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COMMISSION STAFF WORKING PAPER

IMPACT ASSESSMENT

Accompanying the

Communication from the Commission 'Horizon 2020 - The Framework Programme for Research and Innovation';

Proposal for a Regulation of the European Parliament and of the Council establishing Horizon 2020 – the Framework Programme for Research and Innovation (2014-2020);

Proposal for a Council Decision establishing the Specific Programme implementing Horizon 2020 – The Framework Programme for Research and Innovation (2014-2020);

Proposal for a Council Regulation on the Research and Training Programme of the European Atomic Energy Community (2014-2018) contributing to the Horizon 2020 – The Framework Programme for Research and Innovation

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Disclaimer: this report commits only the Commission's services involved in its preparation and does not prejudge the final form of any decision to be taken by the Commission.

1. PROCEDURAL ISSUES AND CONSULTATION OF INTERESTED PARTIES

1.1. Introduction

This Staff Working Document presents in full the impact assessment of the Commission's proposals on "Horizon 2020", the Framework Programme for Research and Innovation and covers the ex ante evaluation required for every new EU expenditure programme. The report thus pertains to: the Horizon 2020 Framework Programme for Research and Innovation in the European Union (2014-2020) and the specific programme implementing it, which have their legal bases in the Treaty on the Functioning of the European Union; the European Atomic Energy Community Programme (2014-2018) contributing to Horizon 2020, which has its legal basis in the Euratom Treaty; and the Commission Communication providing the overall political narrative and background to these legislative proposals. A separate Staff Working Document deals with the impact assessment of the Commission's proposals for the Rules for Participation of Horizon 2020. The Rules for Participation define the rights and obligations of legal entities intending to take part in the Horizon 2020 actions and establish the principles for the exploitation and dissemination of the results of these actions. The Rules therefore offer important avenues for simplification, and it was decided to prepare a separate impact assessment for this issue in view of the importance attached to it by the Commission and external stakeholders.

"Horizon 2020", the Framework Programme for Research and Innovation, brings together the successor of the 7th Framework Programme for Research, the successor to the Competitiveness and Innovation Framework Programme (CIP, comprising the innovation-related parts of the Entrepreneurship and Innovation Programme (EIP), the Information Communication Technologies Policy Support Programme (ICT-PSP), and the Intelligent Energy Europe Programme (IEE)), and the European Institute of Innovation and Technology (EIT). The decision to bring together all EU research and innovation funding in a coherent, from-research-to-innovation overarching framework was taken on 29 June 2011 by the College in order to make participation easier, increase scientific and economic impact, and maximise value for money. This Impact Assessment accompanies the Horizon 2020 proposals and attempts to assess their expected impacts on Europe's economy and society. The information is organised in six chapters which follow the Commission's Impact Assessment Guidelines.

In accordance with feedback received from the Impact Assessment Board, the report was revised in the following ways. The intervention logic was clarified by redrafting the problem definition and linking it more clearly to the lessons learned from the past; reducing the number of operational objectives, making them more concrete, and formulating suitable accompanying performance indicators; and clarifying the contribution of different Horizon 2020 instruments, in particular the innovative financial instruments. The differences between the policy options were explained in more detail. The report was also revised to provide more detail on the cost-effectiveness of the various options. The impacts of the 46 percent (2011 constant prices) budget increase in EU research and innovation funding proposed by the Multi-annual Financial Framework Communication were more fully analysed. More details were provided on the implementation of the preferred Horizon 2020 policy option: the rationale was explained behind the identification of the three priorities and the six societal challenges, the analysis of the funds allocation under Horizon 2020 was improved, and more details were provided on the funding schemes to be used under Horizon 2020.

1.2. Organisation and timing

The Commission's Directorate-General for Research and Innovation is the lead DG for this initiative.

Along with the Secretariat General and DG RTD, the following Directorates-General participated in the inter-service Impact Assessment Steering Group (IASG): DG EAC, DG ENER, DG ENTR, DG ENV, DG INFSO, DG JRC, DG MOVE. At both central and decentralised level, the expertise and inputs of other Commission services (among which DG AGRI, DG BUDG, DG ECFIN, DG EMPL, DG ESTAT, DG REGIO, DG SANCO and the Legal Service) was also drawn upon. Several strategic orientation meetings were held at the level of the Directors General of the Research and Innovation Family DGs as well as with the Directors General of the so-called Policy DGs. Finally, the draft IA report was pre-screened by both Commission internal as well as external experts in the area of EU policy evaluation, impact assessment, research and innovation.

Preparation of the Horizon 2020 Impact Assessment involved the following procedural steps in the past twelve months:

- Developing a Roadmap describing the process (2010);
- Setting up an inter-service Impact Assessment Steering Group to oversee the process (2010-2011);
- Consultation of stakeholders and interested parties through a variety of methods (2009-2011);
- Carrying out the IA analysis making extensive use of quantitative and qualitative evidence (2010-2011);
- Presenting the findings to a wide constituency of Commission DGs (IASG, Research & Innovation Family DGs, User DGs) as well as external experts (2011);
- Submitting the Horizon 2020 IA report to the IAB (IAB opinion scheduled for September 2011).

1.3. Consultation and expertise

Early discussions on the future of EU research and innovation funding

Discussions on the future of EU research and innovation funding started two years into the current programming cycle. Some early views relating to future research and innovation funding were included in the 2009/2010 interim evaluations of 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 aging, 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 (for example, the Swedish Presidency in July 2009; the Hungarian Presidency in February 2011). In 2011, two major stakeholder conferences were organised in Brussels. The first one was held on 25 January 2011 entitled "Ready to Grow? Shaping future EU support for business", attended by over 550 participants (among those were innovation agencies, industries, universities, NGOs, intermediary associations). The second conference on the Framework Programme for Research and Innovation Funding was held on 10 June 2011. The conference concluded the public consultation on the Green Paper (see below) and was attended by over 650 participants from Europe's research and innovation community.

Throughout 2010 and in anticipation of the debate on the Multi-annual Financial Framework 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 ways employed to consult stakeholders and interested parties

- ü Public consultation on Green Paper describing the Common Strategic Framework for Research and Innovation
- ü Public consultation on the successor to the Competitiveness and Innovation Framework Programme (CIP)
- ü FP6 ex-post evaluation (chair Ernst Rietschel) with view on future, February 2009
- ü FP7 interim evaluation (chair Rolf Annerberg), November 2010
- ü 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
- ü Large stakeholder conferences for successor of CIP (Jan 2011) and CSF (June 2011) held in Brussels
- ü Expert Panels and Stakeholder Conferences for ERC, Marie Curie, EIT, …
- ü EU Presidencies: Lund conference on future of EU research (Sweden, July 2009); FP7 interim evaluation conference (Hungary, February 2011)
- ü Wide range of position papers on future EU research and innovation funding during EU budget preparations
- ü Thematic stakeholder consultations: ICT, transport, health, biotechnology, space,…
- ü Discussion with representatives of national administrations (CIP Joint Management Committees meeting, meetings of EIP Management Committee).

The Green Paper stakeholder consultation

After these early discussions - and following in the tracks of the Europe 2020 strategy, the Innovation Union Flagship Initiative and the EU Budget Review - the Commission took the initiative to launch a public consultation on the future of EU research and innovation funding. The consultation was based on a Green Paper entitled 'From Challenges to Opportunities: Towards a Framework Programme 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. 2078 responses were received in total, including an unprecedented 775 position papers and 1303 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 or are still ongoing 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. According to the provisions laid down in the EIT Regulation, the specific EIT related aspects will be dealt in a dedicated impact assessment.

Furthermore, each of the Directorates General in the Research and Innovation Family (EAC, ENER, ENTR, ENV, INFSO, MOVE, JRC) organised specific consultations on the challenges and objectives to be addressed through the proposed funding programme through a series of dedicated workshops with key experts and Member State representatives, the outcomes of which have been channelled into the design of the Framework Programme for research and innovation.

Main stakeholder views on future policy options by actor

These various discussions and consultations revealed striking similarities within each group of actors. The key messages to emerge were as follows:

- **Industrial enterprises** emphasized 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, 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, such as a common set of rules for participation for the different strands of action. They also welcomed a policy option that would bridge research and innovation more strongly and focus stronger on the dissemination of results of research projects to allow for valorisation into new products, processes and services.
- **Universities and research centres** equally emphasized the need for further simplification, but also expressed strong support for research actions linked to societal challenges as well as basic research funding through ERC. Distributing EU research and innovation funding according to excellence was considered a key principle by the academic research community (but also other actors emphasized this) of any future EU research and innovation research 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 emphasized the need for a European-level framework for research and innovation support actions, thereby discarding the "renationalisation" option. Several Member States emphasized to continue with those aspects of the current programme that work well and are very much appreciated, such as Marie Curie actions, Risk Sharing Finance Facilities and transnational collaborative research (the academic community added the European Research Council in this list). The Structural Funds should be used to unlock the full research potential 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").

Extensive use of quantitative and qualitative evidence for CSF IA report

- ü Ex-post and interim evaluations (FP6, FP7, CIP, EIP, ICT-PSP, IEE, Marie Curie, ERC, …)
- ü Foresight and forward looking studies
- ü Statistical data (FP, CIP, Community Innovation Survey, …)
- ü Analyses of science, technology and innovation indicators (EC, ESTAT, OECD, …)
- ü Econometric modelling exercises (NEMESIS/DEMETER …)
- ü Academic literature reviews on, amongst others, impacts of research and innovation
- ü Sectoral competitiveness studies
- ü Expert Panels and Expert Hearings
- ü On-line surveys among FP and CIP beneficiaries

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, on the 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, recognizes these challenges and argues that Europe faces a moment of transformation. This perspective is taken up in the Commission's MFF Communication of June 2011, 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 has published a Communication on "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 to move towards smart, sustainable, inclusive growth, and along the way to tackle its pressing societal challenges, as recognized in the EU Multi-annual Financial Framework for 2014 to 2020 (EC, 2011e). Box 1 shows why research and innovation are key engines of productivity and growth.

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 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 micro-economic literature has produced a number of clear conclusions:
  - *The returns to 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 per cent (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 to public R&D are high*:
    - The rate of return for publicly funded R&D usually exceeds 30 percent.
    - Each extra 1 percent in public R&D generates an extra 0.17 percent in productivity growth (Guellec and van Pottelsberghe de la Potterie, 2001/2004).
  - *The returns to private R&D are high*:
    - Firms' returns to their own investment in research usually range from 20 to 30 percent. Societal returns to firm investment in research usually range from 30 to 40 percent.
    - Each extra 1 percent in business R&D generates an extra 0.13 percent in productivity growth (Guellec and van Pottelsberghe de la Potterie, 2001/2004).
  - *Research and innovation are vital for industrial competitiveness:*
    - The ability to innovate (in addition to size, productivity, and 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).
  - *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 instance, an increase in business R&D by 1 percent is associated with an increase in business employment of 0.15 percent (Bogliacino and Vivarelli, 2010).

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 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 the US, China and Taiwan, 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

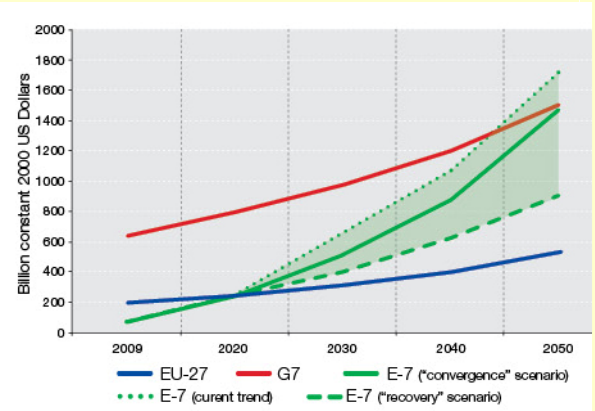
be successful Europe must stimulate coordinated research aimed at addressing these challenges and improve the way it is transformed into new products and processes. And it must enhance the interaction between research and innovation actions and the sectoral policies related to the challenges.

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.

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 left figure below shows the potential trends in R&D spending. Under conservative assumptions for growth and R&D spending[i], 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 right figure below, 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%).

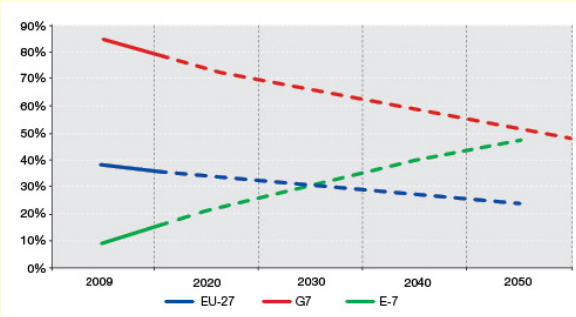
Long-term trends in R&D spending - emerging economies, G7 countries, EU-27



***Source**: DG Research and Innovation*

Data: HSBC estimates of GDP growth, OECD, World Bank

World shares of PCT patents[ii] - emerging economies, G7 countries, EU-27



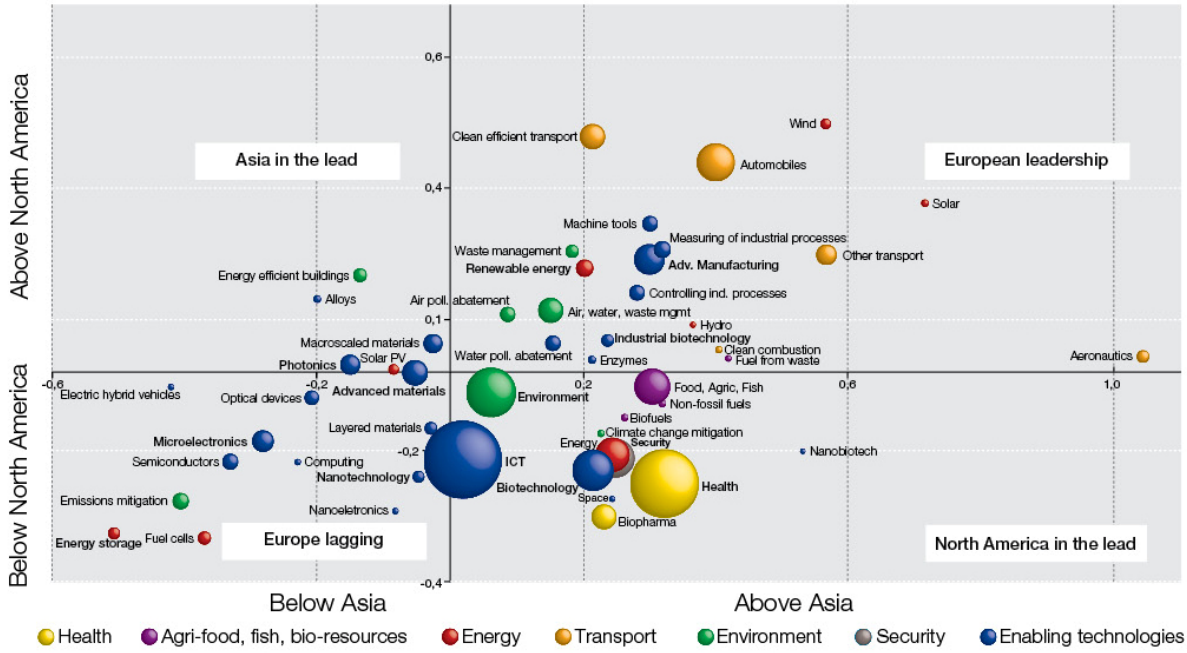
***Source**: DG Research and Innovation*

Data: OECD patent database

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 US. 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.

Figure 1: Europe's technological performance compared with North America and Asia[iii]



Source: *DG Research and Innovation*

Data: *OECD patent database and specific studies*[iv]

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 big part of the solution, science, technology and innovation are not a panacea. For greening the economy, for instance, recycling will need to be stepped up, business incentives will need to be changed (by, for instance, shifting taxation from labour to resource use), business models will need to be adapted (by, for instance, paying for services instead of products), consumers will need to be incentivised to mend 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 health care 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 to what they can achieve in terms of breakthroughs. They have mixed success in forging links with innovation, and creating spin-off companies. 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 recognize 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 EU recognizes 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 percent 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 (like 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.

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 of them 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 to avoid duplication between different national and regional funding actions. This sub-optimal 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.

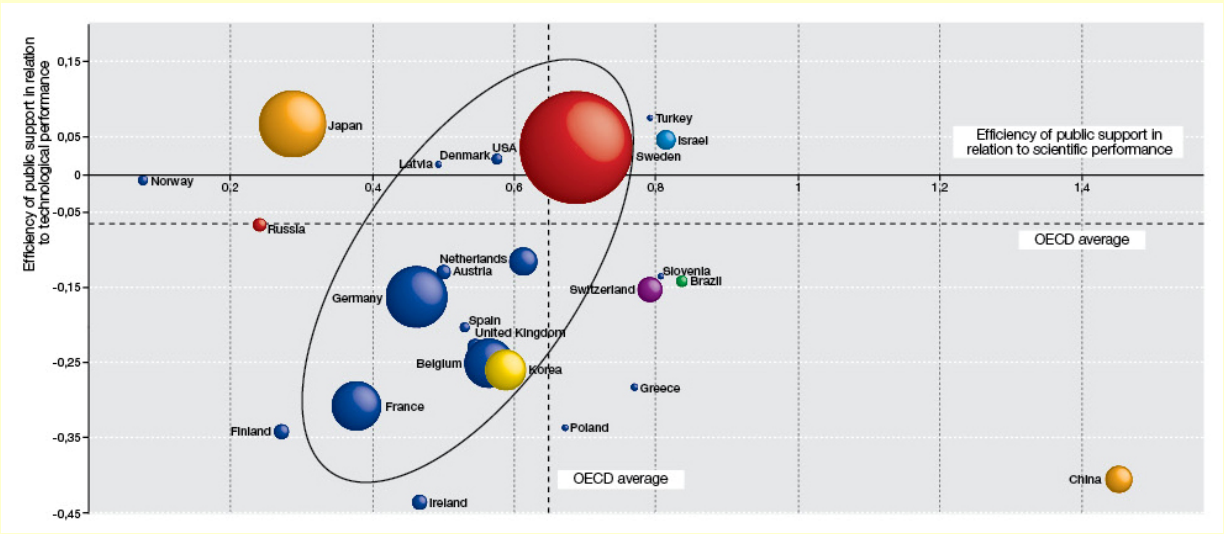
According to several recent estimates (NMP Scoreboard, 2011; Roco et al., 2010; OECD 2009), the Union spends around €1.5 billion annually (including the 27 Member States' national funding and EC funding), which is considerably more than the USA (€1 billion), Japan (€0.47 billion) and China (€0.1 billion).

However, as highlighted in a recent Communication of the EC (2009), "despite these relatively high levels of funding, the EU is not as successful in deploying nanotechnology as for example the US, 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 to 16.1% for the USA, 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 US, followed by companies in East Asia (24%), Europe (15%), and other world regions (8%).

The figure below shows the scientific and technological performance of selected developed and emerging countries (expressed in terms of the number of patents per 1M€ of public R&D support (2000-2005) and the number of highly cited publications per 1M€ 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 US 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 the nanotechnology[v]



Source: DG Research and Innovation

Data: Larsen et al (2011), Roco et al (2010), OECD (2008, 2009)

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 instance, on top of generic innovation barriers, there are additional ones that slow down its 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). What investment does take place 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 to 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 and Annex 2). 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 Multi-annual Financial Framework so as to propel Europe into premier position in establishing the 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.

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. It does this through measures to coordinate national funding, and through implementing collaborative research and mobility actions.

Coordinated funding and agenda-setting

EU initiatives help to coordinate funding across national borders and to re-structure 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 compartmentalized national research councils, but no mechanism to promote EU-wide competition for funds and to encourage higher scientific quality.
- Thanks to 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 joins up compartmentalized 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 deployment of innovative technologies, i.e. ICT applications at real scale (through CIP-PSP) 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 (ProInno, Europe Innova initiatives, environmental policies, security policies…).
- Through its Marie Curie actions, the EU set standards for innovative research training and career development and put 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 to 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 harmonized laws in these areas (Annex 1).
- Working in trans-national 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 labs 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 at 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: DG Research and Innovation, DG Environment

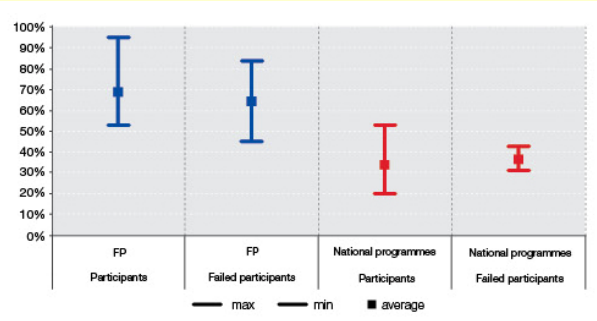
See the third section of Annex 2 for details on how EU research programmes provide European Added Value

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 (Box 4) – 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: DG Research and Innovation
Data: FP data based on 20 studies of additionality of EU support; national programme data based on studies for Member State programmes in Austria, Belgium (x2) and Finland, and in 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 below summarizes 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.

See the third section of Annex 2 for more details on how EU research supports strategic projects that would not have taken place otherwise

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 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; 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 (2014-2018) 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 FP, the innovation-related part of the CIP, and the 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, micro-economic benefits, and downstream macro-economic, 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 providing them with large-scale knowledge returns (Annex 1). 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 (Annex 1). 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 – Box 5 and Annex 2). The FP has funded excellent, often inter-disciplinary, collaborative research on a very wide range of topics (Annex 0-Box 1 and Annex 1).

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) (Annex 1). 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 (Annex 1). 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 (Annex 1). 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 (Annex 1). In addition, the results of FP direct and indirect actions have supported EU-level policy formulation (Annex 1). The FPs' positive impacts on innovation have translated, down the line, into large-scale positive macro-economic, social and environmental impacts (Chapter 5 and Annexes 2, 4 and 5).

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, 2010) found that the FP has a big 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 percent of businesses stated that their participation had made significant contributions to the development of new products and processes and in around 10 percent 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 (Forfas, 2009), each project produced, on average, 0.1 patent applications and 0.4 new or significantly improved commercial product or service. 80 percent 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 1200 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 percent of respondents and equally well according to 50 percent 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.

See Annex 1 for more evidence on the impact of European programmes on national research and innovation systems

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 compartmentalized 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. Thanks to the FP, the EU leads in the creation and use of research infrastructures of pan-European importance: thanks to 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 inter-disciplinary 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 achieved a better coordination of R&D in Europe and supported a more coherent use of resources (Annexes 1 and 2).

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 to eco-innovation is contributing positively to the achievement of the Europe 2020 objective of smart and sustainable growth by facilitating access to finance of 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 3 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 a 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 instance, 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 instance, 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 (Annex 1).

3. OBJECTIVES

In order to tackle the problems identified in section 2, it is important to clarify the objectives of EU action in the field of research and innovation. The following objectives have been identified.

General objective

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

Specific objectives

In order to achieve these general objectives, 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 Union policies*

- *Help to better integrate the knowledge triangle - research, researcher training and innovation*

Operational objectives

To reach the specific objectives above, 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 trans-national 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 EU Budget Review (COM (2010) 700) put forward some general key principles that are of particular importance for the area of research and innovation - focussing 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 his 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 (BAU); Improved business-as-usual (BAU+); Horizon 2020 - Framework Programme for research and innovation; and Renationalisation. The complete discontinuation option is also considered but to a lesser extent (when assessing macro-economic impacts). Assessing the business-as-usual option is in accordance with Commission 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 is 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 Multi-annual Financial Framework as separate instruments, with separate objectives, and in their current formats. The next Multi-annual Financial Framework therefore includes a "Framework Programme of the European Community for Research, Technological Development and Demonstration Activities" composed of 5 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 2 specific programmes (one on fusion energy research, and nuclear fission and radiation protection, and one on the activities of the Joint Research Centre in the field of nuclear energy), a CIP including innovation-related actions, and the EIT.

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 like under the business-as-usual option, the next Multi-annual Financial Framework therefore includes a "Framework Programme of the European Community for Research, Technological Development and Demonstration Activities" composed of 5 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 2 specific programmes (one on fusion energy research, and nuclear fission and radiation protection, and one on the activities of the Joint Research Centre in the field of nuclear energy), a CIP including innovation-related actions, and the EIT. However, a certain measure of integration is pursued as these programmes and instruments are put together under a 'common roof'. This means, first, 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 maximization 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, however. Second, 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". Third, 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 put together into a single framework: Horizon 2020, the Framework Programme for Research and Innovation. The current separation between research and innovation is fully overcome; seamless support is provided from research to innovation, from idea to market. Horizon 2020 sets out three strategic policy objectives for all research and innovation actions closely linked to the Europe 2020 agenda and the flagships on Innovation Union, Digital Agenda, Industrial

Policy, Resource-efficient Europe, Agenda for New Skills for New Jobs and Youth on the Move: raising and spreading the levels of excellence in the research base; tackling major societal challenges; and maximising competitiveness impacts of research and innovation. The selection of actions and instruments is driven by policy objectives and not by instruments. To address its aims, Horizon 2020 is structured around three complementary and interlinked priorities - (1) Excellent Science; (2) Industrial Leadership; (3) Societal Challenges – and 2 additional parts supporting those priorities: JRC non-nuclear direct actions and EIT. Horizon 2020 provides the context for a major simplification and standardisation of implementing modalities. The simplification concerns both funding schemes and administrative rules for participation and dissemination of results. The new single set of simplified rules applies across the three blocks of Horizon 2020, while allowing for flexibility in justified cases. The Horizon 2020 option also includes an expanded use of externalisation of the implementation of research and innovation actions and a greater reliance on innovative financial instruments. 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.

Option 4. Bring to an end EU level R&D financing and re-nationalise R&D and innovation policies

The renationalisation option consists of discontinuing EU research and innovation programmes and of spending those funds at Member State level, either on domestic issues or to engage in inter-governmental collaboration. The complete discontinuation option, on the other hand, which as already mentioned will be assessed to a lesser extent (when assessing macro-economic 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 – BAU, BAU+, 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 BAU option suffers from a lack of clarity of focus and from an under-developed 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 6 societal challenges through research, innovation, and the training and skills development of researchers. It puts together 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 EU research and innovation funding around three objectives - tackling societal challenges, strengthening competitiveness, and raising the excellence of the science base (see Chapter 1 for more details).

Critical mass, flexibility, excellence

Ex-post evaluations have shown that the BAU option (and therefore also the BAU+ option) achieves critical mass,[vi] is flexible to a certain extent, and promotes excellence. The Horizon 2020 goes further by enhancing programme flexibility. It maintains cross-thematic joint calls, problem-oriented work programmes promoting inter-disciplinary research, and the scope for integrating emerging priorities but also strengthens bottom-up schemes and makes work programmes less prescriptive. The Horizon 2020 option therefore responds better than the BAU and BAU+ 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 (see Chapter 1 for full details). 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 BAU 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 the Horizon 2020 option's potential in terms of time and money saved by applicants and participants 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 BAU 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 BAU 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 BAU and BAU+ 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.

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

5.3. EU research and innovation programmes involve large numbers of SMEs:

- About 11,200 SMEs (16.9% of total) participated in FP6. Some 7,000 individual SMEs have so far participated in FP7. If current trends continue, 20,000 SMEs will have received €6 billion of FP7 funding (+/- 11% of the total) by the end of the programme. 14.4% of the 'Cooperation' collaborative research budget (€1.77 billion) has been granted to SMEs during the first 4 years of FP7 (2007-2010). SME dedicated calls are expected to increase the EU contribution to SMEs towards the 15% target set by the FP7 Decision. Some thematic priorities like 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; approx. 30% seeks exploitation opportunities and translates research results into products and services; more than 40% conduct technology intelligence and networking activities, not being positive about marketable results. 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).

See Annex 1

Coherence in terms of knowledge triangle and broader horizontal policy coordination

As demonstrated by ex-post evaluations, under the BAU option, knowledge triangle coordination is weak: research, innovation, and researcher training and skills development are the subject of 3 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 BAU 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 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 SET-plan. Because of these reasons, the Horizon 2020 option responds best to demands from all types of stakeholders for closer knowledge triangle and broader horizontal policy coordination (see Chapter 1 for full details).

Structuring and leverage effects

The BAU option produces strong structuring effects (permanent changes in the European R&D landscape, see Annex 1 for details) 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 like 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 BAU option produces very strong scientific and technological impacts and substantial innovation impacts (see Box 9 and Annex 1). 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" in a number of ways: by increasing the emphasis on research project output; by pro-actively 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 industrial ones, 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 (see Chapter 1 for full details).

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 for 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. This situation has even worsened since the financial crisis in 2008/2009. Therefore the RSFF fills in 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 demonstrate that they have acted as a cornerstone investor in 17 venture capital funds leveraging €1.3 billion of total investment in growth-oriented SMEs. The leverage effect of the GIF, 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 economics literature has demonstrated that public subsidies for R&D produce crowding-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 (Annex 2).
- An econometric analysis of Community Innovation Survey micro-data carried out by JRC in collaboration with DG Research & Innovation has concluded that FP support has a crowding-in effect on the level of companies' R&D investments (Box 8).
- These findings are confirmed by a wide range of ex-post evaluations:
  - The Clean Sky Joint Technology Initiative mobilises about €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 €10-20 million via involvement in supporting fund raising activities.
  - A recent external evaluation of EIT suggests that the overall leverage effect of its KIC funding will be between 4 and 5 to 1 (€1 of EIT funding produces €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.
  - 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: €1 of FP funding resulted in €10 of coordinated research funding.
- A survey among FP6-IST programme participants (WING, 2009) showed that about two thirds (~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 €528 million, of which only €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 safety assessment of nuclear power plants. With an EU contribution of just €5.75 million out of a total budget of €38 million it generates for each €1 FP funding more than €6 additional research funding.

See Annex 1 for additional evidence on leverage effects

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 focused on complex, long-term, risky exploration rather 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 micro-economic benefits. These innovation impacts were assessed on the basis of the following range of evidence:

National evaluations of EU programmes (Box 6)

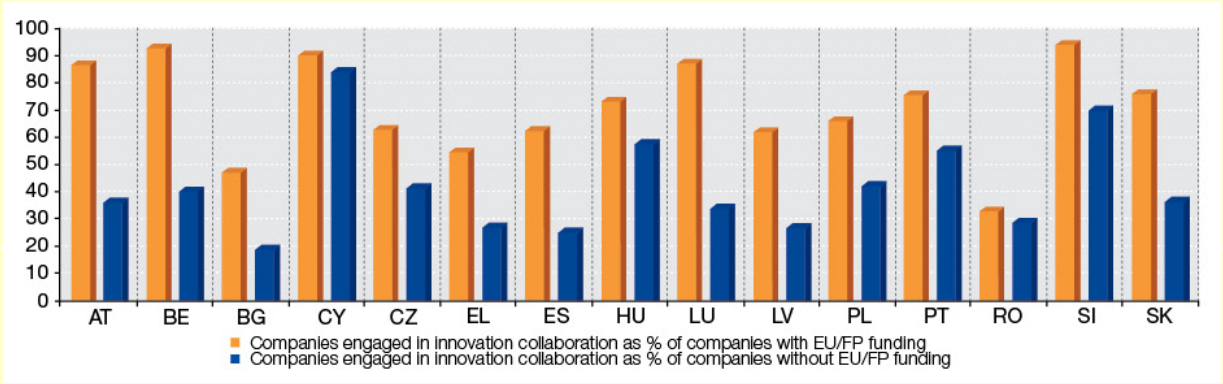
Cross-cutting EC ex-post evaluations of EU programmes

- For instance, according to the FP5&6 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 of such outputs; 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 instance, according to an FP6-wide survey (IDEA Consult, 2009c), industrial organisations clearly expected commercial returns. Almost half of them (47 percent) stated they were likely to very likely, and 60 percent of this group expected these returns within 2 years (90 percent within 5 years).

Statistical and econometric analyses of Community Innovation Survey micro-data

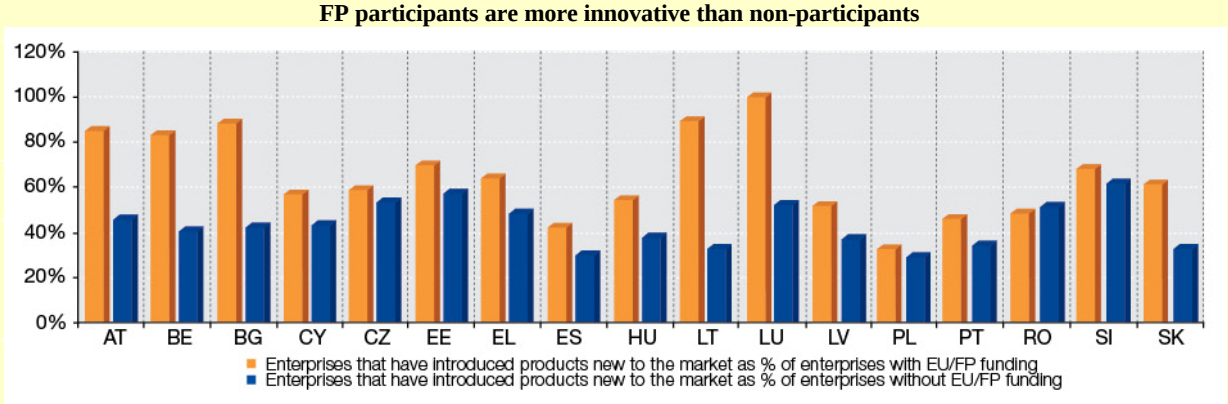
- In collaboration with DG Research & Innovation, JRC carried out a dedicated analysis of micro-data for 13 Member States available from the third round of the Community Innovation Survey. Data of the fourth and fifth rounds were of insufficient quality. Through a multi-equation model, the impact was assessed of FP funding on company R&D expenditure, on research and innovation collaboration, and on innovation. 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) both also at national and, more strongly, at international (beyond Europe) levels.
- In addition, Eurostat carried out in collaboration with DG Research & Innovation 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 below.

FP Participants collaborate more than non-participants



Source: Eurostat – Note: Data concern manufacturing sector

FP participants are more innovative than non-participants



Source: Eurostat – Note: Data concern manufacturing sector

Economic and competitiveness impacts

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 BAU option produces strong economic and competitiveness impacts, which through slightly better innovation impacts are slightly enhanced under the BAU+ 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 macro-economic effects over and above the BAU option by 2030: +0.53 percent for GDP, +0.79 percent for exports, and -0.10 percent 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 percent (0.53+0.39) of GDP, 1.37 percent (0.79+0.58) of exports and -0.15 percent (0.10+0.05) of imports.

Social, environmental and EU policy impacts

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 BAU option produces strong social, environmental and EU policy impacts. As for social impacts, according to a survey among FP5-7 project coordinators in the area of "Food, Agriculture and Fisheries, and Biotechnology" research,

close to 5 percent of all projects resulted directly in the creation of a new company. 82 percent of all projects created jobs for the duration of the project and 35 percent of all projects created new jobs after the end of the project. 38 percent 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 1200 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 (Forfas, 2009), 80 percent 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 a 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 (European Commission, 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 co-operation, role of SMEs.

The clearest environmental impacts are produced by FP-funded environmental research. According to an EC-commissioned evaluation of FP6 environmental research (EPEC, 2008), for instance, EU environmental research contributed to the knowledge base and development of methods and tools for environment related policy. The study found, for instance, 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 2004-2010 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 policy-making through the use of their outcomes by stakeholders such as IPCC and WMO. Yet other kinds of FP-funded research also produce clear environmental impacts. According to a FP6-wide participation survey (IDEA Consult, 2009c), for instance, 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 (Forfas, 2009), for instance, 50 percent 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 instance, point to strong employment effects – +0.21 percent - over and above the BAU 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) percent of 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 assures best 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.

Box 10: Assessing the macro-economic impacts of EU research and innovation programmes

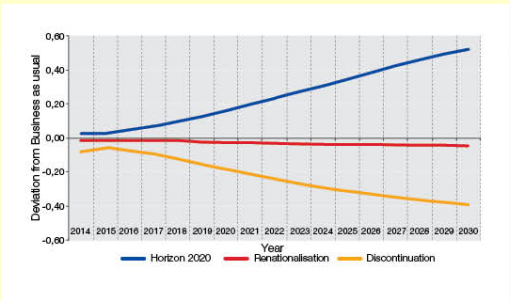
The aggregate macro-economic impacts of an expenditure programme can be assessed by making use of a mathematical model based on known, inferred, and assumed parameters. Over the past few years, the use of mathematical models for the ex-ant evaluation of policy effects increased significantly within the 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 macro-econometric model built by a Commission-funded consortium of European research institutes under the 5th Framework Programme. Nemesis has also been used by the Commission for the ex-ante impact assessment of FP7 and for assessing the macro-economic impacts of achieving the 3 percent objective, by the OECD, by a number of French government institutions, etc. For the Horizon 2020 impact assessment exercise, DG Research & Innovation developed in collaboration with the DEMETER consortium running Nemesis a number of scenarios including the Horizon 2020, renationalisation and discontinuation scenarios. The DEMETER consortium produced for each of these scenarios results on GDP, exports, imports, and employment through 2030 compared to the business-as-usual scenario. These results are presented in the figures below. 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 BAU.

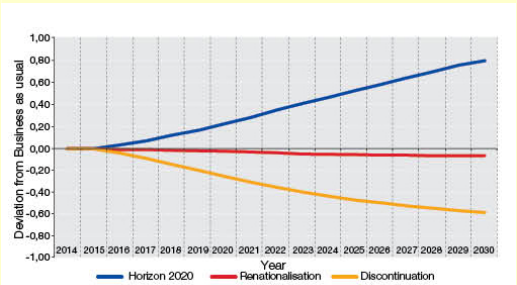
The OECD model was developed originally by Guellec and Van Pottelsberghe (2004) to assess the effect of public, business and foreign- performed R&D on the growth of total factor productivity (TFP) of industry. This model has been adapted by the Joint Research Centre in Ispra to estimate the effects of the Sixth and Seventh Framework Programmes on the growth of total factor productivity of the EU and associate countries. Results indicate that every 1€ invested by the FP generates on average 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 DG Economic and Financial Affairs of the European Commission. 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. Under assumptions 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 combined this with efforts to close the high-skilled education expenditure gap, then the resulting impact is an extra 2.34% of GDP by 2050, converging on a long run steady state addition of 5.64% of GDP.

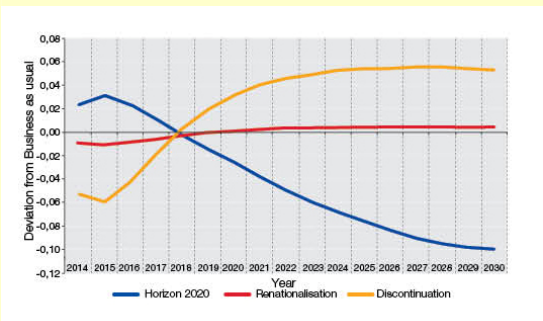
Impact of the different options on GDP



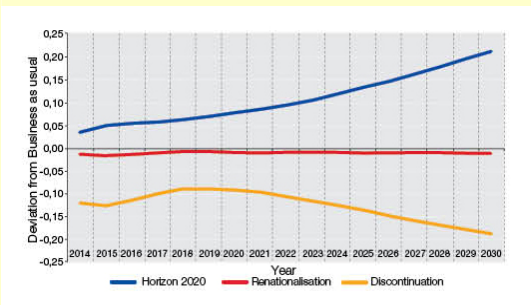
Impact of the different options on Exports



Impact of the different options on Imports



Impact of the different options on Employment



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 the period 2014 to 2020, and projected future outlays for 2021-2030. 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 on the Rules for Participation). These costs were considered for the scenarios BAU/BAU+ 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 of the different options (see separate impact assessment on 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 include also 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 on 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:

- 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, the 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 levels of administrative costs for the Commission; and reducing the administrative burden for participants, significantly improving accessibility

- Offer greater coherence by enhancing the coordination of 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 link closely with the objectives, and in particular to increase the 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 rationalise and simplify 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 (for example, 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 indentified and that the instruments may adapt over time to increase their 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.

5.4. 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 BAU+, Horizon 2020, and renationalisation options with the BAU option.

Compared to the BAU, option, the Horizon 2020 option would have clarity of focus and benefit from a well-developed intervention logic. Like the business-as-usual option, it 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 improve significantly 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, a stronger output orientation, a better dissemination of research results, clearer technological objectives, enhanced industrial and SME participation and thus enhanced leverage, the funding of demonstration activities, and the 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.

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

Dimension	BAU+	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)

Notes: (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.

The BAU+ option would allow for some alignment of objectives and achieve a certain measure of measure of simplification producing positive 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.

5.5. Details on the implementation of Horizon 2020

Structured around 3 priorities

As mentioned in the previous chapter, Horizon 2020 is structured around three complementary and interlinked priorities: (1) Excellent Science; (2) Industrial Leadership; (3) Societal Challenges:

- Raising and spreading the levels of "**Excellent Science**" is necessary to underpin future EU competitiveness and wellbeing. This block is designed to meet the needs of the scientific community, and to develop talent within Europe and attract leading researchers to Europe. The priorities will be largely identified by scientists. This block shall cover (i) the European Research Council; (ii) Future and emerging technologies; (iii) Marie Curie actions; and (iv) Research infrastructures. These instruments have so far produced clear European added value and high impact. Their added value derives from: EU-wide competition for excellence; the pooling of pan-European knowledge and financial resources so as to achieve critical mass in the construction, exploitation and transnational use of (new) research infrastructures; and the efficient organisation of large-scale cross-border and cross-sectoral researcher mobility. All instruments respond to the Innovation Union political commitments, and aim at creating an attractive and world class research base in Europe.
- "**Industrial Leadership**" should support entrepreneurs and innovative companies focusing on research and innovation to achieve industrial leadership in key enabling technologies. It will also address important market failures such as private sector under-investment in R&D and insufficient financing for growth of innovative SMEs and for early stage eco-innovative companies in Europe through the following actions: (a) Leadership in enabling and industrial technologies of ICT, nanotechnology, advanced materials, biotechnology, advanced manufacturing and processing and space; (b) Access to risk finance; (c) Innovation in SMEs. This block will be designed to boost industrial competitiveness by stimulating the business and SME community towards more innovation efforts including by developing a strategic alignment between EU and private resources (e.g. through Joint Technology Initiatives). The new debt and equity financial instruments (designed in compliance with EU debt and equity platforms) will play a key role in leveraging private commitments. Available for the implementation of all parts of Horizon 2020, as well as for any EU policy with a research and innovation dimension, these financial instruments will also be supported by a set of accompanying measures in view of creating a more innovation and investment-friendly ecosystem.
- Focusing resources for "**Societal Challenges**" responds directly to the major challenges identified in the Europe 2020 strategy and flagship initiatives. This block will support activities from research to market, including: R&D projects, applications of key technologies (e.g. ICT, bio, nano), pilot and demonstration projects, market uptake and replication projects, public procurement of innovative products, processes and services, appropriate support for standardisation and regulatory activities as well as innovation inducement prizes. EU-level action is imperative in order to build the **critical mass** of resources and competences required for addressing the pan-European and often global

challenges, to bring together the necessary broad range of actors (governments, business, academia, users) from different countries, sectors and perspectives, and to link closely to EU policies. To maximise impact there will be a strict focus on a limited number of major challenges that "speak" to the citizen. The research and innovation agendas compiled to meet these challenges must serve the policy objectives at EU level (energy, transport, health, environment, etc.). Where appropriate, efforts will be pooled with Member States, international and/or private partners. The European Institute of Innovation and Technology (EIT) will pool together with different initiatives funded under Horizon 2020 to enhance the synergies and impact of the EU action.

In addition, to these three priorities, Horizon 2020 comprises two additional parts supporting those three priorities: JRC non-nuclear direct actions and EIT.

Focused on 6 societal challenges

In particular in its priority "Societal Challenges", Horizon 2020 will focus on the resolution of six societal challenges: (i) health, demographic change and wellbeing; (ii) food security, sustainable agriculture, marine and maritime research and the bio-economy; (iii) secure, clean and efficient energy; (iv) smart, green and integrated transport; (v) climate action, resource efficiency and raw materials; and (vi) inclusive, innovative and secure societies.

These societal challenges have been identified on the basis of the following criteria: (1) corresponding to the major challenges facing Europe as identified in Europe 2020 and the MFF Communication on the basis of sectoral policy analyses, and lending clarity and visibility to EU intervention; (2) corresponding to the concerns of Europe's citizens and being understandable by them; (3) corresponding to demands expressed by Member States as well as other public and private actors of the European R&I system; and (5) balancing continuity and change, investing in areas of strength and investing in areas of relative weakness where Europe has to catch up (i.e. European R&I weakness with regard to competitors), alignment and complementarity with the priorities of the Member States. This identification thus builds on the interim and ex-post evaluations of Community interventions, and on analyses of the strengths and weaknesses of European R&I across disciplines and S&T domains, and is set in the context of the Europe 2020 strategy.

With respect to previous and current programmes' thematic priorities, the differences are not necessarily in the basic coverage of scientific disciplines but in the inter-disciplinary articulation of the challenges; in the priorities which have changed within each broad area; and in the objectives-oriented research and innovation. Some domains (previous and current programmes' thematic priorities) will be scaled back, thanks to the integrated approach offered by the common framework, which enables to look at the full landscape of tools and interventions. Thus for instance the domain of cultural heritage will be downscaled in the programme. It is being taken up in Joint Programming activities. Other forms of intervention will be taken out altogether, based on in-depth interim (e.g. FP7) and ex-post (e.g. FP6) evaluations which have allowed to rethink and revise the support approach. This is the case for some forms of SMEs funding and for the Networks of Excellence.

Below we detail the content of each challenge as well as its associated objectives:

- *Health, demographic change and well-being*: The challenge is to improve the life-long health and well-being of all while maintaining economically sustainable care systems. EU objectives will focus on disease prevention through the development of effective preventive tools (e.g. vaccines), effective health and disease surveillance and preparedness, and effective screening programmes. This will enhance effective health

promotion, supported by a robust evidence base, which improves well-being and is cost effective. There will be support for activities aiming at understanding disease and improving diagnosis in order to better prevent, manage, treat and cure diseases. Effective data-sharing with strong international focus and linking data with large-scale cohort studies will be essential, as will be the translation of research findings into the clinic, in particular through the conduct of clinical trials. Efforts will be deployed to improve decision-making in prevention and treatment, to identify and support the dissemination of best practices in the health and care sectors, and to support integrated care and the wide uptake of technological and organisational innovations empowering in particular older persons as well as disabled persons to remain active and independent. Doing so will contribute to increasing, and lengthening the duration of, their physical, social, and mental well-being.

- *Food security, sustainable agriculture, marine and maritime research and the bio-economy*: The challenge is to secure sustainable supplies of safe and high-quality food and other bio-based products, by providing productive, resource-efficient and resilient production systems, while accelerating the conversion towards low-carbon, resource-efficient and sustainable bio-based European industries. EU activities will be focused on: "Sustainable Agriculture and Forestry", aiming for more productive, resource-efficient and resilient agriculture and forestry systems in order to supply sufficient food and bio-materials without compromising natural resources; "Safe and Sustainable Food and Healthy Diets", aiming to meet the demands of citizens for safe, healthy and affordable food, and to make the food and feed industry more sustainable and more competitive; "Unlocking the Potential of Aquatic Living Resources", aiming to optimise the contribution to secure food supplies by developing sustainable and environmentally friendly fisheries and competitive European aquaculture in the context of the global economy and to boost marine innovation through biotechnology to fuel smart "blue" growth; and "Sustainable and Competitive Bio-based Industries", aiming to promote low carbon, resource efficient, sustainable and competitive European bio-based industries. Specific objectives are to transforming conventional industrial processes and products into bio-based resource and energy efficient ones, the development of integrated biorefineries, utilising biomass from primary production, biowaste and bio-based industry by-products, and opening new markets through supporting standardisation, regulatory and demonstration/field trial activities and others.

- *Secure, clean and efficient energy*: The challenge is to ensure the transition to a reliable, sustainable and competitive energy system, in the face of increasing resource scarcity, increasing energy needs and climate change. This will be achieved through several broad lines of actions: "Reduction of energy consumption and carbon footprint through smart and sustainable usage" will consist of research and testing at full scale of new concepts, non-technological solutions, more efficient and affordable technology components and systems with in-built intelligence, to allow real time energy management for near zero emission buildings, renewable heating and cooling, highly efficient industries and mass take up of energy efficiency solutions, as well as fostering EU smart cities; "Low cost, low carbon electricity supply & single European electricity grid" will consist of the development of innovative renewables and carbon capture and storage technologies of larger scale, lower cost and environmentally safe, as well as new, smart electricity grid technologies, systems and market designs to plan, monitor, control and safely operate interoperable networks in an open and competitive market; "Alternative fuels and mobile energy sources" will aim to make bio-energy more competitive and sustainable, to reduce time-to-market of hydrogen and fuel cells and to bring new options with long term

potential to maturity. In addition, there will be support for multi-disciplinarily research for future and emerging energy technologies and joint realisation of pan-European research programmes and world-class facilities as well as support of socio-economic research for public acceptance and engagement, user involvement and economic, social and environmental sustainability; development of tools, and methods and models for a robust and transparent policy support.

- *Smart, green and integrated transport*: The challenge is to achieve a European transport system that is resource-efficient, environmentally-friendly, safe and seamless for the benefit of citizens, the economy and society. The purpose of EU support is to minimise transport's impact on climate and the environment by improving its efficiency in the use of natural resources, and by reducing its dependence on fossil fuels through specific objectives like reducing resource consumption and greenhouse gas emissions and improving vehicle efficiency; accelerating the development and deployment of a new generation of electric and other low or zero emission vehicles, including through breakthroughs in engines, batteries and infrastructure; exploring and exploiting the potential of alternative fuels; optimising the use of infrastructures, by means of intelligent transport systems and smart equipment; and increasing the use of demand management and public transport, particularly in urban areas. Another EU objective is to reconcile growing mobility needs with improved transport fluidity, through innovative solutions for seamless, inclusive, safe, secure and robust transport systems and specific objectives like reducing congestion, improving accessibility and matching user needs by promoting integrated door-to-door transport and logistics; enhancing inter-modality and the deployment of smart planning and management solutions; and drastically reducing the occurrence of accidents. Another objective is to reinforce the competitiveness and performance of European transport industries through specific objectives like developing the next generation of innovative transport means and preparing the ground for the following one and working on novel concepts and designs, smart control systems and interoperable standards, efficient production processes, shorter development times and reduced lifecycle costs. Horizon 2020 will also support improved policy making which is necessary to promote innovation and meet the challenges raised by transport. Specific objectives are to improve the understanding of transport related socio-economic trends and prospects, and provide policy makers with evidence-based data and analyses.

- *Climate action, resource efficiency and raw materials*: The challenge is to achieve a resource efficient and climate change resilient economy that meets the needs of a growing global population within the natural limits of a finite planet. Tackling this challenge will focus on the development of climate change adaptation and mitigation measures through the generation of evidence for informed, early and effective action and the networking of the required competences. Specific objectives will focus on: improving the understanding of climate change and the provision of reliable climate projections; assessing impacts, vulnerabilities and developing innovative cost-effective adaptation measures; supporting mitigation policies. Another objective will be to provide knowledge for the management of natural resources that achieves a sustainable balance between limited resources and the needs of society. Specific objectives will focus on: furthering our understanding of the functioning of ecosystems, their interactions with social systems and their role in sustaining the economy and human well-being; and providing knowledge and tools for effective decision making and public engagement. EU action will also try to provide innovative solutions for a sustainable supply of raw materials and for their substitution by economically attractive alternatives. Specific objectives will focus on: improving the understanding of the availability of raw materials; promoting their sustainable supply and

use; and finding alternatives for critical raw materials. All forms of eco-innovation that enable the transition to a green economy will be supported. Specific objectives will focus on: strengthening eco-innovative technologies, services and products and enhancing their market uptake; supporting innovative policies and societal change; measuring and assessing progress towards a green economy; and fostering resource efficiency through digital systems. The last objective is to ensure the delivery of the long-term data and information required to address this challenge, i.e. data infrastructures for earth observation and monitoring that provide timely, accurate information, forecasts and projections. Free, open and unrestricted access to interoperable data will be encouraged.

- *Inclusive, innovative and secure societies*: The challenge is to foster inclusive, innovative and secure European societies in a context of unprecedented transformations and growing global interdependencies. The objective of "Inclusive societies" is to support policymakers in designing policies that prevent the increase in inequalities as well as the development of various forms of divisions in European societies and with other world regions. This will be achieved through: building resilient and integrative societies in Europe; generating smart, sustainable and inclusive growth; closing the research and innovation divide in Europe; strengthening Europe's role as a global actor; and promoting digital inclusiveness. The objective of "Innovative societies" is to foster the development of innovative societies and policies in Europe through the engagement of citizens and users in R&I and the promotion of coordinated R&I policies in the context of globalisation. This will be achieved through: support social and user-driven innovation and creativity; promote smart digital public services in Europe; strengthen the evidence base for the Innovation Union and the European Research Area; and promote coherent and effective cooperation with third countries. The objective of "Secure societies" is to support EU policies for internal and external security and to ensure cyber security, trust and privacy in the Digital Single Market. This will be done by developing solutions that address security gaps and lead to the prevention of security threats. Specific objectives are to: prevent and combat serious and organised crime; increase the security of infrastructures and utilities; fighting crime and terrorism; manage crises and disasters; integrate civilian and military capabilities; increasing trust in digital societies and tackle cyber security; and coordinate and structure the research security area in Europe.

Allocating financial resources optimally

Under Horizon 2020, only those kinds of activities will be supported that have passed the European added value test. Under the proposal on the next MFF (EC, 2011e), the funding for Horizon 2020 amounts to €80 billion (constant 2011 prices), which represents a 46 percent increase with respect to comparable funding under the MFF 2007-2013 (constant 2011 prices). The allocation of the Horizon 2020 budget across its three priorities and two additional parts is closely linked to the achievement of the aforementioned objectives. The largest share of the Horizon 2020 budget, between 40 and 50 percent, will be assigned to "Societal Challenges". The reason is that this priority contributes most directly to the achievement of the Europe 2020 objectives, that investment in applied research tightly focused on societal challenges will generate the quickest and broadest societal and economic returns, and that this priority meets most explicitly the short- to medium-term concerns of Europe's citizens, its Member States, and the EU. The feasibility of allocating a much larger share of the budget (60-70 percent) to "Societal Challenges" was considered but rejected since this would negatively affect Europe's generic long-term (basic research) and short-term (applied research) research and innovation capabilities and therefore the achievement of the

objectives "Strengthen Europe's science base" and "Boost Europe's industrial competitiveness through promoting technological leadership and getting good ideas to market".

The remainder of the budget will be divided more or less equally between the highly complementary "Excellent Science" and "Industrial Leadership" priorities, and therefore between intricately linked basic research and generic applied research, and between closely associated scientific excellence and industrial innovation and competitiveness, strengthening the whole innovation cycle. The feasibility of favouring one of those two tightly related priorities over the other in terms of budget share was considered but rejected since capabilities have to be balanced across the whole innovation cycle. Favouring "Excellent Science" over "Industrial Leadership" would compromise Europe's shorter-term innovation capabilities while the reverse would negative affect Europe's longer-term competitiveness.

As regards the allocation of the Horizon 2020 budget within each priority, this has been based on the following carefully considered criteria. Investment is focused on those activities and areas that have the greatest potential in terms of (1) quickly improving the everyday lives of European citizens and maximising value for money; (2) rapidly reducing escalating costs for European citizens, businesses and governments (e.g. health care, energy); (3) swiftly creating new market and employment opportunities for European businesses and citizens; (4) improving Europe's investment and performance position with respect to established and emerging competitors and maximising synergies with the Member States; (5) addressing problems of research and innovation fragmentation and lack of critical mass and maximising economies of scale, scope and complementarity; (6) leveraging public and private resources; (7) addressing specific research and innovation financing needs (e.g. to bridge the so-called "valley of death"); and (8) reducing over-subscription rates.

From research to innovation, from idea to market - Providing "seamless support"

Innovation is a complex, diversified activity with many interacting components. Many attempts have been made to construct models to shed light on the way innovation is generated within firms, and how it is influenced by what goes on outside firms. One useful approach is the “chain-link model” (Kline and Rosenberg), which conceptualises innovation in terms of interaction between market opportunities and the firm’s knowledge base and capabilities. Each broad function involves a number of sub-processes, and their outcomes are highly uncertain. Accordingly, there is no simple progression; it is often necessary to go back to earlier stages in order to overcome difficulties in development. This means feedback between all parts of the process. A key element in determining the success (or failure) of an innovation project is the extent to which firms manage to maintain effective links between phases of the innovation process: the model emphasizes, for instance, the central importance of continuous interaction between marketing and the invention/design stages. In the chain-link model, research is viewed not as a source of inventive ideas but as a form of problem-solving, to be called upon at any point. When problems arise in the innovation process, as they are bound to do, a firm draws on its knowledge base at that particular time, which is made up of earlier research findings and technical and practical experience. The research system takes up the difficulties which cannot be settled with the existing knowledge base, and so extends it if successful.

In Horizon 2020, the "seamless support from research to innovation, from idea to market" is operationalised through a number of flexible funding schemes (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) that, compared to current EU interventions in the field of research and

innovation, increase the emphasis on research project output; pro-actively support research result dissemination, demonstration, and piloting; strengthen support for market take-up; fund projects that cover a number of stages in the innovation chain; support SME research and innovation throughout; and comprise supply as well as demand measures:

- *Research and innovation grant*: funding in order to undertake projects of all sizes and types. The project may cover all or some parts of the full range of research and innovation activities, including fundamental research, industrial R&D, training, mobility and career development, prototyping and design, dissemination, demonstration, pilots, testing and user involvement, market replication, support to research and innovation infrastructures, standard setting, networking and coordination. [It may be used to support programmatic approaches which would combine some or all of the activities mentioned above and which would include consortia selecting, on a competitive basis, the appropriate third parties to carry out part or all of these activities note – subject to legal check]. It may also include funding to support public procurement contracting authorities to undertake pre-commercial procurement or public procurement of innovative solutions (as defined below), including co-funding the budget of specific calls that have a high EU added value. Research and innovation grants shall be the principal funding scheme in Horizon 2020. They may be used to target specific categories of participants such as SMEs or participants from third countries.
- *Training and mobility grant*: funding to single beneficiaries, funding bodies or trans-national consortia to undertake projects or activities specifically relating to training, mobility and career development of researchers. This funding scheme shall be used in particular for the implementation of the Marie Curie Actions.
- *Programme co-funding*: funding to bodies managing research and innovation programmes. The activities to be supported include networking and coordination between programmes in different countries, as well as co-funding the budget of specific calls and actions that have a trans-national nature. The types of programmes may include: R&D programmes, innovation support services, researcher training, mobility and career development programmes. Programme co-funding may be used to support public-public partnerships and programme level cooperation with third countries or programmes managed by international organisations.
- *Coordination and support grant*: funding for accompanying measures, notably: dissemination, awareness raising and communication actions; networking, coordination or support services; policy dialogues and mutual learning exercises and expert support (for instance for evaluation, assessment or review), studies (including design studies for new infrastructure).
- *Debt finance and equity investments*: in research and innovation, as set out in Annex I under "access to risk capital".
- *Prizes*: Prizes may take the form either of a reward for past achievements or of inducement prizes to be awarded for the achievement of a pre-specified target.
- *Procurement*: contracts in order to obtain, against payment of a price the supply of movable or immovable assets, the execution of works or the provision of services. This may include: (1) Public pre-commercial procurement, which is an approach to procuring R&D services which involves risk-benefit sharing under market conditions, and competitive development in phases, where there is a separation of the R&D phase from deployment of commercial volumes of end-products; (2) Public procurement of innovative solutions, which refers to the case where contracting authorities act as a launch

customer for innovative goods or services which are not yet available on a large-scale commercial basis, and may include conformance testing.

In the design of these instruments, special attention has been paid to the consistency between the objectives pursued and the eligibility criteria and other conditionality provisions for participation analysed in the other IA report on the Rules for Participation.

Linking with other policies

The Commission Communication on the next MFF, EU's future financial framework, has underlined that boosting research and innovation performance is the only way for Europe to support sustainable growth and create good and well-paid jobs that will withstand the pressures of globalization. Horizon 2020 will bring together all EU research and innovation-related instruments in an overarching integrated framework with a single set of Rules for Participation. Horizon 2020 has clear links with other major EU programmes and multiple interfaces are envisaged.

Horizon 2020 intends to make participation in EU research and innovation programmes more simple and attractive, in particular for small and medium sized enterprises (SMEs), facilitate their access to financing and help them ultimately bring the fruits of their innovation to market. As such, there are close links between Horizon 2020 and the proposed new programme for **European Competitiveness and SMEs**. The National Contact Points for SMEs will be built into the Enterprise Europe Network and facilitate diffusion of information as well as collection of feedback from participants and stakeholders. Sharing a broad concept of innovation underlying both Horizon 2020 and the European Competitiveness and SMEs programmes, the focus of the first one will be predominantly on innovative SMEs whereas the latter programme will target non-innovative SMEs.

With sustainable economic growth increasingly related to the capacity of regional economies to change and to innovate, future **Cohesion Policy** funds will put a much greater effort into creating a regional environment that encourages innovation and research and development through support for capacity building. The Cohesion policy funds will take forward the concept of "smart" specialisation and include measures aimed at creating a stairway to excellence for researchers, innovators, institutions and businesses. This will allow less favoured regions to fully engage with Horizon 2020 by enabling regional actors to enter transnational R&I collaborations. In return, these actors bring home new knowledge and access to new networks which will strengthen regional excellence and will facilitate regional research and innovation capacity building and strategy development. The R&I family of DGs will be closely involved in the development of both smart specialisation (through the Smart Specialisation Platform) and the implementation of the staircase to excellence through the detailed provisions of the programming documents, and notably the Operational Programmes. In addition, Horizon 2020 will complement these actions through targeted measures ensuring better coordination, cooperation and information exchange between the two EU funding programmes, for instance by promoting contacts between the National Contact Points for Horizon 2020 and the Structural Funds' Managing Authorities or by a more pro-active communication towards regional authorities on projects submitted and/or funded through Horizon 2020. Measures such as policy learning, networking and twinning schemes will enhance the connections between researchers, innovators and their institutions in all Member States and regions.

Stronger interfaces will also be developed with the future **Common Agricultural Policy**, where innovation is foreseen as an important component of rural development. The future Common Agricultural Policy of the EU continues with further reforms freeing up funds to

promote internationally competitive quality foodstuffs, innovation in farming and food processing, as well as sustainable rural development, including the diversification of rural economies. Horizon 2020 will support these policy objectives through funding research and innovation projects that support innovation in agriculture (such as finding way to use by-products of agricultural crops and waste products to produce energy), help find solutions to diseases, and make farming more environmentally friendly and more in line with consumers' preferences. Horizon 2020 will put in place take-up measures (e.g. dissemination) allowing to valorise better research results. Along the same lines, interfaces will also be reinforced with the **Common Fisheries Policy** which already contains specific elements for strengthening innovation.

Future **Education programmes** (e.g. mobility schemes, skills and competence development, life long learning, universities, doctoral programmes, etc.) will benefit from the potential to share implementation tasks (e.g. a one stop shop for mobility programmes) and an enhanced role for the EIT (with its mission of integrating education, research and innovation) within Horizon 2020.

Complementarities and synergies will be further developed with the **External policy instruments** (enlargement, neighbourhood and development) with the latter continuing to support capacity building that is necessary to enable third countries and regions to engage more effectively in collaborative research under Horizon 2020, particularly that addressing societal challenges of common interest.

The continuation with joint programmes under Article 185 of the Treaty, and joint undertakings under Article 187 of the Treaty under Horizon 2020, based on a clear set of criteria, will link existing programmes at **Member State level** with EU policies in the area of research and innovation. As they represent initiatives where Member States have jointly decided to pool their resources, Horizon 2020 will support Joint Programming Initiatives (JPI) in the development of their Strategic Research Agendas through coordination and support measures. Where the challenge addressed by a JPI is clearly in line with the priorities of Horizon 2020, its instruments may be used to provide further support, for instance through the ERA-NET scheme or through the co-funding of national programmes. New initiatives on the basis of Article 185 will only be considered when a JPI has demonstrated its capacity for significant collaboration and the necessary scale and scope to support the full integration of national programmes. Building on the experience of the Public Private Partnerships under the EU economic recovery plan, the possibilities for establishing such Partnerships without recourse to new legislative procedures has also been strengthened. This will allow such initiatives to be implemented in a streamlined manner while ensuring a greater clarity of roles and responsibilities.

5.6. 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 on the rules for participation). They will be crucial in reducing barriers-to-entry, especially for small and medium enterprises and for participants from the new Member States. It should thus bring in new capabilities and ideas, and reduce the concentration of participation and the rigidity of networks. It will have a positive impact on dissemination and valorisation. It will also help to 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 a scale and such a scope. Externalisation will be scaled up, with all that it entails in terms of locating premises, hiring staff, establishing procedures, and so on. 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 structural funds. Horizon 2020 does not cover education policies beyond the EIT. Nor does it cover IPR 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 researcher skill development should be coordinated not only with other knowledge triangle actors, policies, programmes and initiatives but also with sectoral ones, 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 instance, 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 the adaptability**: Horizon 2020 will run over seven 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 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, the implementation and the 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 above).

§ 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 the table below. Clear results targets will be set for each indicator - for example, X patent applications, or Y publications in high impact journals, per million € funding. (More details will be provided in the Legislative Financial Statement of the Horizon 2020 proposal.)

- **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 over-burden 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 at 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 above).

§ **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 a growing 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 in particular include the following elements:

§ The aforementioned key indicators will be analyzed in Annual Horizon 2020 Monitoring Reports, which will present key data and indicators on the implementation of Horizon 2020. This report 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 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.

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

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NOTES

[i] The graph is based upon GDP growth forecasts made by HSBC (The World in 2050 – Quantifying the Shift in the Global Economy, HSBC, 4 January 2011), and uses data from OECD and the World Bank. The "G7" is the group of seven industrialized nations: Canada, France, Germany, Italy, Japan, UK and the US; "E7" is a group of rapidly emerging economies: Brazil, China, India, Indonesia, Mexico, Russia and Turkey. The 3 scenarios are as follows (1) In 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 at 5%. (2) 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%. (3) The "Recovery" scenario assumes that G7 countries will - by 2020 - spend at least 3% of GDP into research 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.

[ii] 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 the left figure in Box 6. 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).

[iii] (1) For each technology field the graph shows on the X axis 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). (2) The broad technology domains are shown in bold.

[iv] Data for broad technology domains taken from a study by Research Division INCENTIM, MSI, Faculty of Business & Economics, KULeuven, Università Commerciale Luigi Bocconi, KITES); Data for enabling technologies taken from "European Competitiveness in Key Enabling Technologies" by 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), May 28th, 2010 (Study commissioned for European Commission DG Enterprise); All other data from OECD Patent Database.

[v] 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: Peter Bjørn Larsen, Els Van de Velde; Eveline Durinck, Henrik Noes Piester, Leif Jakobsen and Hanne Shapiro (2011), "Cross-sectoral Analysis of the Impact of International industrial Policy on Key Enabling Technologies", published by European Commission, DG Enterprise and Industry; M.C. Roco, C.A. Mirkin, and M.C. Hersam (eds.) (2010), "Nanotechnology Research Directions for Societal Needs in 2020 - Retrospective and Outlook", NSF, WTEC report, Springer, Berlin and Boston ; OECD (2008, 2009), "Inventory of National Science, Technology and Innovation Policies for Nanotechnology", OECD, Paris.

[vi] 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 instance, 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 instance, less emphasis on artificially large consortia.