.13 % in productivity growth (Guellec and van Pottelsberghe de la Potterie, 2001, 2004).

- Research and innovation are vital for industrial competitiveness.

- Research and innovation allow European firms to deal with the competitive threat posed by the low-cost and increasingly high-tech BRIC (Brazil, Russia, India and China) and small East Asian economies.

- The ability to innovate (in addition to size, productivity, the skill intensity of the workforce) is positively related to firms' export performance. It also supports more complex internationalisation strategies, such as exporting to a larger number of markets, to more distant countries and producing abroad through FDI or international outsourcing (Navaretti et al., 2010).

- On the other hand, firms' export status induces product innovations (learning by exporting). This may be due to the interaction between exporters and foreign customers and in particular the need of a domestic firm to modify its products when entering and staying in a foreign market (Bratti and Felice, 2010).

- Domestic research is necessary to be in a position to absorb the results of foreign research (international spillovers).

- Each extra 1 % in foreign R & D generates an extra 0.44 % in productivity growth. This means that R & D not only benefits highly R & D-intensive countries but also R & D followers, but they must carry out a minimum of R & D to be able to absorb the results of others (Guellec and van Pottelsberghe de la Potterie, 2001, 2004).

- Technological change boosts employment.

- The often accepted view that innovation destroys jobs is wrong: innovations have a positive and significant effect on employment, which persists over several years (Van Reenen, 1997).

- For example, an increase in business R & D by 1 % is associated with an increase in business employment of 0.15 % (Bogliacino and Vivarelli, 2010).

- Research-intensive sectors create more and better jobs.

- Long-term, high-quality jobs stay in industries where there is a high degree of innovative content and where innovation, manufacturing, and end-user demand are tightly integrated.

- R & I can significantly help economies re-emerge from deep crises. Finland and South Korea responded to their economic crises in the 1990s by investing heavily in R & D while severely constraining public spending; these investments helped their strong re-emergence in knowledge-based economies (CaSE, 2010).

Annex 5: Information on econometric modelling used in the report (NEMESIS) – Description, assumptions and results

NEMESIS is a general equilibrium model built by a European Commission-funded consortium of European research institutes under the fifth framework programme. NEMESIS has been used by the European Commission for the *ex ante* impact assessment of FP7 and to assess the macroeconomic impact of achieving the objective of investing 3 % of Europe's GDP in research and innovation (3 % objective), by the OECD, by a number of French government institutions, etc.

For the Horizon 2020 impact assessment, the Directorate-General for Research and Innovation developed, in collaboration with the DEMETER

Figure A5.1: **Impact of the different options on GDP**

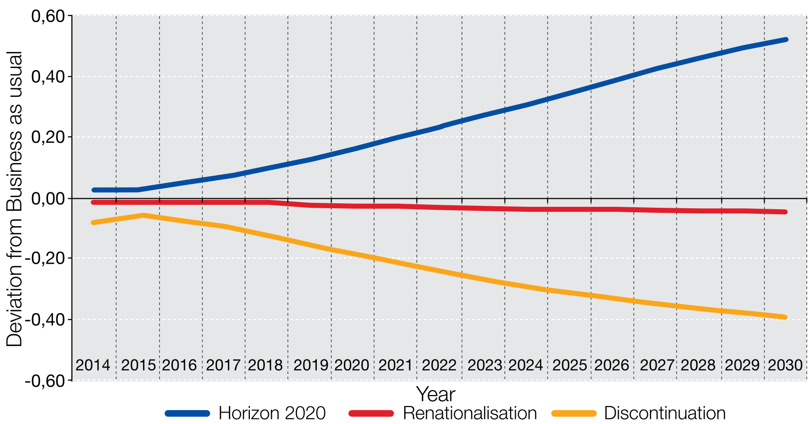


Figure A5.2: **Impact of the different options on exports**

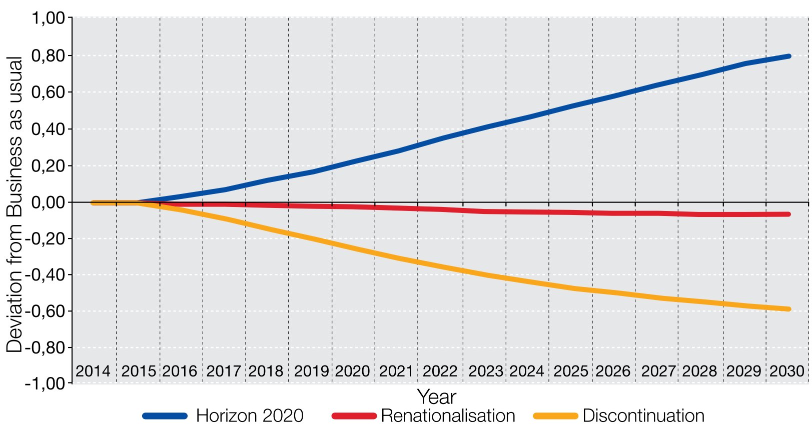


Figure A5.3: **Impact of the different options on imports**

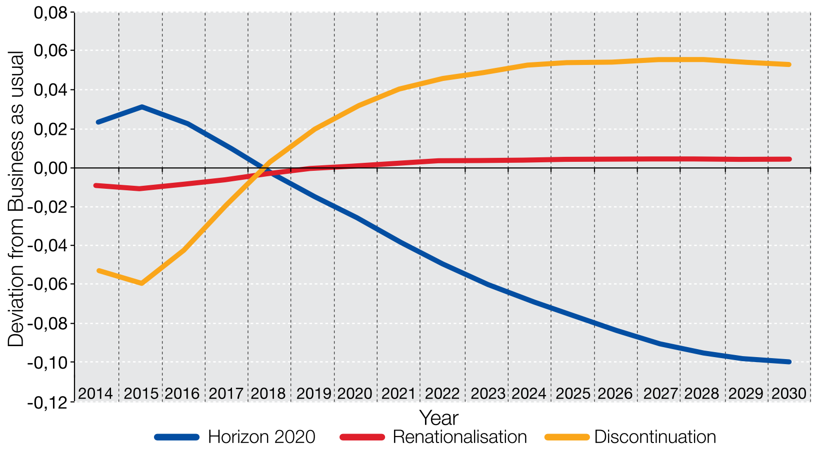
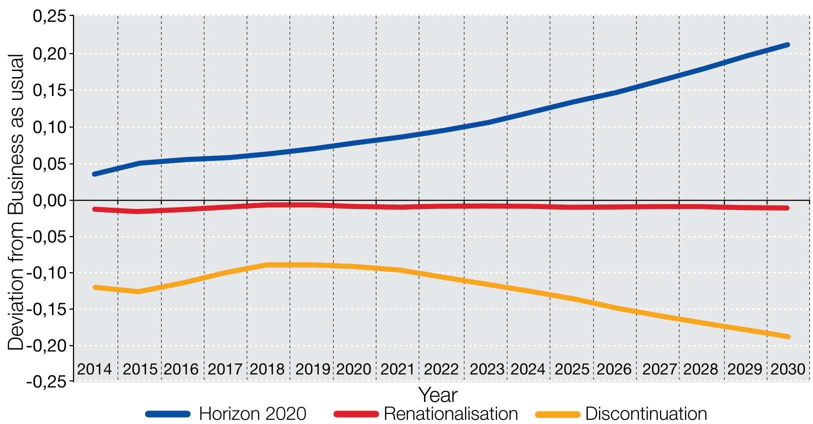


Figure A5.4: **Impact of the different options on employment**



consortium operating NEMESIS, five different future-oriented scenarios: (i) business-as-usual; (ii) Horizon 2020 – common strategic framework for research and innovation; (iii) Horizon 2020 – common strategic framework for research and innovation and achievement of the 3 % objective; (iv) renationalisation; and (v) discontinuation.

These scenarios were operationalised through a number of key model parameters including the real EU and national research and innovation funding growth rates; the allocation of EU research and innovation funding to EU Member States, to basic versus applied research, and to sectors; the EU and national research and innovation funding crowding-in factors and multipliers; the intersectorial and international spillovers. The scenarios and the specific assumptions underpinning each of them are detailed in Figure A5.1. The difference between the BAU, Horizon 2020 and other scenarios hinged mainly on the scale of EU research and innovation funding, and on the size of the crowding-in effect and the economic multiplier associated with the intervention.

All BAU assumptions were based on academic literature. The BAU FP and national net private sector funding crowding-in effects of 0.7 and 0.5, for example, were derived directly from Guellec and Van Pottelsberghe (2000), EC (2004).

The Horizon 2020 assumptions were necessarily based on deduction and analogy. Because of simplification and, therefore, enhanced industrial participation, and because of closer knowledge triangle coordination and, therefore, enhanced valorisation of research results, crowding-in effects and economic multipliers, for example, were assumed to be higher than those associated with the BAU option.

The DEMETER consortium produced results on GDP, exports, imports, and employment through 2030 for each of these scenarios. In Figures A5.1 to A5.4, these results are presented as deviations from the business-as-usual scenario.

Table 14

	Business as usual	Preferred		Renationalisation	Discontinuation - Cost of non-Europe
		CSF	CSF+3%		
FP funding real growth rate 2014-2020	€8,31 billion (2014 prices) spent in 2014; thereafter adjusted for inflation (2%) only	2014: 10,70 billion; 2015: 11,40 billion; 2016: 12,12 billion; 2017: 12,87 billion; 2018: 13,65 billion; 2019: 14,45 billion; 2020: 15,27 billion (current prices, no need anymore to adjust for inflation; already done)	2014: 10,70 billion; 2015: 11,40 billion; 2016: 12,12 billion; 2017: 12,87 billion; 2018: 13,65 billion; 2019: 14,45 billion; 2020: 15,27 billion (current prices, no need anymore to adjust for inflation; already done)	€8,31 billion (2014 prices) spent in 2014; thereafter adjusted for inflation (2%) only	€8,31 billion (2014 prices) spent in 2014; thereafter adjusted for inflation (2%) only (negative effect)
FP funding real growth rate 2021-2030	Continuation of above	Increase further every year by 450 million and adjust for inflation (2%)	Increase further every year by 450 million and adjust for inflation (2%)	Continuation of above	Continuation of above (negative effect)
National funding real growth rate 2014-2020	Constant (latest available) national R&D intensity	Constant (latest available) national R&D intensity	Reach National Reform Plan (NRP) R&D intensity objectives by 2020 (sent)	Constant (latest available) national R&D intensity	Constant (latest available) national R&D intensity reduced by discontinued FP amount
National funding real growth rate 2021-2030	Continuation of above	Continuation of above	Once objectives reached, constant R&D intensity	Continuation of above	Continuation of above
Allocation of FP funding to EU MS	Like under FP7	Based on innovation performance	Based on innovation performance	Like under FP7	Like under FP7 (negative effect)
Allocation of FP funding to basic and applied research	40% basic, 60% applied	40% basic, 60% applied	40% basic, 60% applied	40% basic, 60% applied	40% basic, 60% applied
Allocation of FP applied research funding to sectors within MS	Grand-fathering	Grandfathering	Grandfathering	Grandfathering	Grandfathering

	Business as usual	Preferred		Renationalisation	Discontinuation - Cost of non-Europe
		CSF	CSF+3%		
FP funding crowding-in factor for the private sector (net additional funding generated)	0.9	1.1	1.1	0.7	0.9 (negative effect)
FP funding crowding-in factor for the public sector	0.5	0.5	0.5	0	0.5 (negative effect)
National funding crowding-in factor for the private sector (net additional funding generated)	0.7	0.7	0.7	0.7	0.7
National funding crowding-in factor for the public sector	0	0	0	0	0
Multiplier for R&D resulting from EC funding	6 percent better than national	15 percent better than national	15 percent better than national	National	National
Multiplier for R&D resulting from national funding	National	National	National	National	National
Intersectorial spillovers	+	+	+	+	+
International spillovers	+	+	+	+	+

Annex 6: EURATOM

1. Procedural issues and consultation of interested parties

This annex contains supplementary information on the Euratom research and training programme (2014–18). Following the European Commission's decision of 29 June 2011 to bring together all EU research and innovation funding in a coherent, from-research-to-innovation overarching framework, the Euratom research and training programme, hereinafter the Euratom programme, is an integral part of 'Horizon 2020', the framework programme for research and innovation (2014–20).

The Commission's proposal for the Euratom programme concerns research and training actions in the following fields: nuclear fission and radiation protection, nuclear fusion. The construction and related activities for the ITER project are subject to a separate proposal for a supplementary research programme and, therefore, are not covered in this document.

For general information on the organisation of the impact assessment exercise, including the consultation and use of expertise, refer to the main report on the impact assessment for Horizon 2020. The following section provides specific information on consultation and expertise for preparation of the Euratom programme.

Two workshops (consultations complimentary to the dedicated consultation on the basis of the Green Paper) have been organised with the objective of discussion the energy challenge of the future EU research and innovation programmes with experts and representatives of governments. Both workshops covered nuclear and non-nuclear issues. The first workshop with non-governmental experts (from SET-Plan technology platforms and research centres) took place on 23 June 2011. Stakeholders emphasised the substantial contribution of nuclear energy with regard to energy security and reducing greenhouse gas emissions as well as the leading position of European industry in nuclear energy. The second workshop with representatives from governments took place on 14 July 2011. Most delegations agreed on the importance of nuclear energy's contribution to the European Energy and Climate policy objectives.

Extensive evidence has been used for preparation of this report (for details large refer to specific footnotes):

- Euratom FP7 interim evaluations;
- quantitative input to the fusion part of the IA by an expert group appointed by the Commission;
- report of the Consultative Committee for Fusion (CCE-FU) 'Strategic Orientation of the Fusion Programme' which details the main objectives of the fusion R & D programme and possible programme scenarios with different volume and pace of activities and consequences for the long term outlook of fusion research;
- input from Euratom's Scientific and Technical Committee (STC).

2. Problem definition

2.1. Challenges for nuclear research and training

Nuclear energy is a mature low-carbon energy technology that is deployed at the industrial scale in many EU Member States ([34]). Radiation is also used in industry and research, and in medical diagnostic and therapeutic techniques.

The main challenges as regards current nuclear technology in order for it to further contribute to competitiveness, security of supply and the decarbonisation of European energy systems are to ensure continuing high levels of safety, develop solutions for management of ultimate waste and maintain nuclear skills. Equally important is the need to ensure a robust system of radiation protection, taking into consideration the benefits of the uses of radiation in medicine and industry. In view of the increasing concerns about the risk of non-proliferation and the threat of nuclear terrorism, it is also necessary to develop appropriate

34. Belgium, Bulgaria, Czech Republic, Germany, Spain, France, Hungary, the Netherlands, Romania, Slovenia, Slovakia, Finland, Sweden, the United Kingdom.

safeguards in order to assure nuclear security in Europe and worldwide.

Advanced nuclear technology has the potential to make a major contribution to the realisation of a sustainable and secure baseload energy supply for the EU in a few decades from now (35) (36). The first steps to realise this potential are to demonstrate the feasibility of fusion as a power source and to construct and operate next-generation fast neutron reactor (FNR) demonstrator plants. Efforts to make advanced nuclear energy a reality can be justified by the availability of fuel (hydrogen and lithium in the case of fusion, or uranium and thorium with 50–100 times increased utilisation compared with present reactors in the case of FNRs — are inexpensive and readily available), no risk of severe accidents in the case of fusion, and limitation to the reactor site of the impacts of severe accidents in the case of FNRs. Fusion plants will produce only a limited amount of short-lived radioactive waste, and FNRs will be able to consume much of their own long-lived waste, though geological disposal of the ultimate waste will still be required to eliminate burdens on future generations.

To address these challenges and to bring benefits to the European citizens, a substantial research effort is needed to provide solutions for the following issues.

(a) **Nuclear safety of current and future power plants:** Research will need to address issues of relevance for Europe arising from a detailed analysis of the Fukushima accident (37), in particular any identified in the 'stress tests' being carried out in the EU (38). It is also important to maintain ongoing research on issues of importance to the current fleet of reactors, in particular related to lifetime extensions and long-term operation. The current nuclear fleet in Europe is mostly based on Light Water Reactors (LWR) that have been in operation for 25+ years on average. Current plans in most EU Member States are to extend their lifetimes on a case-by-case basis beyond 40 years, and possibly beyond 50 years. Key R & D issues are related to meeting safety requirements for long-term operation focusing on ageing of structures, systems and components. Other important issues are ageing mechanisms, monitoring and prevention and mitigation measures. Finally, research can also lead to improved efficiency of existing plants through reducing uncertainties in such areas as fuel performance (39). The focus on safety will also need to extend to fundamental design work on next-generation systems.

(b) **Management of ultimate waste:** As indicated in the Commission's revised draft proposal for a Council directive on the management of spent fuel and radioactive waste (40), all EU Member States produce radioactive waste, which is generated by civil nuclear power and radioisotope applications in medicine, industry research and education. More than half of all Member States have accumulations of spent nuclear fuel, or residues from the reprocessing of this fuel, as a result of the operation of nuclear power plants. The general principle is that those who benefit today from these activities should manage the resulting waste in a safe and sustainable manner. This is also the overwhelming view of European citizens (41), whose acceptance of nuclear energy is also strongly correlated to the implementation of solutions to safely manage nuclear waste. The R & D work carried out over last three decades has confirmed that deep geological disposal is the most appropriate solution for long-term management of spent fuel, high-level waste, and other long-lived radioactive wastes (42). This scientific consensus now needs to be turned into an engineering reality, and this will be the focus of attention over the coming decade (43). In addition to the implementation of geological disposal of ultimate waste, it is of

35. Llewellyn Smith, C. H., 'Prospects for fusion', *Nuclear Physics*, 751 (2005) 442c–452c; see also *The Sustainable Nuclear Energy Technology Platform — A vision report* (http://www.snetp.eu/).
36. Final Report of the European Fusion Power Plant Conceptual Study (PPCS), EFDA, 2005.
37. http://www.iaea.org/newscenter/focus/fukushima/
38. http://ec.europa.eu/energy/nuclear/safety/stress_tests_en.htm
39. Strategic Research Agenda of the Sustainable Nuclear Energy Technology Platform, SNETP, 2010.
40. Proposal for a Council Directive on the management of spent fuel and radioactive waste, COM(2010) 618 final of 3 November 2010.
41. Special Eurobarometer 297 — *Attitudes towards radioactive waste*, June 2008.
42. For example, see online (http://ec.europa.eu/research/energy/pdf/euradwaste_08_en.pdf) and 'Radioactive waste in perspective', OECD NEA, 2010.
43. *Vision Report of the Implementing Geological Disposal of Radioactive Waste Technology Platform*, 2010 (http://www.igdtp.eu/).

great importance to minimise upfront the waste production to the maximum extend. This may be done by developing specific working techniques, processes and procedures leading to waste minimisation. For minor actinides contained in spent fuel, research in partitioning and transmutation need to be pursued to demonstrate the feasibility to reduce the lifetime and radiotoxicity of the ultimate waste.

(c) **Education and training in the nuclear field:** As a generation of nuclear physicists and engineers retires and a series of nuclear 'phase-out' policies in some Member States leaves a gap in new talent entering the workforce, education and training have become driving concerns for every sector in the nuclear field ([44]). This is a crucial issue even for countries phasing out their nuclear programmes, as existing facilities need to be operated for at least the next 15 years. Nuclear expertise is also needed for all industrial and medical applications based on ionising radiations, as well as for decommissioning activities related to old nuclear installations. Maintaining knowledge in these disciplines, along with appropriate programmes of nuclear education and training, are essential prerequisites for a high level of nuclear safety and nuclear safety culture ([45]).

(d) **Next-generation fission systems:** Today's light water reactor technology uses less than 1 % of the energy content of the mined uranium, which limits the sustainability of nuclear energy to a few decades because of the finite nature of the world's uranium reserves ([46]). By contrast, fast neutron reactors can extract 50–100 times more energy from the same quantity of uranium, making nuclear much more sustainable ([47]). Furthermore, fast reactors are able to produce far less high-level long-lived waste, with a lower heat load, thereby greatly facilitating the management in future geological repositories. However, many R & D challenges remain, for example to address cost competitiveness, enhanced safety and non-proliferation, requiring innovation both in reactor designs as well as fuel and fuel cycle technology ([48]). Though next-generation fast neutron reactors are not expected to be widely deployed commercially before 2040, prototypes and demonstrators need to be designed and constructed in the next decade to enable sufficient return from experience before commercial deployment. Similarly, work on advanced high and very high temperature reactors can lead to the development of cogeneration systems capable of providing low-carbon process heat for many industrial processes. In parallel to these advances on so-called Generation-IV systems, a broad-based programme of R & D is needed in key areas such as materials, numerical simulation and safety. In many of these areas, there are important synergies with research on materials and technologies for fusion power plants.

(e) **Nuclear safeguards and security:** Expansion of civil nuclear technology worldwide brings with it an increasing concern about the risk of nuclear non-proliferation and the threat of nuclear terrorism. Safeguards of sensitive nuclear materials which rely on profound knowledge and expertise will therefore necessitate continued research and innovation efforts at EU and worldwide level.

(f) **Radiation protection**: Radiation protection research is particularly important in view of the rapidly growing use of radiation in medical diagnostic and therapeutic techniques, which is responsible for a significant rise in public exposure, especially at low doses ([49]). Further multidisciplinary research is needed to determine the mechanisms involved and to quantify the risks of latent cancers and vascular diseases at these low doses. Radiation protection in emergency situations such as under accidental conditions on and off-site require continued attention and improvements.

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44. *Nuclear education and training — Cause for concern?* OECD NEA, 2000.
45. The need for a nuclear education culture has been underlined by the Council of the European Union; see *Conclusions on the need for skills in the nuclear field*, 2891st Competitiveness (Internal Market, Industry and Research) Council meeting, Brussels, 1 and 2 December 2008.
46. Uranium 2009: Resources, Production and Demand (Red Book); OECD, IAEA, August 2010.
47. *Assessment of Nuclear Energy Systems Based on a Closed Nuclear Fuel Cycle with Fast Reactors — A report of the International Project on Innovative Nuclear Reactors and Fuel Cycles* (INPRO), IAEA, 2010.
48. *Gen-IV International Forum — 2009 Annual Report*, OECD Nuclear Energy Agency (http://www.gen-4.org/PDFs/GIF-2009-Annual-Report.pdf).
49. *Report of the High-Level and Expert Group on European Low Dose Risk Research*, January 2009 (http://www.hleg.de/fr.pdf).

(g) Move toward demonstration and feasibility of fusion as a power source: To demonstrate the feasibility of fusion as a power source, research must be carried out using existing and future research facilities such as the Joint European Torus (JET) and W7-X. This will increase the knowledge base and maximise the scientific output of the ITER project, a scientific experiment moving beyond present understanding in the key areas of plasma physics and technology. To achieve this, the research programme must: (i) develop operational scenarios that will secure and even exceed the baseline performance; and (ii) ensure the rapid and efficient start-up of future fusion facilities, and protect the investment by minimising the chances of unexpected technical problems that would delay exploitation or incur extra cost for these facilities.

(h) Prepare the future generation of fusion researchers and engineers: To carry out research on fusion, Europe must ensure that it will have a sufficient number of highly skilled professionals (operators of large fusion devices including ITER, fusion scientists, programme leaders and engineers for design and construction). Fusion research programmes should encourage talented young scientists and engineers to develop their careers in Europe, and to ensure that Europe will have the necessary human resources to exploit ITER in an international and competitive environment, avoiding the risk of ceding the future leadership of fusion research to our international partners.

(g) Lay the foundations for fusion power plants: While ITER is the major step towards demonstration of feasibility of fusion as a power source, it is also necessary to launch the preparations for a demonstration power plant (DEMO) to demonstrate the commercial generation of electricity using fusion. The challenge is to position Europe so that it can build rapidly on the results from the ITER project and move as quickly as possible to the demonstration power plant, retaining a significant share of the intellectual property of fusion technology.

(h) Involve industry more closely and promote innovation: Industry must be integrated into the development of fusion power plant studies, enhancing the transfer of knowledge and creation of spin-offs from the programme as well as developing the skills and capacities necessary for a European fusion industry of the future. Already, industry is deeply involved in the construction of ITER, particularly as a supplier of high-tech components. Fulfilling these contracts will involve the transfer to European industry of expertise and know-how built up over a long period in the European fusion programme. This will stimulate innovation and increase the competitiveness of European high-tech industry. To meet the challenges inherent in this process, the Commission has launched the Fusion Industry Innovation Forum (FIIF) bringing together representatives of major industries, fusion research institutes and the Commission.

2.2. What is the situation in the private sector?

Fission

The assessment of the corporate R & D investments in nuclear energy is based on a limited number of companies, reflecting the consolidated situation in this sector in Europe and worldwide. French companies (AREVA, EdF) largely dominate the total corporate R & D investments in nuclear fission. Corporate research into all nuclear fission-related aspects amounted to around EUR 550 million in 2007, of which R & D investment in nuclear reactor technology may be in the order of EUR 200 million (i.e. more than one third) ([50]). More recent data on the true level of investments in nuclear R & D is not available. However, an order of magnitude estimate of corporate R & D investments can be derived from the 2010 EU Industrial R & D Investment Scoreboard ([51]), which shows that companies with substantial activities in nuclear sector (utilities and construction) ([52]) spent almost EUR 1 200 million on R & D (for nuclear, renewables and fossil sources) of which approximately 71 % (EUR 852 million) was spent by AREVA and EdF alone. The electricity industrial sector is described by the 2010 EU Industrial R & D Investment Scoreboard as a medium-low R & D intensity sector (between 1 % and 2 % of net sales is spent on R & D).

50. *R & D Investment in the Priority Technologies of the European Strategic Energy Technology Plan*, JRC, 2007.
51. http://iri.jrc.ec.europa.eu/research/scoreboard_2010.htm
52. AREVA, EDF, Vatenfall, Iberdrola, EnBW Energie Baden-Württemberg AG, Fortum, CEZ, URENCO.

The main focus of R & D investment in the nuclear sector is lifetime extension of currently operating plants and, in countries where the political and societal climate is right, technology developments in evolutionary LWR technology linked with new build projects ([53]). The R & D efforts of the private sector are to a certain extent fragmented and often duplicated owing to the fact that European utilities operate in an increasingly competitive market.

Financing schemes for waste management are based on the 'polluter-pays principle', often involving a small levy on the price of nuclear electricity. Either electricity utilities make provisions in their accounts or, increasingly, state-managed ring-fenced funds are established ([54]).

The nuclear industry is currently not prepared to invest heavily in the development of Generation-IV reactors because this technology is still 20–30 years away from possible commercial deployment and, as a result, there is considerable political, regulatory and economic uncertainty. The public sector continues to have a role at the stage of pre-commercial research in advanced technology, also in a context of international cooperation (e.g. the Generation-IV International Forum ([55]), but industry will be expected to contribute much more significantly during the next stage in the development of advanced systems, beyond the design and construction of demonstration plants, entering into a first-of-a-kind commercial plants and further replication.

Fusion

Fusion energy R & D is funded only by the public sector: the private sector does not yet invest in fusion because the time horizon is too long (2040–50). The generation of electricity from fusion power requires the control and understanding of very complex physical processes which can only be achieved using large experimental infrastructures. Many scientific milestones have already been achieved, the most important of which is the controlled generation of fusion energy in the JET device in 1997 ([56]). While this was a significant marker on the path to commercial fusion power, it is still distant from commercial exploitation and, therefore, entirely supported by public funding. ITER will bring commercial fusion power a step closer, but it illustrates the timescales involved: the detailed ITER design, including necessary experimentation and component prototyping, took close to 10 years (followed by about 5 years of international negotiations on legal structures and siting) and the lifetime of the project is 30 years ([57]). Moreover, ITER is still an experiment and therefore carries the risk that it will not achieve all its aims. This risk has been mitigated by spreading the cost among seven partners in an international consortium, which also maximises the scientific and industrial expertise available to the project.

Private investment will be a necessary aspect of the demonstration fusion power plant (DEMO) which will follow ITER. By that stage, the technology will have matured to a point where industrial investment can take over the commercialisation of fusion power in the time frame beyond 2050. Even though the private sector does not invest in fusion, it is involved in public procurements for fusion (ITER, JET and smaller fusion facilities), which brings mutual benefits (technology transfer, development of new products and new skills) ([58]).

2.3. What is the situation in the public sector of Member States?

Fission and radiation protection

Member States contribute to research on issues of political and societal concern such as nuclear safety, radioactive waste management and radiation protection. This stems from the societal decision to exploit nuclear technology and the associated shared responsibility of the state with the licence holder to ensure appropriate levels of health protection for

53. Some corporate reports indicate that corporate research priorities cover, to some extent, the challenges indicated in Section 1, in particular: lifetime plant management, improvement of fuel utilisation, development of new LWR reactors (generation III), and waste management. Some companies have also indicated investments in the front and back end of the nuclear fuel cycle. Prepared on the basis of the latest version of annual reports from the following companies: AREVA, EDF, Vatenfall, Fortum.
54. Sixth situation report on radioactive waste and spent fuel management in the European Union, COM(2008) 542 final of 8 September 2008 and SEC(2008) 2416 final/2 of 16 July 2010.
55. http://www.gen-4.org/
56. Keilhacker, M. et al. (2001), 'The scientific success of JET', *Nucear Fusion*, 1, 1925.
57. Article 24 of the Agreement on the Establishment of the ITER International Fusion Energy Organization for the Joint Implementation of the ITER Project, OJ L 358, 16.12.2006, p. 62.
58. Commission's survey (2009) of companies involved in upgrade and construction projects in fusion.

Table 15: **Breakdown of Budget for R & D in the nuclear field**

The most recent data available, million euro								
	Germany 2009	%	France 2008	%	Finland 2008	%	Belgium 2007	%
Light-water reactors (LWRs)	21.1	50.2%	9.1	2%	0.3	3%	24.0	61%
Other converter reactors	0.0	0%	38.3	9%	0.0	0%	0.0	0%
Fuel cycle	10.7	25.4%	66.2	15%	2.3	25%	3.6	9%
Nuclear supporting technology	0.0	0%	316.1	71%	6.8	72%	11.8	30%
Nuclear breeder	0.0	0%	9.1	2%	0.0	0%	0.0	0%
Other nuclear fission	10.2	24.4%	7.0	2%	0.0	0%	0.0	0%
Total	**42.0**	**100%**	**445.7**	**100%**	**9.5**	**100%**	**39.4**	**100%**

Source: IEA

workers and citizens. In particular, publicly funded research can ensure that an appropriate balance between the risks and benefits is maintained and that regulations neither unduly prevent exploitation of potentially beneficial technologies nor expose individuals to unjustified risks. However, the available data demonstrate that these efforts are fragmented and underfunded in some areas (LWR, nuclear supporting technology, Generation-IV). In addition, research priorities differ between Member States, as demonstrated in Table 15 (latest available IEA data shown for Member States for which a breakdown is provided ([59]).

The very rough estimate prepared using IEA data for the period 2000–09 ([60]) shows that public R & D expenditure in Member States was focused on nuclear supporting technology (48 %), this category of expenditure concerns nuclear safety, radiation protection and decommissioning, control of fissile materials), followed by the fuel cycle (32 %) and R & D specifically related to light water reactors including safety and environmental aspects (11 %). Expenditure that can be classified as Generation-IV (nuclear breeders, high temperature reactors, advanced gas-cooled reactors) accounted for only about 7 % (EUR 43 million in 2007).

According to the JRC report ([61]), Member States' R & D investment in nuclear reactor R & D (reactor technologies and fuel cycle) amounted to around EUR 253 million in 2007. This represents about 43 % of the total estimated expenditure in all nuclear fission-related R & D (EUR 587 million). Similar to the situation in corporate R & D expenditure, public funding for R & D is largely concentrated within France. In 2007, France accounted for more than half of the total EU Member States public investment in nuclear-related research. This result is in line with France's large share of nuclear generating capacity in Europe (i.e. about 50 %). Other Member States investing significantly in nuclear research included Italy, Germany and the Netherlands.

59. Data from http://wds.iea.org
60. This estimate is based on IEA data available for some Member States only: Belgium (2007 only); Czech Republic (2003–07); Denmark (2000–07); Germany (2000–09); Spain (2000–06); France (2000–08); Italy (2000–07), Hungary (2000–09); Netherlands (2000–03, 2005–06); (Austria (2000–08); Slovakia (2002–04, 2008–09); Finland (2000–08); Sweden (2003–09).

61. *R & D Investment in the Priority Technologies of the European Strategic Energy Technology Plan*, JRC, 2009.

Table 16: Expenditure of EU Member States and Switzerland on fusion R & D in 2007 and 2008

Expenditure of EU Member States and Switzerland on fusion R&D in 2007 and 2008				
Country	2007 (mln EUR)	% of total	2008 (mln EUR)	% of total
Austria (ÖAW)	3.3	1.1%	3.1	1.0%
Belgium (LPP ERM – KMS)	4.9	1.6%	5.5	1.8%
Bulgaria (BAS)	0.2	0.1%	0.5	0.2%
Czech Rep (IPP.CR)	3.1	1.0%	1.3	0.4%
Denmark (RISØ)	1.9	0.6%	1.8	0.6%
Finland (TEKES)	4.2	1.4%	2.8	0.9%
France (CEA)	45	14.5%	46.3	14.9%
Germany (IPP. FZJ. FZK)	120	38.6%	137.7	44.2%
Greece (HR)	1.2	0.4%	1.6	0.5%
Hungary (HAS)	1.2	0.4%	1.0	0.3%
Ireland (DCCU)	1.2	0.4%	1.1	0.4%
Italy (ENEA)	52.1	16.8%	41.3	13.3%
Latvia (UoL)	0.3	0.1%	0.6	0.2%
Lithuania (LEI)	0.1	0.0%	0.2	0.1%
Luxembourg (ME)	0.1	0.0%	0.0	0.0%
Netherlands (FOM)	11.3	3.6%	9.7	3.1%
Sweden	5.2	1.7%	4.3	1.4%
Poland (IPPLM)	1.6	0.5%	1.6	0.5%
Portugal (IST)	4.4	1.4%	4.8	1.5%
Romania (MEdC)	1	0.3%	1.0	0.3%
Slovakia (AECU)	0	0.0%	0.7	0.2%
Slovenia (MHEST)	1.2	0.4%	1.3	0.4%
Spain (CIEMAT)	11.5	3.7%	10.2	3.3%
Switzerland (CRPP)	13.2	4.2%	12.6	4.0%
UK(former UKAE. now CCFE)	22.6	7.3%	20.5	6.6%
TOTAL	**310.8**	**100.0%**	**311.4**	**100.0%**

Source: European Commission, 2011, Expenditure is not indicated for Estonia, Cyprus and Malta as fusion labs in these Member States are part of Finnish, Greek and Italian Association respectively.

Fusion

R & D in fusion energy is fully publicly financed in Europe and all research activities are coordinated within the integrated European fusion programme [62]. The total expenditure on fusion in 2007 and 2008 amounted to EUR 582.48 and 607.24 million (direct expenditure of Member States 53 % and 51 % respectively with the remaining part funded by Euratom) [63].

The expenditure of Member States on fusion R & D in 2007 and 2008 is shown in Table 16. Four EU Member States (Germany, France, Italy and the United Kingdom) and Switzerland (a participant in the EU fusion programme since 1978) account for more than 80 % of the overall expenditure, with Germany accounting for approximately 40 %. Duplication and fragmentation of efforts of Member States is avoided by the fact that all national R & D programmes are coordinated through instruments of the European fusion programme (Contracts of Association and the European Fusion Development Agreement).

2.4. Why is EU-level intervention necessary?

The challenge of nuclear safety and diminishing nuclear skills in Europe can be tackled effectively by exploiting synergies between the research efforts of Member States and the private sector, and between scientific disciplines and technological sectors. An EU-level, intervention can strengthen the research and innovation framework in nuclear technologies and coordinate Member States' research efforts thereby avoiding duplication, retaining critical mass in key areas and ensuring public financing is used in an optimal way. An EU-level programme could also take on the high-risk and long-term R & D programme in fusion energy, thereby sharing the risk and generating a breadth of scope and economies of scale that could not otherwise be achieved.

Nuclear research is the only area of research that has a direct mandate in the treaties (Articles 2, 4 and 7, and also Annex 1, of the Euratom Treaty [64]. The European added value of nuclear research is explicit in the Euratom Treaty itself and the Commission has an obligation to put forward an R & D programme to complement those in Member States.

The justification for intervention by Euratom is based mainly on the need to ensure high and uniform levels of nuclear safety in Europe.

In the area of lifetime extension, the main challenge for Euratom is to ensure the availability and acceptance of standard tools and methodologies across Europe [65]. Owing to the nuclear safety implications, it is unacceptable that plant lifetime extension decisions in one country are not based on the same criteria and techniques as in others. The aim of public intervention is to ensure consistency and harmonisation especially to guarantee high and uniform levels of nuclear safety. Funding on lifetime extension by the utilities themselves is often proprietary and at significantly higher levels than the public component.

The justification for intervention by Euratom in the area of management of radioactive waste is similar to the case of nuclear safety and plant lifetime management. The issue of long-term management of waste is one of high public concern, and action by Euratom ensures that a common European view on key issues related to long-term safety prevails, that harmonised standards and practices are put in place, and also that technology transfer takes place from the most to the least advanced Member States. This is particularly important in view of the recently adopted EU Directive on the management of radioactive waste that seeks to end 'wait and see' attitudes regarding waste management in some smaller Member States.

A similar approach is needed in the area of education and training. The role of the Euratom's is to stress common programmes, transferability and mutual recognition of qualification and skills so that the nuclear sector, and society as a whole, benefits — again, the driver for this is the need to ensure high levels of nuclear safety and to promote an appropriate safety culture.

62. More details are available online (http://ec.europa.eu/research/energy/euratom/fusion/eu-fusion/index_en.htm; http://www.efda.org/).
63. Source: European Commission.
64. http://eur-lex.europa.eu/en/treaties/index.htm

65. This is the focus of the NULIFE project (http://www.nulife.vtt.fi) and related projects — the NULIFE network, once up and running, will be able to provide a service for industry which will ensure common standards.

During the last 10 years, the Euratom programme has fostered greater cooperation between nuclear research and industrial actors ([66]). This has been largely through the establishing of broad-based 'technical forums' in key areas (and the defining of related Strategic Research Agendas, SRA), and the strengthening and focusing of Member States R & D efforts as a result of the overall framework provided by the SET-Plan. The establishing of SRAs and the implementation of the SET-Plan in the nuclear field has resulted in restructuring of the R & D activities in fission and cooperation in key R & D infrastructure projects. These efforts need to continue, encouraging true joint programming between Member States, establishing legal entities and public-private partnerships where necessary (in particular driven by industry as end-users), and the decompartmentalisation of research sectors to maximise synergies between scientific and technological disciplines (not only between, for example, advanced fission and fusion, but also between nuclear and non-nuclear energy).

2.5. What is the added value of nuclear research at EU level?

The European added value of the Euratom programme is demonstrated by the following achievements in increasing nuclear safety, concentrating Member States' R & D efforts and strengthening innovation.

(a) **The Euratom R & D programme provides a flexible and effective instrument to support research in nuclear safety:** Although it is still too early to draw final conclusions from the Fukushima accident and the results of the nuclear stress tests in the EU, already the events in Japan are provoking a widespread reassessment of nuclear safety in Europe. Initially, this is concentrating on regulatory practice and demonstrating resistance to extreme external hazards, but there may be important implications for research. The Euratom programme is an appropriate instrument to coordinate and carry out the necessary activities. This was the case following the Chernobyl accident, with a substantial EU investment of EUR 40 million over 20 years in the PHEBUS programme (core melt experiments in controlled conditions) and Euratom funding in other areas such as emergency management and rehabilitation of contaminated territories. In fact, Europe is the only region of the world maintaining significant competences in the area of radioecology — the study of the impact of radioactive contamination on ecosystems in general. The project STAR ([67]), a Network of Excellence, to ensure long-term sustainability of the radioecology research sector, was launched at the beginning of 2011; following the events at Fukushima, discussions have already begun to add a Japanese partner in the consortium.

(b) Action at European level (Euratom) can quickly **mobilise a wider pool of excellence, competencies and multidisciplinarity** than is available at national level.

In the fission area, projects such as NULIFE (understanding of the factors affecting the lifetime of nuclear power plants), STAR (skills in radioecology), DoReMi (low dose research) and SARNET-2 (research on severe accidents in nuclear power plants) are ensuring that competences in key technical sectors can be pooled and retained in Europe, requiring the bringing together of expertise from many Member States, and the establishing of legal entities to ensure sustainability and long term access to research results.

The achievements of the fusion programme resulting from joint exploitation of JET, rely on the collective endeavours of researchers and engineers from all across Europe (about 350 persons per year), supported by Euratom funding for mobility. Euratom finances two mobility schemes, one used generally for short visits to JET and between associations (approximately EUR 5 million per year) and the other aimed mainly at longer-term participation in the collective exploitation of JET (stays of up to 4 years).

(c) Action at European level (Euratom) can help generate an **optimum programme of activities and maximise knowledge sharing** and information dissemination, lowering the overall costs of achieving a given objective.

66. See, for example, conclusions of the interim evaluation of the Euratom seventh framework programme (http://ec.europa.eu/research/evaluations/index_en.cfm?pg=fp7-evidence).

67. Details are available online (http://www.irsn.fr/).

The extensive network of collaborations between fusion laboratories (associations) and the collective exploitation of JET help bring the best expertise to bear on all the research issues, and provide Europe-wide sharing of expertise. A growing majority of publications (about 57 %) originate from the joint efforts of two or more laboratories in different Member States. These papers also have a higher than average number of citations.

Euratom projects in the field of partitioning and transmutation, from the EUROTRANS project in FP6 to those focused on the design of the MYRRHA facility, represent a comprehensive and integrated programme of research on accelerator-driven systems and related lead-cooled technology. This programme is also notable for the involvement of large numbers of PhDs and postdoctoral researchers and the interaction with other research in Generation-IV systems. All this, including the decision by the Belgian Government to construct MYRRHA, would not have been possible without Euratom involvement.

(d) Action at European level (Euratom) can have a **strong leverage effect on coordinating national efforts**, through the use of funding instruments that promote the European Research Area.

These effects are demonstrated well in the case of the **European fusion programme** where Euratom provides much less than half of the funding of the participating laboratories, but is able to ensure strong coordination of their efforts: (i) national funding agencies accept a limitation of their independence by allowing the scientific assessment of the programme and proposals for its evolution to be done collectively by representatives of Euratom associated laboratories and Member States with strong input by the Commission; (ii) all the significant fusion facilities have been built with financial support from Euratom, which requires that their operation be open to researchers from all the association laboratories; (iii) smaller associations can concentrate on scientific topics or subsystems for any device in Europe and make important contributions while still maintaining the visibility of their own identity; (iv) in addition to formal training activities, the extensive exchanges of personnel between the associations ensure a Europe-wide dissemination of expertise; (v) in some cases, the management of the programme of the facilities is shared with the other participating associations.

Structuring effects of technology platforms/technical forums in fission R & D: All major stakeholders in fission and radiation protection research are now grouped in technical forums: SNETP, IGDTP and MELODI, thereby promoting strategic planning, sharing resources and even joint programming, with a strong participation of industry in the two former forums.

(e) Action at European level (Euratom) can take on high-risk, high-cost, long-term programmes beyond the reach of individual Member States, **sharing the risk and generating a breadth of scope and economies of scale** that could not otherwise be achieved.

The scientific and technological feasibility of fusion will be demonstrated by ITER. This has to be done at very large scale and cannot be broken down into smaller projects that could be handled at national level. On this scale, it is necessary to pool financial resources and scientific expertise, and to share risk, in an international cooperation. Together, the seven international partners (EU plus China, India, Japan, Russia, South Korea and the United States) will prove the feasibility of fusion as an energy source, and Europe as host will obtain the largest share of the economic and scientific benefits.

Another example is the Joint European Torus (JET) the world's leading fusion experiment, with a volume of fusion plasma about 10 times larger than that in any other fusion device, and a configuration and performance closer to that of ITER than any other device. The total expenditure for construction, upgrade and exploitation of this European facility during 1978–2010 amounts to approximately EUR 2 000 million. The majority of this funding has come from the Community budget, but there has also been strong support from the Member States. In particular, the construction and operation of JET has only been possible because of the pooling of scientific and industrial expertise from all the Member States. The contributions of JET to the development of fusion must not be underestimated: (i) it is the only current fusion device which can operate with the fuel mixture of genuine fusion reactors; (ii) it holds all the records for peak and sustained production of controlled fusion power; (iii) it is the most ITER-relevant machine for studies in preparation for ITER technology and operations; (iv) it is the only present fusion device in which the essential fusion technology of remote handling has been developed and used for major interventions; (v) it is the most useful experiment for the training of future operational staff for ITER.

The High Performance Computer for Fusion (HPC FF) is a valuable new tool for the fusion programme. Fusion modelling requires powerful computer resources; increasingly realistic simulations that are able to take into account the full ITER plasma will be an essential tool for the safe and efficient operation of ITER. The HPC FF computer, hosted and operated by the Jülich Supercomputing Centre at the Forschungszentrum Jülich Fusion Association in Germany, is among the 30 most powerful computers in the world. Euratom capital investment amounted to around EUR 7.4 million, while the total budget including the capital investment and exploitation over 4 years will be around EUR 16.8 million, with contributions from the entire European fusion community.

(f) Action at European level (Euratom) can help give credibility to the EU's long-term policies on energy and **increase the willingness of investors to release capital for projects with particular importance for nuclear safety or with long lead times** and **significant technology and market risk.**

The **SARNET-2** project is an excellent example of the leverage effect of EU funding — the total budget is EUR 38 million but the EU contribution is just EUR 5.75 million (i.e. 16 % of total costs). The project will continue the efforts of a number of European R & D organisations, including safety authorities, industry and universities, to network their research capacities in the area of severe reactor accidents, thus enhancing the safety of existing and future nuclear power plants. This Network of Excellence defines joint research programmes and develops common computer tools and methodologies for safety assessment of nuclear power plants, and ultimately ensures sustainable integration of the key R & D organisations in this sector.

The European Sustainable Nuclear Industrial Initiative (ESNII) constitutes one of the three technology pillars of SNETP and is moving forward with the design and construction of three fast reactor technologies of the next-generation (Gen-IV). Euratom is co-funding cross-cutting topics and pre-commercial research, though national public and private investors will probably be responsible for funding construction of the demonstrator plants (ASTRID, MYRRHA and ALLEGRO).

The closer involvement of industry in fusion development has been launched by the establishment of the **Fusion Industry Innovation Forum**, which will have an increased role in future EU research programmes, especially in relation to the preparation for the construction of DEMO. As well as providing the foundations for creating a strong fusion industry in the future, in the short term, the Forum will promote technology transfer and dissemination in order to maximise innovation.

(g) In international cooperation, it makes it easier for our international partners to interact with a **single interlocutor** and build common actions.

In all matters concerning **ITER and the Broader Approach**, Euratom is the signatory of the agreements, and the Commission is the sole interlocutor for matters of governance. This is essential for such complex international projects. The Commission has also taken the responsibility for establishing **bilateral agreements with third countries** (especially the ITER partners), which provide an umbrella under which collaborative research of mutual benefit can take place with standardised provisions on, for example, intellectual property matters.

The **Generation-IV International Forum** (GIF) is fostering multilateral cooperation in research on next-generation nuclear technology. Euratom and all major civil nuclear power programme countries are cooperating though the exchange of results on pre-conceptual design research on six advanced systems. All research stakeholders in Europe can benefit from Euratom membership of GIF, in particular by being a partner in a relevant Euratom FP project. The dialogue in the GIF is also helping to establish future partnerships for design and construction of demonstrator plants.

2.6. EU performance in nuclear research — comparison with the United States and Japan

Fusion

Overall, the EU (Member States and Euratom) devotes the largest worldwide budget to fusion research (Table 17) and dominates fusion science and technology.

Analysis of peer-reviewed journals and citations show strong European leadership in fusion R & D. **Europe, through its fusion laboratories, co-authored the largest number of articles published during the period 2003–10** in five international peer-reviewed journals in the field of plasma physics and fusion ([68]), with an **average number close to 800 articles per year** (Figure A6.1).

Europe's leadership in fusion is further underlined by the fact that **436 of most cited 1 000 articles** published in these five journals were prepared on research **co-funded by Euratom**. **On average, each of these 436 articles resulted in 25 citations** (similar to the United States (26) and better than Japan (21)) with the **best article yielding 141 citations**.

Some countries, such as Russia and the United States, have had fusion R & D programmes well established since the 1950s, while others such as China, India and South Korea have developed more recently (1990s–2000s) in parallel to intensification of the ITER programme. All the ITER partners are pursuing the tokamak approach, but none have facilities

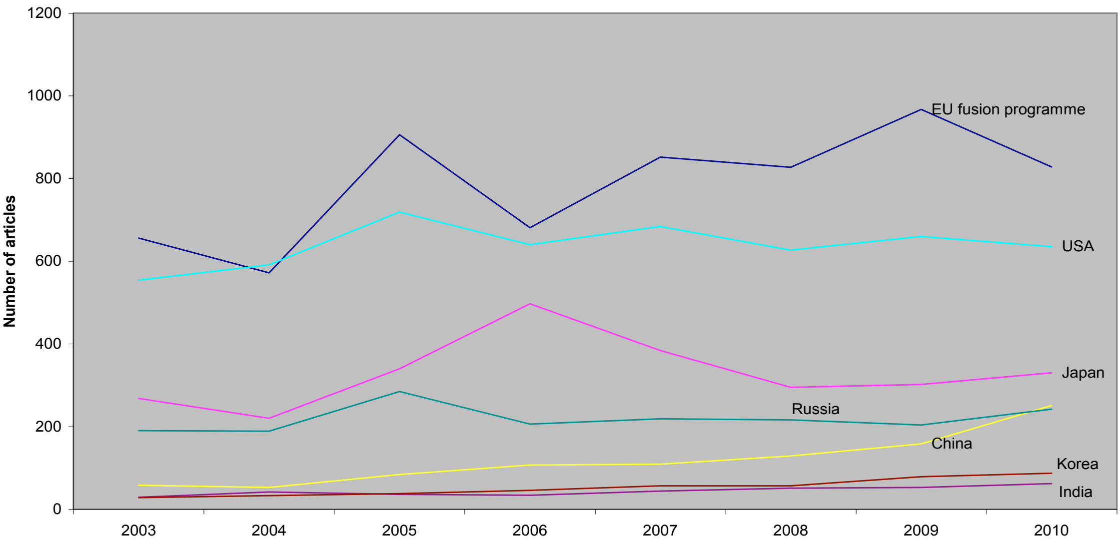
68. Journals analysed in the Scopus database (http://www.scopus.com): *Nuclear Fusion*, *Plasma Physics and Controlled Fusion*, *Fusion Engineering and Design*, *Fusion Science and Technology*, *Journal of Fusion Energy*.

Table 17: **Annual budgets for fusion energy research estimates in million Euro**

	2007	2008	2009	2010	2011
EURATOM (1) (including ITER)	271.8	295.9	388.7	438.9	438.0
EU Member States (1)	310.8	311.4	About 300 million euro / year		
Total for Europe (1)	582.6	607.3	About 700 million euro / year		
USA(2)	232.2	215.1	355.4	321.3	307.5
Japan (2) (3)	115.9	150.5	152.7	N/A	N/A

Sources: European Commission, US Department of Energy, IEA
1. Magnetic confinement R&D only
2. Includes Magnetic confinement R&D and inertial confinement
3. May not include all administrative and running costs.

Figure A6.1: **Number of articles published co-authored by Euratom, 2003–10**



Source: Calculated on information from Scopus.com

comparable to JET. The rate of progression of Asia is fast and impressive, and Europe will have to adapt its effort to this evolving situation in order to benefit from its past investments.

Fission

Recent data indicate that Europe spends less on fission R & D than Japan and the United States (assuming that expenditure in 2009–11 has remained at the 2008 level in Table 18). The European R & D sector in fission is dominated by France and covers a wide range of activities in all relevant areas, though it is particular strong in nuclear safety, geological disposal and radiation protection. Regarding research in advanced systems, the situation is less favourable, even despite projects such as ASTRID and MYRRHA. Annual figures collected by the Generation-IV International Forum (GIF, unpublished) show that Europe is investing similar amounts in pre-conceptual design research on advanced systems as other GIF members, but that Asia is much further advanced regarding development of demonstrator reactors, with high temperature reactors and sodium-cooled fast reactors under construction in China, India and Japan, and Russia also advancing rapidly. These countries are also dominating the market for new build of current nuclear technology.

Table 18: **Annual budgets for research in fission and radiation protection in million EUR**

	2005	2006	2007	2008	2009	2010	2011
(1) Euratom budget	49.5	53.1	48.7	49.5	51.7	51.0	52.0
(2) EU Member States	598.8	577.6	585.9	514.0	N/A	N/A	N/A
Europe. Total (1+2)	648.3	630.7	634.6	563.5	N/A	N/A	N/A
USA	379.7	288.0	394.2	489.2	560.7	593.4	N/A
Japan	1981.6	1861.8	1880.4	1868.1	1835.5	N/A	N/A

Sources: European Commission. IEA. US Department of Energy
IEA database is incomplete and does not cover all Member States

Europe's performance in the area of nuclear fission R & D can be measured in patents registered in the European Patent Office [69]. For the period 1990–2008, the European industry and research sector (from 27 Member States) has been granted about 1164 patents (51 % of all registered by EPO) in the field of nuclear reactors and nuclear power plants. Other major players are the United States and Japan (37 % and 11 % respectively). However, the majority of these patent applications concern current, not future, reactor systems. Without continued efforts in nuclear research and innovation, ranging from present reactors to Generation III and IV, the EU will quickly lose its technological leadership since in other parts of the word, advanced reactor systems are under construction or already in operation.

3. Objectives for the future Euratom research and training programme

In order to tackle the problems identified in Section 2, it is important to clarify the objectives of Euratom's actions in the field of nuclear research and training.

The overall objective of the Euratom research and training programme (2014–18) will be to improve nuclear safety, security and radiation protection, and to contribute to the long-term decarbonisation of the energy system in a safe, efficient and secure way. This will reinforce the three objectives of the Horizon 2020 programme: strengthening excellence in the science base; creating industrial leadership and competitive frameworks; tackling societal challenges.

69. Calculated using data from Eurostat.

For the attainment of its objective, the Euratom programme will strengthen the research and innovation framework in the nuclear field and coordinate Member States' research efforts, thereby avoiding duplication, retaining critical mass in key areas and ensuring that public funding is used in an optimal way. The programme will continue to promote the European Research Area and the further integration of new Member States and associated countries.

While it is for each Member State to choose whether or not to make use of nuclear power, the role of the Union is to develop, in the interest of all its Member States, a framework to support cutting-edge research on nuclear fission technologies, with special emphasis on safety, security, radiation protection and non-proliferation. In order to maintain the Union's nuclear expertise, the programme will further enhance its role in training.

The Commission proposed in its communication *A Budget for Europe 2020* (EC, 2011n) that, for projects such as ITER, where the costs and/or the cost overruns are too large to be borne just by the EU budget, funding should come from outside the MFF after 2013. This will enable the EU to continue to fully meet its international commitments. Therefore, ITER construction and related activities are not subjects of the Euratom research and training programme, and a separate proposal for a supplementary research programme for ITER construction will be prepared.

In order to achieve the overall objective, the following specific objectives must be attained by **indirect actions**.

(a) **Support safe operation of nuclear systems**
Research to underpin the safe operation of reactor systems (including fuel cycle facilities) in use in Europe or, to the extent necessary, in order to maintain broad nuclear safety expertise in Europe those reactor types which may be used in the future, focusing exclusively on safety aspects, including all aspects of the fuel cycle such as partitioning and transmutation.

(b) **Contribute to the development of solutions for the management of ultimate waste**
Research activities on remaining key aspects of the geological disposal of spent fuel and long-lived radioactive waste with, as appropriate, demonstration of the technologies and safety, and to underpin development of a common European view on the main issues related to waste management from discharge of fuel to disposal. Research activities related to management of other radioactive waste streams for which industrially mature processes currently do not exist.

(c) **Develop and maintain nuclear competences**
Promote training and mobility activities between research centres and industry, and support maintaining nuclear competences in order to guarantee the availability of suitably qualified researchers, engineers and employees in the nuclear sector over the longer term.

(d) **Foster radiation protection**
Research will focus, in particular, on the risks from low doses (from industrial, medical or environmental exposure) and on emergency management in relation to accidents involving radiation, to provide a scientific basis for a robust, equitable and socially acceptable system of protection.

(e) **Move toward demonstration of feasibility of fusion as a power source by exploiting existing and future fusion facilities**
Support common research activities undertaken by members of the European Fusion Development Agreement to ensure the rapid start-up of high performance operation of ITER including, inter alia, the use of relevant facilities (including JET), integrated modelling using high performance computers, plus training activities to prepare the ITER generation of researchers and engineers.

(f) **Laying the foundations for future fusion power plants**
Support for joint activities undertaken by members of the European Fusion Development Agreement to develop and qualify materials for a demonstration power plant requiring, inter alia, preparatory work for an appropriate material test facility and negotiations for the Union's participation in a suitable international framework for this facility.
Support for joint research activities undertaken by members of the European Fusion Development Agreement that will address reactor operation issues and develop and demonstrate all relevant technologies for a fusion demonstration power plant. Activities include preparation of complete demonstration power plant conceptual design(s) and exploration of the potential of stellarators as a power plant technology.

(g) **Promote innovation and EU industry competitiveness**
Implement or support a knowledge management and technology transfer from the research co-funded by this programme, including ITER, to industry exploiting all innovative aspects of the research. In the longer term, the programme will support the preparation and enhancement of a competitive nuclear industry, in particular for fusion through the implementation of a technology roadmap to a fusion power plant with active industrial involvement in the design and development projects.

(h) **Ensure availability of research infrastructures**
Support construction, the use and continued availability of, appropriate access to, and cooperation between key research infrastructures within the scope of Euratom programme.

Direct actions by the Joint Research Centre will contribute to the Euratom programme's overall objective by attaining the following specific objectives:

(a) improve nuclear safety including fuel and reactor safety, waste management and decommission, and emergency preparedness;

(b) improve nuclear security including nuclear safeguards, non-proliferation, combating illicit trafficking and nuclear forensics;

(c) raise excellence in the science base for standardisation;

(d) foster knowledge management, education and training;

(e) support EU policy and legislation on nuclear safety and security.

4. Policy options

The Euratom research and training programme is an integral part of the Commission's proposal for Horizon 2020, the framework programme for research and innovation. Therefore, an analysis of general policy options presented in the main report on the impact assessment for Horizon 2020 also applies to the Euratom programme.

The following section provides supplementary information and analysis of policy options (scenarios) for the fusion research programme.

Scenario 1 aims at the shortest path to demonstrate electricity production from a DEMO fusion reactor by 2040; **Scenario 2** takes full benefit of ITER exploitation but with a slower rate of progress on power plant-related activities; **Scenario 3** curtails the research programme, delaying DEMO by more than 10 years and compromising the capability of EU industry to become a main actor in the eventual worldwide fusion energy market.

Evaluation of these scenarios is supplemented by the analysis of risks and benefits of fusion research.

5. Analysing the impacts and comparing options

5.1. Analysis of scenarios for fusion research

Given the potential of fusion to satisfy future energy requirements, and assuming that it will have to take as soon as possible a substantial share of baseload electricity production in the future, it is appropriate to consider reaching the ultimate objective as quickly as possible with the **first scenario** requiring an increased level of activities and resources. This scenario assumes that an ambitious programme is put in place to provide fusion energy electricity to the grid from a demonstration reactor by 2040 and prototype power plants available by 2050. In-depth assessments by the fusion community have shown that this scenario requires the completion of the ITER construction and achievement of first plasma by 2020, followed by the start of the deuterium and tritium operation by 2027. DEMO design by industry supported by the fusion community should start as soon as scientific results, materials and engineering data are available from ITER exploitation and from other complementary activities, probably a little before 2030. In addition to the present spectrum of research activities, the early implementation of two other projects with long lead times is essential if such a rate of progress is to be achieved: the development and testing of 'tritium breeding modules' (TBMs) for tritium self-sufficient operation of fusion reactors (a TBM programme was established by the ITER Council in 2009 and TBMs will be tritium-tested in the ITER facility from 2027); and preparation for an ad hoc fusion specific neutron source so that its construction could start by 2020. The first scenario would require a re-evaluation of current funding schemes and structure of the research programme in Europe and the way it is implemented, especially in order to favour more rapid industrial take-up of the technology

Pros: Demonstrating fusion energy potential to produce electricity by 2040 and putting power plants in the grid by 2050, maintaining EU leadership and optimally positioning EU industry to exploit the commercial potential.

Cons: High-cost scenario during the period until 2020.

The **second scenario** assumes that fusion is less urgently needed to complement/substitute other energy sources. It partially omits/postpones some activities and generally has a lower level of activity during the period 2014–20, postponing a number of developments beyond 2020, implying acceptance of a longer timescale. As in the first scenario, reassessment of the Euratom funding approach is necessary.

Pros: A level of activities maintaining the overall goal of the research programme, at an average cost until 2020 that may be comparable to the average level in FP7.

Cons: Higher risk than the first scenario and the pace may be slowed, depending on capacity, to address scientific/technical/industrial issues during development, and likely higher total cost to reach the ultimate objective owing to delays.

The **third scenario** implies a severe curtailment and/or postponement of R & D activities including for ITER systems (e.g. heating systems, Test Blanket Modules) with the consequent risks and likelihood of delays in ITER construction and a slow start of its operation. In this scenario, the EU fusion programme would essentially consist of the EU contribution (subject to separate decision) to the (likely delayed) ITER project accompanied by limited other fusion activities. The EU, the major contributor to the ITER project, would not reap the full benefits of its investment and the exploitation of the ITER facility would mainly benefit our international competitors. In addition, the EU's progress towards DEMO and fusion energy would be substantially delayed.

It should be emphasised that the most important part (and corresponding cost) of Europe's efforts to establish feasibility of fusion as a power source during the period covered Horizon 2020 will be, by far, the EU contribution to ITER construction (subject to a separate decision on the supplementary research programme). It, therefore, appears sound, subject to the availability and distribution of resources under Horizon 2020, to opt for the first scenario in order that fusion energy is available as soon as possible.

5.2. Where are the risks and benefits of future EU investments in nuclear research?

The main benefit of the fusion research is, in the very long term, to provide solutions for the development of fusion as a viable alternative for a large-scale and low-carbon baseload energy source. The fusion programme proposed for 2014–18 will bring the following specific benefits.

- **Efficient operation of ITER:** the R & D programme will expand the existing knowledge and prepare staff to ensure that Europe will have the human resources to exploit ITER in an international and competitive environment.

- **Acceleration of development of fusion power plants:** in parallel to R & D for ITER, the programme will lay the foundations for fusion power plants by driving forward the significant physics and technology developments that are required.

- **Contribution to the EU competitiveness:** the body of expertise created by the fusion research community will provide immediate technology transfer benefits for industry and services ([70]).

- **Spin-off benefits of fusion research:** besides the promise of bringing sustainable energy supply in the future, fusion R & D is yielding additional societal benefits which should be taken into account in the allocation of public R & D funds ([71]). Fusion research has pushed many of the cutting-edge technologies to new limits and, in many cases, innovative solutions to challenging problems have found applications far beyond the bounds of fusion (cooled high heat flux components in space applications, improvement in Magnetic Resonance Imaging (MRI), applications in brakes and clutches used in trains and motor racing) ([72]).

- **Reduction of risks regarding future exploitation of fusion energy:** research can further reduce economic, environmental and social risks (see Table 19).

The main risk for fusion research is that it is still at the experimental stage and it may fail to deliver results (i.e. demonstrate the feasibility of fusion as an energy source). Such a failure will result in economic loss in term of investments made and

70. For details, see online (http://ec.europa.eu/research/energy/pdf/200905_fusion_industry.pdf).
71. Edgard Gnansounou, Denis Bednyagin, *Estimating Spillover Benefits and Social Rate of Return of Fusion Research, Development, Demonstration and Deployment Program — Conceptual Model and Implications for Practical Study*, EFDA Socio-Economic Research on Fusion, EPFL, Switzerland, 2007.
72. For details, see online (http://ec.europa.eu/research/energy/pdf/spin_off_en.pdf).

Table 19: **Risks and benefits of fusion energy**

Risks and benefits of fusion energy	
Benefits	
Economic	• The scale and sustainability of fusion energy production will not be limited by fuels (deuterium and tritium) • High energy density and no major land use • Possible source of stable base-load energy supply • Preliminary analyses based on set of assumptions indicate competitive costs of electricity from fusion
Environmental	• No CO_2 emissions from fusion operations, very low carbon emissions for the whole life-cycle • The maximum radiological doses to the public arising from the most severe conceivable accident driven by in-plant energies would be well below the level at which evacuation would be considered and would be comparable to typical annual doses from natural causes • After a few decades, the total radiotoxic potential of the activated material arising from the operation and decommissioning of the fusion plant will have decreased to a low value. All of this material, after remaining in situ for a few decades, may, if desired, be cleared or recycled, with little, or no, need for repository disposal • No possibility for runaway reactions or meltdown, and much smaller quantities of highly radioactive material than in fission reactor. A Fukushima-type melt-down accident cannot happen in a fusion reactor • Fusion has significant proliferation advantages compared to fission. Any illicit use of fusion neutrons for transmutation to produce fissionable materials would be easily detectable
Social	• Important domestic added value (European technological leadership) • Negligible human health impacts
Risks	
Economic	• Fusion's role in the energy mix is very sensitive to the costs • Availability factor for future power plant • Fusion will be able to enter the market in the second half of the century if environmental constraints are applied consistent with a maximum atmospheric CO_2 concentration in the range of 550 to 650 ppm
Environmental	The main nuclear risk associated with fusion is the use of tritium as fuel
Social	Need to teach society about new source of energy

Sources: Final Report of the European Fusion Power Plant Conceptual Study (PPCS) EFDA 2005; *Study on safety and environmental impact of fusion*, EUR (01) CCE-FU / FTC 8/5, EFDA April 2001; *Power plant conceptual studies in Europe*, D. Maisonnier, D. Campbell, I. Cook, Nucl. Fusion 47 (2007) 1524–1532; *Revised assessments of the economics of fusion power*, W.E. Han, D.J. Ward / Fusion Engineering and Design 84 (2009) 895–898, *Economically competitive fusion*, David J. Ward and Sergei L. Dudarev, December 2008, Materials Today, Vol. 11, No 12,

lost opportunities for using resources for other purposes.

5.3. Risks and benefits of fusion energy

Table 19 shows possible benefits and risks related to the eventual exploitation of fusion energy (summary of assessments made in numerous peer-reviewed journals and studies).

6. Evaluation and monitoring

To achieve the objectives set out in Section 3, it is vital to put in place an appropriate system for Euratom's programme evaluation and monitoring. The Euratom programme will follow the key principles for the evaluation and monitoring presented in Chapter 6 of the main report of the impact assessment of the Horizon 2020 framework programme for research and innovation.

To monitor progress, specific indicators, separate for direct and indirect actions, will be used.

6.1. Indicators for indirect actions

(a) Support safe operation of nuclear systems

Indicator: Percentage of overall programme funding going on projects likely to lead to a demonstrable improvement in nuclear safety practice in Europe

Current: XX % (2011)

Target: XX % (2018) *Data for this indicator will be provided later*

(b) Contribute to the development of solutions for the management of ultimate waste

Indicator: Number of geological repositories for spent nuclear fuel and/or high-level waste that are planned in Europe and for which a *safety case* has been prepared and construction application made

Current: 0 (2011)

Target: 3 (2018)

(c) Develop and maintain nuclear competences

Indicator: Training through research — number of PhD students and postdoctoral researchers involved in Euratom fission projects

Current: Approximately 200 (total for 2006–11)

Target: 300 (total for 2014–18)

Indicator: Number of fellows and trainees in the fusion programme

Current: On average, 27 per year (2011)

Target: 40 per year (2018)

(d) Foster radiation protection

Indicator: Percentage of funding going to projects likely to have a demonstrable impact on regulatory practice regarding radiation protection

Current: XX % (2011)

Target: XX % (2018) *Data for this indicator will be provided later*

(e) Move toward demonstration and feasibility of fusion as a power source by exploiting existing and future fusion facilities

Indicator: Number of publications in high-impact journals

Current: Approximately 800 (2010)

Target: Maintain current levels (2018)

Description of the indicator: Source of data — Scopus.com database. Note that with the fusion programme's emphasis shifting from research to technology development, this indicator may be lower in the future. This indicator concerns articles where at least one contributing author is from the European fusion laboratory participating in the Euratom programme and is calculated using the five most important international peer-reviewed journals in the field of plasma physics and fusion: *Nuclear Fusion, Plasma Physics and Controlled Fusion, Fusion Engineering and Design, Fusion Science and Technology, Journal of Fusion Energy*.

(f) Lay the foundations for future fusion power plants by developing materials, technologies and conceptual design

Indicator: Percentage of the Fusion Roadmap's milestones established for a period 2014–18 reached by the Euratom Programme;

Current: New indicator, 0 %

Target: 90 %, including report on fusion power plant conceptual design activities (2018)

Description of the indicator: A new indicator which will be based on the roadmap for the fusion programme to be developed before 2014.

(g) Boost Europe's industrial leadership in fusion technologies through development of the technology transfer process

Indicator: Number of spin-offs from the fusion research under Euratom programme

Current: 33 % of contracts resulted in spin-offs (2011)

Target: 50 % (2018)

Description of the indicator: New products or services developed by companies involved in the fusion research

Indicator: Patents applications generated by European fusion laboratories

Current: 2–3 new patents per year (2011)

Target: On average 4–5 new patents per year (2018)

(h) Ensure availability of research infrastructures for nuclear research

Indicator: Number of researchers using fusion research infrastructures through mobility support

Current: Approximately 800 (2008)

Target: 1 200 (2018);

Description of the indicator: Mobility scheme under fusion programme supports short-term visits of European scientists to the fusion facilities such as JET

6.2. Indicators for direct actions

(a) Improve nuclear safety including, fuel and reactor safety, waste management and decommissioning; and emergency preparedness
Indicator: Scientific productivity (number of major JRC annual work programme deliverables: reports and publications to support nuclear fuel and reactor safety, waste management, decommissioning and emergency preparedness)
Current: 45 (2010)
Target: 50 (2018)

(b) Improve nuclear security including nuclear safeguards, non-proliferation, combating illicit trafficking and nuclear forensics
Indicator: Scientific productivity (number of major JRC annual work programme deliverables: reports and publications to support nuclear safeguards, non-proliferation, combating illicit trafficking and nuclear forensics)
Current: 15 (2010)
Target: 20 (2018)

(c) Raising excellence in nuclear science base for standardisation
Indicator: Scientific productivity (number of major JRC annual work programme deliverables: reports and publications to support EU standardisation)
Current: 30 (2010)
Target: 30 (2018)

(d) Foster knowledge management, education and training
Indicator: Scientific productivity (number of major JRC annual work programme deliverables: reports and training programmes)
Current: 20 (2010)
Target: 18 (2018)

(e) Support to EU policy and evolving legislation on nuclear safety and security
Indicator: Policy support impact (number of JRC reports used as reference for EU legislation)
Current: 0 (2010)
Target: 2 (2018)
Indicator: Policy support productivity (number of major JRC annual work plan deliverables with tangible impact at the level of nuclear policy-makers: reports and training programmes)
Current: 40 (2010)
Target: 45 (2018)

Annex 7: Horizon 2020 — The framework programme for research and innovation

EUROPEAN COMMISSION

Brussels, 30.11.2011
COM(2011) 808 final

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN

PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL

COMMITTEE AND THE COMMITTEE OF THE REGIONS

Horizon 2020 — the framework programme for research and innovation

(Text with EEA relevance)

{SEC(2011) 1427 final} {SEC(2011) 1428 final}

1. A changed context

Since the launch of the seventh framework programme (FP7), the economic context has changed dramatically. A recession triggered by the 2008 financial crisis led to the adoption of stimulus packages to kick-start the economy. While slowly recovering from the downturn, Europe is now faced with a public debt crisis and fears of a new recession. Public authorities across Europe need to act decisively to cope with this changed context. The key challenge is to stabilise the financial and economic system in the short term while also taking measures to create the economic opportunities of tomorrow.

Fiscal consolidation and structural reform are necessary but not sufficient to secure Europe's global competitiveness. Smart investment, notably in research and innovation, is vital in order to maintain high standards of living while dealing with pressing societal challenges such as climate change, an ageing population, or the move towards a more resource-efficient society.

Research and innovation help deliver jobs, prosperity, quality of life and global public goods. They generate the scientific and technological breakthroughs needed to tackle the urgent challenges society faces. Investment in this area also leads to businesses opportunities by creating innovative products and services. Although the Union is a global leader in many technologies, it faces increasing competition from traditional competitors and emerging economies alike and must therefore improve its innovation performance.

Research and innovation have therefore been placed at the centre of the Europe 2020 strategy ([73]) to promote smart, sustainable and inclusive growth. This includes the headline objective of increasing spending on R & D to 3 % of GDP by 2020. The Innovation Union ([74]) flagship initiative provides a comprehensive set of actions for stepping up research and innovation performance. Within this policy context, the Commission's proposals for the post-2013 Union Budget ([75]) reflect its ambition to invest in Europe's future, ensuring that every euro provides maximum benefit to European citizens.

73. COM(2010) 2020 final of 3 March 2010.
74. COM(2010) 546 final of 6 October 2010.
75. COM(2011) 500 final of 29 June 2011.

2. Horizon 2020: a break from the past

The name of the Union's new funding programme for research and innovation — Horizon 2020 — reflects the ambition to deliver ideas, growth and jobs for the future. Horizon 2020 will be a key tool in implementing the Innovation Union flagship initiative, in delivering on the commitments made therein and in responding to the conclusions of the 4 February 2011 European Council and to the European Parliament's Resolution of 12 May 2011 on the Innovation Union ([76]).

Horizon 2020 brings together all existing Union research and innovation funding, including the framework programme for research, the innovation related activities of the competitiveness and innovation framework programme and the European Institute of Innovation and Technology (EIT) ([77]). This approach is widely recognised by stakeholders as the way forward ([78]) and has also been supported by the European Parliament in its Resolution of 27 September 2011 ([79]), the European Economic and Social Committee ([80]) and the European Research Area Committee ([81]).

The set of proposals for Horizon 2020 consists of:

- a proposal for Horizon 2020 ([82]), laying down the general objectives, rationale and Union added value, the financial envelope and provisions on control, monitoring and evaluation;
- a proposal for a single specific programme to implement Horizon 2020 ([83]), laying down the implementation modalities and the content in terms of the broad lines of activities;

76. P7 TA(2011)0236.
77. Activities in the field of nuclear energy are an integral part of Horizon 2020, yet they are subject to a separate proposal under the Euratom Treaty. Funding for ITER will be outside the EU budget and subject to a supplementary programme.
78. http://ec.europa.eu/research/horizon2020/pdf/consultation-conference/summary_analysis.pdf
79. P7 TA(2011)0401.
80. CESE 1163/2011.
81. ERAC 1210/11.
82. Proposal for a Regulation of the European Parliament and of the Council establishing Horizon 2020 — The Framework Programme for Research and Innovation (2014–20), COM(2011) 809 final of 30 November 2011.
83. Proposal for a Council Decision establishing the Specific Programme implementing Horizon 2020 — The Framework Programme for Research and Innovation (2014–20), COM(2011) 811 final of 30 November 2011.

- a proposal for a single set of Rules for Participation and Dissemination ([84]), laying down the modes of funding and reimbursement of costs, conditions for participation, selection and award criteria and the rules on ownership, exploitation and dissemination of results; and

- a separate proposal for the part of Horizon 2020 corresponding to the Euratom Treaty ([85]).

These proposals are accompanied by the necessary ex-ante impact assessments ([86]). Complementary to this package, there is also a separate proposal for a revision of the EIT Regulation.

Key novelties:

Horizon 2020 has a number of new features that make it fit for purpose to promote growth and tackle societal challenges. These include:

- Major simplification through a simpler programme architecture, a single set of rules, less red tape through an easy to use cost reimbursement model, a single point of access for participants, less paperwork in preparing proposals, fewer controls and audits, with the overall aim to reduce the average time to grant by 100 days;

- An inclusive approach open to new participants, including those with ideas outside of the mainstream, ensuring that excellent researchers and innovators from across Europe and beyond can and do participate;

- The integration of research and innovation by providing seamless and coherent funding from idea to market;

- More support for innovation and activities close to the market, leading to a direct economic stimulus;

- A strong focus on creating business opportunities out of our response to the major concerns common to people in Europe and beyond, i.e. 'societal challenges';

- More possibilities for new entrants and young, promising scientists to put forward their ideas and obtain funding.

3. Focusing resources on key priorities

Horizon 2020 will focus resources on three distinct, yet mutually reinforcing, priorities, where there is clear Union added value. These priorities correspond to those of Europe 2020 and the Innovation Union.

(1) **Excellent Science**. This will raise the level of excellence in Europe's science base and ensure a steady stream of world-class research to secure Europe's long-term competitiveness. It will support the best ideas, develop talent within Europe, provide researchers with access to priority research infrastructure, and make Europe an attractive location for the world's best researchers. This will:

- support the most talented and creative individuals and their teams to carry out frontier research of the highest quality by building on the success of the *European Research Council*;

- fund collaborative research to open up new and promising fields of research and innovation through support for *Future and Emerging Technologies* (FET);

- provide researchers with excellent training and career development opportunities through the *Marie Skłodowska-Curie actions* ([87]) ('Marie Curie actions');

84. Proposal for a Regulation of the European Parliament and of the Council laying down the rules for the participation and dissemination in Horizon 2020 — The Framework Programme for Research and Innovation (2014–20)', COM(2011) 810 final of 30 November 2011.
85. Proposal for a Council Regulation on the Research and Training Programme of the European Atomic Energy Community (2014–18) complementing Horizon 2020 – The Framework Programme for Research and Innovation, COM(2011) 812 final of 30 November 2011.
86. SEC(2011) 1427 final of 30 November 2011 and SEC(2011) 1428 final of 30 November 2011.

87. Through this name, the Commission pays tribute to this outstanding Nobel prize winning scientist and the remarkable contribution she made to the advancement of the state of science in Europe.

- ensure Europe has world-class *research infrastructures* (including e-infrastructures) accessible to all researchers in Europe and beyond.

(2) **Industrial Leadership**. This will aim at making Europe a more attractive location to invest in research and innovation (including eco-innovation), by promoting activities where businesses set the agenda. It will provide major investment in key industrial technologies, maximise the growth potential of European companies by providing them with adequate levels of finance and help innovative SMEs to grow into world-leading companies.
This will:

- build *leadership in enabling and industrial technologies*, with dedicated support for ICT, nanotechnologies, advanced materials, biotechnology, advanced manufacturing and processing, and space, while also providing support for cross-cutting actions to capture the accumulated benefits from combining several Key Enabling Technologies;
- facilitate *access to risk finance*;
- provide Union wide support for *innovation in SMEs*.

(3) **Societal Challenges**. This reflects the policy priorities of the Europe 2020 strategy and addresses major concerns shared by citizens in Europe and elsewhere. A challenge-based approach will bring together resources and knowledge across different fields, technologies and disciplines, including social sciences and the humanities. This will cover activities from research to market with a new focus on innovation-related activities, such as piloting, demonstration, test beds, and support for public procurement and market uptake. It will include establishing links with the activities of the European Innovation Partnerships.
Funding will be focused on the following challenges:

- *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.*

Sustainable development will be an overarching objective of Horizon 2020. The dedicated funding for climate action and resource efficiency will be complemented through the other specific objectives of Horizon 2020 with the result that at least 60 % of the total Horizon 2020 budget will be related to sustainable development, the vast majority of this expenditure contributing to mutually reinforcing climate and environmental objectives. It is expected that around 35 % of the Horizon 2020 budget will be climate related expenditure.

The EIT will play an important role by combining excellent research, education and innovation, thus integrating the knowledge triangle. The EIT will do so primarily through the Knowledge and Innovation Communities (KICs). In addition, it will ensure that experiences are shared beyond the KICs through targeted dissemination and knowledge sharing measures.

The Joint Research Centre's activities will be an integral part of Horizon 2020, providing robust, evidence-based support to Union policies. This will be driven by customer needs complemented by forward-looking activities.

Nuclear energy research and innovation, to be supported under the Euratom Treaty, will allow the Union to develop, in the interest of all its Member States, the most advanced technologies for nuclear safety, security, radiation protection and non-proliferation.

The way in which the Horizon 2020 budget is distributed over its strategic objectives equally reflects how it has been adapted to operate in a changed context. The budget distribution within Horizon 2020:

- is fully aligned with Europe 2020 by implementing Innovation Union, prioritising the Digital Agenda, inclusiveness, energy, resource efficiency, industrial technologies, climate action and contributing to the Union's external policies;

- prioritises spending with immediate impact on growth and jobs through major investment in risk finance, SMEs and large-scale pilots and demonstrators for key technologies;

- continues to invest in Europe's future by providing a major boost to the European Research Council, strengthening research on Future and Emerging Technologies (FET), increasing the possibilities for training, mobility and career development for young talents and giving an important role to the EIT;

- leverages other public and private sources of funding to maximise its effect on progressing towards the 3 % target.

Horizon 2020 will be a seven-year programme and there may be significant shifts in the broader economic and policy context as the programme progresses. Ensuring Horizon 2020's continued relevance will therefore also require adjusting priorities and resources, as and when necessary. As such, flexibility clauses have been included in the proposal in this respect.

The implementation of Horizon 2020 will also take a strategic approach to programming of research and innovation, using joint actions and modes of governance aligning closely with policy development yet cutting across the boundaries of traditional sectoral policies. This will be based on sound evidence, analysis and foresight, with progress measured against a robust set of indicators.

As regards the funding of research activities involving human embryonic stem cells, the Horizon 2020 legislative package is fully in line with the approach supported by the European Parliament and the Council upon their adoption of the FP7 legislation, as set out in the Commission's statement of 2006 ([88]).

4. Simplifying access and optimising management

Horizon 2020 must attract the most excellent researchers and innovative enterprises. This requires further simplification of rules and procedures for participants. The FP7 interim evaluation report concluded that major steps towards further simplification were needed, through an approach based on an adequate balance between risk taking and trust in participants ([89]).

Horizon 2020 will build on the impetus given by the Communication on simplification ([90]) and the Commission Decision on three measures for simplifying the implementation of FP7 ([91]) by introducing important new features, as also called for by the European Parliament in its Resolution of 11 November 2010 ([92]).

Simplification in Horizon 2020 will target three overarching goals: to reduce the administrative costs of the participants; to accelerate all processes of proposal and grant management and to decrease the financial error rate.

Simplification will be achieved along several dimensions:

- Structural simplification is provided through:
  - a simpler programme architecture centred on three strategic objectives, making it easier for participants to identify where funding opportunities exist;
  - a single set of participation rules, on issues such as eligibility, evaluation or IPR, applying to all components of Horizon 2020, with deviations only possible when justified by specific needs.

- Simpler funding rules that take into account stakeholders' preference for a reimbursement of actual costs, will include:
  - a simpler reimbursement of direct costs, with a broader acceptance of beneficiaries' usual accounting practices;
  - the possibility of using unit personnel costs (average personnel costs), including for SME owners without a salary;

88. OJ L 412, 30.12.2006, p. 1.

89. http://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/fp7_interim_evaluation_expert_group_report.pdf
90. COM(2010) 187 final of 29 April 2010.
91. C(2011) 174 final of 24 January 2011.
92. P7 TA(2011)0401.

– simplification of time-recording by providing a clear and simple set of minimum conditions; in particular abolition of time-recording obligations for staff working exclusively on a Horizon 2020 project;

– indirect costs covered by a single flat-rate applied to the direct costs as a general rule — removing a major source of financial errors and complexity;

– one single reimbursement rate for all participants and activities in the same project;

– lump sums, prizes, output based funding for specific areas where this has proved appropriate.

- A revised control strategy will achieve a new balance between trust and control and between risk taking and risk avoidance through:

– an extension of the guarantee fund to all actions in Horizon 2020 and *ex ante* financial capacity checks required only for coordinators;

– a reduction of the number of certificates on financial statements by requiring only one such certificate per beneficiary at the end of the project;

– a reduction of the audit burden on participants through an *ex post* control strategy with emphasis on risk-based control and fraud detection, a single-audit concept and a reduction of the limitation period for *ex post* audits from 5 to 4 years;

– This revised approach should translate into a maximum of 7 % of Horizon 2020 beneficiaries being subject to audit over the whole programming period.

In parallel, the Commission will continue to streamline, harmonise and accelerate procedures and processes linked to programme and project implementation. This will include a renewed approach to comitology, with a strong focus on involvement of programme committees in discussions on strategic planning and on ensuring links to nationally funded activities. Moreover the Commission will build on progress made in increasing the quality, efficiency and consistency of implementation via a single user-friendly IT platform providing a one-stop shop for participants (e-Horizon 2020) and through further steps towards externalising the Union's research and innovation funding. In this respect, the use of the existing executive agencies will be optimised, including through a possible redistribution of tasks to achieve greater specialisation.

Through all of these elements, the Commission deems it possible to reduce the average time to grant by 100 days for Horizon 2020 as compared to the current situation.

Partnership approaches on the basis of Articles 185 and 187 of the Treaty will also be continued. A more extensive use of financial instruments will also be an important part of the externalisation effort, building on the debt and equity platforms currently being set up. The EIT will, through a careful planning of its activities, align its work closely to the priorities of Horizon 2020. By expanding the number of KICs and taking up activities relating to dissemination and knowledge sharing, it will be able to manage a larger budget than it does today.

5. A broad and seamless approach to innovation

The Innovation Union flagship initiative highlights the need for Europe to develop a distinctive approach to innovation built on its unique set of values. Horizon 2020 takes a broad approach to innovation that is not limited to bringing new products to the market, but also covers processes, systems or other approaches, including by recognising European strengths in design, creativity, services and the importance of social innovation. Funding for these activities will be meshed with the support for research and technological development.

Stronger support will be given to the market take-up of innovation, including by the public sector. This will include more proof-of-concept, piloting and demonstration. It will involve a better use of the potential of research infrastructures, as well as setting technical standards, pre-commercial procurement and strengthened loan and equity financing. New approaches such as inducement prizes, that reward the achievement of specific goals, will encourage the involvement of a wider range of innovators. The European Innovation Partnerships will be tasked with tackling technical, legal and operational barriers to innovation in Europe, hereby establishing solid links between supply and demand side measures.

Major innovations often come from unforeseen breakthroughs or the new application of existing or emerging technologies. Horizon 2020 will allow Europe's brightest and most creative minds to extend the frontiers of knowledge by strengthening bottom-up activities such as the ERC and FET, the Marie Curie Actions and the dedicated SME instrument. Furthermore, for each of the societal challenges, topic descriptions in calls for proposals will, more than in the past, allow plenty of scope for applicants to propose innovative solutions of their own choice.

Horizon 2020 will promote exchange of ideas and perspectives by deploying a seamless approach across all of its constituent parts. The same rules will apply, allowing participants to move swiftly between different parts. Bridging actions will be put in place to bring projects and results from one part into contact with related projects in other parts.

Joint activities between the different parts of Horizon 2020 will be needed in particular to ensure a seamless connection between support for the enabling and industrial technologies and their applications to societal challenges. Specific provisions have been made to enable this approach and to incentivise cross-cutting actions, including the ability to combine budgets in an efficient manner.

Following on from recommendations made by the High-Level Group on Key Enabling Technologies (KETs) ([93]), 'Leadership in enabling and industrial technologies' will allow treating KET's as a key priority of Horizon 2020, highlighting their importance for growth and jobs. This includes a dedicated budget of EUR 6 663 million for the KETs of photonics, micro and nanoelectronics, nanotechnologies, advanced materials, biotechnology and advanced manufacturing and processing. As part of this integrated approach to KETs, dedicated support will be provided for activities exploiting the accumulated benefits from combining a number of KETs, in particular through support for larger-scale pilot line and demonstrator projects.

6. Strengthening the participation of SMEs

The Innovation Union flagship initiative includes a commitment to ensure strong participation by SMEs in Horizon 2020. SMEs have significant innovation potential and they have the agility to bring revolutionary technological breakthroughs and service innovation to the market. Strengthening the approach to SMEs, including enhancing the participation of micro-enterprises, is vital if Horizon 2020 is to help the fast-growing companies of today to become the multinationals of tomorrow.

Horizon 2020 takes an integrated approach to SMEs. Through this approach, it is expected that around 15 % of the total combined budget for all societal challenges and the enabling and industrial technologies will go to SMEs. A number of novelties under Horizon 2020 will encourage the participation of SMEs.

Simplification will be of particular benefit to SMEs, as they often lack the resources to cope with high administrative burdens. This will include setting up a single entry point for SMEs wishing to participate in Horizon 2020. Equally, the strengthened emphasis on innovation activities will increase SME participation as these activities are of direct relevance to them.

These horizontal measures will be supplemented with SME-specific actions, consolidating support that was previously dispersed over several programmes into a streamlined set of instruments.

First, a new SME instrument, building on the SBIR ([94]) model, the principles of which are described in 'Innovation in SMEs', will be used consistently across all societal challenges as well as for the enabling and industrial technologies. The instrument will allow SMEs to put forward their most innovative ideas for addressing Union-level challenges. The instrument will meet the needs of all SMEs providing innovative solutions to specific challenges, irrespective of whether these are high-tech and research-driven or

93. http://ec.europa.eu/enterprise/sectors/ict/files/kets/hlg_report_final_en.pdf

94. Small Business Innovation Research (http://www.sbir.gov).

social and service-driven innovations, through the following features:

- *Only SMEs will be allowed to apply for funding.* They can bring with them other partners but one of the major novelties of this instrument is that it allows for single participant projects;

- *Support will be provided in different phases.* A feasibility phase will allow an assessment of project potential. A main grant will allow the SME to undertake the project, maintain ownership of IPR and outsource tasks where needed. Follow-up support will be provided indirectly through services such as help in accessing venture capital, innovation support or public procurement.

Second, a dedicated activity for research-intensive SMEs is included in 'Innovation in SMEs'. This will support the next stage in the Eurostars ([95]) scheme implemented in partnership with Member States ([96]). It will be accompanied by measures to build SME innovation capacity, such as networking and brokering, and also allow SMEs to 'spin in' technology by connecting to researchers and innovators across Europe.

Third, 'Access to risk finance' will have a strong SME focus, as called for by the European Council. For the debt facility, the SME focus will be strengthened by working with financial intermediaries at national and regional levels. The Equity facility will focus on early-stage investments, while having the possibility to make expansion and growth-stage investments in conjunction with the equity facility under the Programme for the Competitiveness of Enterprises and SMEs. The Equity facility and the SME-related component of the Debt facility will be implemented as part of two EU financial instruments that provide equity and debt to support SMEs' R & I and growth, in conjunction with the equity and debt facilities under the Programme for the Competitiveness of Enterprises and SMEs.

7. International cooperation

International cooperation with third countries is necessary to address effectively many specific objectives defined in Horizon 2020. This is the case in particular for all the societal challenges addressed by Horizon 2020, which need to be tackled at the global level. International cooperation is also essential for frontier and basic research in order to capture the benefits from emerging science and technology opportunities. Promoting the international mobility of researchers and innovation staff is crucial for enhancing this global cooperation. Activities at the international level are equally important to enhance the competitiveness of European industry by promoting the take-up and trade of novel technologies, for instance through the development of worldwide standards and guidelines, and by promoting the acceptance and deployment of European solutions outside Europe.

The aim of international cooperation in Horizon 2020 will be to strengthen the Union's excellence and attractiveness in research, to tackle global challenges jointly and to support the Union's external policies. The focus of international cooperation in Horizon 2020 will be on cooperation with three major country groupings:

(1) industrialised and emerging economies;

(2) enlargement and neighbourhood countries; and

(3) developing countries.

Where appropriate, Horizon 2020 will promote cooperation at regional or multilateral level. International cooperation in research and innovation is a key aspect of the Union's global commitments and has an important role to play in the Union's partnership with developing countries, which are often disproportionately affected by global challenges. This cooperation will promote inclusive growth and progressing towards the achievement of the Millennium Development Goals and other goals agreed in the framework of international sustainable development.

Horizon 2020 will continue with the principle of general openness, while encouraging reciprocal access to third country programmes. In addition, a range of targeted actions will be implemented taking a strategic approach to international cooperation on the basis of common interest and mutual benefit and promoting coordination and synergies with Member States

95. http://www.eurostars-eureka.eu/
96. http://www.eurekanetwork.org/

activities. Dedicated support measures to assist the strategic approach and the process of priority setting are included in the 'Inclusive, innovative and secure societies' challenge.

8. Spreading excellence and widening participation

Horizon 2020 will continue to allocate funding on the basis of competitive calls for proposals and through independent and merit-based peer review, selecting only the best projects without any consideration of geographical distribution.

Such an approach does, however, need to be complemented with measures to ensure that Horizon 2020 is open to a wide range of participants, including new entrants, and that excellence prevails wherever it exists. Talent therefore needs to be nurtured and supported to grow into excellence, enabling researchers and innovators across Europe to benefit from Horizon 2020's instruments, networks and funding. This will include forging close links with activities in the higher education sector, notably the Erasmus For All programmes and the Knowledge Alliances.

Union funding has assisted in building up and spreading excellence across Europe both through FP7 and the Cohesion policy funds. The 'Regions of Knowledge' and 'Research Potential' activities of the FP7 Capacities specific programme have been met with great interest, but evidence suggests that it would be more efficient if similar actions were pursued under Cohesion policy ([97]).

Therefore the Commission proposes a clearer division of labour between Horizon 2020 and the Structural Funds, while strengthening interactions. Support for regions in building up their research and innovation capacity will be provided through Cohesion policy, which will take forward the concept of smart specialisation and include measures to allow researchers and innovators across Europe to grow into excellence.

Complementary measures under Horizon 2020 will aim at widening participation across the whole of the programme. This will include ensuring better coordination, cooperation and information exchange between the two Union funding programmes. Support will also be given in 'Inclusive, innovative and secure societies' to policy learning and advice with the aim to reform research and innovation policies. This will also involve networking and twinning schemes enhancing the connections between researchers and innovators in all Member States and regions. In this way, the drive for excellence that is a hallmark of Horizon 2020 combined with the capacity-building elements of the Structural Funds will allow pockets of excellence to emerge and grow in developing regions. These will raise the international attractiveness of the regions concerned and act as focal points for their further economic development. In this respect, the specific circumstances of the Outermost Regions should also be taken into account.

9. Completing the European Research Area

Completion of the European Research Area (ERA) is urgently needed to avoid costly overlaps and unnecessary duplication of activities. It entails building a genuine single market for knowledge, research and innovation, enabling researchers, research institutions and businesses to circulate, compete and cooperate across borders. Remaining gaps will be addressed through the ERA framework, to be presented by the Commission in 2012.

Horizon 2020 will strengthen the support given to promoting researchers' careers and mobility (including through the Marie Curie actions) and to ensuring the networking and opening up of large-scale research infrastructures as well as achieving an 'online' ERA ('Research Infrastructures'). In order to contribute to the attractiveness of the research career, Horizon 2020 will pay adequate attention to the European Charter for Researchers and Code of Conduct for the Recruitment of Researchers, together with other relevant reference frameworks defined in the context of the ERA, while respecting their voluntary nature. Further steps will be taken towards Open Access, to ensure that research results are available to those who need them. It will also involve actions to remove barriers preventing women from pursuing successful scientific careers.

97. Expert Group on synergies between FP7, CIP and the Cohesion Policy Funds (ftp://ftp.cordis.europa.eu/pub/fp7/docs/seg-final_en.pdf).

The Commission is committed to reaching the target of 40 % female participation in its advisory structures and it will ensure that gender differences are reflected in the content of calls for proposals, and in evaluation processes, where appropriate. Increased female participation will improve the quality of research and innovation while helping to address the existing deficit of highly qualified and experienced scientists necessary for enhanced European competitiveness and economic growth.

The 'Inclusive, innovative and secure societies' challenge will support policy coordination across Europe, providing a strong evidence base to help Member States in implementing adequate policy mixes. As a novel measure, the work programmes will contain information on how coordination with national research and innovation funding is ensured, making it an element of discussion in the programme committees.

Horizon 2020 will support approaches aimed at pooling and leveraging other sources of funding through a simplified ERA-NET scheme, providing support from coordination of national programmes up to the co-funding of joint calls for proposals. A clear set of criteria for joint programmes under Article 185 and joint undertakings under Article 187 will enable a stronger set of initiatives to go forward, taking account of the experience and evaluations under FP7 as well as the revisions to the financial regulations.

Joint Programming Initiatives (JPI) have been an important development in pooling resources to generate critical mass in addressing challenges shared by Member States. Horizon 2020 will aid JPIs in the development of their Strategic Research Agendas. Where the challenge addressed by a JPI is in line with the priorities of Horizon 2020, ERA-NET or co-funding may be used to provide further support. New Article 185 initiatives will only be considered provided there is a clear commitment from the Member States and when a JPI has demonstrated its capacity for significant collaboration and the scale and scope needed to support full integration of national programmes.

Building on the experience of the public private partnerships under the European economic recovery plan, there will be greater scope for establishing such partnerships without recourse to new legislative procedures. This will allow such initiatives to be implemented in a streamlined manner while ensuring greater clarity of roles and responsibilities.

10. Meeting our shared ambitions

Europe's taxpayers have a right to know how their money is invested. Because research and innovation are vital to people's futures, it is important to bring the research and innovation activities funded through Horizon 2020 to the attention of the general public, showing in particular the added value of Union level action. This will generate better public understanding, engagement and debate. Information and communication measures will therefore be an integral part of Horizon 2020 implementation.

These measures will also focus on communicating the outcomes of research to policymakers, companies, innovators and other researchers, including by promoting Open Access.

Meeting our shared ambitions, which are central to Europe 2020 and the Innovation Union, requires ambitious policies. The Commission is convinced that its proposal for Horizon 2020 and the radical overhaul it entails will enable the Union Budget to play a key role in driving the step change in research and innovation performance that Europe needs. Horizon 2020 is designed to last until the end of this decade. Its projects will continue well into the next decade and the impact of its funding should be felt beyond that. It is therefore truly an investment for the future.

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Annex 9: Glossary

Applied research: Original investigation undertaken in order to acquire new knowledge. Contrary 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: (i) pure basic research which is carried out for the advancement of knowledge, with no positive efforts being made to apply the results to practical problems; (ii) oriented basic research which 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.

Business-as-usual (BAU): 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 multiannual financial framework as separate instruments, with separate objectives, and in their current formats. In the 'business-as-usual+' (BAU+) scenario, the FP, the innovation-related part of the CIP, and the EIT remain separate instruments and retain their current formats. However, they are put together under a 'common roof', and loose coordination mechanisms are established between them and their objectives are loosely aligned. In addition, the implementing modalities of each individual programme and initiative are simplified. No single set of simplified rules applies across the three programmes.

BRIC countries: Brazil, Russia, India and China

Collaborative Projects: Support to framework programme-funded research projects carried out by consortia with participants from different countries. The size, scope and internal organisation of projects can vary from field to field and from topic to topic. Projects can range from small or medium-scale focused research actions to larger integrating projects which mobilise a significant volume or resources for achieving a defined objective.

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).

Common Research Data Warehouse (CORDA): CORDA and E-CORDA (External Common Research Data Warehouse — the analogue destined to external stakeholders) are databases containing data on applicants/proposals and signed grants/beneficiaries with regards to a specific Framework Programme for Research. CORDA is updated daily with data coming from a wide variety of systems and applications. It, therefore, contains almost up-to-date information on framework programme activities. E-CORDA is a 'snapshot' of CORDA extracted semi-annually, the data of which undergoes further quality controls and interpretation.

CORDIS: The Community Research and Development Information System (CORDIS) is a huge Internet information system comprising information on past and ongoing projects, calls for proposals, partner search facilities, an electronic proposal submission system (EPSS) and other features.

COST: An intergovernmental framework for European cooperation in the field of S&T, allowing the coordination of nationally funded research on a European level. COST actions cover basic and pre-competitive research as well as activities of public utility.

CREST: The Scientific and Technical Research Committee (CREST), composed of representatives of

Member States, is a high-level advisory board to the Commission and the Council in the field of RTD.

Development of a European Multi-model ensemble system for seasonal to inter-annual prediction (DEMETER): This EU-funded project aims to develop a well-validated European coupled multi-model ensemble forecast system for reliable seasonal to inter-annual prediction. A fundamental aspect is to establish the practical utility of such a system, particularly to the agriculture and health sectors.

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, as well as support for innovation and SME policy-making through contracts and grants.

ERA-NET: The principal means for the FP to support the coordination of national and regional research programmes.

EU-12: The 12 countries that have joined the EU since 2004 (Bulgaria, Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Romania, Slovenia and Slovakia).

EU-15: Before 1 May 2004, the European Union consisted of 15 Member States (Belgium, Denmark, Germany, Ireland, Greece, Spain, France, Italy, Luxembourg, the Netherlands, Austria, Portugal, Finland, Sweden, and the United Kingdom).

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 an Euratom framework programme under the Euratom Treaty which covers training and research activities in the nuclear sector.

EUREKA: A pan-European network for market-oriented, industrial R & D. EUREKA supports the competitiveness of European companies through international collaboration in creating links and networks of innovation. The objective is to bring high-quality research and development efforts to the market and to use the multiplying effects of cooperation.

European Added Value (EAV): EU support to research and innovation is provided only when it can be more effective than national funding. It does this through measures to coordinate national funding, and through implementing collaborative research and mobility actions.

European Higher Education Area (EHEA): The EHEA was launched in March 2010, along with the 10th anniversary of the Bologna Process, during the Budapest-Vienna Ministerial Conference. As the main objective of the Bologna Process since its inception in 1999, the EHEA was created to ensure more comparable, compatible and coherent systems of higher education in Europe.

European Institute for Innovation and Technology (EIT): The EIT is an institute of the European Union established in March 2008, to increase European sustainable growth and competitiveness by reinforcing the innovation capacity of the 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, boosting innovation and entrepreneurship. The KICs focus on priority topics with high societal impact.

European Patent Office (EPO): The European Patent Organisation is an intergovernmental organisation 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 Space Agency (ESA): Established in 1975, ESA is an intergovernmental organisation dedicated to the exploration of space (17 Member States). Its mission is to shape the development of Europe's space capability. By coordinating the financial and intellectual resources of its members, it can undertake programmes and activities far beyond the scope of any single European country.

European Strategy Forum on Research Infrastructures (ESFRI): ESFRI is a strategic instrument to develop the scientific integration of Europe and to strengthen its international outreach. The competitive and open access to high-quality research infrastructures supports and benchmarks the quality of the activities of European scientists, and attracts the best researchers from around the world. The mission of ESFRI is to support a coherent and strategy-led approach to policymaking on research infrastructures in Europe, and to facilitate multilateral initiatives leading to the better use and development of research infrastructures, at EU and international level.

European Technology Platform (ETP): ETPs are industry-led stakeholder forums 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 have been grouped in one large multiannual programme, the framework programme for research and technical development. While FP1 to FP6 were conceived for a period of 4 years, FP7 is synchronised with the duration of the EU's financial perspective and covers the period 2007–13. The FPs are elaborated and proposed by the Commission and have to be adopted by the European Parliament and the Council in co-decision.

Future and Emerging Technologies (FET): FET are the incubator and pathfinder for new ideas and themes for long-term research in the area of information and communication technologies, to promote high-risk research, offset by potential breakthrough with high technological or societal impact.

Government Budget Appropriations or Outlays on R & D (GBAORD): All appropriations allocated to R & D in central government budgets. Data on government R & D appropriations therefore refer to budget provisions, not to actual expenditure (i.e. GBAORD measures government support for R & D using data collected from budgets).

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.

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 the 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.

Institute for Prospective Technological Studies (IPTS): The Institute for Prospective Technological Studies is one of the seven scientific institutes of the European Commission's Joint Research Centre (JRC). It promotes and enables a better understanding of the links between technology, economy and society. Its mission is to provide customer-driven support to the EU policymaking process by developing science-based responses to policy challenges that have both a socioeconomic as well as a scientific/ technological dimension.

Intellectual Property Rights (IPR): They cover all aspects of owning, protecting and giving access to knowledge and pre-existing know-how.

Intelligent Energy Europe Programme (IEE): The Intelligent Energy — Europe programme is the EU's tool for funding action to save energy and encourage the use of renewable energy sources in Europe.

Intergovernmental Panel on Climate Change (IPCC): The IPCC is the leading international scientific body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organisation (WMO) to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socioeconomic impacts.

International Thermonuclear Experimental Reactor (ITER): ITER is an international research and engineering project which is currently building the world's largest and most advanced experimental tokamak nuclear fusion reactor. The ITER project aims to make the transition from experimental studies of plasma physics to full-scale electricity-producing fusion power plants. The project is funded and run by seven members — the EU (which shares 45 % of the cost), China, India, Japan, Russia, South Korea and the United States (each sharing 9 % of the cost).

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, Spain, Italy, the Netherlands). 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 Emerging 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.

Marie Curie Actions: The main objective of the FP's Marie Curie Actions is to strengthen training, the career prospects and mobility of European researchers in order to provide support for the development of world-class human resources.

Multiannual Financial Framework (MFF): In order to improve the budgetary procedure, the European Parliament, the Council and the Commission conclude (since 1988) interinstitutional agreements covering the budget process and the distribution of the budget. These agreements are established for several years, and are also known as EU 'Financial Perspective'.

New Econometric Model for Environmental and Sustainable Development and Implementation Strategies (NEMESIS): The NEMESIS model is a large-scale econometric model at the macro and sectoral levels, which has been built by a Community funded *consortium* of European research institutes. It comprises roughly 70 000 equations. The model can be used for several purposes, which include the assessment of structural (mainly R & D and environmental) policies, the study of the short and medium-term consequences of a wide range of economic policies, short and medium-term forecasting (up to 8 years) at the macro and sectoral levels, and building long-term baseline scenarios (up to 30 years).

Open Method of Coordination (OMC): A relatively new and intergovernmental means of governance in the EU, based on the voluntary cooperation of Member States. It rests on soft law mechanisms such as guidelines and indicators, benchmarking and sharing of best practice, not on official sanctions for laggards. Rather, the method's effectiveness relies on a form of peer pressure and naming and shaming, as no Member States wants to be seen as the worst in a given policy area.

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.

Patent Cooperation Treaty (PCT): The Patent Cooperation Treaty makes it possible to seek patent protection for an invention simultaneously in each of a large number of countries by filing an international patent application. Such an application may be filed by anyone who is a national or resident of a PCT contracting State. It may generally be filed with the national patent office of the contracting State of which the applicant is a national or resident or, at the applicant's option, with the International Bureau of the World Intellectual Property Organisation in Geneva.

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.

Research and experimental development (R & D): R & D comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, 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.

R & D intensity: Gross Domestic Expenditure on R & D (GERD) expressed as a percentage of Gross Domestic Product (GDP).

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.

Rules of participation for the framework programme: They set out the framework that governs the relationship between the Commission and the institutions that participate in the programme, covering aspects such as procedures for calls for proposals, types of grants, levels of financing, consortia composition, the evaluation process, financial management of projects, and dissemination of project results. The rules of participation are adopted by the European Parliament and the Council in co-decision on a proposal from the Commission (Article 167 TEC).

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.

Stakeholder: Any person or organisation with an interest in or affected by EU legislation and policymaking is a ‘stakeholder’ in that process. The European Commission makes a point of consulting as wide a range of stakeholders as possible before proposing new legislation or new policy initiatives.

Strategic Energy Technology Plan (SET Plan): The SET Plan, presented by the Commission, aims to help achieve European objectives and face up to the energy challenges, by increasing research to reduce costs and improve performance of existing technologies, and by encouraging the commercial implementation of these technologies in the short term, and in the longer term by supporting development of a new generation of low-carbon technologies.

Technology Platforms: Introduced in FP7, they 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 — national and European — public and private resources.

Valley of Death: The gap between basic knowledge generation and the subsequent commercialisation of knowledge in marketable products, is known in broad terms as the ‘Valley of Death’ issue.

Annex 10: Acronyms

BAU	Business-As-Usual
BRIC	Brazil, Russia, India and China
CIP	Competitiveness and Innovation Framework Programme
CIP-PSP	CIP Policy Support Programme
CORDA	Common Research Data Warehouse
CSF	Common Strategic Framework for research and innovation
EAV	European Added Value
EHEA	European Higher Education Area
EIB	European Investment Bank
EIP	Entrepreneurship and Innovation Programme
EIT	European Institute of Innovation and Technology
EPO	European Patent Office
ERA	European Research Area
ERA-NET	European Research Area network
ERC	European Research Council
ESFRI	European Strategy Forum on Research Infrastructures
Eurostat	Statistical Office of the European Union
ETP	European Technology Platform
EU-12	The 12 countries that joined the European Union since 2004.
EU-15	The 15 countries that were members of the EU before the 2004 enlargement.
Euratom	European Atomic Energy Community
FDI	Foreign Direct Investment
FET	Future and Emerging Technologies
FP	Framework Programme for Research and Technological Development
GBOARD	Government Budget Appropriations or Outlays on Research and Development
GDP	Gross Domestic Product
IAB	Impact Assessment Board
IASG	Impact Assessment Steering Group
ICT	Information and Communication Technologies
IEAE	International Atomic Energy Agency
IEE	Intelligent Energy — Europe programme
IPCC	Intergovernmental Panel on Climate Change
IPTS	Institute for Prospective Technological Studies (JRC)
IST	Information Society Technologies
ITER	International Thermonuclear Experimental Reactor
ITRE	European Parliament Committee on Industry, Research and Energy
JRC	European Commission's Joint Research Centre
JTI	Joint Technology Initiative
KET	Key Emerging Technologies
MCA	Marie Curie Actions
MFF	Multiannual Financial Framework
OECD	Organisation for Economic Cooperation and Development
OMC-NET	Open Method of Coordination network
PCT	Patent Cooperation Treaty
PPP	Public-Private Partnership
R & D	Research and Development
RSFF	Risk-Sharing Finance Facility
S&T	Science and Technology
SET Plan	Strategic Energy Technology Plan
SMEs	Small and Medium-sized Enterprises

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