EUROPEAN COMMISSION

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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

Annexes

{COM(2011) 808 final}
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ANNEXES

ANNEX 0: LIST OF BOXES PRESENTING COMPLEMENTARY INFORMATION ON CONCEPTS AND EVIDENCE USED IN THE REPORT

Box 1: European research and innovation programmes support scientific excellence

Excellence has been one of the main principles underlying EU research support, and one of the keys to its success has been its ability to attract top scientists, top institutions, and first-rate projects.

Attracting top scientists: European Union research programmes have always attracted top level researchers. FP funded scientists tend to have a better publication and citation performance than their non-FP peers (e.g. see European Policy Evaluation Consortium, 2009). The FP also helps to attract leading researchers who might otherwise have pursued their careers in the US. For example, two-thirds of the ERC's grant-holders in neurosciences have had post-doctoral experience in the US. Moreover, between 2008 and 2011, six of the 17 Europeans who were awarded prestigious research prizes were ERC grantees.

Attracting leading institutions: EU research and innovation programmes have also attracted the very best research institutions. The interim evaluation of FP7 concluded that ""the list of organisations that have obtained the largest amounts of funding from FP7 can be read as a Who's Who of European research quality".

- Leading universities: About half of top university participants in FP6 rank among the world's best 100 universities, and 94 percent rank among the world's best 400 universities (Academic Ranking of World Universities 2010).
- Top industrial performers: Compared to the average company in their sector, FP industrial participants are more R&D-intensive, more innovative, better networked and more focused on international markets, and patent more (Polt et al., 2008). 31 out of 34 European companies in the Top 100 R&D investing companies received funding under FP6.
- Excellent public research centres: The FP provides support to Europe's leading public research centres such as the Max Planck Gesellschaft, the Fraunhofer Gesellschaft, the CNRS and the Commissariat à l'Energie Atomique which occupy key positions in FP projects and networks.

Financing first-rate projects: FP proposals are peer-reviewed and scored according to three criteria: scientific excellence, project management quality, and potential impact. The mean score for 'scientific quality' was 4.4 out of 5 (minimum 4) and the mean sum for the three criteria was 13.1 out of 15. As a result, EU research is recognized as leading in a number of fields. For example this is the case in several environmental research areas (EPEC, 2008), where, according to peer reviewers, the impact of EU research is particularly high for projects in three areas: climate change, water and soils, and natural hazards. Not surprisingly, EU funded projects are also visible and influential in the top scientific literature. In 2010, at least one ERC funded project reported its findings in either Nature or Science every two weeks.

See Annex 1 for more detail on how EU research and innovation programmes support excellence

Box 2: EU research and innovation programmes produce value for money

The impact of public R&D is significant and widely documented (Annex 2). For example:

- Studies have shown that the rate of return for publicly funded R&D usually exceeds 30 percent, and that each extra 1 percent in public R&D generates an extra 0.17 percent in productivity growth.
- Estimates of the impact of UK Research Council spending suggest that a cut of £1 billion in annual spending would lead to a fall in GDP of £10 billion.
- Spending by the US National Institute of Health supported nearly 488,000 jobs and produced US$68 billion in new economic activity in 2010.

EU research programmes produce excellent value for money for the European taxpayer not only because they generate the significant impacts of public R&D outlined above, but also because EU projects are selected to have a higher impact than national public R&D support (see Box 9). Specific studies have examined the effects of EU funding and have demonstrated the following economic impacts:

- €1 of Framework Programme funding leads to an increase in industry added value of around €13.
- Member States' own evaluations demonstrate the high impact of the FP: the FP's annual contribution to, for instance, UK industrial output exceeds £3 billion.
- On the basis of econometric modelling, the long-term impact of FP7 has been estimated at an extra 0.96 percent of GDP, an extra 1.57 percent of exports, and a reduction of 0.88 percent in imports.
- The long-term employment impact of FP7 was estimated at 900,000 jobs, of which 300,000 in the field of research.
- The potential value added generated by eco-innovation pilot and market replication projects under CIP could be calculated in some € 3.4 million per million € invested (DG ENV, ref. Varma, 2007).

In addition, to these excellent economic returns, EU research actions have also generated major social and environmental impacts (Box 20 and 21).

See Annex 1 sections 2.10, 2.11, 2.12 for more details of how EU research actions offer value for money

Box 3: Assessing the leverage effects of EU research and innovation programmes

EU research and innovation programmes leverage private funding, 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 18).
- 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 multiplier effect of the FP7 Risk-Sharing Finance Facility, 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), 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) 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.
  - 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 4: Assessing the impact of the direct research actions of the Joint Research Centre

As the Commission's Directorate-General responsible for direct research, the JRC is known for its support to EU policies and its contributions to sustainable development, competitiveness and the security and safety of nuclear energy. It makes science more visible in the work of the Commission in support of more evidence-based policy processes.

To underpin proposals for its 2014-2020 programme the JRC prepared an impact report with a steering group of external experts, presenting new facts about the outcomes and impacts of the direct research actions of the JRC with:

- an analysis of the policy impact of JRC activities in 2010
- case studies of specific impact for long-term JRC support
- an estimate of JRC's economic impact
- expectations for future impact

The analysis of JRC internal output and impact data for the year 2010 shows that around 85% of the JRC actions achieved a verifiable tangible "policy impact". Roughly 75% of these impacts occur in the Commission and relate to EU policies.

The case studies in the report show JRC actions in selected examples achieving cost-benefit ratios from 1:40 up to as high as 1:250 (cf. annex 1 success stories).

The economic impact of the JRC is placed into the perspective of a recent study commissioned by the European Association of Research and Technology Organisations (EARTO), reporting that 275 RTOs in Europe with a combined annual turnover of around EUR 20 billion generate an estimated economic impact of the order of EUR 100 billion.

Cost-benefit ratios for the JRC are favourable and its return on investment is sizeable and significant. Nevertheless, the external experts place strong emphasise on the huge importance of the JRC's impact on intangible EU assets, such as enhanced human capital, knowledge creation and sharing, competitiveness from setting European standards, better policy decision making.

Regarding future impact of the JRC, the baseline is a scenario with permanent institutional support to EU policies leading to continued significant impact and return on investment in policy areas where science plays a sensitive role, i.e. in areas involving people's health, people's safety, the environment as well as the competitiveness of the European economy.

On top of this baseline, new activities will address priority areas in the Commission's flagship initiatives and generate relevant impacts for the achievement of the Europe 2020 strategy.

Developments giving rise to new environmental, economic and political situations beyond the Europe 2020 strategy cannot be predicted, but the experience is that the JRC is able to respond quickly and effectively to sudden events and crises. In these situations the JRC is likely to generate further impact through flexibility and quick response.

ANNEX 1: PAST ACHIEVEMENTS AND LESSONS LEARNED

This annex aims to provide an overview of the outputs, effects and impacts achieved by the Framework Programmes for Research and Technological Demonstration (FP), the Competitiveness and Innovation Programme (CIP), and the European Institute of Technology and Innovation (EIT). As required by the Commission's impact assessment guidelines, past FP achievements were discussed at length in the April 2005 ex-ante impact assessment accompanying the proposal on FP7. In order to avoid duplication, this annex focuses as far the FP is concerned in the first place on evidence produced since that date. For this reason, the evidence presented below pertains in particular to FP6 and FP7.

SUMMARY ON PAST ACHIEVEMENTS AND LESSONS LEARNED

The different programmes integrated into the Common Strategic Framework for Research and Innovation – the FP, the CIP and EIT - have achieved large impacts in the course of their history.

FP achievements

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

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

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

The FP has generated large numbers of patents and enabled participants to increase their turnover and profitability, raise their productivity, increase their market share, obtain access to new markets, reorient their commercial strategy, improve their competitive position, enhance their reputation and image, and reduce commercial risk. In addition, the results of FP direct and indirect actions have supported EU-level policy formulation.

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

The FP has produced so-called "structuring effects": durable changes in the EU research and innovation landscape. If it were not for the FP, the European Research Council, promoting excellence across Europe, would not have been created; the EU would then have been left with a landscape of 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 Marie Curie Actions, the EU has created the right framework for researchers' careers and free movement of knowledge. 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. Collaborative research projects, international cooperation actions, mobility actions, and research infrastructure actions have generated durable, cross-sectoral, inter-disciplinary research and innovation networks across Europe as well as with the world's most dynamic and fastest growing research nations that have remained alive after the end of EU funding. European Technology Platforms and ERA-NETs have served as useful focusing devices that have helped stakeholders identify and explain their R&D needs jointly, easing the process of developing mutually supportive policies at EU and Member State levels. Joint Technology Initiatives have focused and aligned key actors in their respective areas, serving as a support to develop coherent sectorial strategies. Article 185 and Joint Programming initiatives have achieved a better coordination of R&D in Europe and supported a more coherent use of resources.

CIP achievements

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

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

EIT achievements

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

While European research and innovation programmes have been successful, there are important lessons to be learned from the past, from stakeholder feedback, and from analytical studies. Research, innovation and education should be addressed in a more coordinated manner and in coherence with other policies and research results better disseminated and valorised into new products, processes and services. The intervention logic of EU support programmes should be developed in a more focused, concrete, detailed and transparent manner. Programme access should be improved and start-up, SME, industrial, EU12 and extra-EU participation increased. Monitoring and evaluation need to be strengthened (for details see section 3).

DETAILED EVIDENCE ON PAST ACHIEVEMENTS

THE FP ACHIEVES A VAST REACH

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

The case of collaborative research is illustrative. Collaborative research constitutes the largest component of the Framework Programme. It accounted for 70% of the budget under FP6 and accounts for 64% of the budget under FP7. A statistical analysis performed on shared-cost action participation data[1] across FPs shows that the FP funds large numbers of projects bringing together different types of participants from all Member States as well as from other countries.

- **The FP funds thousands of research projects and participations with critical mass:** From FP2 to FP5, the growth in the collaborative research budget was accompanied by increases in the number of collaborative research projects (from 2779 in FP2 to 6712 in FP5) and participations (from 13 000 to 44

000). As from FP6, more emphasis was put on achieving a 'critical mass' of resources within a project: fewer projects were funded but they became of a greater size than before. The average number of participations per project doubled (from 6.5 to 13) and the average Commission funding per project increased by 278%, from €1.4 million to €3.9 million. The average EU funding per participation also increased from € 196 000 to € 283 000. FP7 appears to maintain this trend towards larger projects with higher funding per project and per participation (Table1).

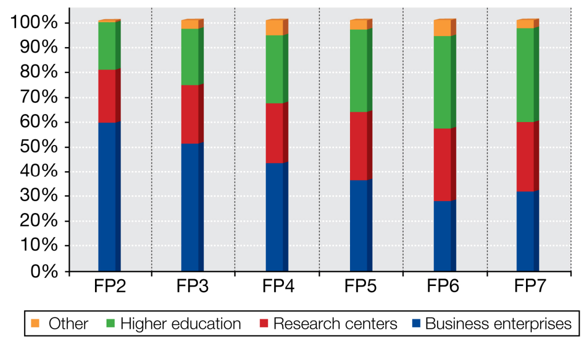
Table 1: The changing features of FP shared-cost research actions

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

Source: DG Research & Innovation

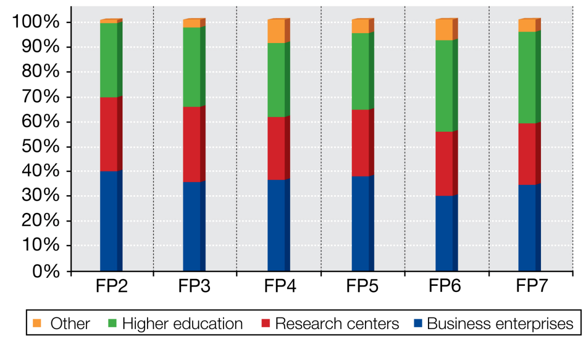
- **FP research funding and participations are allocated in a balanced manner to different types of research actors:** Available shared-cost action data show an increasingly balanced allocation of funding and participations to the different types of research actors: business enterprises, research centres,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

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



*Note: * Partial FP7 data (to 01.2011); Source: DG Research & Innovation*

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



*Note: * Partial FP7 data (to 01.2011); Source: DG Research & Innovation*

- **FP collaborative research actions involve a significant number of SMEs**

  SMEs accounted for 19.1% of FP7 shared cost action participations so far and 15.8% of FP7 shared cost funding disbursed so far (only MS). Among 'Private for profit' participants (mainly business enterprises), SMEs accounted for 49.5% of participations and 45.1% of funding. For shared cost actions, the 15 percent SME participation target appears to be achieved.

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

Table 2. FP6 and FP7 participations and funding by country

Countries		FP6				FP7*			
		Participations		FP funding		Participations		FP funding	
		No	%	mln €	%	No	%	mln €	%
Member States	DE - Germany	7.089	15,80%	2.338	19,17%	5.041	15,09%	1.954	18,1%
	UK - United Kingdom	5.146	11,47%	1.583	12,98%	3.600	10,78%	1.322	12,3%
	FR - France	5.007	11,16%	1.572	12,89%	3.378	10.1%	1.324	12,3%
	IT - Italy	4.344	9,68%	1.139	9,35%	3.243	9,71%	976	9,1%
	ES - Spain	2.915	6,50%	716	5,88%	2.218	6,60%	686	6,4%
	NL - Netherlands	2.562	5,71%	827	6,79%	1.953	5,85%	711	6,6%
	SE - Sweden	1.692	3,77%	533	4,37%	1.226	3,67%	432	4,0%
	BE - Belgium	1.645	3,67%	470	3,85%	1.516	4,54%	465	4,3%
	EL - Greece	1.434	3,20%	322	2,64%	1.013	3.00%	299	2,8%
	AT - Austria	1.208	2,69%	323	2,65%	900	2,69%	297	2,8%
	DK - Denmark	1.096	2,44%	303	2,49%	682	2,04%	253	2,4%
	PL - Poland	944	2,10%	141	1,16%	569	1,70%	114	1,1%
	FI - Finland	902	2,01%	264	2,16%	792	2,40%	284	2,6%
	PT - Portugal	683	1,52%	125	1,03%	532	1,59%	125	1,2%
	HU - Hungary	594	1,32%	99	0,81%	377	1,13%	65	0,6%
	CZ - Czech Republic	582	1,30%	91	0,75%	376	1,13%	67	0,6%
	IE - Ireland	447	1,00%	119	0,98%	398	1,19%	130	1,2%
	SI - Slovenia	310	0,69%	54	0,45%	249	0,75%	47	0,4%
	RO - Romania	237	0,53%	28	0,23%	286	0,86%	42	0,4%
	BG - Bulgaria	187	0,42%	23	0,19%	166	0,50%	20	0,2%
	SK - Slovakia	155	0,35%	21	0,17%	120	0,36%	20	0,2%
	EE - Estonia	146	0,33%	21	0,17%	120	0,36%	20	0,2%
	LT - Lithuania	131	0,29%	15	0,13%	101	0,30%	13	0,1%
	CY - Cyprus	102	0,23%	15	0,12%	92	0,28%	17	0,2%
	LV - Latvia	89	0,20%	12	0,10%	62	0,19%	7	0,1%
	LU - Luxembourg	73	0,16%	16	0,13%	55	0,16%	11	0,1%
	MT - Malta	37	0,08%	5	0,04%	44	0,13%	5	0,0%
	JRC	148	0,33%	29	0,24%	119	0,36%	33	0,3%
	Total Member States	39.757	88,59%	11.176	91,67%	29.109	87,13%	9.740	90,5%
Candidate Countries	HR - Croatia	63	0,14%	8	0,07%	78	0,23%	13	0,1%
	IS - Iceland	64	0,14%	18	0,15%	48	0,14%	11	0,1%
	MK - FYROM	33	0,07%	3	0,02%	29	0,09%	3	0,0%
	TR - Turkey	194	0,43%	31	0,25%	185	0,55%	30	0,3%
	Total Candidate Countries	354	0,79%	60	0,49%	340	1,02%	58	0,5%
Associated countries	CH - Switzerland	1.380	3,07%	336	2,76%	1.156	3,46%	420	3,9%
	IL - Israel	493	1,10%	147	1,20%	388	1,16%	142	1,3%
	NO - Norway	770	1,72%	211	1,73%	516	1,54%	180	1,7%
	Total Associated Countries	2.648	5,90%	695	5,70%	2.161	6,47%	755	7,0%
Third Countries	US - United States	113	0,25%	11	0,09%	166	0,50%	20	0,2%
	AU - Australia	58	0,13%	3	0,02%	69	0,21%	2	0,0%
	CA - Canada	66	0,15%	2	0,01%	68	0,20%	2	0,0%
	JP - Japan	16	0,04%	1	0,00%	26	0,08%	2	0,0%
	CN - China	224	0,50%	28	0,23%	153	0,46%	17	0,2%
	IN - India	66	0,15%	9	0,08%	125	0,37%	20	0,2%
	BR - Brazil	92	0,20%	12	0,09%	82	0,25%	12	0,1%
	RU - Russian Federation	263	0,59%	39	0,32%	203	0,61%	30	0,3%
	Rest of the world	1.186	2,64%	153	1,25%	908	2,72%	110	1,0%
	Total	**44.880**		**12.192**		**33.410**		**10.768**	

*Note: * Partial FP7 data (to 01.2011); Source: DG Research & Innovation*

- **The FP brings together participants from a large number of countries: EU Member States, associated countries and third countries: No less than 243 countries participated in FP6 including** 27 EU Member States, 5 Associated Countries, 3 Candidate Countries and 108 third countries from all continents. After the Member States and Associated Countries, the so-called BRIC countries (Brazil, Russia, India, China) accounted for most FP participations and funding (Table 2).

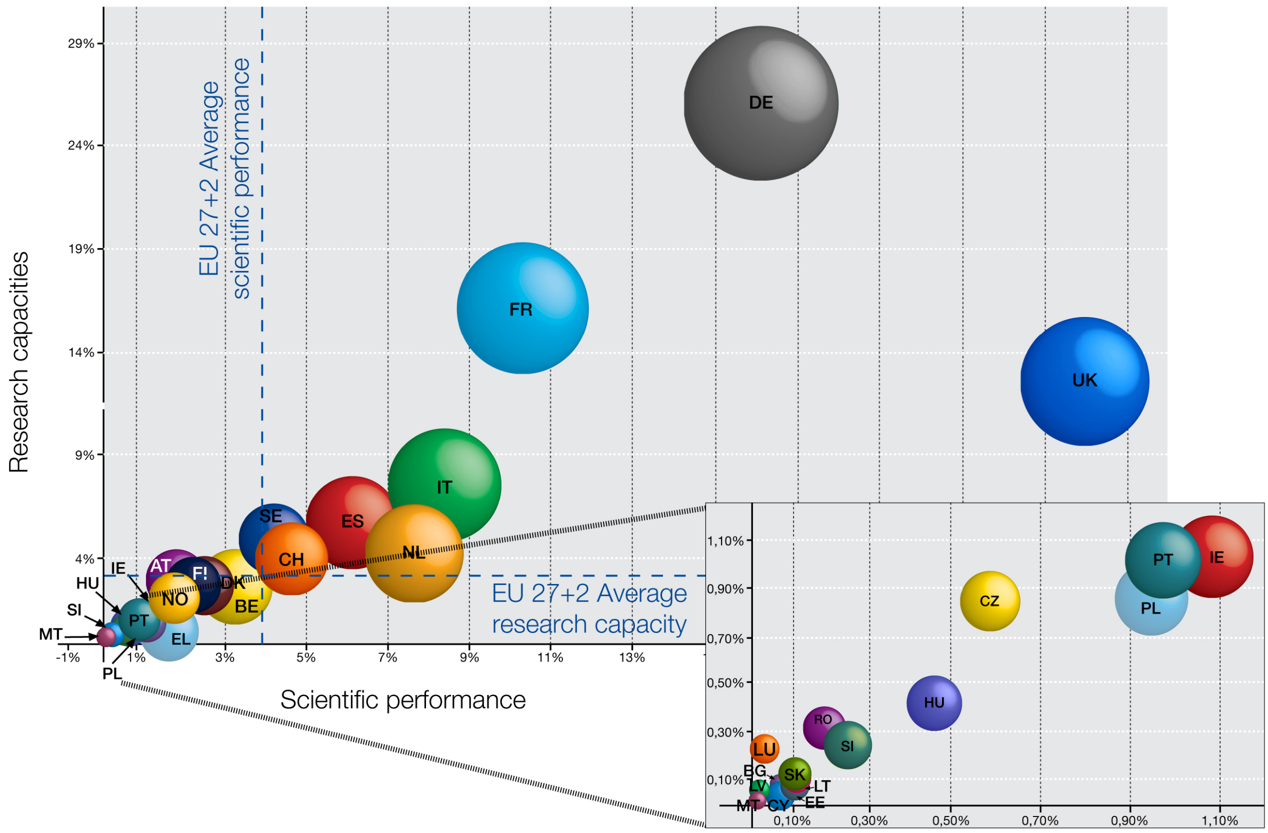
- **The FP brings together participants from a large number of regions:** FP6 funding reached 256 of the 271 EU27 Member State regions (NUTS 2 level), from Crete and Cyprus in the South to Lapland (FI) in the North and from Algarve (PT) to the Black Sea (RO).

- **The extent of involvement in the FP of individual EU Member States, associated countries, and EU regions is in line with their economic and research capabilities.**

  FP collaborative research funding is awarded on the basis of scientific excellence, not nationality, large economies with large research capabilities like Germany, France, the United Kingdom and Italy therefore account for the highest share of both FP funding and participations (Table 2, Figure 3). The opposite is true for smaller and new Member States, which do not have the research capabilities to absorb large amounts of FP funding. The statistical analysis shows that there is a very strong correlation (0,98) between the magnitude of FP funding received by a Member State and the size of its economy: the share of FP funding received by a country is in 96% related to its share of the EU GDP.

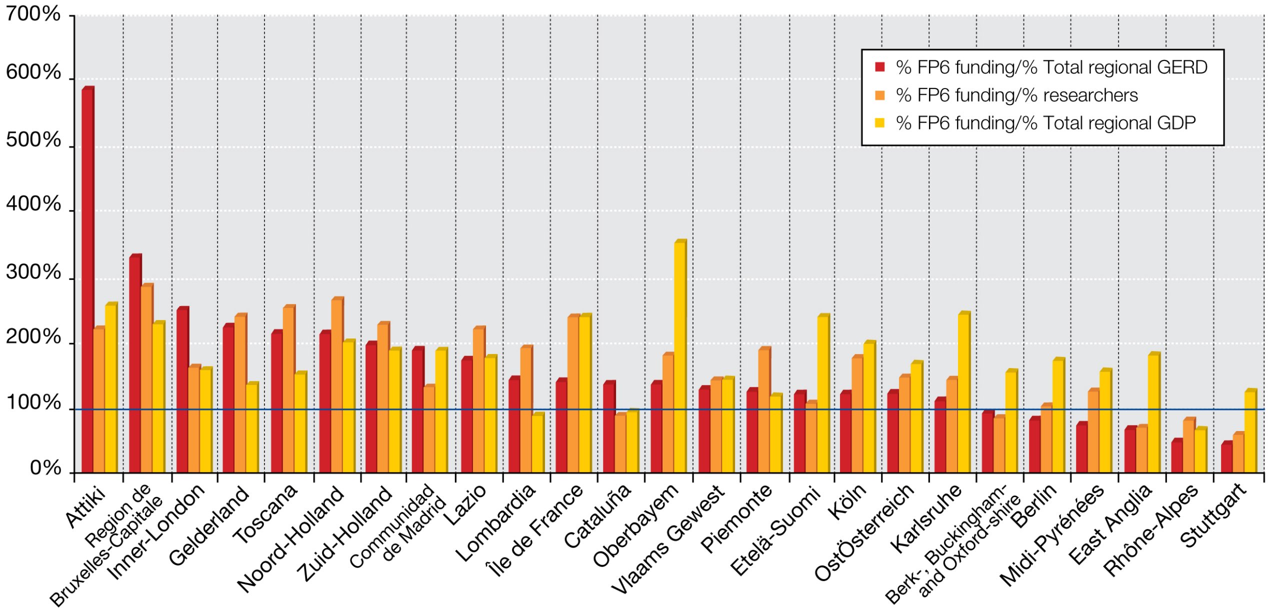
  The same pattern is replicated at regional level: FP participations and funding are concentrated in regions where research activities are concentrated. The top regional recipients of FP funding are the well-known European centres of scientific excellence and innovation performance, including Northern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

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



Source: *DG Research & Innovation,*
Data: *Eurostat,, Science Metrix / Scopus (Elsevier)*
Note: *Research capacities=share of EU27+NO+ CH GERD*
Scientific performance= share ofEU27+NO+CH highly cited publications
Size of bubble is proportional to FP7 funding received

Figure 4. Top 25 regional recipients of FP6 funding

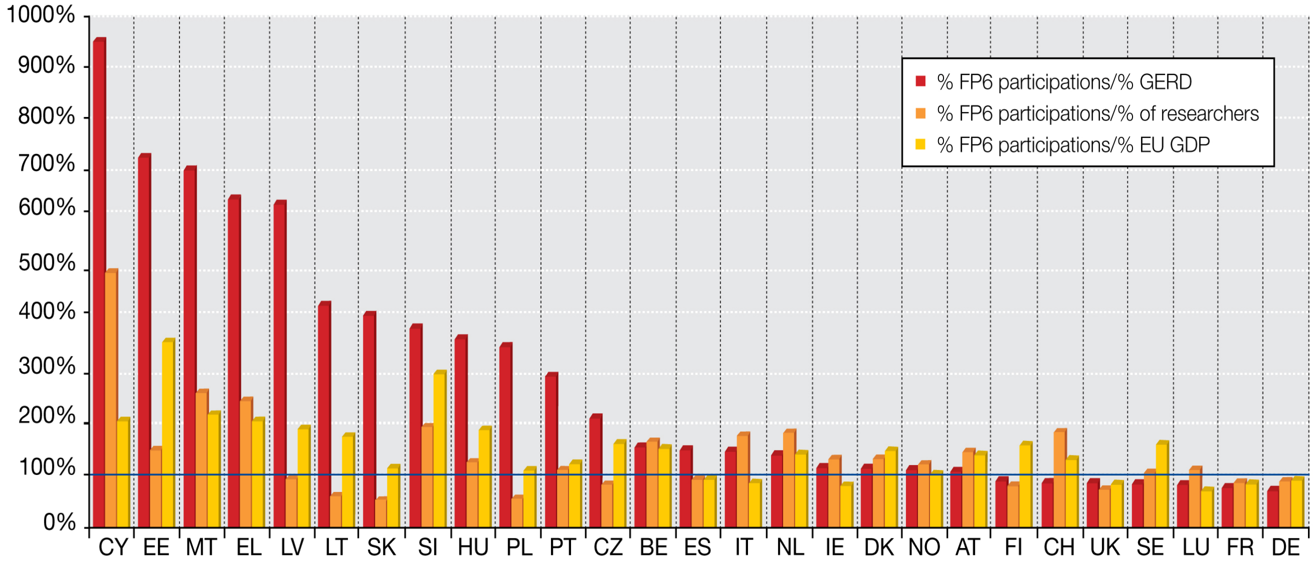


Source: DG Research & Innovation, Data for EU 27

- **Small and new EU Member States and their regions participate more intensely and benefit more from the FP than their research and economic capabilities and scientific and technological performance would suggest**

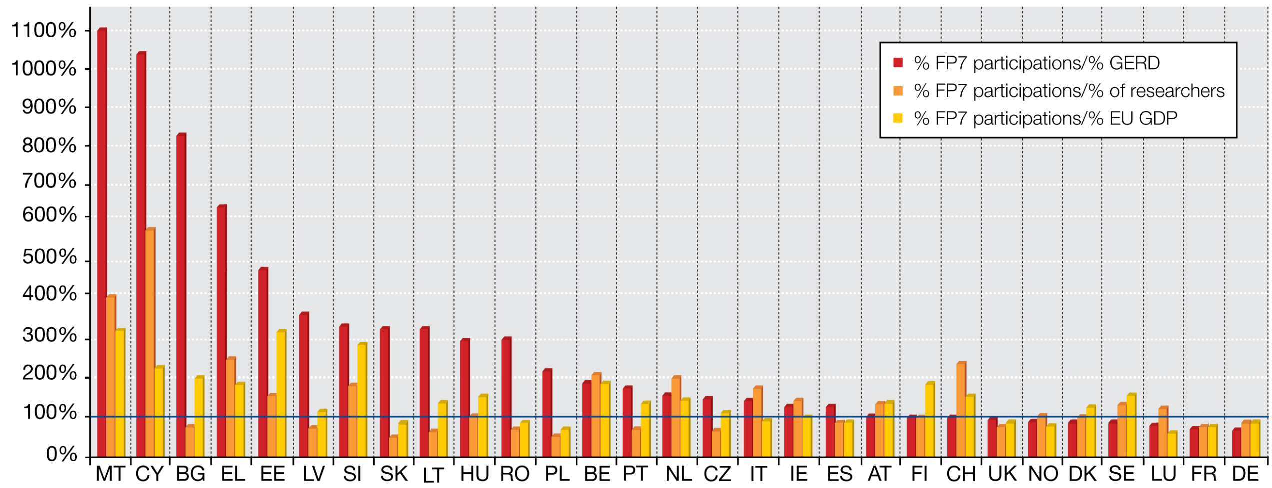
  When ranking Member States in terms of their share of FP participations or funding divided by their share of EU GDP, European researchers or GERD, smaller Member States tend to receive more funding and account for more participations than their economic performance and research capabilities could suggest. (Figures 5, 6, 7 & 8).

Figure 5: New Member States participate more intensively in the FP6



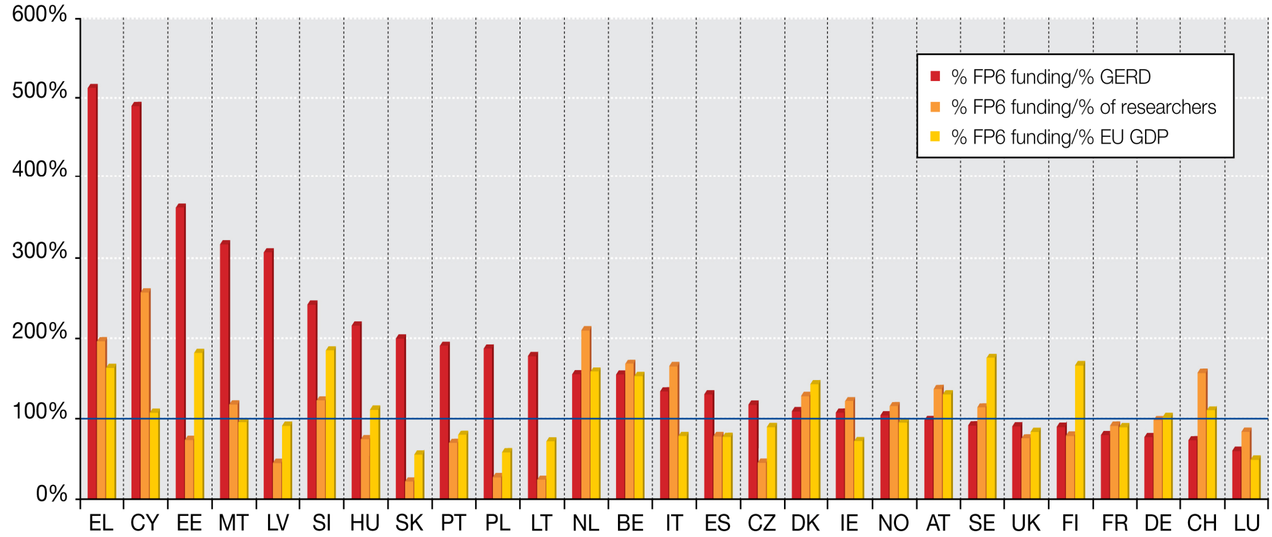
Source: DG Research & Innovation, Data for EU 27+NO+CH

Figure 6: New Member States participate more intensively in the FP7



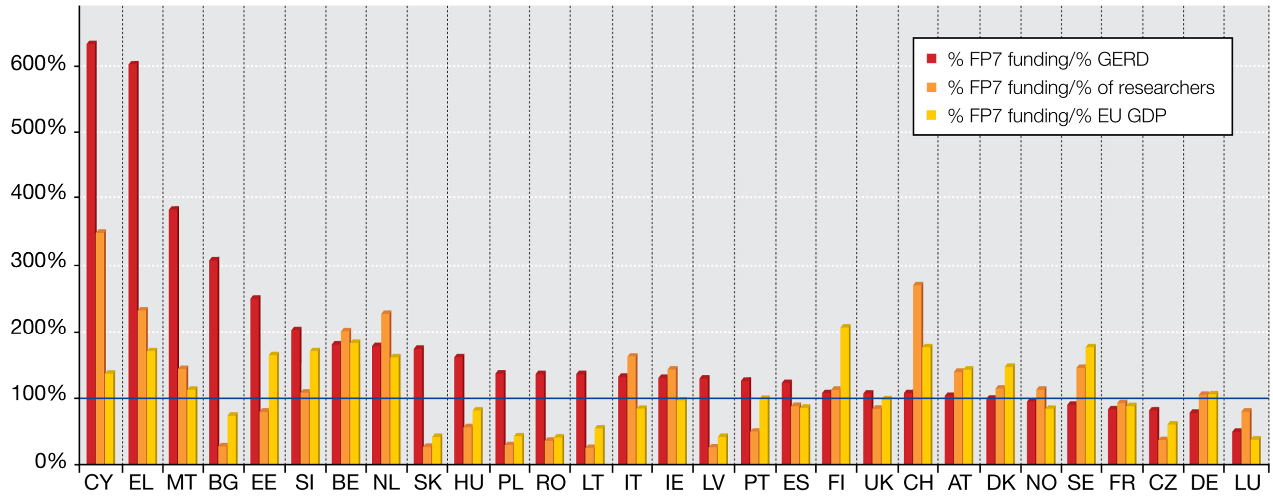
Source: DG Research & Innovation, Data for EU 27+NO+CH

Figure 7: Smaller MS benefit more from FP6 funding in relative terms



Source: DG Research & Innovation, Data for EU 27+ NO+CH

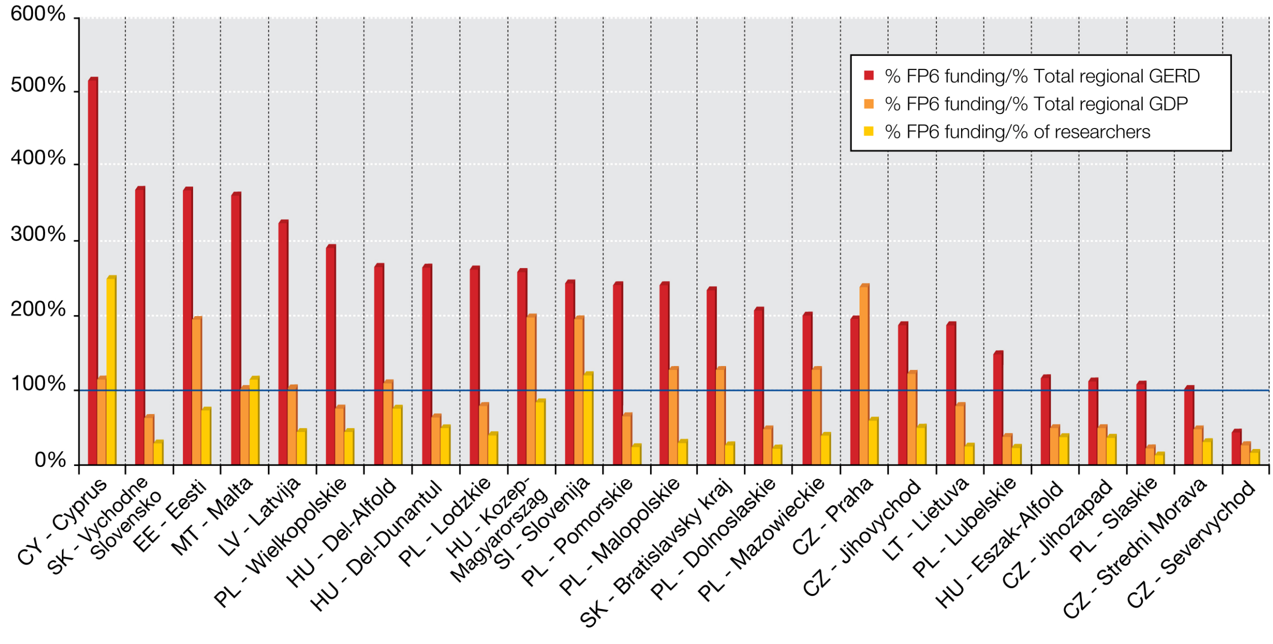
Figure 8: Smaller MS benefit more from FP7 funding in relative terms



Source: DG Research & Innovation, Data for EU 27+ NO+CH

At regional level as well, peripheral and less research-intensive regions obtain much more FP6 funding per euro of research investment (GERD) than more research-intensive regions. This is particularly true for EU-10 regions, which obtain up to 5 times more than their research investment would suggest (Figure 9). In conclusion, it could be put that FP is an important alternative source of funding for less favoured regions and contributes to filling in the investment gap.

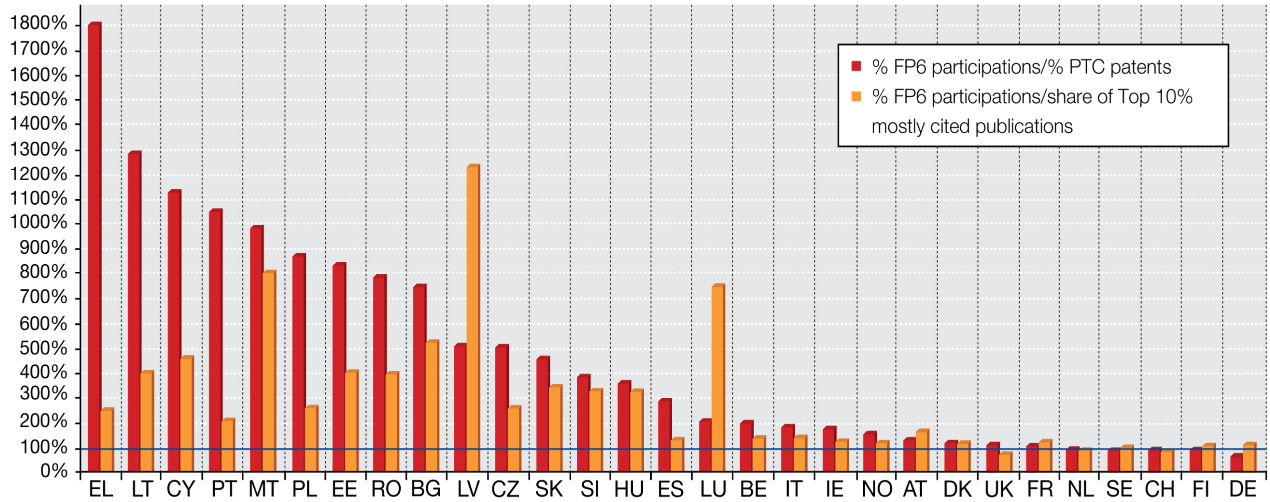
Figure 9: EU-10 regions benefit more from FP funding in relative terms



Source: DG Research & Innovation

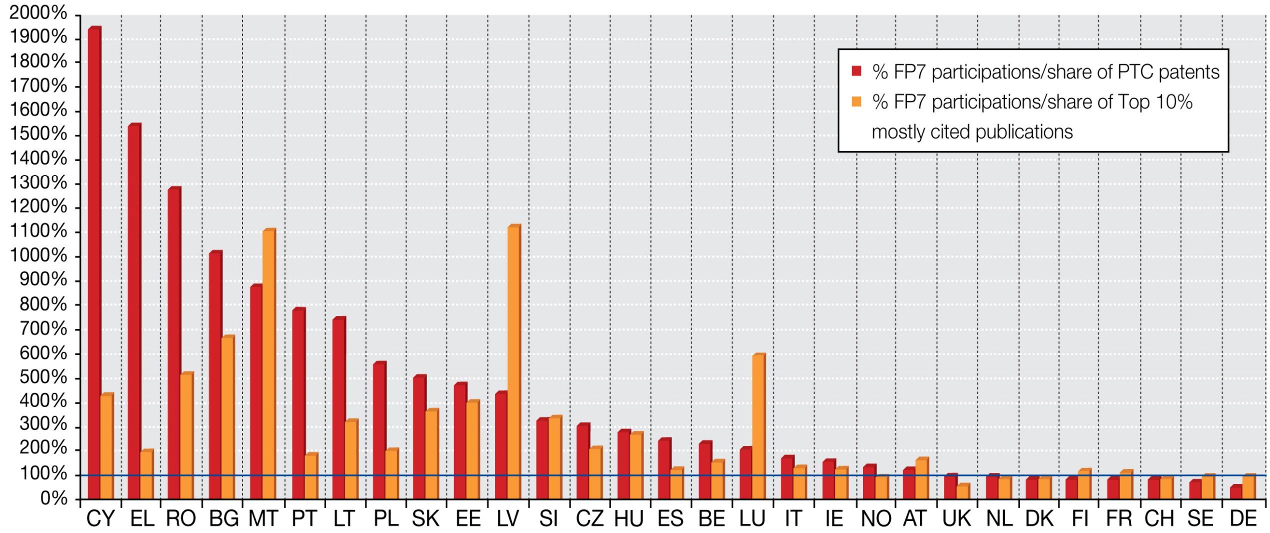
New Member States also participate more intensely in the FP and receive more FP funding than their scientific (share of top 10% most cited publications) or technological performance (share of PCT (Patent Cooperation Treaty) patents) would suggest (Figure 10, 11, 12 & 13).

Figure 10: New Member States participate more intensely in FP6 than their R&D output would suggest



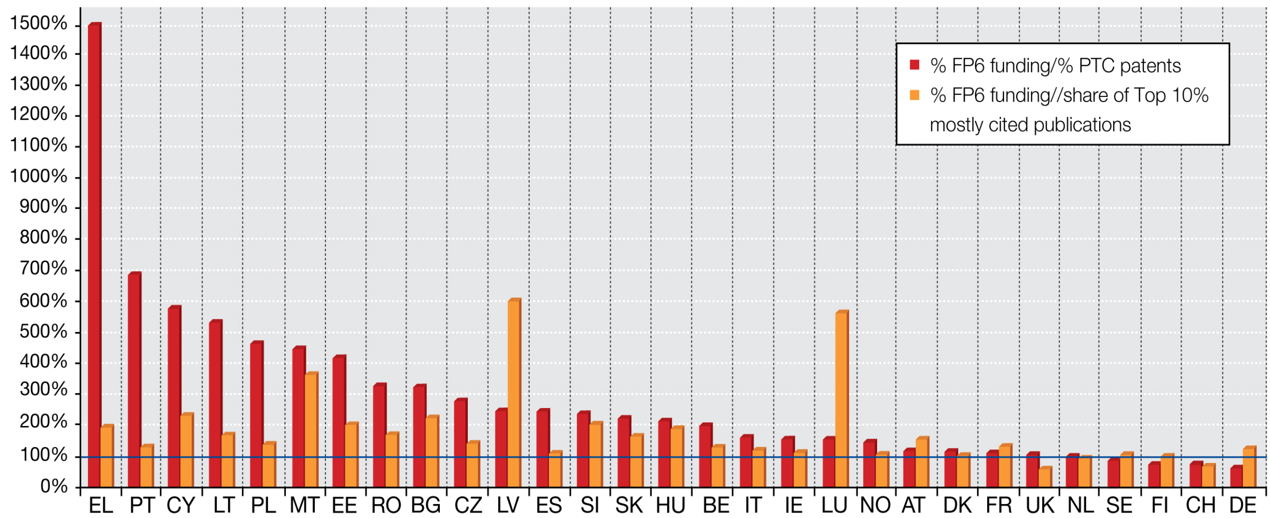
Source: DG Research & Innovation, Data for EU 27+ NO+CH

Figure 11: New Member States participate more intensely in FP7 than their R&D output would suggest



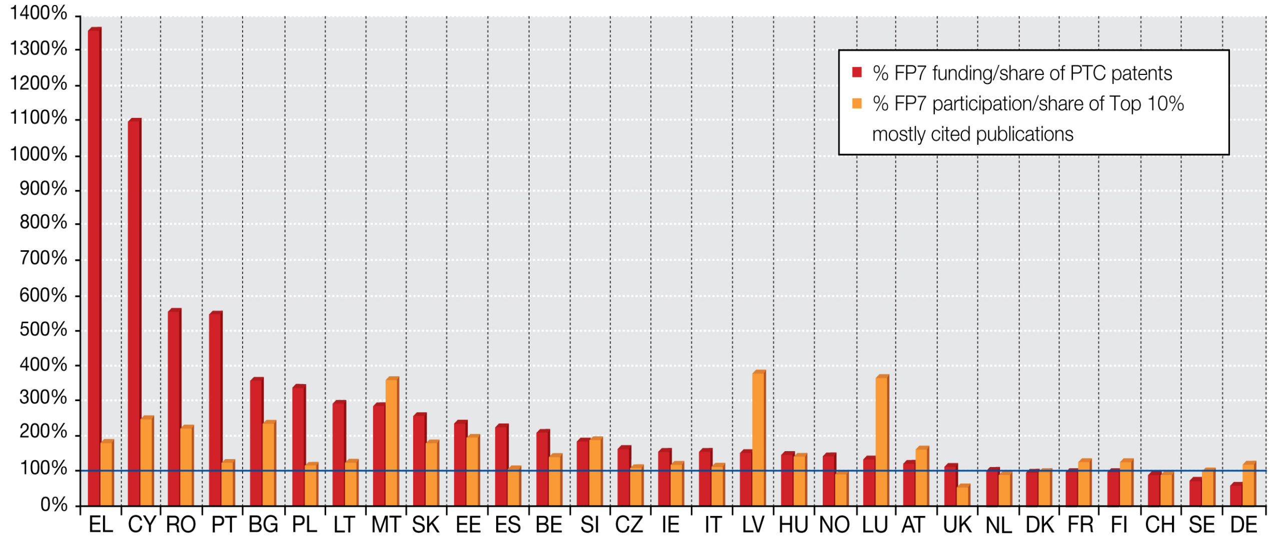
Source: DG Research & Innovation, Data for EU 27+NO+CH

Figure 12: New and Smaller Member States benefit more from FP6 than their R&D output would suggest



Source: DG Research & Innovation, Data for EU 27+NO+CH

Figure 13: New and Smaller Member States benefit more from FP7 than their R&D output would suggest



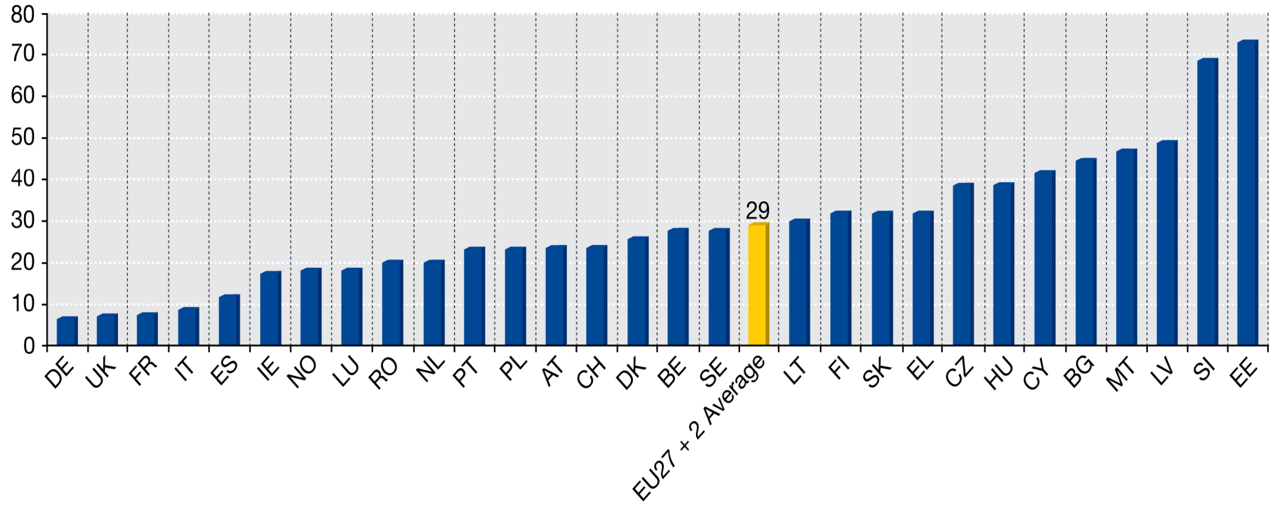
Source: DG Research & Innovation, Data for EU 27+NO+CH

- **The benefits from FP participations go beyond FP funding received: A Member State obtains, in average, 29€ of net knowledge return from every 1€ invested in the FP.**

  Participating in a FP collaborative research project offers access to EU-wide knowledge exchange networks. In other words, a single project participant benefits from and accesses the funding received by all project participants combined. An analysis of national knowledge returns from the FP, which takes account of the collaborative research network multiplier, shows that all countries enjoyed net positive knowledge returns under FP6. The average return was 29€ per 1€ invested for the EU 27, Norway and Switzerland (Figure 14). This represents an increase of about 8€ compared to FP5.

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

Figure 14: Net knowledge return per 1€ invested in the FP6



Source: *DG Research & Innovation,*
Note: *[Value of shared-cost contracts in which each country participating (no double counting))/Contribution to FP shared cost actions budget) – 1]; EU-27 + 2(NO and CH) contribution to FP6 shared-cost actions budget calculated on the basis of the shared of their GDP in the EU27+NO+CH GDP.*

THE FP INVOLVES TOP (A-TEAM) RESEARCHERS AND ORGANISATIONS IN HIGH-QUALITY RESEARCH

The FP6 ex-post evaluation (Rietschel et al., 2009) concluded that FP6 involved top-quality researchers in first-rate projects performing high-quality research. This conclusion was based on:

- **A FP-wide bibliometric study**: This study demonstrated that the publication and citation performance of FP project 'lead scientists' is better than that of their non-FP peers (EPEC, 2009).
- **Thematic bibliometric evidence**: An ex-post impact assessment of the 'Global Change and Ecosystems' sub-priority found, based on peer review and bibliometric indicators, that the work was of high scientific quality (EPEC, 2008).
- **The FP5&6 Innovation Impact study**: This study found that, compared to the average company in their sector, FP industrial participants are more R&D-intensive, more innovative, better networked and more focused on international markets, and patent more (Polt et al., 2008).
- **A FP6-wide participation survey**: This study found that participants with high and very high R&D capabilities represented around 80% of all FP6 survey respondents. Under FP5, the share was 60% (IDEA Consult, 2009c).
- **Self-assessments submitted to the FP6 expert group**: Twenty-four Commission research managers provided self-assessments to the FP6 ex-post evaluation expert group. Eight said independent reviews had confirmed that nearly all the research in their portfolio was of international standard. Another 7 said that at least two-thirds was of international standard.
- **The pan-European perception of the quality of FP-funded research**: In many countries, the receipt of FP funding is seen as a quality indicator for the scientists, research groups and organisations involved. For this reason, some research councils actively support EU applications while some universities provide matching funding.

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

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

- **An analysis of FP7 top funding recipients**: The FP7 interim evaluation concluded that "there can be little doubt that FP7 attracts the top EU researchers from universities and RTOs" since "the list of organisations that have obtained the largest amounts of funding from FP7 can be read as a *Who's Who* of European research quality".
- **An analysis of FP7 collaborative research proposal evaluation scores**: FP proposals are peer-reviewed and scored according to three criteria: scientific excellence, project management quality, and potential impact. The mean score for 'scientific quality' was 4.4 out of 5 (minimum 4) and the mean sum for the three criteria 13.1 out of 15, far above the minimum of 10 specified in the programme rules and according to the evaluation expert panel an objective measure of average proposal quality.
- **An analysis of ERC proposal evaluation scores**: The FP7 interim evaluation concluded that the ERC is attracting applications of high quality as some 56% of the total number of applications was evaluated as above the threshold set by the evaluation criteria.
- **Self-assessments submitted to the FP7 expert group**: Seven out of 10 self-assessments submitted to the evaluation expert panel said that 'nearly all' or 'a majority' of the research funded was world-leading. The other self-assessments said there was not yet enough information to judge.

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

- **The FP supports Europe's industrial R&D champions**: All FP6 and FP7 shared-cost action top industrial participants (in terms of funding, in terms of participations) are European companies figuring in the ranking of 'Top 1000 Global R&D Investing Firms'.[2] The top FP6 industrial participant, for instance, was Siemens AG (€46,4 million, 150 participations) while the top FP7 industrial participant so far is SAP AG (€53 million, 55 participations).
- **The FP funds Europe's most excellent universities**: About half of the 50 FP6 shared-cost action top university participants rank among the world's best 100 universities while 94 percent rank among the world's best 400 universities (Academic Ranking of World Universities 2010). The top 100 European universities in the 2008 Leiden ranking received about half of the FP7 funding disbursed at that time to European higher education institutions.
- **The FP provides support to Europe's leading public research centres**: Leading European public research centres like the Max Planck Gesellschaft, the Fraunhofer Gesellschaft, the CNRS and the Commissariat à l'Energie Atomique are top FP participants occupying key positions in FP projects and networks. Under FP6, for instance, these four institutes accounted for €562,9 million of funding and 1244 participations.
- **The FP connects Europe with global centres of excellence**: 8 of the world's top 10 non-European universities (Academic Ranking of World Universities 2010) participated in FP6 and FP7-funded collaborative research: MIT, the California Institute of Technology, and the Universities of Harvard, Berkeley, Princeton, Stanford, Columbia and Chicago. Moreover, in both FP6 and FP7, one could find other world centres of excellence participating like the Universities of Tokyo and Kyoto, Universities of Toronto, British Columbia and Melbourne, as well as Australian National University.

Other evidence concurs:

- According to a Dutch FP impact study (Technopolis), "bibliometric research and over 100 interviews held in the Netherlands, confirmed that the European research programmes produce high quality research and attract the best European researchers".
- According to EC-commissioned study on ICT research performance in FP (Bocconi University, 2010): "*DG INFSO projects have been highly effective in attracting top quality researchers and research teams from the research fields relevant for the ICT area"*.
- As demonstrated by a study analysing participation of Top European universities (selected with Leiden crown indicator) in the FP6 they had a key role in terms of participation and funding, with a leading role in coordination of projects (JRC-IPTS, 2009).

FP RESEARCH IS OFTEN HELPFULLY INTER-DISCIPLINARY

- There is substantial evidence that inter-disciplinary research is more productive than mono-disciplinary research. In this respect, the FP7 interim evaluation (Annerberg et al., 2010) concluded that the FP promotes cross-disciplinary research in an implicit and generic way through work programmes and calls for proposals that target certain problems, challenges or application areas. Virtually all Commission self-assessments submitted to the evaluation expert panel gave scores of 5 or 6 out of 6 for cross-disciplinarity.
- An EC-commissioned evaluation of FP6 environmental research (EPEC, 2008) concluded that several projects addressed new issues and initiated new approaches, in particular research with a strong interdisciplinary component.

THROUGH THE FP, LARGE NUMBERS OF SCIENTISTS ARE TRAINED

- Training is the core preoccupation of the FP's **Marie Curie actions**, which promote cross-border, cross-sectoral and cross-disciplinary researcher mobility, as well as skills and career development:
  - The FP6 ex-post evaluation (Rietschel et al., 2009) noted that FP human resource actions are almost universally judged to be a major success. FP6 human resources and mobility schemes involved 8, 000 organisations and supported some 12,500 fellows.
  - The FP7 interim evaluation (Annerberg et al., 2010) noted that the specific programme People is making a valuable contribution to the development of researcher human capital and that "the Marie Curie actions, through their bottom-up approach, have promoted excellence and have had a pronounced structuring effect on the research landscape". In the period 2007-2010, 38 calls were launched and concluded in People programme resulting in nearly 5,500 projects retained for funding. During that period, over 6,400 researchers benefited from individual fellowships and grants to enhance their career prospects. Nearly 400 ITN and IAPP networks were selected for funding providing training and knowledge transfer to more than 6,500 researchers.
  - The German Federal Ministry of Education and Research noted that the FP offers good opportunities for supporting upcoming scientists. Young scientists become involved in international research networks and have the opportunity to perform research at foreign institutions within the framework of mobility programmes. In particular, universities and non-university research institutions emphasize the opportunities for supporting young talent through participation in the mobility programmes (Federal Ministry of Education and Research, 2009).
- There is a training element in **European Research Council** advanced grants, with preliminary analysis of the financial reports revealing that advanced grant teams typically consist of two doctoral students and two post-docs in addition to the principal investigator (Annerberg et al., 2010).

- Training is also provided through the FP's **research infrastructure** actions, which facilitate access to unique and expensive infrastructures of European importance. Nine out of 10 researchers say that without FP funding they would not have been able to access vital research facilities, which is often a precondition for successful frontier research. Under FP6, about half of the 26 000 users who benefited from access were young researchers (undergraduate, postgraduate and post-doc). This highly trained personnel forms an invaluable human capital resource for serving current and future industrial needs (Table 3).

Table 3: Status of users at research infrastructures during FP6

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

- Large numbers of scientists have been trained through FP-funded **collaborative research**:
  - According to an EC-commissioned evaluation of the FP5 Growth programme, projects had generated or were expected to generate 2,152 doctorates (Ramboll Management and Matrix Knowledge Group, 2008).

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

  - According to a survey among FP5-7 project coordinators in the areas of Food, Agriculture and Fisheries and Biotechnology research, almost 80% of projects trained at least one PhD student and 73% at least one post-doctoral researcher. 18% of projects trained more than 10 PhDs, which provides evidence of the impact of the FP on the training of young researchers. Significant efforts were also made the train other personnel: over 50% of projects trained graduate, technical and administrative personnel (EC, 2011h).
  - According to an Austrian FP impact study (Technopolis, 2010b), "it is important to note that training of young researchers not only occurs in the human resources oriented measures (People Programme and ERC Starting Grant) but also in the 'traditional' cooperative FP projects".
  - According to an Irish evaluation of FP6, each project produced, on average, 2.3 newly trained/qualified personnel (Forfas, 2009).

THE FP IMPROVES PARTICIPANTS' R&D AND INNOVATION CAPABILITIES

- The FP7 interim evaluation (Annerberg et al., 2010), referring to a UK evaluation of the FP identifying important participant capability impacts (see below), considered it "reasonable to infer that similar outcomes will have occurred elsewhere".
- A study of FP6 behavioural additionality (IDEA Consult, 2009b) found that FP-funding increased FP participant organisations' ability to network with universities, public research institutes and firms; that FP project management experience was already or would be used in other R&D and innovation projects within the organisation; and that FP-funding helped to formalise the R&D and innovation processes, in particular for very small and young organisations and for organisations coming from candidate countries.
- A study of the impact of FP6 on new Member States (COWI, 2009) found that FP6 "had an important impact on research organisations' interests and capacity in networking and … inspired a networking approach to the management and implementation of research projects with more focus on cooperation, consortia- creation, multi-disciplinarity, communication and management skills". It also produced "an

increase in skills and research capabilities of its key research staff" and resulted in the "development of administrative capacity/competence to handle international project management processes".

- A FP6-wide participant survey (IDEA Consult, 2009c) concluded as follows: "The learning effects of participating in a project under FP6 appear to be high for individual organizations. Much of the experience gained, both technological and managerial, can and will be used again in future R&D projects".
- A survey among FP6-IST programme participants (WING, 2009) found that more than 80% of participants consider that EU projects have enabled them to significantly extend their knowledge base and RTD capability, develop new skills and competence and explore new technology paths that they would have not addressed otherwise. The same share of participants highlighted the important impact of their FP participation on networking and the building of new long-term strategic partnerships allowing them to gain access to complementary expertise.
- The same survey-based study (WING, 2009) showed that around 75% of industrial participants found that their participation has helped improve their innovation capacity and explore new opportunities, including the successful re-use of knowledge developed within projects in another context (WING 2009).
- An Irish evaluation of FP6 participation (Forfas, 2009) found that "the primary benefits came in the form of improved relationships and networks, increased knowledge and capabilities (both scientific and technological), and enhanced reputation and image".
- A Spanish evaluation of FP6 participation (Zabala Innovation Consulting SA (2010) found that "for 52% of the surveyed researchers, participation in the FP6 contributed to strengthening their research teams, above all due to the scientific excellence offered by the acquisition of capabilities and abilities during the project".
- A Swedish longitudinal evaluation of FP participation (VINNOVA, 2008) found that "FP money has been one of the factors enabling the [automotive] industry in general, and Volvo AB in particular, to maintain the high level of technological capabilities that have so far protected vehicles design and production activities in Sweden, which from a scale logic are anomalous". It noted that "the survey confirmed the earlier finding that capacity building was an important aspect of the FP projects and also showed more clearly that participants were involved because of the opportunities for technical learning offered".
- A UK evaluation of FP6 and FP7 found that the FP has a big impact on the nature and extent of UK researchers' international relationships and networks, as well as on their knowledge base and scientific capabilities. Other notable outcomes include increased scientific reputation, an improved ability to attract and retain world-class researchers and a positive impact on researcher careers. Lastly, FP has a positive impact on the attitudes, outlook and connectedness of individual researchers, as well as serving as a training ground for project management and administration.

THE FP PRODUCES LARGE NUMBERS OF HIGH-QUALITY, OFTEN COLLABORATIVE SCIENTIFIC OUTPUTS

- According to an EC-commissioned evaluation of the FP5 Growth programme (Ramboll Management and Matrix Knowledge Group, 2008), projects had generated or were expected to generate 18,974 publications.
- According to an EC-commissioned study on FP6 network effects (AVEDAS et al., 2009), the number of publications produced between one year after the starting month of the project and the end of 2007 by the principal investigators of 2003-2005 FP6 projects (n=1,312) amounted to 32,466.
- According to the same study, FP6 projects produced increased co-publication activity between project partners, i.e. two partners from the same FP6 project published one or more articles together after having participated together in FP6. Publications from FP6 principal investigators, either with or without other FP6 partners, had a 50% higher impact than the world average. Co-publications by collaborating FP6 partners had significantly higher impact (around 2 times the world average) than publications in which FP6 partners did not co-publish.

- According to an EC-commissioned evaluation of FP6 environmental research (EPEC, 2008), EU environmental research is leading in several environmental research areas. According to peer reviewers, the scientific and technological impact of EU environmental research is particularly high for projects in three areas: climate change (4.6/5), water and soils (4.5/5), and natural hazards (4.4/5). According to a bibliometric analysis, three areas of EU environmental research can be distinguished for their higher impact factor: climate change, water and soils, and biodiversity and ecosystems. Climate change in particular is the area in the sub-priority "global change and ecosystems" that receives the highest ranking in almost al types of impact, especially as regards scientific impacts. All projects in the Climate change area are unanimously qualified as being of high scientific quality, producing "excellent new science".
- According to a German evaluation of FP6 (Federal Ministry of Education and Research, 2009), scientific personnel participating in FP6 stated that a substantial part of their publications was due to their participation in the FP.
- According to an Irish evaluation of FP6 (Forfas, 2009), each project produced, on average, 12.7 publications (of which 5.3 in refereed journals and books) and 5.2 conferences, seminars or workshops.
- Bibliometric analyses of FP6 projects (EPEC, 2009) indicate a high productivity of papers in high-quality journals by FP funded scientists in the *Food, Agriculture and Fisheries and Biotechnology* area. For FP6 Food, coordinators were found to perform better than non-FP funded peers.
- The results of survey performed by DG Research & Innovation among FP5-7 coordinators showed that the EU funded research in Food, Agriculture and Fisheries and Biotechnology area produced on average 4.4 publications per project. Some projects have produced particularly high numbers of publications in peer review journals (e.g. 400 publications by fisheries projects SEAFOODPLUS and IMAQUANIM; 120 publications by the agriculture FP6 project EUSOL).
- An analysis undertaken by the EC showed that around 50% of all FP6 projects in the domain of ICT produced at least one scientific article included in a high-impact journal (ISI Web of Science - ISI WoS) database and that 82% of projects produced at least one other publication outside the WoS database. For FP7-ICT, the share of projects reporting at least one scientific article in the ISI WoS database was 32% (at the end of the first two years of the programme), and 71% of projects under FP7-ICT produced at least one other publication outside of the ISI WoS database.

THE FP PRODUCES NUMEROUS TECHNOLOGICAL OUTPUTS AND INNOVATIONS

- For firms, FP collaborative research projects are more than self-financed collaborative research projects focused on risky, complex and long-term exploration rather than on short-term exploitation. So firms participate in the FP mainly to achieve knowledge- and technology-related objectives, less to achieve direct commercialisation-related objectives. In addition, FP projects are not and should not be assessed as stand-alone R&D activities; they form part of a wider portfolio of R&D projects.
- Notwithstanding the above, the FP has a significant positive impact on innovation and competitiveness: FP-funded research produces large numbers of patents, innovations and micro-economic benefits:
  - An EC-commissioned evaluation of the FP5 Growth programme (Ramboll Management and Matrix Knowledge Group, 2008) found that – although exploitation was not the primary objective - exploitation objectives were achieved in 54 percent of the projects. Projects had generated or were expected to generate:
    - The creation of 248 spin-off companies
    - 3,724 prototypes, demonstrators, pilots
    - Some 7.2 billion euro additional sales
    - 891 million euro in cost reduction
    - 1,077 patent applications
    - 204 registered designs and other forms of IPR protection
    - The safeguarding of 37,588 jobs and 8,038 new jobs

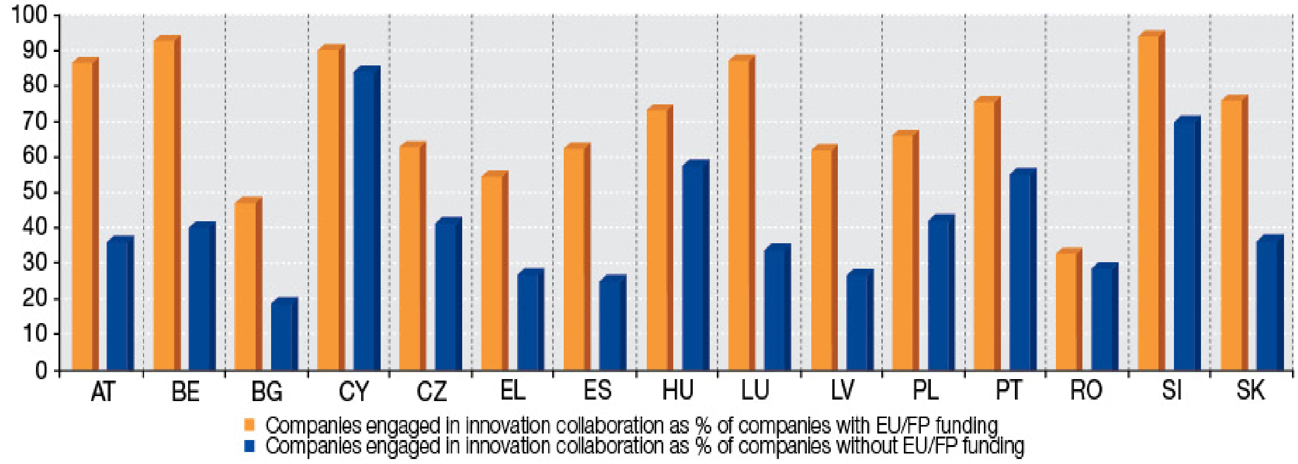
§ 310 inputs into technical standards

- According to an EC-commissioned study on FP6 behavioural additionality (IDEA Consult, 2009b), projects would have led to a smaller range of potential applications and a smaller number of marketable products if continued without FP6 funding.
- According to an EC-commissioned study on FP6 network effects, FP6 resulted in increased competitiveness of the European Research Area because of inter alia the development of new and improved research methods and techniques and more commercial or industry-based approaches in the research. The same study found the following answers for the question "what outcomes has the FP6 led to that your organisation would not have achieved if it had not been involved in FP6?": "New or improved commercial products, services": about 2.8 out of 5; "Patents, intellectual property": about 2.9 out of 5.
- According to an FP6-wide survey (IDEA Consult, 2009c), industrial organisations clearly expected commercial returns. Almost half of them (47 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).
- 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.
- According to a Finnish evaluation of FP6 (TEKES, 2008), "commercialisable output is not the core objective of the FPs but EU collaboration nonetheless contributes significantly to the creation of innovation".
- According to a German evaluation of FP6 (Federal Ministry of Education and Research), scientific personnel participating in FP6 stated that a substantial part of their patent applications was due to their participation in the FP. Large, export-oriented companies as well as companies in the field of cutting-edge technology and the knowledge-intensive service sector were more likely to take part in FP6 than in federal or Länder programmes 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.
- According to an Irish evaluation of FP6 (Forfas, 2009), each project produced, on average, 0.1 patent applications, 0.4 new or significantly improved commercial product or services, and 0.4 new or significantly improved scientific or industrial processes.
- A Swedish long-term evaluation of the FP (VINNOVA, 2008) found significant impacts on the ability to compete in vehicles and in electronics (especially telecommunications). In ICT, FP participation in European and global standardisation had been a key factor in building the Swedish telecommunications industry’s position in mobile telephony, while in vehicles, the FP had, together with complementary national programmes, been instrumental in supporting the Swedish industry’s technical specialisations, especially in safety and combustion.
- According to a Swiss evaluation of FP5 and FP6 (State Secretariat for Education and Research, 2009), participation generated both knowledge and jobs.
- According to a UK evaluation of the FP (Technopolis, 2010), a majority of UK business participants stated that their involvement in the FP had yielded important commercial benefits. In terms of immediate project outputs, a significant proportion of business respondents reported having made or gained access to new or significantly improved tools or methodologies and in a large minority of cases, firms reported the creation of formal elements of intellectual property. Beyond these immediate project results, around 20 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.

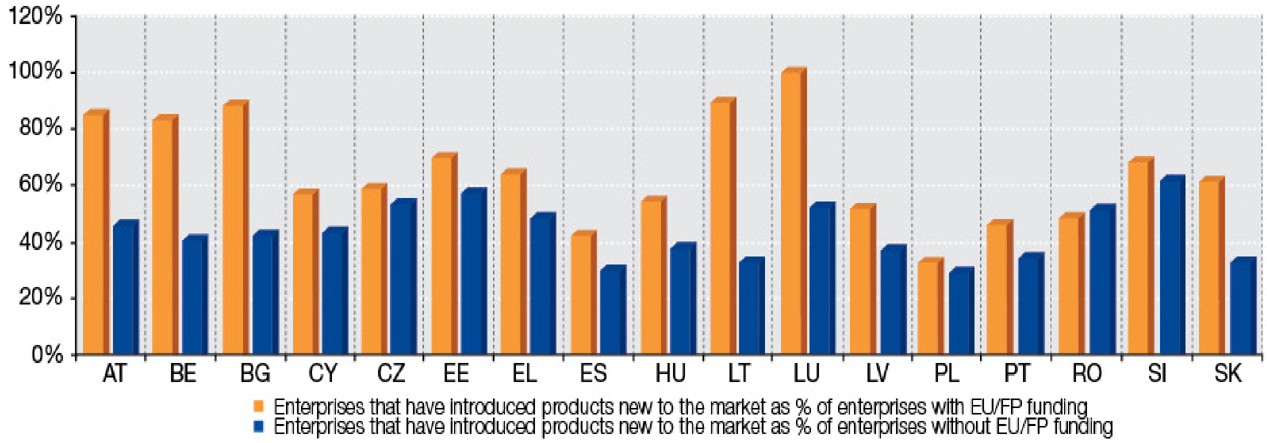
- An econometric analysis of Round 3 Community Innovation Survey micro-data covering 18 European countries carried out by the Joint Research Centre's (JRC) Institute for Prospective Technological Studies (IPTS) found that the FP has a positive impact on incremental innovation (new to the firm) and, even more, on radical innovation (new to the market). The FP fosters collaboration and has a positive impact on R&D intensity via collaboration and directly. The higher the R&D intensity, the more incremental and radical innovation.
- An analysis of 2006 Community Innovation Survey micro-data confirmed the above results by showing that FP participants collaborate more, patent more, and are more innovative than non-participants.
- The EC-commissioned analysis of Prospects for Research and Innovation in Food, Agriculture, Fisheries and Biotechnologies (Report from Independent Experts to the European Commission, 2011a) concluded that, scientific productivity in some FP6 Food research projects was combined with strong technological outputs (patents and innovation, in particular in biotechnology and food projects) and/or with attention to policy needs (in the remaining areas of research). This suggests a cross-fertilisation between science, technology and policy development that has contributed to excellence.
- The results of survey performed by DG Research & Innovation among FP5-7 coordinators (Coordinator Survey, 2010) showed that the EU funded research in Food, Agriculture and Fisheries and Biotechnology area produced on average 0.5 patent and 0.69 new innovative products per project funded.
- The EC-commissioned analysis of impact of FP agricultural and forestry research (Report from Independent Experts to the European Commission, 2011b), concluded that a significant proportion of projects had developed more “technological” than “scientific” results, the average of technological invention being four per project in FP6. Where the nature of the research allowed it, projects successfully delivered on patents and new products. For example in the area of plant health research nearly 15% of projects led to patent applications and 30% to commercial products, models and processes.
- An analysis of random sample of projects funded by Security Theme in FP7 showed that they produced 0.51 patents or other forms of Intellectual Property per project.
- Evidence from the Community Innovation Surveys shows that 340 firms from the manufacturing sector of food and beverages that have introduced a new product or new process have received funds from FP5 and FP6 programmes what suggest a significant role of the FPs funding in improving the innovation performance of firms

Figure 15: FP participants collaborate more than non-participants



Source: Eurostat- Note: Data concern manufacturing sector

Figure 16: FP participants are more innovative than non-participants



Source: Eurostat- Note: Data concern manufacturing sector.

EU RESEARCH & INNOVATION PROGRAMMES SUPPORT EUROPEAN AND NATIONAL POLICIES

- According to an EC-commissioned evaluation of the FP5 Growth programme (Ramboll Management and Matrix Knowledge Group, 2008), projects had generated or were expected to generate 423 inputs into EU legislative texts.
- According to an EC-commissioned evaluation of FP6 environmental research (EPEC, 2008), EU environmental research contributes to the knowledge base and development of methods and tools for environment related policy. The study found that:
  - o 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.
  - o 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.
  - o All natural hazards projects contributed to some extent to regional, national and European policies in the field of natural hazards, guidelines and standards.
  - o Water and soil projects played a large role in the formulation and implementation of the Water Framework Directive.
  - o Earth observation projects had direct impacts on policy-making through the use of their outcomes by stakeholders such as IPCC and WMO.
- According to an Irish evaluation of FP6 (Forfas, 2009), each project counted, on average, 0.4 new or significantly improved regulation or policy.
- Research in the field of security contributed to development of EU policies in the domains such as EU internal security, EU disaster response capacity, the EU CBRN and Explosives Action Plans, the Critical Infrastructure Protection, Health Security or also violent radicalisation, privacy and data protection. Since 2007 a total number of 20 Council and Commission policy documents reflect the use of security research resulting data (Table 4)

Table 4. Impact of FP7 Security Research as addressed in EU policy documents

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

Source: SG Vista + Council Secretariat

- According to a survey among FP5-7 coordinators in the area of Food, Agriculture and Fisheries and Biotechnology research (Coordinator Survey, 2010) more than 60% of FP projects have provided inputs to European policies, 56% to national policies, and 25% to international agreements.
- The analysis of the EURLEX database demonstrates that 73 separate FP projects in the fields of Food, Agriculture and Fisheries and Biotechnology where quoted 103 times by different EU produced documents. The average new decision support tool/policy recommendations per project is estimated to respectively 2, 1.7, 1 and 0,8 per project in the field of Fisheries & Aquaculture, Agriculture, Food and Biotechnologies (EC, 2011h).
- The analysis of FP5-FP7 funded research (Report from independent experts to the European Commission, 2011b) in plant and animal health has had a great impact on the further development of legislative measures governing disease surveillance, control and eradication, animal welfare and use of wastes. New methods were also developed which became initially European and later international standards. Results from the animal health projects have had a great influence on the work of the World Organisation for Animal Health (OIE), for example to develop international standards for disease control, animal welfare and trade, recognized by the World Trade Organisation (WTO).
- The analysis of FP5-FP7 funded research (Report from independent experts to the European Commission, 2011c) in the fisheries and aquaculture areas has had significant impact on the formulation and implementation of the Common Fisheries Policy, in particular with regards to developing the scientific basis of fisheries management, monitoring of stocks, environmental requirements and developing sustainable aquaculture with an increased involvement of research institutes from Mediterranean Partner countries, new member states and candidate countries.

THE FP PRODUCES STRUCTURING EFFECTS: DURABLE CHANGES IN THE EUROPEAN RTDI LANDSCAPE

- **Through the FP, the European Research Council was created, which promotes excellence across Europe:**
  - The European Research Council would not have been created without an EU initiative. The EU would then have been left with a landscape of 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.
  - The FP7 interim evaluation (Annerberg et al., 2010) noted that there is evidence suggesting that a level of compatibility (even calibration) has developed between the ERC and national research councils as the latter increasingly 'accept' the ERC evaluation results as a basis for awarding grants to highly-rated researchers who fail to be funded by ERC. The ERC suggests that national research councils or agencies are adopting similar funding schemes to the ERC model, and ERC grantees are often offered improved conditions by their host institutions, while ERC applicants are offered national funding.
- **Because of 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. No less than 10 next generation European infrastructures [e.g. IAGOS (In-service Aircraft for a Global Observing System), ESS (European Spallation Source) and SHARE (Survey of Health, Ageing and Retirement in Europe)] are currently being built by groups of Member States and these facilities would not have seen the light

of day if it were not for EU action. In addition, without EU funding measures to facilitate access to unique and expensive infrastructures, 9 out of 10 researchers say that they would not have been able to access vital research facilities, which is a often a precondition for successful frontier research. For example:

  - § The IA-SFS project has created the largest network of free electron lasers and synchrotrons in the world, serving several thousand European scientists and allowing a wide range of applications.

  - § The European Grid Infrastructure gives European researchers access to the aggregated processing power of 200 000 computers in the world's largest distributed computing infrastructure ever built, with over 290 sites in more than 50 countries.

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

- **Thanks to FP mobility and career actions, a framework for training and career development of researchers and free movement of knowledge is being created**:

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

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

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

  - o An important achievement of the Framework Programme has been to establish instruments and mechanisms (e.g. European Technology Platforms, Joint Technology Initiatives) that facilitate the joint development and implementation of strategic research agendas by the private sector and for public-private partnership. These strategic research agendas have played a key role in boosting the competitiveness of the sectors involved.

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

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

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

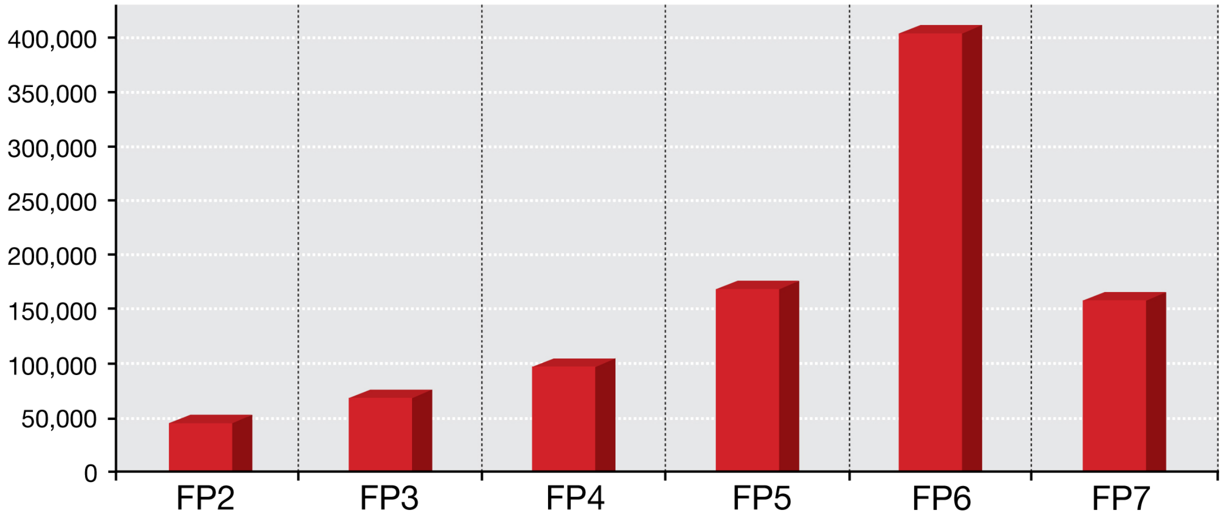
  - o One of the pioneering achievements of the Framework Programme has been to establish instruments and mechanisms (e.g. ERA-NET, Article 185) for the joint programming of Member State research. This has led to a new approach to research funding involving countries pooling and coordinating their own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

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

- According to the same FP6 ex-post evaluation, ERA-NETs considerably changed the views of policymakers and implementers. ERA-NETs enabled RTD funders to appreciate the value of cooperating and coordinating research activities and to change their practices. ERA-NETs enabled cooperative priority setting by sharing strategic intelligence. ERA-NETs encouraged the synchronisation of national research programmes. Small countries like Norway found that ERA-NETs enabled them to fill gaps in the national research portfolio and increased the exposure of national research performers to competition. Many of the ERA-NETs made good progress toward issuing joint calls and added value to the European RTD funding portfolio. In some cases joint calls involved large amounts of money and in a handful of areas the common programming which resulted was in areas of national significance, producing quite large calls, e.g. €35m and €15m in the Plant Genomics network.
- An evaluation of ERA-NET Plus – which facilitates joint calls through topping up the joint national funding with FP7 funds (33% of the joint call) - found that it is contributing to the pooling national resources, succeeding in bringing together efforts to meet joint challenges, and acting in some cases as a bridging mechanism (Annerberg et al., 2010).
- An Interim Evaluation of the 'Ambient Assisted Living' (AAL) Article 185 concluded that it made progress towards its objectives and that its overall direction was positive. The evaluation report added that it was a remarkable achievement that, in just a few years, the countries supporting the AAL programme engaged in such close cooperation. It was strong evidence of their interest that they increased their financial contributions significantly beyond the minimum required. AAL also achieved a high level of SME participation at about 40% compared with less than 20% in the first call of the FP7 ICT & Ageing Programme (Annerberg et al., 2010).

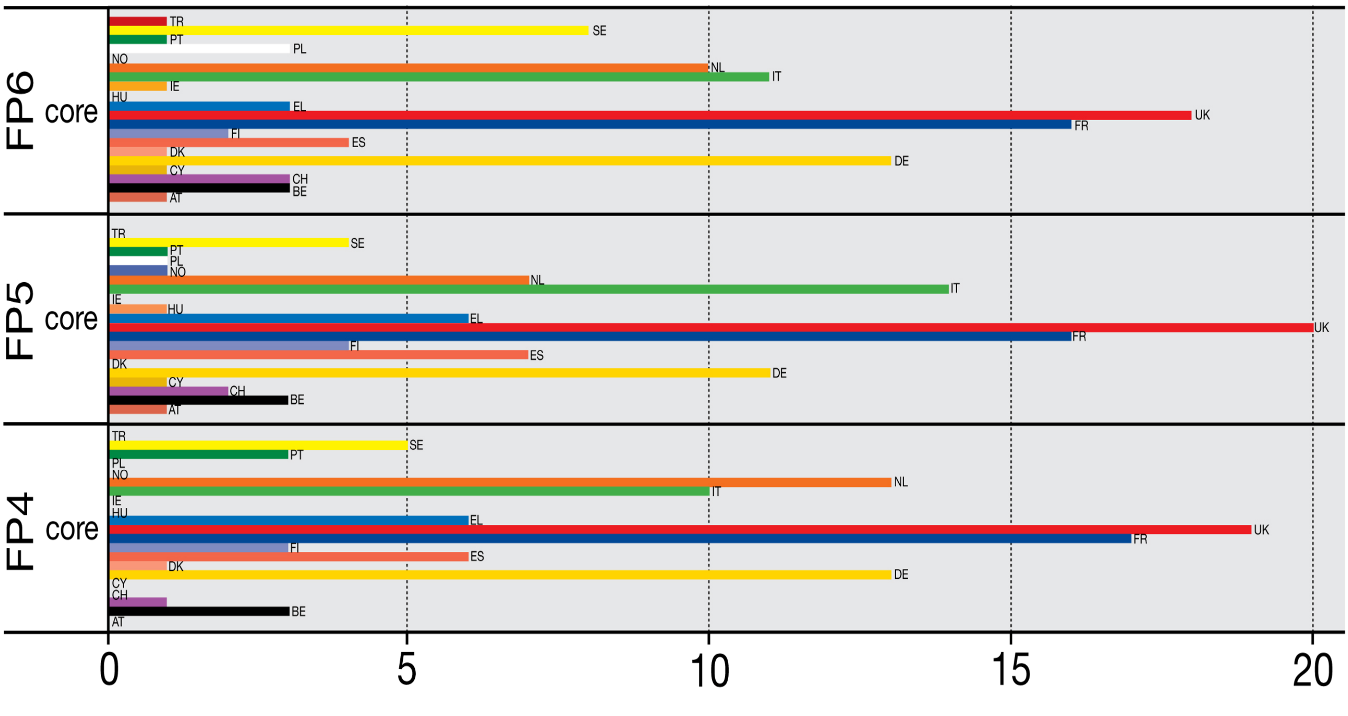
- **FP-funded collaborative research produces cross-border, cross-sectoral, inter-disciplinary networks that are durable, well structured, and well integrated into global innovation networks:**
  - ***The FP produces large numbers of cross-border links and networks:***
    - JRC-IPTS (2011) argues that the "FPs have been pivotal for transforming informal nation-based networks of research collaborations within epistemic communities of academics and industrial researchers into formal collaboration arrangements between organisations at European level. The networks formed by the organisations have become almost as important an outcome of FPs as the scientific and technological results of research projects conducted by them".
    - Protogerou et al. (2010) found that ICT collaborative research funded under FP4, FP5 and FP6 had produced complex networks and that the introduction of new instruments in FP6 had considerably increased interconnectivity compared with the previous FPs, thus contributing to the implementation of the European Research Area initiative.
    - An analysis of FP participation data shows that under FP6, the number of trans-national collaborative links reached 400 000 (Figure 17), more than double the number of links created under FP5. This increase of connections in FP6 is due to a changing dynamic at the project level: the average number of participants per project doubled from FP5 to FP6 and the average number of Member States per project increased from 4 to 6 (Table1). After four years of implementing FP7, the number of collaborative links almost reached that of FP5, namely 154.000. However it seems that at the end of FP7 less collaborative links will be created than under FP6, as the projects, in average engage less participations.

Figure 17: Collaborative links (national+international) established through FP funded shared-cost actions



Source: DG Research & Innovation
*Note: * Partial FP7 data (to 01.2011);*

Figure 18: FP core organisations: percentage distribution by countries and FP



Source:JRC IPTS (2011)

o ***The networks created by the FP are well structured:***

§ JRC-IPTS (2011) shows that, over time, FP collaborative research networks have increased in size and created a highly dense and integrated structure. At the core of this structure, well-connected organisations (mainly higher education organisations and research centres) are situated, which not only participate in a large number of projects but are also directly linked with a large number of other core organisations and local partners. These key FP players come from across the EU and associated countries but the majority are from France, Germany, the United Kingdom, Italy and the Netherlands (Figure 18).

§ The same study shows that this group of key players, which participate in most projects and create most collaborative links, has not been renewed since FP2 (table 5).

§ Protogerou et al. (2010) found that ICT collaborative research funded under FP4, FP5 and FP6 had produced complex networks structured around a core of organizations, mainly universities and research institutes assuming a very influential role over time.

§ The FP6 ex-post evaluation (Rietschel et al., 2009) found that, in the area of IST, FP-funded projects had produced networks involving key 'hubs' (for example, the Fraunhofer Institutes) connected to large numbers of participants.

§ An EC-commissioned FP6-wide study of FP6 network effects (AVEDAS et al., 2009) found that there was a high degree of organisational embeddedness and network stability in the FP. In each of the five FP6 thematic areas, there was a small number of closely-knit organisations in the core that dominated the network, i.e. they were highly connected to one another through several projects, while the remaining organisations were in the network periphery and connected to the core but not connected to one another. The actors in the core – the central actors coordinating the projects – were primarily large national research associations (e.g., Fraunhofer Gesellschaft, CNRS, INSERM) and universities in all thematic areas except in IST where industry was also a central actor.

o ***The networks created by the FP are durable:***

§ According to an EC-commissioned FP6-wide survey (IDEA Consult, 2009c), 56 percent of respondents had already participated in FP5. In addition, 86 percent of respondents said they would continue to collaborate with other members on new activities after the network funding had been discontinued, demonstrating the value placed on the relationships that had been built.

§ In the same vein, a study by JRC-IPTS (2011) shows that the share of organisations 'returning' to the FP increases from one FP to another reaching 50% in FP6 (Table 5). This points to a perfect balance between network stability and renewal.

Table 5. Distribution of returning actors and new entrants within the 100 core organisations (%)

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

Source: JRC IPTS (2011)

o ***The networks created by the FP are well integrated into global innovation networks:***

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

- **FP mobility actions promote the same kinds of durable cross-border, cross-sectoral, inter-disciplinary networks:**

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

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

- **The FP structurally increases the attractiveness of Europe as a place to carry out research:**
  - The FP7 interim evaluation (Annerberg et al., 2010) noted that the specific programme People has been an important instrument to make Europe attractive to the best researchers and to implement the EU's career development policy.
  - It also noted that, according to an analysis by the ERC Executive Agency, a significant share of all applicants have been working in the US, indicating that the programme is having an effect on attracting top researchers back to Europe.

- **Indirectly and directly, the FP influences the design of Member State research policies, especially in the EU12:**
  - Marie Curie Actions set a valuable bench-mark for the working conditions and employment standards of EU-researchers with active participation in the 'European Partnership for Researchers' and the 'Code of conduct for the recruitment of researchers', promoting mobility and better careers for researchers in Europe.
  - The Open Method of Coordination (OMC), including exercises such as policy mix peer reviews, helped Member States devote more effort to the Barcelona goal.
  - The Science in Society programme had some remarkable structuring effects on ERA in the field of participatory technology assessment, capacity-building of civil society organizations, and promoting open science in academic journals.
  - According to an EC-commissioned study on the impact of FP6 on the EU12 (COWI, 2009):
    - Several new Member States (especially Poland, Lithuania and Romania) have been inspired by the FP to take a more networked approach to funding, moving from single-beneficiary to multi-beneficiary projects.
    - In several new Member States (e.g. Romania and Lithuania, and to lesser extent also Poland, Czech Republic and Slovenia), FP6 priorities have effectively substituted 'national' priorities.
    - In some of the new Member States (Romania, Lithuania, Poland), FP6 has been a vehicle for a transformation and re-orientation of the research policy planning where the programmatic qualities of the FP6 have been used. These qualities include: (1) the strategic and 'applied' approach to research with priority areas; (2) the planning horizon (e.g. adopting a 2007-2013 time horizon); (3) the evaluation procedure for national research proposals.
    - To stimulate an international reorientation of national research, some countries (Romania, Lithuania, Poland) reward submission of FP6 proposals in national research evaluation procedures, using a standardised 'uplift' (for instance in Romania, where an FP6 submitted proposal automatically receives a 5 point bonus; out of 100 points).

THE EU RESEARCH AND INNOVATION PROGRAMMES PRODUCE LARGE MACRO-ECONOMIC IMPACTS

Studies show that EU funding produces large macro-economic impacts:

- See **Annex 5**: An extensive body of academic economics literature has demonstrated that R&D produces large-scale macro-economic effects.

- The FP7 ex-ante impact assessment identified large-scale FP macro-economic effects:
  - €1 of Framework Programme funding leads to an increase in industry added value of between €7 and €14.
  - Member States' own evaluations also demonstrate the high impact of the FP: the FP's annual contribution to, for instance, UK industrial output exceeds £3 billion.

- o On the basis of the NEMESIS econometric model, the long-term FP7 macro-economic impact was estimated at an extra 0.96 percent of GDP, an extra 1.57 percent of exports, and a reduction by 0.88 percent of imports

- The potential value added generated by eco-innovation pilot and market replication projects under CIP could be calculated in some € 3.4 million per million € invested (DG ENV, ref. Varma, 2007).

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

THE FP PRODUCES LARGE SOCIAL IMPACTS

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

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

- On the basis of the **NEMESIS** econometric model, the FP7 ex-ante impact assessment identified large-scale FP7 employment effects. The long-term employment impact of FP7 was estimated at 900,000 jobs, of which 300,000 in the field of research.

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

  - o According to an EC-commissioned evaluation of the FP5 Growth programme, the number of jobs (expected to be) safeguarded amounted to 37,588 while the number of jobs (expected to be) created amounted to 8,038 (Ramboll Management and Matrix Knowledge Group, 2008).

  - o 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.

  - o According to a Dutch FP impact study (Technopolis), "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".

  - o 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%).

  - o A Spanish evaluation of FP6 participation (Zabala Innovation Consulting SA (2010) found that, 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. With regard to the creation of public research organisation posts, the FP performed better than national or regional programmes according to 8.33 percent of respondents and equally well according to 75 percent of respondents.

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

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

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

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

- Through Marie Curie actions, the FP set a valuable bench-mark for the working conditions and employment standards of EU-researchers (Annerberg et al., 2010).
- The FP produces indirect social benefits through relevant natural sciences research:
  - o 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.
  - o According to a Dutch FP impact study (Technopolis), "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:
  - o An evaluation of FP5 and FP6 social and environmental effects (European Commission, 2005a) lists research on the following socially relevant issues:
    - § Human rights (increasing equality of opportunity and entitlement, including among genders; ensuring that ethical issues are appropriately and effectively addressed; ensuring compatibility with the EU's Charter of Fundamental Rights)
    - § Social cohesion (reducing social exclusion; reducing risks of poverty)
    - § Economic cohesion (reducing disparities of income for particular sectors, groups of consumers, citizens, workers)
    - § Employment (increasing employment opportunities (job creation, enterprise creation); increasing quality of employment and of the working environment)
    - § Human capital formation (improving educational achievements in the population; increasing training and life-long learning opportunities; increasing skills and learning capability/flexibility, both within and outside the research community)
    - § Public health and safety (improving the health of the population; reducing safety risks; improving nutrition, food quality and safety)
    - § Social protection and social services (improving accessibility to health services; improving long-term sustainability of health services)
    - § Liveable communities (improving quality of housing, infrastructures, services and the living environment in general)
    - § Culture (preserving cultural diversity while increasing integration; preserving and exploiting cultural heritage)
    - § Consumer interests (improving consumer information and choice; reducing consumers' risks)
    - § Security (preventing crime and increasing protection against terrorism; improving the protection of networks and infrastructures; increasing the interoperability of integrated systems and services)
    - § Governance (increasing participation and social capital formation (through increased accountability, democracy, citizens and stakeholders' empowerment, active citizenry)
    - § International co-operation (promoting co-operation among Member States to reduce inequalities, achieve convergence and enhance social cohesion; promoting socio-economic conditions (e.g. welfare, quality of life, etc.) in non-EU countries)
    - § Role of SMEs (increasing and enhancing the potential contribution of SMEs towards job creation, social cohesion, regional development, etc. (through the improvement of their technological capabilities and their increased involvement in research networks)).

THE FP PRODUCES LARGE ENVIRONMENTAL IMPACTS

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

- According to an EC-commissioned evaluation of FP6 environmental research (EPEC, 2008), for instance, EU environmental research contributed to the knowledge base and development of methods and tools for environment related policy. The study found that:
  - At the international level, EU research related to climate change contributed to the International Panel on Climate Change (IPCC), either directly, through individual researchers involved in the IPCC review, or through references to EU-funded projects in IPCC reports.
  - In the domain of environment and health, there were strong links with EU policy priorities, most notably with the implementation of the Environment and Health Action Plan 2004-2010 as well as with the implementation of European Directives.
  - All natural hazards projects contributed to some extent to regional, national and European policies in the field of natural hazards, guidelines and standards.
  - Water and soil projects played a large role in the formulation and implementation of the Water Framework Directive.
  - Earth observation projects had direct impacts on policy-making through the use of their outcomes by stakeholders such as IPCC and WMO.
    - Environmental challenges are global and need to be tackled together with international partners at the European and global levels. Environmental research requires harmonised sets of data produced through satellite monitoring. The scale of the investment needed and the need for full European/international coverage and for open data access requires EU-level action. The FP7 environmental research priority allocated substantial resources to the development of a "Global Earth Observation System of Systems" (GEOSS) promoting the rapid expansion of full, open access to space and ground-based, water and airborne data and observations. GEOSS is maintained by the 85 member governments and the 61 participating organizations of the Global Earth Observation (GEO) on the basis of a 10-Year Implementation Plan (2005-2015). Inspired by the data-sharing principles developed by the Global Earth Observation (GEO) initiative, agencies involved in Earth Observation are making their data much more easily accessible, free of charge. The international character of GEOSS enables the participants to benefit from both know-how and data from other regions of the world. This represents a clear improvement of the general situation deplored by the EEA (2010) of limitation to the trans-national use of infrastructures funded at national levels. Funded projects under the Global Earth Observation initiative (FP7) play a key role in the development of GEOSS. FP7 examples include: EBONE aimed at building a biodiversity observation system, EUROGEOSS implementing a brokering service for accessing data, and IMPACTMIN aimed at developing monitoring impacts of mining operations using Earth Observations.

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

- According to an evaluation of FP3 and FP4 Brite-Euram projects, for instance, just over one third of industrial participants reported that their project had had at least one environmental impact within their organisation, and the vast majority of these (97%) were positive: 39% cited savings in materials; 32% cited energy savings; and 32% cited reductions in the release of dangerous products.
- According to an EC-commissioned evaluation of the FP5 Growth programme (Deloitte, 2006) – which covered "Key Actions" like "Innovative products, processes and organisation", "Sustainable mobility and intermodality", "Land transport and marine technologies" and "New perspectives for aeronautics", and "Generic Activities" like "New materials and their production and transformation (including steel)" and "Measurement and testing" - the average environmental impact per project was substantial reaching 6.08 percent in terms of the expected reduction of waste and 4.06 percent in terms of the expected energy saving.
- According to an evaluation of a sub-set of FP5 Growth programme projects (Ramboll Management and Matrix Knowledge Group, 2008), nearly 25 percent of all evaluated projects anticipated medium-high or

high benefit with regard to the reduction or prevention of emissions, while about 20 percent anticipated medium-high or high benefit with regard to saving natural resources.

- According to an evaluation of FP5 and FP6 social and environmental impacts (European Commission, 2005a), important projects were, for instance, ExternE (Externalities of Energy) and ExternE-Transport, RECORDIT (Real Cost Reduction of Door-to-Door Intermodal Transport), and ECOSIT (External Costs of Industrial Technologies) that produced results that fed directly into policy formulation in the energy and transport sectors (e.g. the recent revision of the Eurovignette Directive). Similarly, the DYN-GEM-E3 project was instrumental in energy taxation reforms through "the macroeconomic evaluation of energy tax policies within the EU". The POLES model, also developed with EU energy research funding, was used to define the future CO2 emission baseline in the context of post-Kyoto targets".
- According to a FP6-wide participation survey (IDEA Consult, 2009c), the thematic priorities "Sustainable development, global change and ecosystems" and "Nanotechnologies and nanosciences etc." contributed to the sustainable use or production of energy, while the thematic priorities "Sustainable development, global change and ecosystems", "Nanotechnologies and nanosciences", "Aeronautics and space", and "Food quality and safety" contributed to the environment.

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

- According to an Irish evaluation of the FP (Forfas, 2009), 50 percent of all projects made a contribution to "improved environmental preservation or protection".
- A Swedish evaluation of the FP (VINNOVA, 2008) found that "Framework Programmes have positive effects on the behaviour of the research community, competitivity, jobs, regulation and the environment".
- According to a Swiss evaluation of the FP (State Secretariat for Education and Research, 2009), "no fewer than 70 projects from the FP5 environment programme were explicitly referred to in European Commission position papers. The EU Directive on greenhouse gas emission allowance trading was also based on findings from FPs". The evaluation also stated that "while certain significant benefits of Switzerland’s participation in FPs are not measurable, there is no doubt that FPs have various impacts in … environmental (energy, pollution, natural disasters, …) … areas … , even if it is not known to what extent or in what way, precisely".
- According to respondents to a UK evaluation of the FP (Technopolis, 2010), FP activities strengthened previously weak UK capabilities in a number of environmentally relevant research areas ("The FP6 Marie Curie RTN has allowed us FINALLY to tackle an important research area (breeding of a novel fodder legume with tannins for animal nutrition, health and greenhouse gas emissions). An FP7 Marie Curie IEF is similarly enabling us to get involved in a willow breeding programme for the benefit of animals and the environment"). The FP5 STAIRRS and the FP6 SILENCE projects also directly informed the Environmental Noise Directive and railway TSI (Technical Specification for Interoperability) processes.

SUCCESS STORIES

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

- FP-funded collaborative research reduces risk and enables the achievement of pan-European standards. Standards and technologies developed by FP-funded researchers are today found in over 600 million 3G mobile phones, generating more than 250 billion euro of revenues every year to EU companies in products and services.
- FP-funded collaborative research facilitates the growth of innovative SMEs. In 2006, two small research-based companies from Sweden and Belgium, BioInvent and Thrombogenics, received together with academic and clinical partners a 1.9 million euro grant to form the project **ANGIOSTOP**. The firms have since developed an innovative form of treatment for cancer. In 2009, the companies secured a 50 million euro investment from global pharmaceutical giant Roche, with the possibility of increasing this amount to 450 million euro.
- EU funding leverages private investment. In the case of **RSFF**, the volume of loans is 12 times the EU contribution, and the additional leveraged investment in research, development and innovation is 30 times the EU contribution.
- As a result of targeted JRC research costing about 1 million euro, the cost of tests for BSE were reduced and the direct EC subsidy per test could be scaled back from 20 euro to 7 euro resulting in cumulative savings for the Community budget over the period 2002-2006 of about 250 million euro.
- JRC research enabled the launching of the GI2000 initiative and the 2007 INSPIRE directive establishing an infrastructure for spatial information in Europe. The estimated EU, national and regional investments for INSPIRE are of the order of 100 million euro whereas annual benefits of the full implementation of the directive are estimated at 8-12 billion euro.
- The aim of the **SLIC** project was to develop and commercialise a compact device ("lab-on-a-chip") for the extraction, identification and analysis of micro-RNAs, which affect gene regulation. Thanks to the international, collaborative framework of the European project, it was possible to recruit an interdisciplinary team with highly specialised skills, not all of which could be found in a single country. With the technology developed in the SLIC project, the time required for microRNA analysis has been reduced from a day to a quarter of an hour. This is associated with a considerable reduction in the costs of these procedures, which are now widely practised. This innovation entails significant benefits not only in economic terms (the Swiss start-up project coordinator, Ayanda Biosystems, has been approached by the leading companies in the sector), but also for science and health (more rapid and less costly diagnostics).
- Secure communication is an essential requirement for companies, public institutions and citizens. Encryption systems currently used are rendered vulnerable in particular by the continuing growth in computing power. Quantum cryptography, based on the quantum properties of light, ensures communication channels which are demonstrably inviolable. In 2008, the **SECOQC** project enabled the deployment of a telecommunication network based on quantum cryptography – a world first. No European group had expertise in all the technologies that were needed to establish a network of this kind. To succeed, the SECOQC project had to draw on the skills of 40 participants from 11 different countries. The demonstration of the feasibility of an inviolable communication network heralded the birth of a new market. The SECOQC project also led certain partners to jointly develop the first international standards in this new industry.
- The aim of the **CASOPT** project is to produce a paradigm change in the design of complex electromagnetically-driven industrial products. State-of-the-art simulation-based design is to be replaced by optimization-based design. This new approach is the key to achieving the goals of miniaturization, reductions in the quantity of materials required and costs, and improvements in the energy efficiency of products. The research consortium brings together partners from industry and academia in a project based on knowledge transfer. As the CASOPT project is highly multidisciplinary, it was necessary to assemble a team of world-class experts in numerical analysis, simulation, optimization, geometric design and parallel computing. The realization of this project essentially relies on existing site competencies and knowledge transfer among the partners, with support from additionally recruited experts. Synergies arise between the experience of private-sector and university institutions, and also between experienced

researchers and others who are younger and highly motivated. This offers them a unique opportunity to carry out research within a network, and also to develop other research ideas and projects. In the short term, the results of the project will be used in the design of power transmission and distribution systems. The CASOPT project will make it possible to push the performance of products beyond current limits without adversely affecting their reliability or robustness. In addition, highly skilled young students, PhD students or post-docs participating in this type of project can be recruited by industrial partners. In the long term, the project could have a decisive impact on the evolution of industrial design concepts for many different sectors, but also for SMEs, whose product range is also covered.

- FP collaborative research is often pioneering in its domain. The FP project on **Yeast genome** was the first international grant in genomics. Its aim was to reveal the first full set of genes of a eukaryotic genome and in a broader sense, identify basic biological mechanisms common to all living organisms, including man. This 7 years long research involved an international effort of 641 scientists in Europe, USA, Canada and Japan sequencing a total of 12.3 million of DNA base pairs covering the 16 nuclear chromosomes. Europe was not only at the origin of this large research venture, but also provided much of the sustained funding required to ensure the success of this pioneering task. A total of 92 European laboratories and over 400 European scientists have participated in this network. By the end of 2010, this project has generated more than 500 scientific articles reporting yeast DNA sequences and a total of 2,849 patents registered. With the discovery that the yeast genome is similar to that of man, very interesting prospects have opened up for the future understanding of certain diseases - such as cancers and genetic diseases.

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

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

- The objective of the **EDCTP** (European and Developing Countries Clinical Trial Partnership) Article 185 initiative was to accelerate the development of new clinical interventions to fight HIV/AIDS, malaria and tuberculosis in developing countries. The background to the project was that worldwide over 30 million people are living with HIV and close to 3 million people become infected each year. In addition, there are each year close to 250 million cases of malaria worldwide (and close to 900,000 deaths) as well as 9 million cases of tuberculosis. EDCTP involves the European Commission, 16 European countries (14 Member States and 2 Associated Countries), industry, private charities like the Bill and Melinda Gates Foundations, and 29 Sub-Saharan African countries. The conceptualisation and implementation of this project required a level of coordination of a wide range of funding sources that could only be achieved at EU level. EDCTP has so far supported 54 clinical trials on new treatments and vaccines for HIV, malaria and tuberculosis and the training of 158 medical researchers. The US Food and Drug Administration has approved an anti-retroviral formulation for HIV infected children in Africa, which was tested through an EDCTP project. The first African Networks of Excellence for clinical trials in central Africa have been established and there are now national ethics committees in many African countries thanks to EDCTP.
- Pan-European Public Procurement On-line pilot project, funded by ICT-PSP, is creating a standards-based IT transport infrastructure which enables cross-boarder, interoperable public eProcurement with standardised electronic document formats. In results, it is easier for companies to bid for public sector contracts anywhere in the EU in a simpler and more efficient way. 12 Member States or associated countries are currently involved in the pilot.
- The innovative ICTs are used to help people receiving medical assistance anywhere in the EU. The ICT-PSP market demonstration project epSOS is building a service infrastructure demonstrating cross-border interoperability between electronic health record systems in Europe. The medical services are becoming more accessible throughout Europe thanks to removing linguistic, administrative and technical barriers. 23 Member States or associated countries are currently involved in this pilot project.

DETAILED EVIDENCE ON LESSONS LEARNED

While European research and innovation programmes have been successful, there are important lessons to be learned from the past, from stakeholder feedback, and from analytical studies. Research, innovation and education should be addressed in a more coordinated manner and coherent with other policies and research results better disseminated and valorised into new products, processes and services. The intervention logic of EU support programmes should be developed in a more focused, concrete, detailed and transparent manner. Programme access should be improved and start-up, SME, industrial, EU12 and extra-EU participation increased. Monitoring and evaluation need to be strengthened

The need for improved horizontal and vertical policy coordination

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

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

The need for horizontal policy coordination is confirmed by the conclusions of the OECD's work on the most appropriate system of innovation governance. OECD (2005a), for instance, mentions the need to develop "a strategic, horizontal approach", which "should include and develop the innovation policy potential in other ministerial domains and ensure a co-ordinated division of labour between them". And

OECD (2010b) concludes that "given the increasingly central role of innovation in delivering a wide range of economic and social objectives, a whole-of-government approach to policies for innovation is needed".

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

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

The need for focus and a more robust intervention logic

A number of FP ex-post evaluations (Rietschel et al., 2009, v; European Court of Auditors, 2007, paragraph IV) have noted that the programme's design could be improved. The view held is that the FP lacks a transparent, clear and robust intervention logic: the programme has too many objectives, and higher-level objectives are insufficiently translated into lower-level objectives.

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

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

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

The need to lower the barriers to participation

All FP ex-post evaluations - see, for instance, the chapters on participation in the FP6 ex-post (Rietschel et al., 2009) and FP7 interim (Annerberg et al., 2010) evaluations - are unanimous in their view that FP application, contract negotiation and project management procedures are too complex and burdensome and that this results in high barriers to FP application and participation, in general but in particular for first time, start-up, SMEs and EU12 applicants.

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

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

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

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

The need to strengthen monitoring and evaluation

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

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

ANNEX 2: THE NEED FOR PUBLIC INTERVENTION AND EUROPEAN ADDED VALUE

PUBLIC INTERVENTION IN RESEARCH AND INNOVATION IS JUSTIFIED BY MARKET AND SYSTEMIC FAILURES

- The right balance between public and private investment should be struck on the basis of a careful assessment of the presence of market and/or systemic failures that government should address.
- Research is seriously affected by **market failures**, as a result of which there is significant private sector underinvestment in research and a solid basis for public support:
  - A first market failure concerns **risk and uncertainty**. At the start of a research project, it is not at all sure that the research efforts undertaken will actual[illegible]ge and innovation. The challenge of risk and uncertainty is exacerbated by the fact that the cost of R&D is rising, because it becomes more expensive to carry out research and because the life-cycle of products is shortening dramatically (for more on costs of research, see Box hereafter). Levels of risk and uncertainty are especially high when developing the breakthrough technologies required by new techno-economic paradigms, in other words when engaging in radical rather than incremental innovation. A related point is that market prices do not take full account of negative externalities (e.g. polluting activities). As long as markets do not punish environmentally harmful impacts or reward environmental improvements, competition between environmental and non-environmental innovation is distorted and a socially sub-optimal amount of investment occurs.

Striking results of a recent EU survey on Cost of Research

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

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

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

The activities considered by the surveyed companies to be most important in bringing down the cost of research, are:
- aligning R&D with business strategies,
- joining collaborative R&D projects, and
- technological efficiency of the R&D process.

The activities considered by the surveyed companies to be most influential in driving up the cost of research, are:
- complexity of the R&D process,
- environmental legislation, and
- regulation of product markets.

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

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

Source: COST, 2011

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

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

- The need for public support of research also derives from the **system** nature of innovation, and from the importance to invest in human capital and networks to ensure the absorption of knowledge.
  - The innovation systems literature argues that what matters for an economy's innovation performance are the **linkages** and flows of information between the different actors in the innovation system. These linkages and flows are often sub-optimal and government can play a role in strengthening them.
  - As argued above, the dissemination, valorisation and economy-wide **market take-up** of new technologies is an issue of a systemic nature. For instance, electric cars will not be used on a large scale if electric vehicle refuelling points are not widely available. The public sector often has to take the lead in addressing such systemic obstacles to technology uptake. Another good example concerns eco-innovation, which does not concern a single sector in conventional terms but a range of technologies, products, services, business models, and potential target markets. This makes it more difficult for potential investors to evaluate funding opportunities and asses risks than if all investment opportunities were built around a common technology platform. This is especially the case in sub-sectors, such as those not related to energy, which are less known or considered immature and therefore riskier.

PUBLIC INTERVENTION IN RESEARCH AND INNOVATION PRODUCES CLEAR BENEFITS

Public research generates direct economic benefits

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

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

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

- US research estimates that a 10 per cent increase in university R&D increases corporate patenting by between 1 per cent and 4 per cent (Jaffe, 1989; Jaffe and Trajtenberg, 2002) (quoted in RCUK).
- 15 % of new products and 11 % of new processes would have been developed with a substantial delay in the absence of academic research (Mansfield, 1998).
- Approximately 20% of private sector innovations are partially based on public sector research (Tijssen, 2002).
- Cohen, Nelson and Walsh (2002) evaluated for the US manufacturing sector the influence of public (i.e. university and government R&D laboratory) research on industrial R&D, the role that public research plays in industrial R&D, and the pathways through which that effect is exercised. They found that public research is critical to industrial R&D in a small number of industries and importantly affects industrial R&D across much of the manufacturing sector. Public research both suggests new R&D projects and contributes to the completion of existing projects in roughly equal measure overall. Key channels through which university research impacts industrial R&D include published papers and reports, public conferences and meetings, informal information exchange, and consulting.
- A stochastic frontier analysis by the European Commission's Directorate-General Economic and Financial Affairs found significant positive effects on the number of patents and business patents per million inhabitants for a number of independent variables related to public intervention: the public R&D stock, international research cooperation and international researcher mobility (through which access is provided to the stock of foreign R&D), and the share of R&D invested in basic research (Mandl et al., 2008).

High-quality public research attracts private R&D

- Belderbos et al. (2009) found that, controlling for a wide range of host country factors, the number of relevant ISI publications by scientists based in the host country has a substantial positive impact on the propensity to conduct foreign R&D. The effect of academic research is significantly larger for firms with a stronger science orientation in R&D - as indicated by citations to scientific literature in prior patents;
- Doh et al. (sd) found that US MNC R&D location decisions, and the relative levels of R&D investment in a given country location, are mostly influenced by broad, macroeconomic and development factors. Scientific output, and to a lesser extent, institutional quality, appropriability regimes, and telecommunications infrastructure, also influence R&D location, while the presence of existing MNC investment is not found to influence R&D investment.
- Dosi, Llerena and Sylos Labini (2009) presented cross-country comparisons revealing that industry-financed R&D is positively associated with both the per capita number of highly cited researchers and expenditure on higher education R&D. This also held within sectors: in a number of industrial sectors,

R&D intensity was positively correlated with the quality of academic research in selected related fields, and those countries with the highest per capita number of highly cited scientists in relevant fields displayed the highest R&D intensities.

- Guimon (2008) found that the empirical evidence available suggests that, among the factors related to the host country, the main location drivers for R&D-intensive foreign direct investment are the availability of world-class research infrastructure and skilled labour as well as the dynamism of the national innovation system, that is, the degree of interaction and collaboration among different firms and other "knowledge producing and diffusing organizations" (universities and research centres, consultants, industrial associations, etc.).
- Abramovsky, Harrison and Simpson (2007) (quoted in RCUK) investigated the relationship between the location of private sector R&D labs and university research departments in Great Britain. They combined establishment-level data on R&D activity with information on levels and changes in research quality. The strongest evidence for co-location was found for pharmaceuticals R&D but also for other sectors evidence for co-location was found. There is evidence that private sector R&D labs in the UK are disproportionately clustered around highly rated university research departments. This phenomenon is not driven just by university 'spin-outs': in some industries, foreign-owned companies are choosing to locate in close proximity to high quality research. This implies that multinational companies may be sourcing cutting-edge technologies from universities in the UK. The results of this study show that R&D facilities 'cluster' near university departments, particularly in the pharmaceuticals and chemicals sectors. A postcode area (for example, ‘OX’ for Oxford) with a chemistry department rated 5 or 5* by the 2001 RAE is likely to have around twice as many labs doing R&D in pharmaceuticals and around three times as many foreign-owned pharmaceuticals R&D labs compared with a postcode area with no 5 or 5* rated chemistry departments.
- Research also finds evidence that foreign-owned labs in the machinery and aerospace sectors are likely to be located near to materials science and electrical engineering departments rated 4 or below by the RAE (Abramovsky and Simpson, 2008) (quoted in RCUK). This suggests that companies also benefit from proximity to more applied, commercially oriented research activity.
- A recent study analyses the relationship between the number of patenting manufacturing firms and the quantity and quality of relevant university research across UK postcode areas (Helmers and Rogers, 2010) (quoted in RCUK). It finds that different measures of research 'power' and 'quality' positively affect the patenting of small firms within the same postcode area. This indicates that small firms benefit from localised university-industry knowledge transfer.
- A further study of research and local development examines the impact of university business incubators on innovation by firms close by (Helmers, 2010) (quoted in RCUK). Standard business incubators provide start-up companies with a range of support measures, including physical space within the incubator building, training and coaching, business contacts, access to finance, etc. University incubators have the additional advantage that they can draw on the resources available at the university, including academic support, access to research facilities, as well as easy access to the student pool to recruit employees. The study finds that the recent wave of establishment of new university business incubators in the UK has generated local externalities by increasing the patenting propensity of incumbent firms located geographically close to the new university business incubators. Incumbent firms react to the entry of new firms within the same sector by increasing their propensity to patent by 2-6 per cent. The effect is stronger the closer the entrant is geographically located to an incumbent – the strongest impact occurs within a radius of 5-15 kilometres. Beyond 100 kilometres, entry has no economically significant effect on incumbent patenting.
- Recent research on knowledge spillovers from university innovation in the United States confirms that, for companies to use publicly funded research most effectively, geographical location has a significant contribution (Belenzon and Schankerman, 2010) (quoted in RCUK). Analysing patent citations both to university patents and scientific publications, the study finds that knowledge spillovers are strongly localised, sensitive to distances of up to 15 miles. Companies located in the same state as the cited university are substantially more likely to cite one of the university patents than a company located outside the state.

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

- Most recent studies find positive effects of R&D subsidies on R&D investment (Czarnitzki, 2011).
- €1 of public funding for R&D (including defence) leads to additional business R&D of €0.70-0.93 when allocated to business (Guellec and Van Pottelsberghe, 2000; European Commission, 2004).
- A 10 per cent increase in university research increases private R&D by 7 per cent (Jaffe, 1989; Jaffe and Trajtenberg, 2002) (quoted in RCUK).
- A 1% increase in public basic pharmaceutical research leads to a 1.7% increase in industry R&D after eight years. And a 1% increase in public clinical research leads to a 0.4% increase in industry R&D after three years (Toole, 2007) (quoted in CaSE, 2010).
- This additional research expenditure does not just translate into higher researcher wages; it generates additional research (Aerts, 2008; Lokhsin and Mohnen, 2008).

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

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

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

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

THE ADDED VALUE OF EU-LEVEL SUPPORT FOR RESEARCH AND INNOVATION IS UNDISPUTED

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

The literature is unanimous

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

- The FP7 interim evaluation (Annerberg et al., 2010) concluded that "FP7 is assessed to fill in important gaps between national research activities, thus gaining critical mass in many areas and ensuring added value, as the assessments suggest that the FP7 activities are not likely to have been implemented without EU level funding".
- The FP6 ex-post evaluation (Rietschel et al., 2009) concluded that "the activities under FP6 … generated European added value" and that "FP6 was a powerful mechanism for catalysing RTD in Europe that could only be realised through action at the European level", and "[could] find no evidence that plausible alternative approaches would have been more successful in the same timeframe, acknowledging the ambition, scale and importance of FP6".
- The Five-Year Assessment 1999-2003 (European Commission, 2005) concluded that all evidence seen by it "whether at Community or Member State level, consistently emphasised the significant additionality and European added value for the Framework Programmes".

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

Thanks to EU initiatives, the European R&D landscape is radically changing for the better

- **The EU created the European Research Council, which promotes excellence across Europe:**
  - The European Research Council would not have been created without an EU initiative. The EU would then have been left with a landscape of 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.
- **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. No less than 10 next generation European infrastructures [e.g. IAGOS (In-service Aircraft for a Global Observing System), ESS (European Spallation Source) and SHARE (Survey of Health, Ageing and Retirement in Europe)] are currently being built by groups of Member States and these facilities would not have seen the light of day if it were not for EU action. In addition, without EU funding measures to facilitate access to unique and expensive infrastructures, 9 out of 10 researchers say that they would not have been able to access vital research facilities, which is a often a precondition for successful frontier research. For example:
    - The IA-SFS project has created the largest network of free electron lasers and synchrotrons in the world, serving several thousand European scientists and allowing a wide range of applications.
    - The European Grid Infrastructure gives European researchers access to the aggregated processing power of 200 000 computers in the world's largest distributed computing infrastructure ever built, with over 290 sites in more than 50 countries, utilised by 13 000 researchers.
- **The EU makes it easier for private companies to develop and implement joint strategic research agendas, which help to boost their competitiveness and stimulate smart, sustainable and inclusive growth:**
  - An important achievement of the Framework Programme has been to establish instruments and mechanisms (e.g. European Technology Platforms, Joint Technology Initiatives) that facilitate the joint development and implementation of strategic research agendas by the private sector and for public-private partnership. These strategic research agendas have played a key role in boosting the competitiveness of the sectors involved. For example:
    - The Innovative Medicines Initiative is helping to make Europe the most attractive place for pharmaceutical R&D, thereby enhancing access to innovative medicines for patients. It does so by providing new tools and methodologies to remove major bottlenecks in drug development.
    - The Clean Sky joint technology initiative is bringing significant step changes regarding the environmental impact of aviation. Clean Sky will speed up technological breakthroughs and shorten the time to market for new and cleaner solutions tested on full scale demonstrators. It will thus contribute significantly to reducing the environmental footprint of aviation (i.e. emissions and noise reduction but also green life cycle) for future generations.
- **The EU helps bring together compartmentalized national research funding across borders so as to achieve the scale needed to tackle important societal challenges:**
  - One of the pioneering achievements of the Framework Programme has been to establish instruments and mechanisms (e.g. ERA-NET, Article 185) for the joint programming of Member State research. This has led to a new approach to research funding involving countries pooling and coordinating their own national funds across borders. For example:

- § A pilot Joint Programming action has brought together 23 Member States and associated countries to jointly develop and fund a strategic research agenda for tackling neurodegenerative diseases and Alzheimer's.
- § EURAMET is an action aimed at coordinating metrology research across Europe. Involving 22 National Metrology Institutes it pools 44% of overall metrology resources in one initiative, reducing duplication of research and encouraging the more efficient use of resources.

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

- **EU cross-border research, innovation and mobility actions are of systemic importance:**
  - o **Cross-border collaborative research and innovation collaboration actions** are of key importance since they underpin the 'open innovation' paradigm:
    - § It enables the achievement of the **critical mass** required for breakthroughs when research activities are of such a scale and complexity that no single Member State can provide the necessary financial or personnel resources, so when, for instance, a large research capacity is needed and resources must be pooled to be effective or when there is a strong requirement for complementary or comparative knowledge and skills (e.g. in highly inter-disciplinary fields). Telling examples are rare diseases research, space research, ICT, etc. For example, when researching rare diseases the FP helps to bring together the necessary critical mass of patients, expertise, and facilities. There are at least 6000 to 7000 rare diseases, which taken together affect some 20 million European citizens. However, research at national level is often hampered by a thin distribution of patients, few specialised research groups, and a lack of standardisation of available data and material collections.
    - § It enables research addressing **pan-European policy challenges**. Public policy challenges have become increasingly international (e.g. environment, health, food safety, climate change, security) and their resolution has become increasingly dependent upon the establishment of a common scientific base. Moreover, research can lead to the establishment of harmonized laws and standards. Given the shared interest and the scale on which these issues arise, such research activities are best organised in a cross-border collaborative manner.
    - § It reduces risk and enables the achievement of **pan-European standards**. Working in trans-national consortia helps firms to lower research risks, thus enabling certain research to take place. Involving key EU industry players helps reduce commercial risks, by ensuring that research results and solutions are applicable across Europe and beyond, enabling the development of EU- and world-wide standards and interoperable solutions, and offering the potential for exploitation in a market of 500 million people. The FP supports the kind of pan-European research collaboration required to speedily produce industrial standards that can set the tone and be adopted at the global level. ICT research & innovation, for instance, is increasingly organised around new kinds of collaboration involving common, open technology platforms with high spill-over and leverage effects. They allow a much wider range of stakeholders to profit from new developments and further innovate. Federating and partnering at EU level helps ensure that research results and solutions are applicable across Europe and beyond. It enables consensus building, interoperable solutions and the development of EU- and world-wide standards. EU research also provides an important umbrella to facilitate globally interoperable ICT systems, global consensus and standards. Direct EU level actions also support pre-normative research in support of standardisation, harmonization and development of reference materials and methods. Without the FP, Europe would not have been at the origin of the global standard for 2G and 3G mobile communications.
    - § It enables the rapid and wide **dissemination** of research results – to users, industries, firms (SMEs in particular), citizens, etc. – leading to a better exploitation of research, and giving a larger impact than would be possible only at Member State level.
    - § **Growing innovative SMEs**: Innovative SMEs, for instance in the field of ICT and services, play a vital role in generating new ideas and transforming these into business assets. They are agile, able to focus their research and innovation efforts and take fast technical and business decisions. SME involvement in research and innovation at EU level improves their partnerships and alliances with other companies and research labs across Europe. It enables innovative SMEs to develop new

products and services beyond their in-house and national capabilities. And, it allows them to grow and enter new international markets.

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

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

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

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

o A study on ICT under FP4 and FP5 (Databank Consulting et al., 2004) found that FP collaborative research funded mainly two types of R&D projects: (1) "Core" projects: highly interesting, necessary and strategically important projects that occur in the core technology areas of the respondents (58 percent of projects); (2) "Complex-risky" projects: long-term, technically complex, and risky from commercial and technical point of view (26 percent of projects)40 % of industry participants in FP6-IST reported their research in the ICT programmes being of high to very high commercial risk.

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

- An Austrian study on FP4 (Joanneum Research et al., 2001) found that most FP projects were seen as of strategic importance: 37.7% of EU projects were seen as of central importance and 53.7% of EU projects supported other innovation activities. FP projects were closer to the scientific-technological core concentration of the company, more involved, and more application-oriented than nationally funded projects and against this backdrop, FP projects gained a specific strategic significance for companies.
- A Danish study on FP4 (Danish Institute for Studies in Research and Research Policy, 2000) found that more than 90% of participants participated in projects with a research content close to the core of the workplace. Close to 75% of participants indicated that the projects were part of the long-term strategic R&D.
- A Finnish study on FP4 (Luukkonen and Hälikkä, 2000) found that most FP projects were either of strategic/central importance or of potential future importance/supporting other research activities. For big companies, for instance, the shares were over 20 percent and over 55 percent respectively, while for SMEs, the shares were 40 percent and over 40 percent respectively.
- An Irish study on FP4 (Forfas, 2001) found that, generally speaking, the projects undertaken by Irish participants were complex, exciting, long-term projects in core technologies which most organisations considered of strategic importance and high relevance to their organisations.
- A survey covering the whole of FP5 (ATLANTIS Research Organisation et al., 2004) found that most FP5 projects were seen as strategically important projects in core technology areas for the organisations concerned. Typically they were tightly linked either conceptually or more pragmatically with other in-house projects but were only feasible when undertaken in collaboration with others. Projects were generally of a high scientific and technical complexity and skewed towards the longer-term end of the spectrum. Work of an applied R&D nature nevertheless still predominated over more basic research, especially for industrial participants.
- A Finnish study on FP5 (Uotila et al., 2004) found that FP-funded projects were either of high current or of future strategic importance. For big companies, for instance, the shares exceed 20 percent and 55 percent respectively, while for SMEs, the shares exceeded 20 percent and 65 percent respectively.
- A Norwegian study on FP5 (NIFU, STEP and Technopolis, 2004) found that EU-funding seemed to stimulate businesses to get involved in more risky research than otherwise, which could widen their technological horizons and opportunities.
- The Innovation Impact study on FP5 and FP6 (Polt et al., 2008) found that, compared to collaborative research projects funded exclusively via internal R&D budgets, FP projects were, on average, characterised by lower commercial risk, longer term R&D horizon, more interest in 'peripheral' technologies outside the core technologies of participants, and a focus on exploration (rather than exploitation) strategies.
- A survey covering the whole of FP6 (IDEA Consult, 2009) found that "FP funded projects are incomparable with national/regional funded projects, as their objectives and characteristics are very different" (p24) and that "the average research project funded under FP6 [concerns] long-term, strategically highly important, technically highly complex R&D in a core technological area of the organisation. … It is tightly linked with other in-house projects but mainly considered only feasible with external collaborators" (p20).
- A German study on FP6 (Federal Ministry of Education and Research, 2009) found that large, export-oriented companies as well as companies in the field of cutting-edge technology and the knowledge-intensive service sector were more likely to take part in FP6 than in federal or Länder programmes. They concluded that the European and international focus of the FPs was particularly attractive for companies in sunrise sectors.

- **Without the EU programmes, most of these strategically important research and innovation actions would simply not take place or be far less ambitious**
    - Interview-based evidence indicates that in the absence of CIP funding, eco-innovation projects would not have benefited from cross-border cooperation and learning and the resulting EU-wide market scope. Most beneficiaries indicated that they would not have moved forward with the development of the

technology or, had they done so, it would have been at a much smaller scale focusing on the needs and characteristics of the national or regional markets.

- As Table 1 below shows, the FP achieves very high levels of overall "project additionality": without FP funding, the great majority of FP projects would not have been carried out at all (hypothetical case). This is a first key finding that is highly robust: it is a finding valid across a series of FPs and across a range of different actions; it is a finding resulting from Commission-commissioned evaluation studies as well as nationally commissioned evaluation studies; and it is a finding confirmed through control groups: the great majority of rejected FP proposals never got implemented (experimental case).
- A second key finding is that the levels of overall "project additionality" achieved by the FP are much higher than those achieved by most European and non-European national R&D funding schemes (Compare Tables 1 and 2). It seems that there are far fewer substitutes for EU funding than there are for national schemes.
- A third key finding is that the FP achieves very high levels of "behavioural additionality": the great majority of those projects that would have been carried out in the absence of EU funding would have changed dramatically, undermining their strategic importance: they would have been carried out on a smaller scale (with less money, with fewer partners), with a reduced scope (less ambitious), and at a later stage or over a longer period of time.
- A fourth key finding is that the levels of "behavioural additionality" achieved by the FP are much higher than those achieved by most European and non-European national R&D schemes.
- A fifth key finding is that the FP achieves very high levels of "project" and "behavioural" additionality not only overall but also and particularly for strategic projects. This is once more a finding that is highly robust: it is a finding valid across a series of FPs; it is a finding resulting from Commission-commissioned evaluation studies as well as nationally commissioned evaluation studies; and it is a finding confirmed through control groups:
  - A study on ICT under FP4 and FP5 found high levels of project additionality for the FP overall (Table 1) as well as for strategically important projects (below) (Databank Consulting et al., 2004).

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

  - A Finnish study on FP4 (Luukkonen, T. and S. Hälikkä, 2000), found high levels of additionality for the FP overall (Table 1) as well as for strategic projects (below).

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

§ A survey covering the whole of FP5 (ATLANTIS Research Organisation et al., 2004) found high levels of additionality for the FP overall (Table 1) as well as for strategic projects (below).

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

§ A survey covering the whole of FP6 (IDEA Consult, 2009) found high levels of additionality for the FP overall (Table 1) as well as for strategic projects (below).

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

§ According to a survey among participants in FP5/FP6 ICT projects (WING, 2009), the evolution from FP5 to FP6 saw larger enterprises and SMEs shifting their focus towards longer-term research of high strategic importance in what they considered their core R&D area. This trend continued into FP7 and saw further increases in the strategic importance of FP7 ICT research for all stakeholder groups, whereby 70% of all surveyed participants deemed the programme of high to very high strategic importance for their own organisation (Technopolis, 2010c).

Table 1: Evaluations of the FP

FP	Study owner – Scope of the Evaluation	Full Project Additionality (Share of respondents who did (failed applicants) or would (participants) abandon the project in the absence of FP funding	Partial Project Additionality (Share of respondents who did (failed applicants) or would (participants) change the nature of the project in the absence of EU funding) (*: share of total respondents; **: share of respondents who did (failed applicants) or would (participants) not abandon the project)				Reference
			Scale additionality (Share of respondents who did (failed applicants) or would (participants) reduce the scale of the project in the absence of FP funding)	Acceleration additionality (Share of respondents who did (failed applicants) or would (participants) postpone or increase the duration of the project in the absence of FP funding)	Scope additionality (Share of respondents who did (failed applicants) or would (participants) reduce the scope or objectives of the project in the absence of FP funding)	Networking Additionality (Share of respondents who did (failed applicants) or would (participants) reduce the number of (international) partners in the absence of FP funding)	
FP3&4	EC – BriteEuram	• 45% large companies would • 51% SMEs would	• 44% large companies would* • 22% SMEs would*		90% would*		European Commission (2002)
FP4&5	EC – IST	• 73% would					Databank Consulting et al. (2004)
FP4&5	EC – Marie Curie	• 69% would (Cat 20)[1] • 53% would (Cat 30) • 70% would (Cat 40)					Van de Sande et al. (2005)
FP4	National – Austria	70.1% would	86% would**				Joanneum Research et al. (2001)
			40% would**		52% would**	40% would**	
FP4	National – Denmark	70% would	60% would*	50% would*			Danish Institute for Studies in Research and Research Policy

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

							(2000)
FP4	National – Finland	54% would	22% would*	19% would*	17% would*		Luukkonen and Hälikkä (2000)
FP4	National – Ireland	82% would	>70% would**	Almost 40% would**	Almost 80% would**	Almost 40% would**	Forfas (2001)
FP4&5	National – UK	70% would	17% would*				DTI - Office of Science and Technology (2004)
				59% would**	90% would**	64% would**	
FP5	EC – All	• 57% would • 84% did	• 36%would* • 16% did*				ATLANTIS Research Organisation et al. (2004)
			• 76% would** • >40% did**	• 33% would** • >50% did**	• 43% would** • 6% did**	• 70% would** • 43% did**	
FP5	EC – Growth	69.6% would				20.9% would*	Matrix Insight Ltd. (2008)
FP5&6	EC – SME	55% would		45% would*	45% would*		European Commission (2007)
FP5	EC – Research Infrastructure Access	88% would					European Commission (2003)
FP5	National – Finland	70% would	40% would*	36% would*	14% would*		Uotila et al. (2004)
FP5	National – Norway	Almost 95% would	>90% would*	>80% would*	47% would**	<80% would**	NIFU, STEP and Technopolis (2004)
FP5&6	National – Switzerland	• 75% would • 70% did					Interface Institut für Politikstudien and Fraunhofer-Institut für System- und Innovationsforschung (ISI) (2005)
FP6	EC – All	• 66% did • 57% would	29% did* 38% would*				IDEA Consult (2009)
			76% did** 83% would**	60%/57% (start/duration) did** 44%/46% (start/duration) would**	71% did** 78% would**	69% did** 80% would**	
FP6	EC -All	• 59% did (control group I) • 63% did (control group II) • 57% would	• 35% did (control group I)* • 33% did (control group II)* • 39% would*				IDEA Consult (2009)
FP6	National – Finland	80% would	53% would*	39% would*	40% would*		TEKES (2008)
FP6	National – Ireland	56% did					Forfas (2009)
FP6	National – Spain	74% would	23% would*				Zabala Innovation Consulting SA (2010)

Table 2: Evaluations of national R&D support schemes

Study owner – Scope of the Evaluation	**Full** Project Additionality (Share of respondents who did (failed applicants) or would (participants) abandon the project in the absence of national funding	**Partial** Project Additionality (Share of respondents who did (failed applicants) or would (participants) change the nature of the project in the absence of EU funding) (*: share of total respondents; **: share of respondents who did (failed applicants) or would (participants) not abandon the project)				Reference
		Scale additionality (Share of respondents who did (failed applicants) or would (participants) reduce the scale of the project in the absence of national funding)	**Acceleration additionality** (Share of respondents who did (failed applicants) or would (participants) postpone or increase the duration of the project in the absence of national funding)	**Scope additionality** (Share of respondents who did (failed applicants) or would (participants) reduce the scope or objectives of the project in the absence of national funding)	**Networking Additionality** (Share of respondents who did (failed applicants) or would (participants) reduce the number of (international) partners in the absence of national funding)	
Austria - FFF	• 28% would • 31% did	• 57% would* • 47% did*				Falk (2004); Joanneum Research, WIFO and KOF (2004); OECD (2006)
		• 74% would** • 60% did**	Postpone: • 32% would** • 43% did** Lengthen: • 51% would** • 61% did**	• 49% would** • 40% did**		
Flanders - IWT	29% would	46% would*				Georghiou et al. (2004); OECD (2006)
Flanders - IWT	• 41% would • 43% did	• 48% would* • 25% did*				Steurs et al. (2006)
Australia – R&D Start Programme	37% would	90% would**	100% would**		59% would**	OECD (2006)
Finland – TEKES funding	20% would	46% would*		>60% pursued R&D not connected to the short-term needs of business operations >70% realised riskier and more profitable research		OECD (2006)
Norway – Innovation Norway funding	53% would	16% would have reduced scale or postponed*				OECD (2006)

US - ATP	93% would			82% of projects more ambitious than other R&D projects 70% of projects more technically difficult than other R&D projects		OECD (2006)

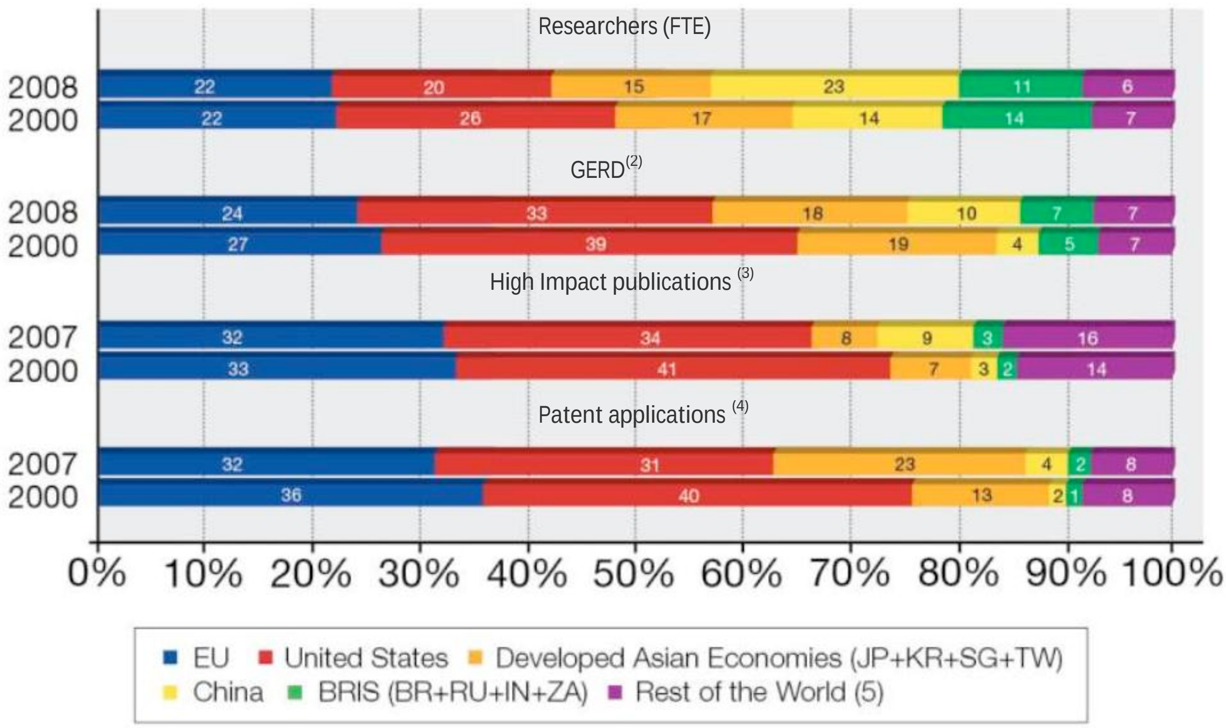
ANNEX 3: EU S&T PERFORMANCE AND INVESTMENT

The global S&T landscape is changing

The last decade has already seen a shifting centre of gravity of scientific and economic activity towards Asia. If one takes the 5 Asian countries (China, Japan, Korea, Singapore and Taiwan) for the latest year:

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

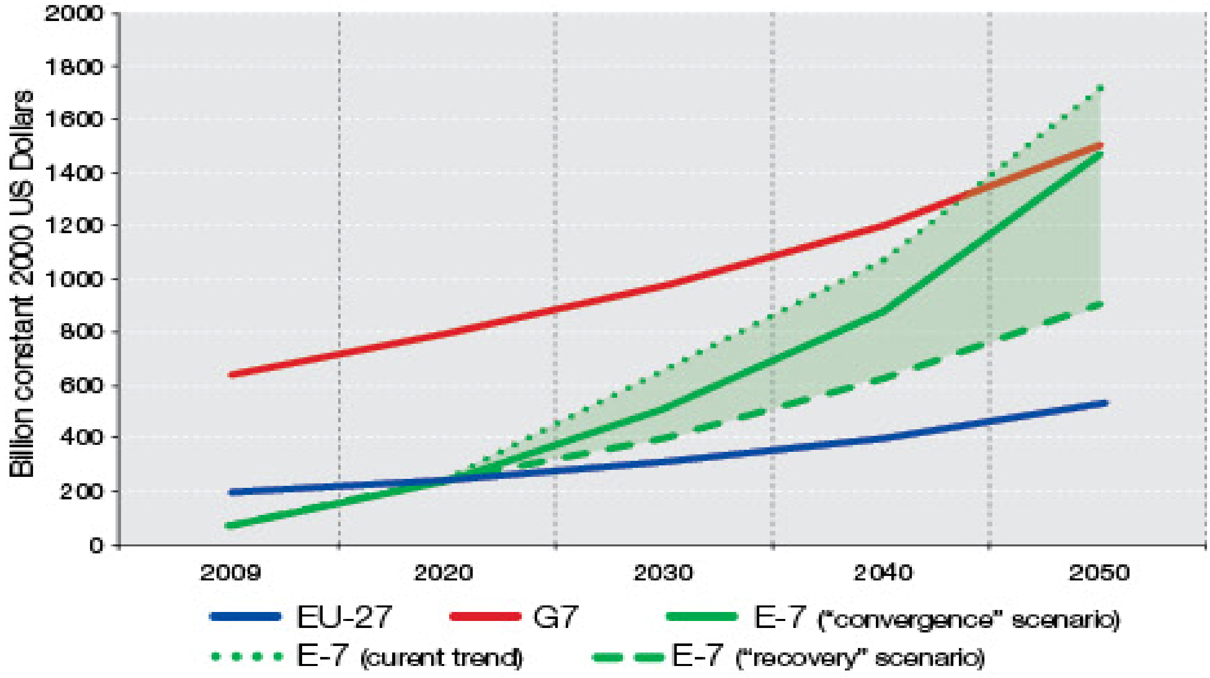
Figure 1: Participation in global R&D - % shares



Source: DG Research and Innovation
Data: Eurostat, OECD, UNESCO, Science Metrix/ Scopus (Elsevier)
Notes: (1) Elements of estimation were involved in the compilation of the data
(2) GERD: shares were calculated from values in current PPS€.
(3) (i) Top10% most cited publications – fractional counting method; (ii) ASIAN-5 does not include Singapore and Taiwan.
(4) Patent applications under the PCT (Patent Cooperation Treaty) at international phase, designating the European Patent Office
(5) The coverage of the Rest of the World is not uniform for all indicators.

If current trends continue over the next three decades, the emerging economies could be as important economically and scientifically as the advanced economies. Under conservative assumptions for growth and for R&D spending[3], the emerging economies could be investing the same volume of R&D as the G7 countries by 2050 (see Figure 2), and by 2020, they could already be investing more than the EU. This expansion of R&D spending by the emerging countries should inevitably lead to their producing more patents in the coming decades. As seen in Figure 3, whereas the G7 currently account for 85% of PCT patent applications compared with only 8% for the E7 countries, by 2050 the G7 share could have diminished to 50%, with the E7 countries at nearly the same level (46%).

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



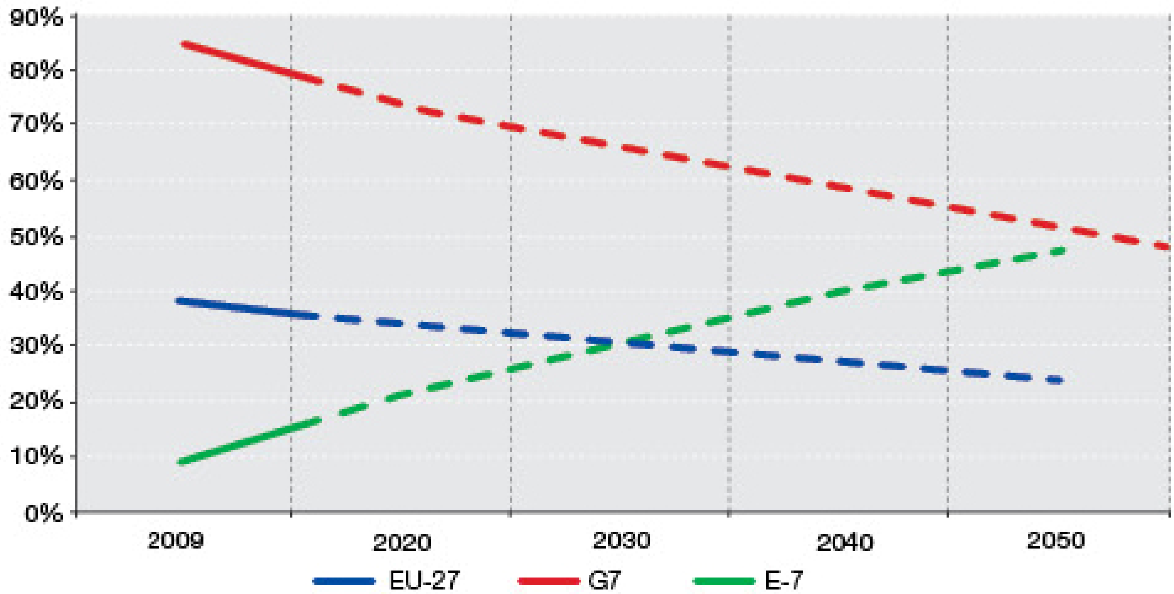
Source: *DG Research and Innovation*

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

Note: *i) "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*

ii) The 3 scenarios are as follows (1) In the "current trend" scenario, the projections are entirely 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 (political commitment) and will continue to increase their investments. After 2020, it is assumed that the annual growth rate of R&D intensity in G7 will be the average annual growth rate during the period 1990-2020.

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



Source: *DG Research and Innovation*
Data: *OECD patent database*

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

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

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

The total government R&D budget for EU-27 increased in 2009 (to 88.6 billion euros, from 86.2 in 2008[4]). In the medium term, the need for fiscal consolidation may place further pressure on the ability of some European governments to maintain their investment in R&D. Business investment in R&D was more affected than public investment in 2009. In EU's business sector, R&D expenditure decreased by -3.07% that year in nominal terms.

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

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

While many fast growing firms are born as SMEs, their R&D intensity is lower in Europe (0.25 in 2007) than it is for the US (0.30) and South Korea (0.56). This lack of investment is in turn reflected in the smaller role played by "young leading innovators" or Yollies – R&D intensive firms which rapidly grow into world leaders due to substantial R&D efforts[5].

And Europe's competitiveness and innovative performance are weak

In Europe total factor productivity stagnated in the last decade compared with around 7% increase since 2000 in the US and Japan[6]. Various studies have pointed to the need to improve the productivity of service sector by increasing R&D in services[7].

While analyses show that growth in trade in manufacturing is largely driven by high technology industries[8], the EU's performance in high technology is far from strong. The share of high-tech and medium-high-tech products in EU exports is lower than that of its main trading partners - 47% in 2008, compared with 60% for the US, 71% for South Korea, and 75% for Japan[9]. Taking a broader view, the overall innovation performance gap has broadened with the US and Japan, while emerging countries are catching up[10].

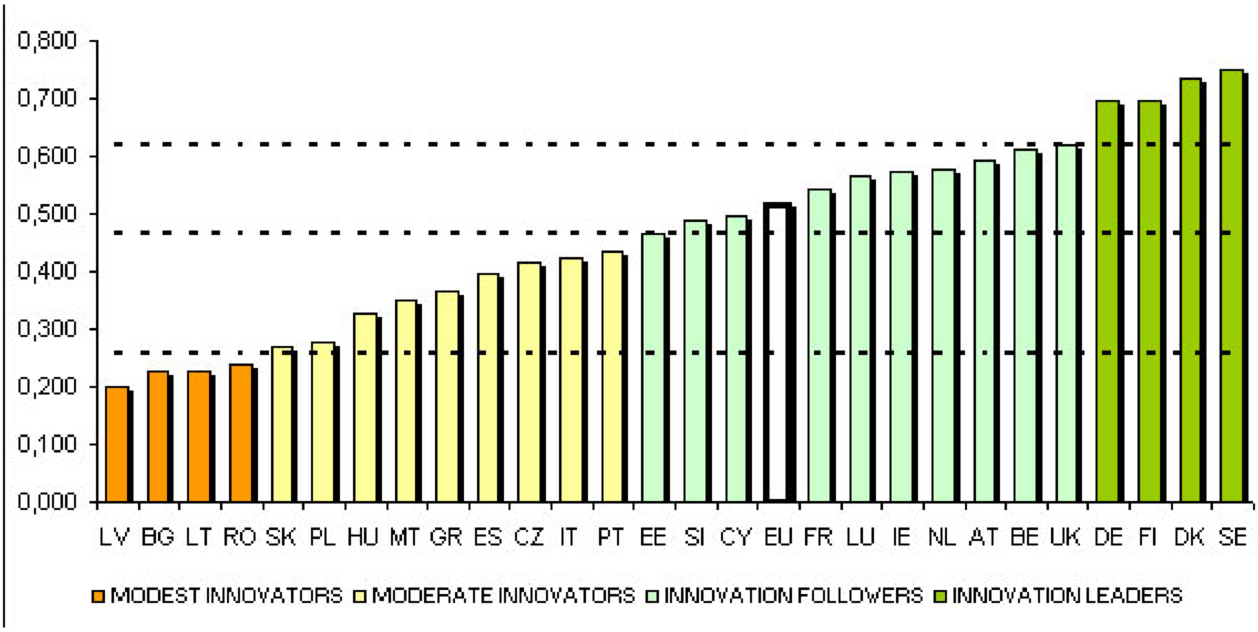
One of the weaknesses of Europe's innovation system is the poor links between public and private research actors, which lower its capacity to maximise the use of local knowledge. The EU produces only 36 scientific co-publications per million population which involve public-private collaboration, whereas the US produces 70 and Japan 56[11].

These weak science-industry links, combined with Europe's underinvestment in private R&D have an impact upon its capacity to introduce technological innovation. In 2007, the EU produced 4 PCT patent applications[12] per billion euro of GDP, slightly below the United States and much lower than Japan and South Korea, which produced 8 and 7 respectively. In 2009, the economic revenues obtained from the licensing of these patents, which in part relates to their quality and usefulness, amounted to 0.2% of the total GDP in Europe[13]. In contrast, these revenues were more than double and triple in Japan and the United States. Moreover, this gap has widened considerably during the past decade.

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

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

Figure 4: EU Member States' innovation performance



Source: *DG Enterprise and DG Research and Innovation, Innovation Union Scoreboard 2010*
Note: *Average performance is measured using a composite indicator building on data for 24 indicators going from a lowest possible performance of 0 to a maximum possible performance of 1. Average performance in 2010 reflects performance in 2008/2009 due to a lag in data availability. The performance of Innovation leaders is 20% or more above that of the EU27; of Innovation followers it is less than 20% above but more than 10% below that of the EU27; of Moderate innovators it is less than 10% below but more than 50% below that of the EU27; and for Modest innovators it is below 50% that of the EU27*

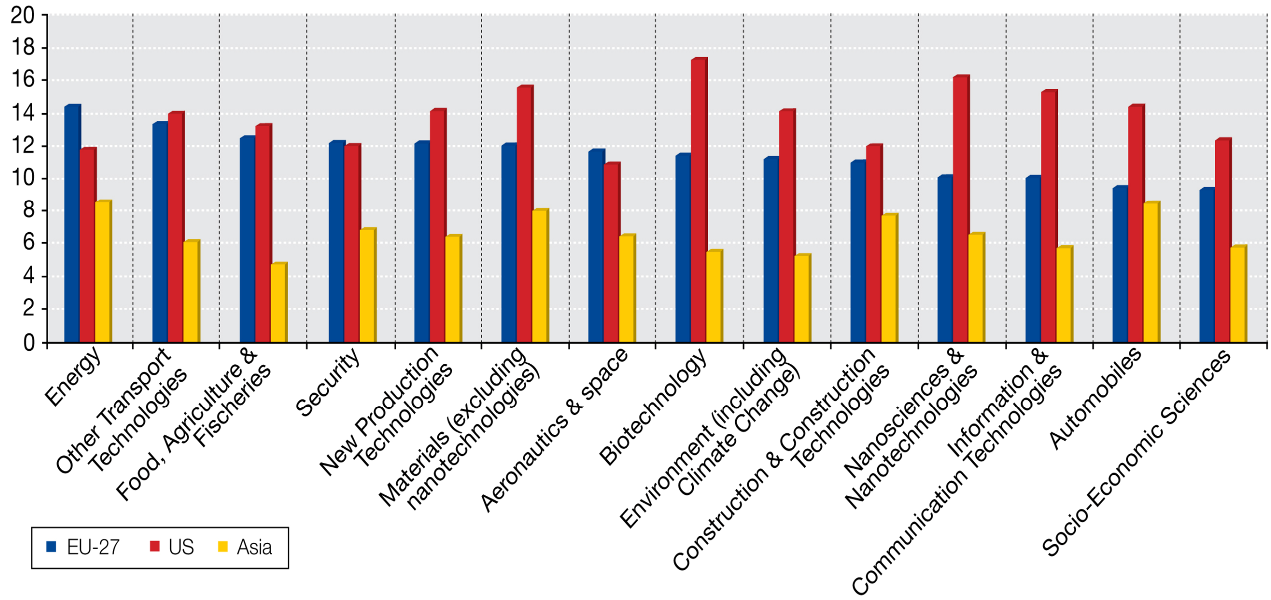
Europe also needs to raise scientific quality

While 15% of US scientific publications are among the top 10% most cited publications worldwide, only 11% of EU publications fall into this category. Meanwhile, China had 7% of its publications in the top ranking in 2007, compared with just under 5% in 2000[14].

When it comes to academic institutions, of the 386 most active research universities in the world 45% are in Europe and 32% in the US[15]. But only eight of the 76 universities in the world with the highest citation impact are located in the EU. 67 are located in the US.

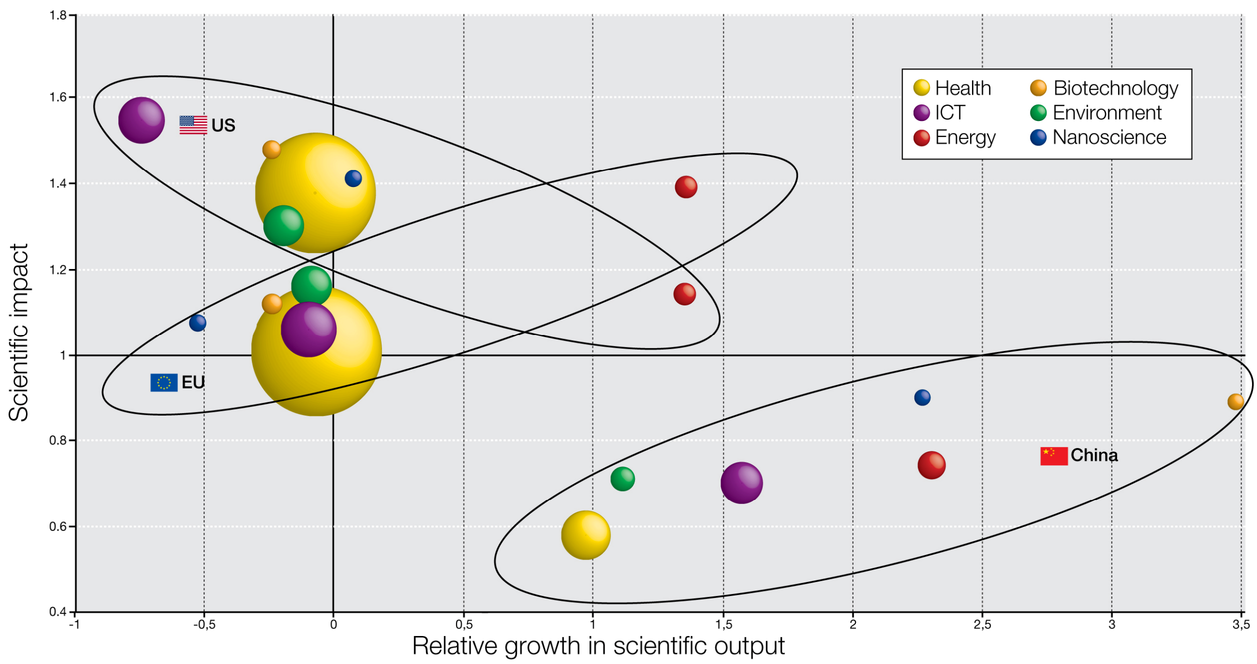
This pattern of the EU falling behind in terms of quality is continued if one looks across different fields. Figure 5 shows a number of S&T areas that relate to the fields of the EU Framework Programme. It can be seen that in almost all areas the US has significantly more publications in the top 10%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

Figure 5: Percentage of scientific publications in the top 10% most cited (2000-2009)



Source: DG Research and Innovation
Data: Science Matrix/ Scopus (Elsevier)

Figure 6: Scientific performance in key fields



Source: DG Research and Innovation

Data: *Science Metrix / Scopus (Elsevier)*
Notes: *Scientific impact = Average of relative citations computed for 2000-2006 publications (with sliding citation time window [N;N+3]) A value above 1 means a country is cited more often than the world average.*
Relative growth in scientific output 2005-2009 compared with 2000-2004. Expressed as the absolute difference in percentage points between growth of country X and the world average growth of publications in the field
Size of bubble is proportional to the volume of publications.

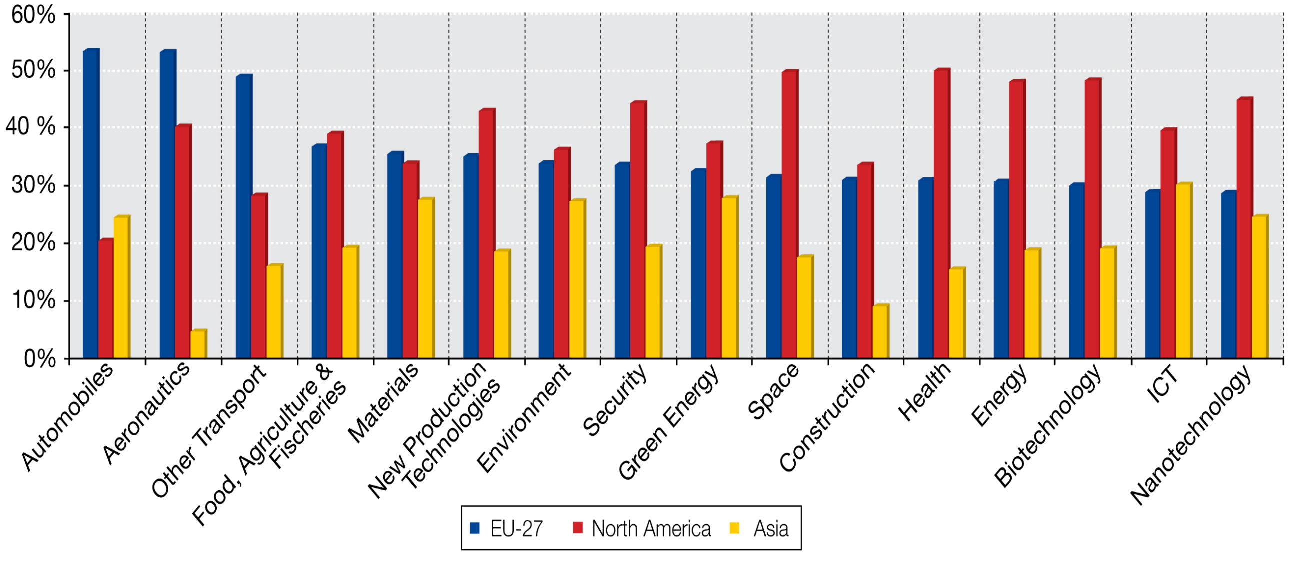
If one looks at scientific impact in key fields in relation to the growth in scientific output in these fields (Figure 6), two trends emerge clearly. Firstly, in the areas of health, environment, nanoscience, biotechnology and ICT Europe's impact falls behind that of the US (albeit that in the environment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

And gain a technological lead over its competitors

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

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

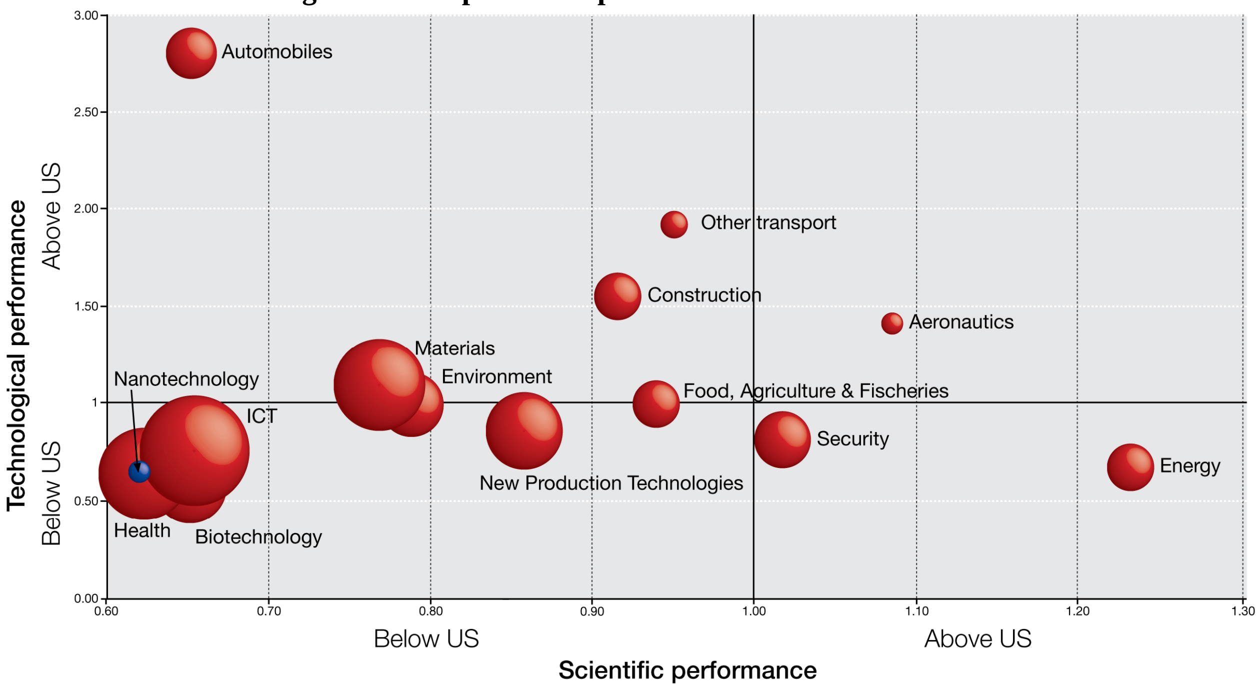
Figure 7: Patent shares 2000-2009 (PCT applications)



Source: DG Research and Innovation

Data: *EPO PATSTAT database (from a study by Research Division INCENTIM, MSI, Faculty of Business & Economics, K.U.Leuven, Università Commerciale Luigi Bocconi, KITES)*

Figure 8: European S&T performance relative to the US



Source: DG Research and Innovation
Data: PCT patents - EPO PATSTAT database (from a study by Research Division INCENTIM, MSI, Faculty of Business & Economics, K.U.Leuven, Università Commerciale Luigi Bocconi, KITES)
Scientific publications - Science Metrix / Scopus (Elsevier)
Notes:
1) Scientific performance is measured in terms of the % of publications in the top 10% most cited category (2000-2006 publications with sliding citation window [N, N+3]). On the X axis the percentage for the EU is divided by that for the US.
(2) Technological performance is measured by the share of global PCT patents for the period 2000-2009 (Patents filed under the Patent Co-operation Treaty (PCT), at international phase, that designate the EPO).
On the Y axis the share for the EU is divided by that for the US.
(3) The size of the bubbles = number of EU-27 patents in the technology field

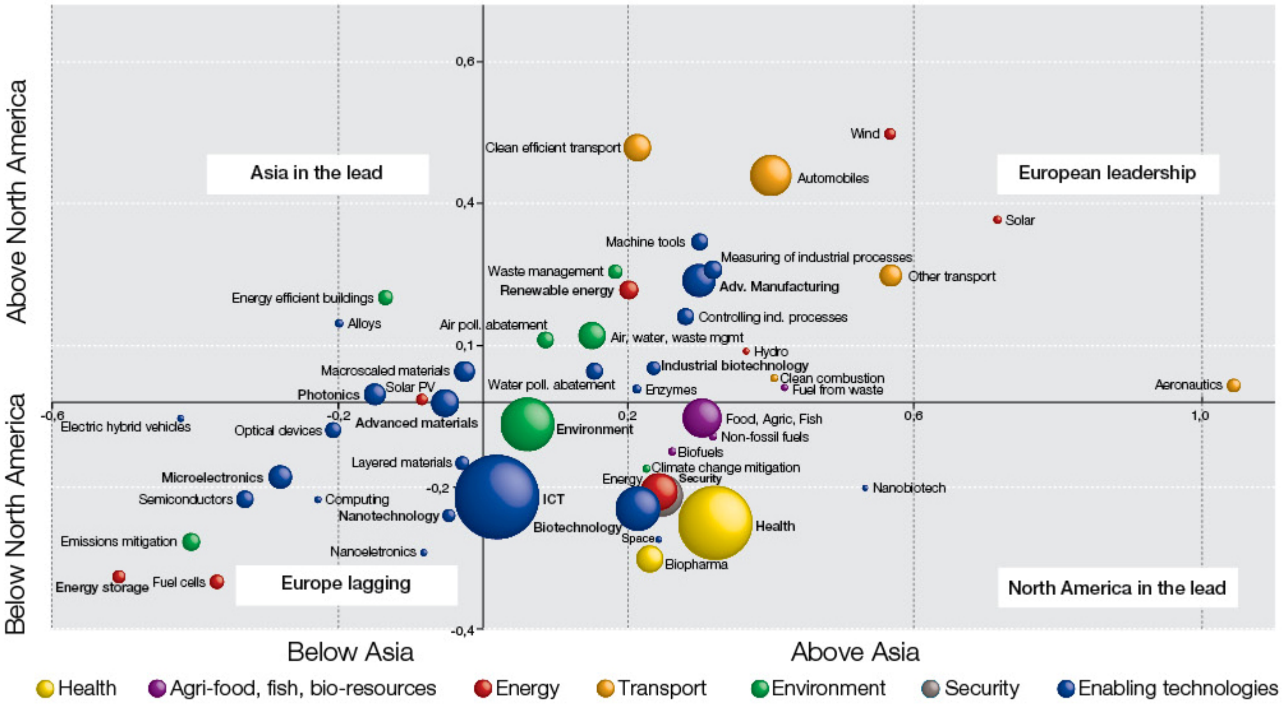
While better harnessing its research and innovation to tackle societal challenges

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

- The EU devotes considerable resources to environmental sciences (in 2008 it invested 5 euros per capita, compared with just 2 for the US and Japan)[16]. It also leads the field in patenting related to air and water pollution control, solid and waste management and renewable energies. For these fields combined it has 35% of all patents, compared with 22% for the US and 20% for Japan[17].
- In health related research the US is the world leader. In terms of public budgets, the US devoted more than 0.2% of GDP to such research, while the EU invested 0.05%[18]. Companies in the US invest almost the twice as much in health R&D compared with their EU counterparts. As a consequence the US leads in patents related to medical technologies, accounting for almost half of all world patents (49% of PCT patent filings), while the EU's share is only one quarter. When it comes to pharmaceuticals, the US also leads with 42% share of patents worldwide, while the EU has 28%.[19].

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

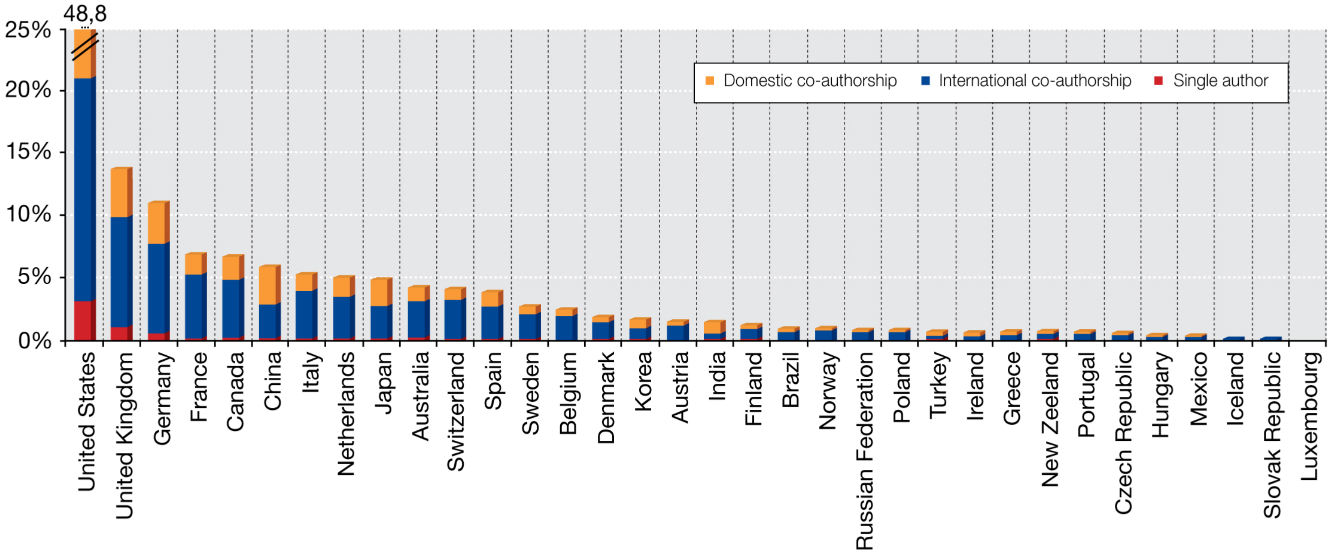
Figure 9: Europe's technological performance compared with North America and Asia[20]



Source: *DG Research and Innovation*

Data: *OECD patent database and specific studies*[21]*. Europe covers EU27, Iceland, Norway and Switzerland; Asia covers Japan, China, South Korea, Singapore and Chinese Taipei.*

Figure 10: Highly cited (top 1%) scientific articles by type of collaboration, 2006-08
as a percentage of highly cited scientific articles worldwide



Source: DG Research and Innovation
Data: OECD, Measuring Innovation: A New Perspective (2010)

And investing in R&D in a more coordinated way

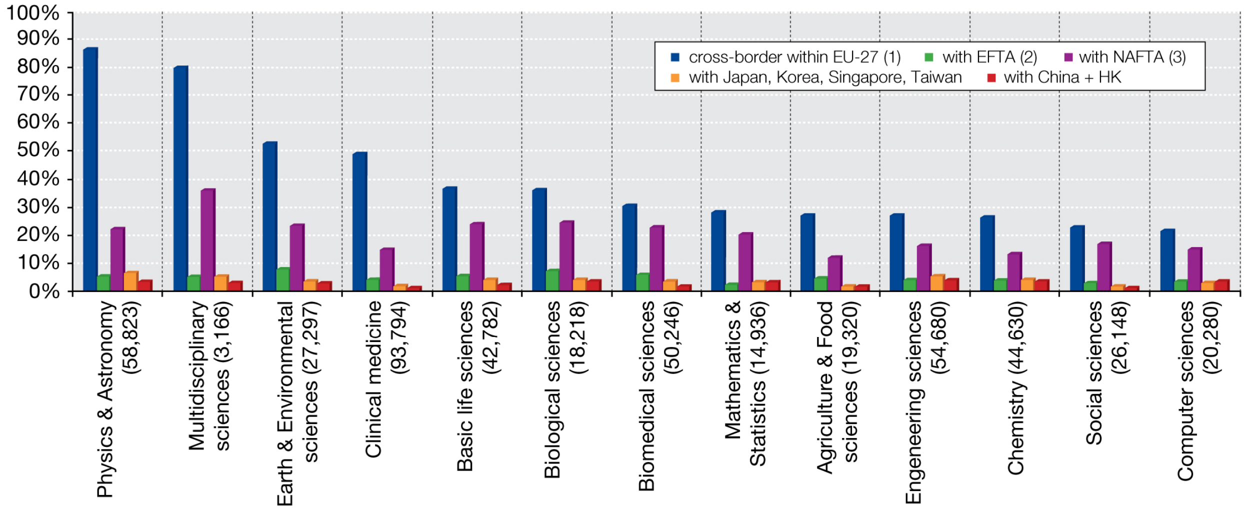
"Integrating the research base by overcoming fragmentation in research" is the first recommendation made in the Interim Evaluation of the Seventh Framework Programme (FP)[22].The national fragmentation of public R&D funding is perceived both as a sub-optimal use of public funding for R&D and as a factor undermining the S&T performance of Europe.

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

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

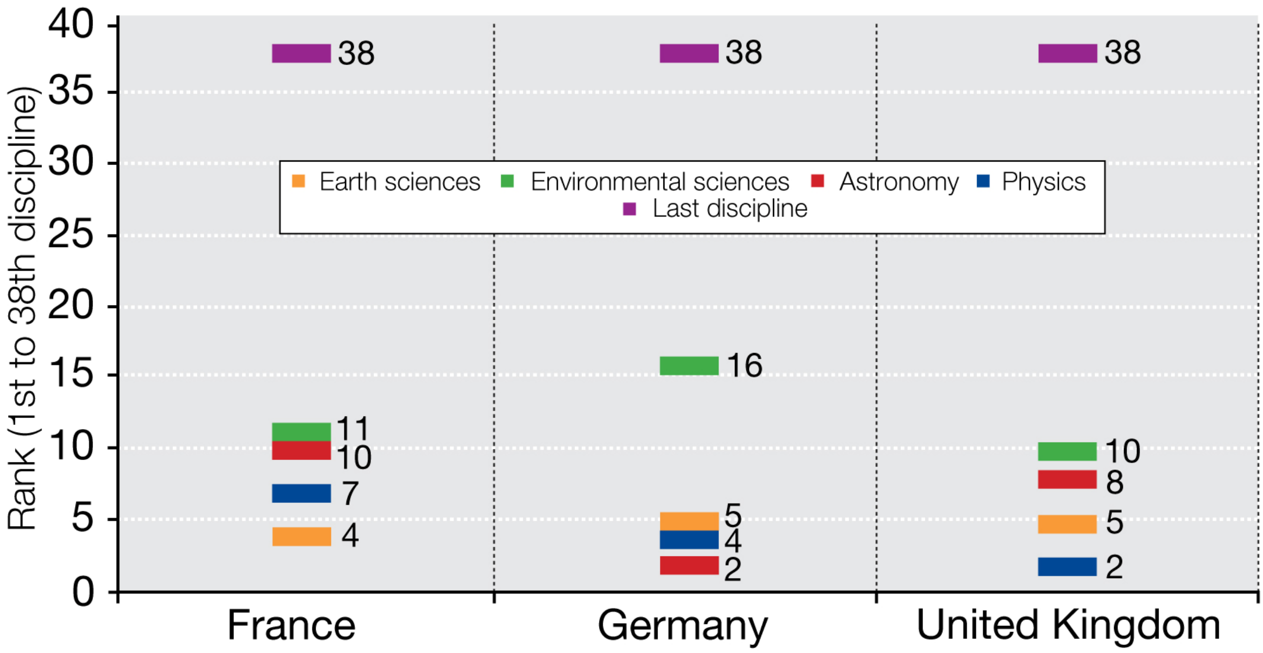
- The highest share of EU scientific publications involving cross-border European collaboration is found in 'Physics and Astronomy', 'Multidisciplinary sciences' and 'Earth and Environmental sciences' (Figure 11).
- And it is in these disciplines[23] where one observes the highest impacts. In the five countries that publish a large part of all EU publications (Germany, France, the United Kingdom, Spain, Italy), publications in these disciplines are more frequently cited than a (world) 'average' publication in the same disciplines[24], and these disciplines are systematically among the disciplines with the highest impact scores in France, Germany and the United Kingdom (see Figure 12). This also holds true in most other EU countries.
- For most countries 'Multidisciplinary sciences' also ranks very high in terms impact, in particular in Germany, France and the United Kingdom where it ranks first.

Figure 11: EU-27 co-publications by main scientific fields, 2006 as % of all EU-27 publications [(4)] (in parenthesis: total number of publications of the field)



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

Figure 12: Rank of Astronomy, Physics, Earth and Environmental sciences among 38 scientific disciplines(1) according to field normalized impact score 2005-2007



Source: DG Research and Innovation
Data: CWTS-Leiden University / Thomson Reuters
Note: (1) The 38 scientific disciplines cover all natural sciences, social sciences and humanities.

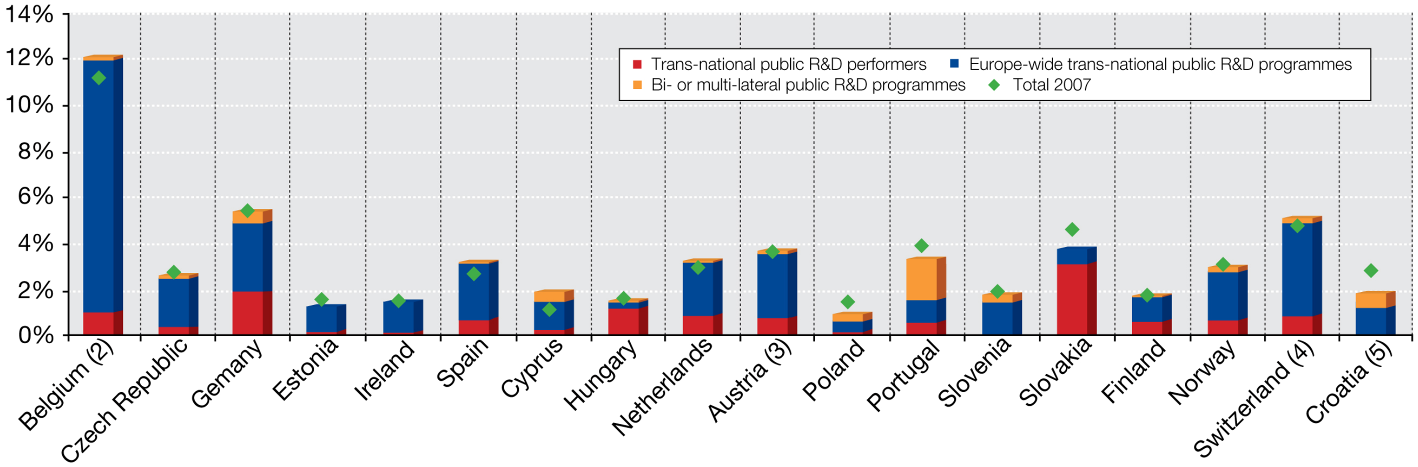
Europe can also make more efficient and effective use of its resources through pooling and sharing them. A good example is that of large scale research infrastructures, where the sharing of costs and access makes sound economic sense.

- The amount of funds required for their construction cannot be provided by a single European State. The total estimated cost of the 51 research infrastructures of the European Scientific Forum for Research Infrastructures (ESFRI) Roadmap[25] is in the order of 84% of total annual capital expenditure[26] in the EU, or 2.7 times the amount of total 2007-2013 Structural Funds earmarked for research infrastructures in the EU.
- In addition, the scientific community that can best make use of one of these facilities is relatively limited in a single country, so that the level of investments for building and operating the facility is incommensurate with the number of domestic users, resulting in a sub-optimal exploitation of these investments.
- Indeed the actual value added of some of these large-scale infrastructures is precisely the pooling of data, the multiplication and diversification of experimental cases and contexts that a single country could not gather alone.

Yet in spite of these benefits of coordination, a recent review of national R&D programmes in 11 European countries showed that very few of them in Europe are genuinely open, in the sense of allocating funding to foreign-based research performers under conditions which are close to the ones applied to domestic actors.[27] The prevailing national approaches to R&D collaboration in Europe are to use EU-level instruments (for trans-national coordination of research activities) rather than opening national funding sources to foreign-based research actors.[28]

However even the trans-national coordination of public R&D funding remains limited: only about 11.1% of public R&D funding in the EU (27 Member States' national R&D budgets plus FP) can be considered as "coordinated public funding of R&D. Of this, 7.5% is attributable to the FP and just 3.6% to various forms of coordinated national funding.[29] Figure 13 shows more detail of these latter forms of coordinated national funding, illustrating how much countries devote from their national R&D budgets to trans-nationally coordinated research. Overall, more than 95% of national R&D budgets are spent nationally without coordination across countries.

Figure 13: National public funding of trans-nationally coordinated research by category [(1)], as a % of total national GBAORD, 2008



Source: DG Research and Innovation
Data: Eurostat
Notes: (1) Experimental data.
(2) BE: Data of some regional authorities in Belgium are probably not included.
(3) AT: federal or central government only.
(4) CH: 2007 value uses 2006 GBAORD as denominator.
(5) HR: 2007 value uses 2008 GBAORD as denominator.

ANNEX 4: THE ECONOMIC ROLE OF SCIENCE, TECHNOLOGY AND INNOVATION

INTRODUCTION

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

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

MODERN 'GROWTH ACCOUNTING' LITERATURE

- The key role played by research and innovation in structural economic growth is highlighted by the modern 'growth accounting' literature, which integrates the concept of intangible assets.
- There are three kinds of intangible assets: (1) scientific R&D and non-scientific inventive and creative activities (scientific and creative property); (2) software, computer programs and computerised databases (computerised information); and (3) firm-specific human capital, organisational capital and brand names (economic competencies) (Innodrive, 2009).
- Intangible capital is an essential ingredient for economic growth (Jona-Lasinio et al., 2011). Labour productivity, which in the long term is commonly viewed as connected to the living standards of the workforce, is strongly promoted by the accumulation of intangible capital (Innodrive, 2009). An econometric analysis shows a positive and significant relation between business investment in intangible capital and overall economic labour productivity growth (Roth and Thum, 2010).
- The OECD estimates indicate that in Member Countries like Austria, Finland, Sweden, the United Kingdom and the United States, investment in intangible assets and MFP growth (linked to innovation and improvements in efficiency) together accounted for between two-thirds and three-quarters of labour productivity growth between 1995 and 2006, thereby making innovation the main driver of growth (OECD, 2010b).

MODERN ECONOMIC THEORY

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

MACRO- AND MICRO-ECONOMIC LITERATURE

- This recognition has been based on an extensive body of macro- and micro-economic literature that has produced a number of clear conclusions:
- The economic returns to public and private research are high:
  - **Total R&D:**
    - Empirical work has established robust relationships at the macroeconomic level between investment in innovation and productivity, and firm-level studies have also found positive and significant effects of R&D on productivity growth (OECD, 2010b).
    - A 0.1 percentage point increase in R&D could boost output per capita growth by some 0.3-0.4 per cent (Bassanini and Scarpetta, 2001).
    - A stochastic frontier analysis by the European Commission's Directorate-General Economic and Financial Affairs found that an economy's R&D intensity has a significant positive effect on the

number of patents per million inhabitants of that economy and that R&D investments are characterised by non-decreasing returns to scale (Mandl et al., 2008).

- § Following a detailed analysis, a team of social scientists has concluded that factors connected with the concept of 'human capital' are responsible for around 70% of the difference in wealth between regions. Three dimensions of human capital are important, one of those relating to productivity and innovation. It is measured by looking at two things: the amount of public and private money being invested in research and technological development (R&D), and the number of patent applications being made in each region (Euractiv).

- o **Public R&D:**
  - § The rate of return for publicly funded R&D usually exceeds 30 percent (Muldur et al., 2006).
  - § 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).
  - § Estimates of the impact of UK Research Council spending on the UK's national output suggest that a cut of £1 billion in annual spending would lead to a fall in GDP of £10 billion (Haskel and Wallis, 2010).
  - § The US$3.8 billion spent by the US government to map the human genome spurred the creation of tens of thousands of jobs and gave rise to an industry that – while slow to deliver medical breakthroughs- now generates about US$67 billion in annual economic activity. The genome-sequencing project triggered many novel types of economic activity, from the manufacture of sequencing machines and other instruments to the devising of genetic test kits and diagnostic materials used for lab experiments. The investment also produced significant economic returns in the form of tax revenues and personal income. The US$3.8 billion, along with subsequent capital provided by the government and the private sector, generated a total return of roughly US$49 billion in direct and indirect federal tax revenues over the last two decades or so. Over the same period, those initial investments also helped to drive US$796 billion in direct and indirect economic output and generate US$244 billion in total personal income. In 2003, for example, the NIH and DOE together invested US$437 million in the Human Genome Project. That directly led to US$552.9 million in economic activity, the creation of 5,025 jobs and US$51 million in federal tax revenue. When the ripple effect is included, the impact was greater: US$1.65 billion of economic output, 12,422 jobs created, and US$125.5 million in federal tax revenue (WSJ).
  - § Spending by the National Institute of Health directly and indirectly supported nearly 488,000 jobs and produced US$68 billion in new economic activity in 2010 (WSJ).
  - § According to UK research, a £1.00 investment in public/charitable CVD research produced a stream of benefits thereafter that is equivalent in value to earning £0.39 per year in perpetuity. The total rate of return for mental health research is 37% (HERG Brunel University et al., 2008).

- o **Private R&D:**
  - § Firms' returns to their own investment in research usually range from 20 to 30 percent (Muldur et al., 2006).
  - § Societal returns to firm investment in research usually range from 30 to 40 percent (Muldur et al., 2006).
  - § 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:
  - o Research and innovation allow European firms to deal with the competitive threat posed by the low-cost and increasingly high-tech BRIC (Brazil, Russia, India and China) and small East Asian economies.
  - o The ability to innovate (in addition to size, productivity, the skill intensity of the workforce) is positively related to firms' export performance. It also supports more complex internationalisation

strategies, such as exporting to a larger number of markets, to more distant countries and producing abroad through FDI or international outsourcing (Navaretti et al., 2010).

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

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

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

- Technological change boosts employment:

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

  - For 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).

- Research-intensive sectors create more and better jobs:

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

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

ANNEX 5: INFORMATION ON ECONOMETRIC MODELLING USED IN THE REPORT (NEMESIS) DESCRIPTION, ASSUMPTIONS AND RESULTS

Nemesis is a general equilibrium model built by a European Commission-funded consortium of European research institutes under the 5th Framework Programme. Nemesis has been used by the European Commission for the ex-ante impact assessment of FP7 and for assessing the macro-economic impact of achieving the objective of investing 3 percent of Europe's GDP in research and innovation ("3 percent objective"), by the OECD, by a number of French government institutions, etc.

For the CSF impact assessment, DG Research & Innovation developed, in collaboration with the DEMETER consortium operating Nemesis, 5 different future-oriented scenarios: (1) Business-as-usual; (2) Common Strategic Framework for Research and Innovation; (3) Common Strategic Framework for Research and Innovation + achievement of the 3 percent objective; (4) Renationalisation; and (5) Discontinuation.

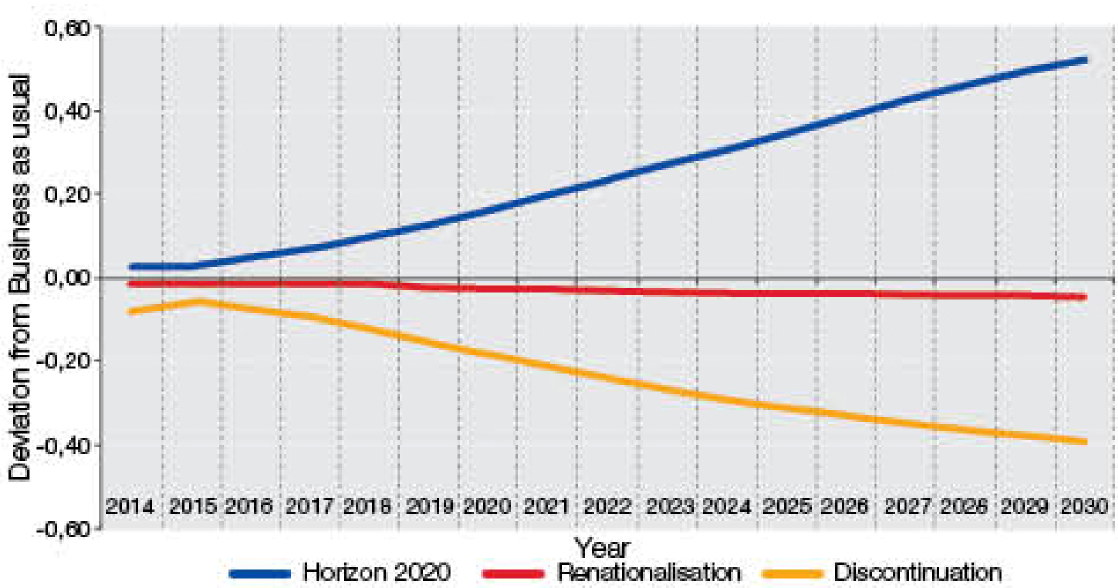
These scenarios were operationalised through a number of key model parameters including the real EU and national research and innovation funding growth rates; the allocation of EU research and innovation funding to EU Member States, to basic vs. applied research, and to sectors; the EU and national research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

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

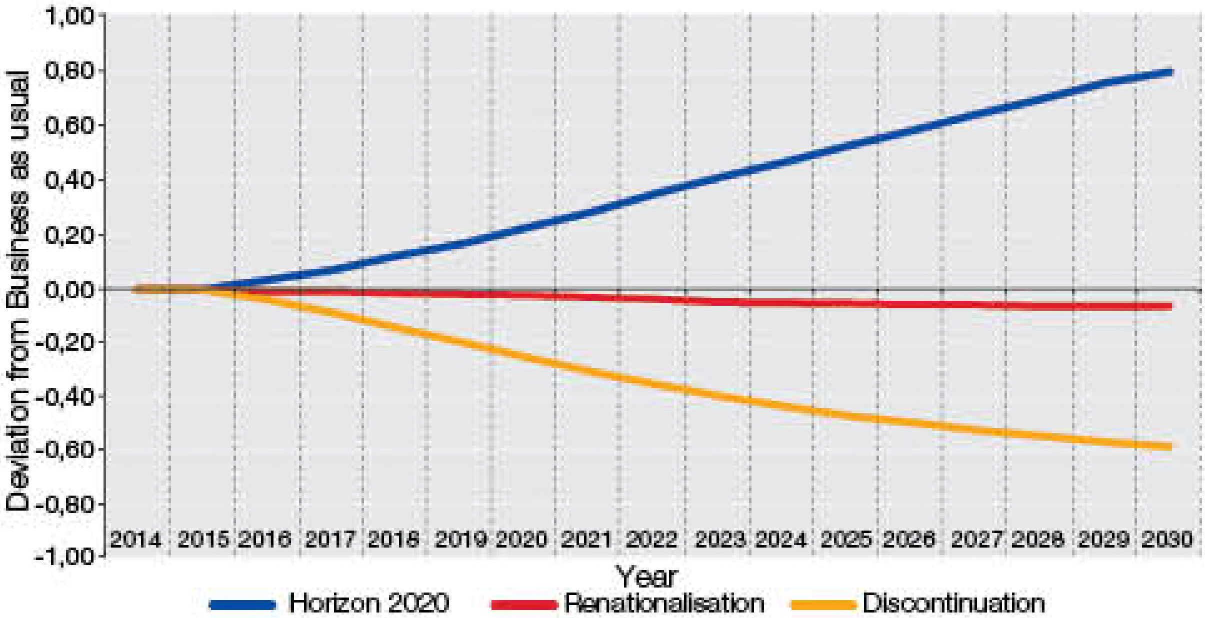
The CSF assumptions were necessarily based on deduction and analogy. Because of simplification and therefore enhanced industrial participation, and because of closer knowledge triangle coordination and therefore enhanced valorisation of research results, crowding-in effects and economic multipliers,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

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

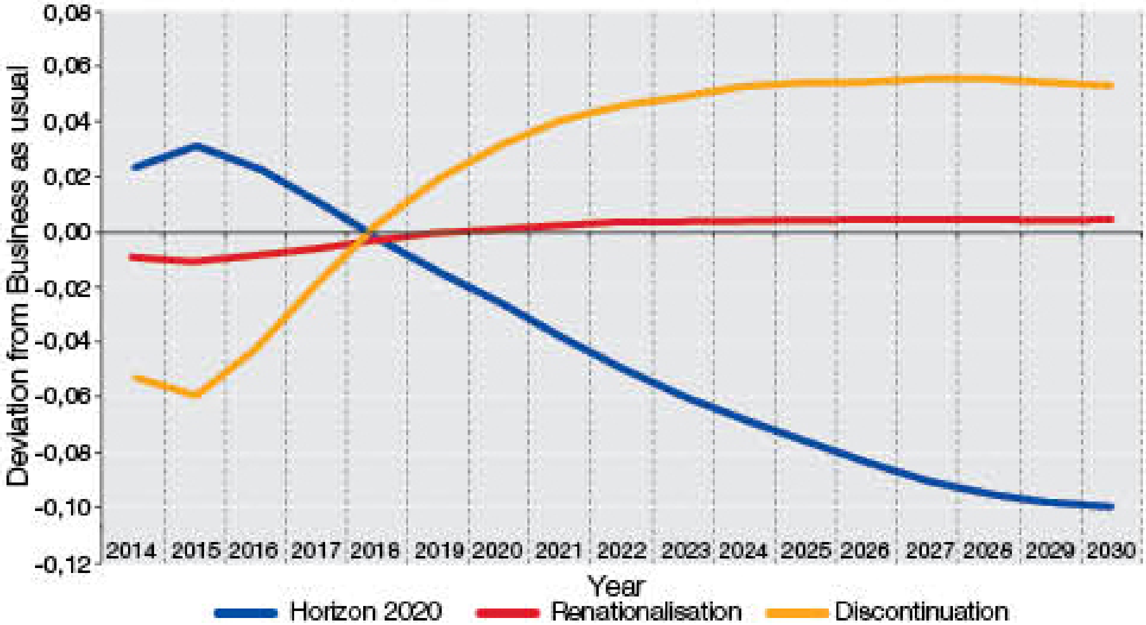
Impact of the different options on GDP



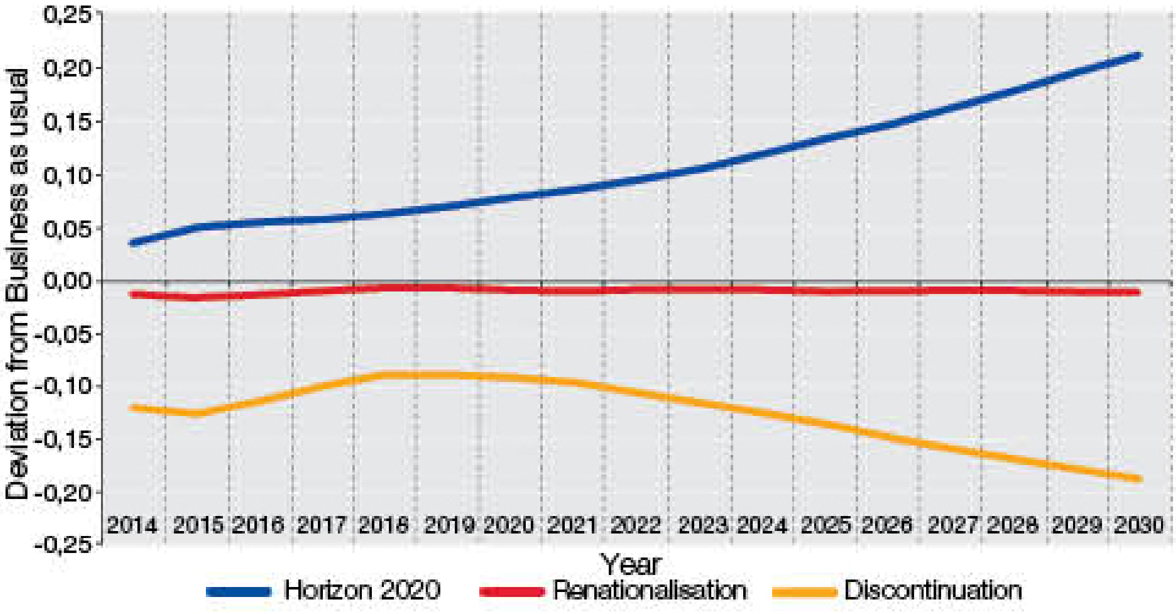
Impact of the different options on exports



Impact of the different options on imports



Impact of the different options on Employment



	Business as usual	Preferred		Renationalisation	Discontinuation - Cost of non-Europe
		CSF	CSF+3%		
FP funding real growth rate 2014-2020	€8,31 billion (2014 prices) spent in 2014; thereafter adjusted for inflation (2%) only	2014: 10,70 billion; 2015: 11,40 billion; 2016: 12,12 billion; 2017: 12,87 billion; 2018: 13,65 billion; 2019: 14,45 billion; 2020: 15,27 billion (current prices, no need anymore to adjust for inflation; already done)	2014: 10,70 billion; 2015: 11,40 billion; 2016: 12,12 billion; 2017: 12,87 billion; 2018: 13,65 billion; 2019: 14,45 billion; 2020: 15,27 billion (current prices, no need anymore to adjust for inflation; already done)	€8,31 billion (2014 prices) spent in 2014; thereafter adjusted for inflation (2%) only	€8,31 billion (2014 prices) spent in 2014; thereafter adjusted for inflation (2%) only (negative effect)
FP funding real growth rate 2021-2030	Continuation of above	Increase further every year by 450 million and adjust for inflation (2%)	Increase further every year by 450 million and adjust for inflation (2%)	Continuation of above	Continuation of above (negative effect)
National funding real growth rate 2014-2020	Constant (latest available) national R&D intensity	Constant (latest available) national R&D intensity	Reach National Reform Plan (NRP) R&D intensity objectives by 2020 (sent)	Constant (latest available) national R&D intensity	Constant (latest available) national R&D intensity reduced by discontinued FP amount
National funding real growth rate 2021-2030	Continuation of above	Continuation of above	Once objectives reached, constant R&D intensity	Continuation of above	Continuation of above
Allocation of FP funding to EU MS	Like under FP7	Based on innovation performance	Based on innovation performance	Like under FP7	Like under FP7 (negative effect)
Allocation of FP funding to basic and applied research	40% basic, 60% applied	40% basic, 60% applied	40% basic, 60% applied	40% basic, 60% applied	40% basic, 60% applied
Allocation of FP applied research funding to sectors within MS	Grandfathering	Grandfathering	Grandfathering	Grandfathering	Grandfathering
FP funding crowding-in factor for the private sector (net additional funding generated)	0.9	1.1	1.1	0.7	0.9 (negative effect)
FP funding crowding-in factor for the public sector	0.5	0.5	0.5	0	0.5 (negative effect)
National funding crowding-in factor for the private sector (net additional funding generated)	0.7	0.7	0.7	0.7	0.7
National funding crowding-in factor for the public sector	0	0	0	0	0
Multiplier for R&D resulting from EC funding	6 percent better than national	15 percent better than national	15 percent better than national	National	National
Multiplier for R&D resulting from national	National	National	National	National	National

funding					
Intersectorial spillovers	+	+	+	+	+
International spillovers	+	+	+	+	+

ANNEX 6: EURATOM

1. Procedural issues and consultation of interested parties

This annex contains supplementary information on the Euratom Research and Training Programme (2014-2018). Following the European Commission's decision of 29 June 2011 to bring together all EU research and innovation funding in a coherent, from-research-to-innovation overarching framework, the Euratom Research and Training Programme, hereinafter the Euratom Programme, is an integral part of 'Horizon 2020', the Framework Programme for Research and Innovation (2014-2020).

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

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

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

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

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

2. Problem definition

2.1. Challenges for nuclear research and training

Nuclear energy is a mature low-carbon energy technology that is deployed at the industrial scale in many EU Member States[30]. Radiation is also used in industry and research, and in medical diagnostic and therapeutic techniques.

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

Advanced nuclear technology has the potential to make a major contribution to the realisation of a sustainable and secure base-load energy supply for the EU in a few decades from now[31,3]. The first steps to realise this potential are to demonstrate feasibility of fusion as a power source and to construct and operate next generation fast neutron reactor (FNR) demonstrator plants. Efforts to make advanced nuclear energy a reality can be justified by the availability of fuel (hydrogen and lithium in the case of fusion, or uranium and thorium with 50-100 times increased utilisation compared with present reactors in the case of FNRs – are inexpensive and readily available), no risk of severe accidents in the case of fusion, and limitation to the reactor site of the impacts of severe accidents in the case of FNRs. Fusion plants will produce only a limited amount of short-lived radioactive waste, and FNRs will be able to consume much of their own long-lived waste, though geological disposal of the ultimate waste will still be required to eliminate burdens on future generations.

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

a) Nuclear safety of current and future power plants: Research will need to address issues of relevance for Europe arising from a detailed analysis of the Fukushima accident[32], in particular any identified in the 'stress tests' being carried out in the EU[33]. It is also important to maintain on-going research on issues of importance to the current fleet of reactors, in particular related to lifetime extensions and long-term operation. The current nuclear fleet in Europe is based mostly on Light Water Reactors (LWR) that have been in operation for about 25+ years on average. Current plans in most EU Member States are to extend their lifetimes on a case-by-case basis beyond 40 years, and possibly beyond 50 years. Key R&D issues are related to meeting safety requirements for long-term operation focussing on ageing of structures, systems and components. Other important issues are ageing mechanisms, monitoring and prevention and mitigation measures. Finally, research can also lead to improved efficiency of existing plants through reducing uncertainties in such areas as fuel performance[34]. The focus on safety will also need to extend to fundamental design work on next generation systems.

b) **Management of ultimate waste:** As indicated in the Commission's revised draft proposal for a Council Directive on the Management of Spent Fuel and Radioactive Waste[35], all EU Member States produce radioactive waste, which is generated by civil nuclear power and radioisotope applications in medicine, industry research and education. More than half of Member States have accumulations of spent nuclear fuel, or residues from the reprocessing of this fuel, as a result of the operation of nuclear power plants. The general principle is that those who benefit today from these activities should manage the resulting waste in a safe and sustainable manner. This is also the overwhelming view of European citizens[36], whose acceptance of nuclear energy is also strongly correlated to the implementation of solutions to safely manage nuclear waste. The R&D work carried out over last three decades has confirmed that deep geological disposal is the most appropriate solution for long-term management of spent fuel, high-level waste, and other long-lived radioactive wastes[37]. This scientific consensus now needs to be turned into an engineering reality, and this will be the focus of attention over the coming decade[38]. In addition to the implementation of geological disposal of ultimate waste, it is of great importance to minimize upfront the waste production to the maximum extend. This may be done by developing specific working techniques, processes and procedures leading to waste minimization. For Minor Actinides contained in spent fuel, research in partitioning and transmutation need to be pursued to demonstrate the feasibility to reduce the lifetime and radiotoxicity of the ultimate waste.

c) **Education and training in nuclear field:** As a generation of nuclear physicists and engineers retires and a series of nuclear 'phase-out' policies in some Member States leaves a gap in new talent entering the workforce, education and training have become driving concerns for every sector in the nuclear field[39]. This is a crucial issue even for countries phasing out their nuclear programmes, as existing facilities need to be operated for at least the next 15 years. Nuclear expertise is also needed for all industrial and medical applications based on ionising radiations, as well as for decommissioning activities related to old nuclear installations. Maintaining knowledge in these disciplines, along with appropriate programmes of nuclear education and training, are essential prerequisites for a high level of nuclear safety and nuclear safety culture[40].

d) **Next generation fission systems:** Today's light water reactor technology uses less than 1% of the energy content of the mined uranium, which limits the sustainability of nuclear energy to a few decades because of the finite nature of the world's uranium reserves[41]. By contrast, fast neutron reactors can extract 50-100 times more energy from the same quantity of uranium, making nuclear much more sustainable[42]. Furthermore, fast reactors are able to produce far less high-level long-lived waste, with a lower heat load, thereby greatly facilitating the management in future geological repositories. However, many R&D challenges remain, for example to address cost competitiveness, enhanced safety and non-proliferation, requiring innovation both in reactor designs as well as fuel and fuel cycle technology[43]. Though next generation fast neutron reactors are not expected to be widely deployed commercially before 2040, prototypes and demonstrators need to be designed and constructed in the next decade to enable sufficient return from experience before commercial deployment. Similarly, work on advanced high and very high temperature reactors can lead to the development of cogeneration systems capable of providing low carbon process heat for many industrial processes. In parallel to these advances on so-called 'Generation-IV' systems, a broad-based programme of R&D is needed in key areas such as materials, numerical simulation and safety. In many of these areas there are important synergies with research on materials and technologies for fusion power plants.

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

f) **Radiation protection**: Radiation protection research is particularly important in view of the rapidly growing use of radiation in medical diagnostic and therapeutic techniques, which is responsible for a significant rise in public exposure, especially at low doses[44]. Further multidisciplinary research is needed to determine the mechanisms involved and to quantify the risks of latent cancers and vascular diseases at these low doses. Radiation Protection in emergency situations such as under accidental conditions on and off-site require continued attention and improvements.

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

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

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

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

2.2. What is the situation in the private sector?

Fission: The assessment of the corporate R&D investments in nuclear energy is based on a limited number of companies, reflecting the consolidated situation in this sector in Europe and worldwide. French companies (AREVA, EdF) largely dominate the total corporate R&D investments in nuclear fission. Corporate research into all nuclear fission-related aspects amounted to around €550 million in 2007, of which R&D investment in nuclear reactor technology may be in the order of €200 million (i.e. ca. more than one-third)[45]. More recent data on the true level of investments in nuclear R&D is not available. However, an order of magnitude estimate of corporate R&D investments can be derived from the 2010 EU Industrial R&D Investment Scoreboard[46], which shows that companies with substantial activities in nuclear sector (utilities and construction)[47] spent almost 1200 million Euro on R&D (for nuclear, reneweables and fossil sources) of which ca. 71% (852 million Euro) was spent by AREVA and EdF alone. The electricity industrial sector is described by the 2010 EU Industrial R&D Investment Scoreboard as a medium-low R&D intensity sector (between 1% and 2% of net sales is spent on R&D).

The main focus of R&D investment in the nuclear sector is lifetime extension of currently operating plants and, in countries where the political and societal climate is right, technology developments in evolutionary LWR technology linked with new build projects[48]. The R&D efforts of the private sector are to a certain extent fragmented and often duplicated owing to the fact that European utilities operate in an increasingly competitive market.

Financing schemes for waste management are based on the "polluter-pays principle", often involving a small levy on the price of nuclear electricity. Either electricity utilities make provisions in their accounts or, increasingly, State-managed ring-fenced funds are established[49].

The nuclear industry is currently not prepared to invest heavily in the development of Generation-IV reactors because this technology is still 20-30 years away from possible commercial deployment and as a result there is considerable political, regulatory and economic uncertainty. The public sector continues to have a role at the stage of pre-commercial research in advanced technology, also in a context of international cooperation (e.g. Generation-IV International Forum[50]), but industry will be expected to contribute much more significantly during the next stage in the development of advanced systems, beyond the design and construction of demonstration plants, entering into a First-Of-A-Kind commercial plants and further replication

Fusion: fusion energy R&D is funded only by the public sector: the private sector does not yet invest in fusion because the time horizon is too long (2040-2050)**.** The generation of electricity from fusion power requires the control and understanding of very complex physical processes which can only be achieved using large experimental infrastructures. Many scientific milestones have already been achieved, the most important of which is the controlled generation of fusion energy in the JET device in 1997[51]. While this was a significant marker on the path to commercial fusion power, it is still distant from commercial exploitation and therefore entirely supported by public funding. ITER will bring commercial fusion power a step closer, but it illustrates the timescales involved: the detailed ITER design, including necessary experimentation and component prototyping, took close to 10 years (followed by about 5 years of international negotiations on legal structures and siting) and the lifetime of the project is 30 years[52]. Moreover, ITER is still an experiment and therefore carries the risk that it will not achieve all its aims. This risk has been mitigated by spreading the cost among seven partners in an international consortium, which also maximises the scientific and industrial expertise available to the project.

Private investment will be a necessary aspect of the demonstration fusion power plant (DEMO) which will follow ITER. By that stage the technology will have matured to a stage where industrial investment can take over the commercialisation of fusion power in the timeframe beyond 2050. Even though the private sector does not invest in fusion, it is involved in public procurements for fusion (ITER, JET and smaller fusion facilities), which brings mutual benefits (technology transfer, development of new products and new skills) [53].

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

Fission and radiation protection: Member States contribute to research on issues of political and societal concern such as nuclear safety, radioactive waste management and radiation protection. This stems from the societal decision to exploit nuclear technology and the associated shared responsibility of the State with the license holder to ensure appropriate levels of health protection for workers and citizens. In particular, publicly funded research can ensure that an appropriate balance between the risks and benefits is maintained and that regulations neither unduly prevent exploitation of potentially beneficial technologies nor expose individuals to unjustified risks. However the available data demonstrate that these efforts are fragmented and underfunded in some areas (LWR, nuclear supporting technology, Generation-IV). In addition, research priorities differ between Member States, as demonstrated by a table below (latest available IEA data shown for Member States for which a breakdown is provided[54]):

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

The very rough estimate prepared on the basis of IEA data for the period 2000-2009[55] shows that public R&D expenditure in Member States was focused on nuclear supporting technology (48% - this category of expenditure concerns nuclear safety, radiation protection and decommissioning, control of fissile materials), followed by the fuel cycle (32%) and R&D specifically related to light water reactors including safety and environmental aspects (11%). Expenditure that can be classified as Generation-IV (nuclear breeders, high temperature reactors, advanced gas cooled reactors) accounted for only about 7% (€43 million in 2007)

According to JRC report[56], Member States' R&D investment in nuclear reactor R&D (reactor technologies and fuel cycle) amounted to around €253 million in 2007. This represents about 43% of the total estimated expenditure in all nuclear fission-related R&D (€587 million). Similarly to the situation in corporate R&D expenditure, public funding for R&D is largely concentrated within France. In 2007, France accounted for more than half of the total EU Member States public investment in nuclear-related research. This result is in line with France's large share of nuclear generating capacity in Europe, i.e. about 50%. Other Member States investing significantly in nuclear research included Italy, Germany and the Netherlands.

Fusion: R&D in fusion energy is fully publicly financed in Europe and all research activities are coordinated within the integrated European fusion programme[57]. The total expenditure on fusion in 2007 and 2008 amounted to €582.48 and 607.24 million (direct expenditure of Member States 53% and 51% respectively with the remaining part funded by Euratom)[58].

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

Expenditure of EU Member States and Switzerland on fusion R&D in 2007 and 2008				
Country	**2007 (mln EUR)**	**% of total**	**2008 (mln EUR)**	**% of total**
Austria (ÖAW)	3.3	1.1%	3.1	1.0%
Belgium (LPP ERM – KMS)	4.9	1.6%	5.5	1.8%
Bulgaria (BAS)	0.2	0.1%	0.5	0.2%
Czech Rep (IPP.CR)	3.1	1.0%	1.3	0.4%
Denmark (RISØ)	1.9	0.6%	1.8	0.6%
Finland (TEKES)	4.2	1.4%	2.8	0.9%
France (CEA)	45	14.5%	46.3	14.9%
Germany (IPP. FZJ. FZK)	120	38.6%	137.7	44.2%
Greece (HR)	1.2	0.4%	1.6	0.5%
Hungary (HAS)	1.2	0.4%	1.0	0.3%
Ireland (DCCU)	1.2	0.4%	1.1	0.4%
Italy (ENEA)	52.1	16.8%	41.3	13.3%
Latvia (UoL)	0.3	0.1%	0.6	0.2%
Lithuania (LEI)	0.1	0.0%	0.2	0.1%
Luxembourg (ME)	0.1	0.0%	0.0	0.0%
Netherlands (FOM)	11.3	3.6%	9.7	3.1%
Sweden	5.2	1.7%	4.3	1.4%
Poland (IPPLM)	1.6	0.5%	1.6	0.5%
Portugal (IST)	4.4	1.4%	4.8	1.5%
Romania (MEdC)	1	0.3%	1.0	0.3%
Slovakia (AECU)	0	0.0%	0.7	0.2%
Slovenia (MHEST)	1.2	0.4%	1.3	0.4%
Spain (CIEMAT)	11.5	3.7%	10.2	3.3%
Switzerland (CRPP)	13.2	4.2%	12.6	4.0%
UK(former UKAE. now CCFE)	22.6	7.3%	20.5	6.6%
TOTAL	**310.8**	100.0%	**311.4**	100.0%
Source: European Commission, 2011, Expenditure is not indicated for Estonia, Cyprus and Malta as fusion labs in these Member States are part of Finnish, Greek and Italian Association respectively.				

2.4. Why EU-level intervention is necessary?

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

Nuclear research is the only area of research that has a direct mandate in the treaties (Articles 2, 4 and 7, and also Annex 1, of the Euratom Treaty[59]). The European added value of nuclear research is explicit in the Euratom Treaty itself and the Commission has an obligation to put forward an R&D programme to complement those in Member States.

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

In the area of lifetime extension, the main challenge for Euratom support is to ensure the availability and acceptance of standard tools and methodologies across Europe[60]. Owing to the nuclear safety implications, it is unacceptable that plant lifetime extension decisions in one country are not based on the same criteria and techniques as in others. The aim of public intervention is to ensure consistency and harmonisation especially to guarantee high and uniform levels of nuclear safety. Funding on lifetime extension by the utilities themselves is often proprietary and at significantly higher levels than the public component.

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

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

During the last 10 years, the Euratom programme has fostered greater cooperation between nuclear research and industrial actors[61]. This has been largely through the establishing of broad-based ‘technical forums’ in key areas (and the defining of related Strategic Research Agendas, SRA), and the strengthening and focusing of Member States R&D efforts thanks to the overall framework provided by the SET-Plan. The establishing of SRAs and the implementation of the SET-Plan in the nuclear field has resulted in restructuring of the R&D activities in fission and cooperation in key R&D infrastructure projects. These efforts need to continue, encouraging true joint programming between Member States, the establishing of legal entities and public-private partnerships where necessary (in particular driven by industry as end-users), and the de-compartmentalisation of research sectors to maximise synergies between scientific and technological disciplines (not only between, for example, advanced fission and fusion but also between nuclear and non-nuclear energy).

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

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

a) **The Euratom R&D programme provides a flexible and effective instrument to support research in nuclear safety**. Although it is still too early to draw final conclusions from the Fukushima accident and the results of the nuclear stress tests in the EU, already the events in Japan are provoking a widespread re-assessment of nuclear safety in Europe. Initially this is concentrating on regulatory practice and demonstrating resistance to extreme external hazards, but there may be important implications for research. The Euratom programme is an appropriate instrument to coordinate and carry out the necessary activities. This was the case following the Chernobyl accident, with a substantial EU investment of EUR 40 million over 20 years in the PHEBUS programme (core melt experiments in controlled conditions) and Euratom funding in other areas such as emergency management and rehabilitation of contaminated territories. In fact, Europe is the only region of the world maintaining significant competences in the area of radioecology – the study of the impact of radioactive contamination on ecosystems in general. The project STAR[62], a Network of Excellence to ensure long-term sustainability of the radioecology research sector, was launched at the beginning of 2011;

following the events at Fukushima, discussions have already begun to add a Japanese partner in the consortium.

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

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

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

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

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

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

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

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

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

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

The scientific and technological feasibility of fusion will be demonstrated by ITER. This has to be done at very large scale and cannot be broken down into smaller projects that could be handled at national level. On this scale it is necessary to pool financial resources and scientific expertise, and to share risk, in an international cooperation. Together the 7 international partners (EU plus China, India, USA, Korea, Russia, Japan) will prove the feasibility of fusion as an energy source, and Europe as host will obtain the largest share of the economic and scientific benefits.

Another example is the Joint European Torus (JET) the world's leading fusion experiment, with a volume of fusion plasma about 10 times larger than that in any other fusion device, and a configuration and performance closer to that of ITER than any other device. The total expenditure for construction, upgrade and exploitation of this European facility during 1978-2010 amounts to ca. 2000 Million EUR. The majority of this funding has come from the Community budget, but there has also been strong support from the Member States. In particular, the construction and operation of JET has only been possible because of the pooling of scientific and industrial expertise from all the Member States. The contributions of JET to the development of fusion must not be underestimated: (a) it is the only current fusion device which can operate with the fuel mixture of genuine fusion reactors; (b) it holds all the records for peak and sustained production of controlled fusion power; (c) it is the most ITER relevant machine for studies in preparation for ITER technology and operations; (d) it is the only present fusion device in which the essential fusion technology of remote handling has been developed and used for major interventions; (e) it is the most useful experiment for the training of future operational staff for ITER.

The High Performance Computer for Fusion (HPC-FF) is a valuable new tool for the fusion programme. Fusion modelling requires powerful computer resources; increasingly realistic simulations that are able to take into account the full ITER plasma will be an essential tool for the safe and efficient operation of ITER. The HPC-FF computer, hosted and operated by the Jülich Supercomputing Centre at the Forschungszentrum Jülich fusion Association in Germany, is among the 30 most powerful computers in the world. Euratom capital investment amounted to around €7.4 million, while the total budget including the capital investment and exploitation over four years will be around €16.8 million, with contributions from the entire European fusion community.

f) Action at European level (Euratom) can help give credibility to the EU's long-range policies on energy and **increase the willingness of investors to release capital for projects with particular importance for nuclear safety or with long lead-times** and **significant technology and market risk.**

Project SARNET-2 is an excellent example of the leverage effect of EU funding – the total budget is €38M but the EU contribution is just €5.75M (i.e. 16% of total costs). The project will continue the efforts of a number of European R&D organisations, including safety authorities, industry and universities, to network their research capacities in the area of severe reactor accidents, thus enhancing the safety of existing and future nuclear power plants. This Network of Excellence defines joint research programmes and develops common computer tools and methodologies for safety assessment of nuclear power plants, and ultimately ensures sustainable integration of the key R&D organisations in this sector.

European Sustainable Nuclear Industrial Initiative (ESNII) constitutes one of the three technology pillars of SNETP and is moving forward with the design and construction of three fast reactor technologies of the next generation (Gen-IV). Euratom is co-funding cross-cutting topics and pre-commercial research, though national public and private investors will probably be responsible for funding construction of the demonstrator plants (ASTRID, MYRRHA and ALLEGRO).

The closer involvement of industry in fusion development has been launched by the establishment of the **Fusion-Industry Innovation Forum**. It will have an increased role in during future EU research programmes, especially in relation to preparation for the construction of DEMO. As well as providing the foundations for creating a strong fusion industry in the future, in the short term it will promote technology transfer and dissemination in order to maximise innovation.

g) In international cooperation, it makes it easier for our international partners to interact with a **single interlocutor** and build common actions.

In all matters concerning **ITER and the Broader Approach**, Euratom is the signatory of the agreements, and the Commission is the sole interlocutor for matters of governance. This is essential for such complex international projects. The Commission has also taken the responsibility for establishing **bilateral agreements with third countries** (especially the ITER partners), which provide an umbrella under which collaborative research of mutual benefit can take place with standardised provisions on, for example, intellectual property matters.

The Generation-IV International Forum (GIF) is fostering multilateral cooperation in research on next generation nuclear technology. Euratom and all major civil nuclear power programme countries are cooperating though the exchange of results on pre-conceptual design research on six advanced systems. All research stakeholders in Europe can benefit from Euratom membership of GIF, in particular by being a partner in a relevant Euratom FP project. The dialogue in the GIF is also helping to establish future partnerships for design and construction of demonstrator plants.

2.6. EU performance in nuclear research - comparison with USA and Japan

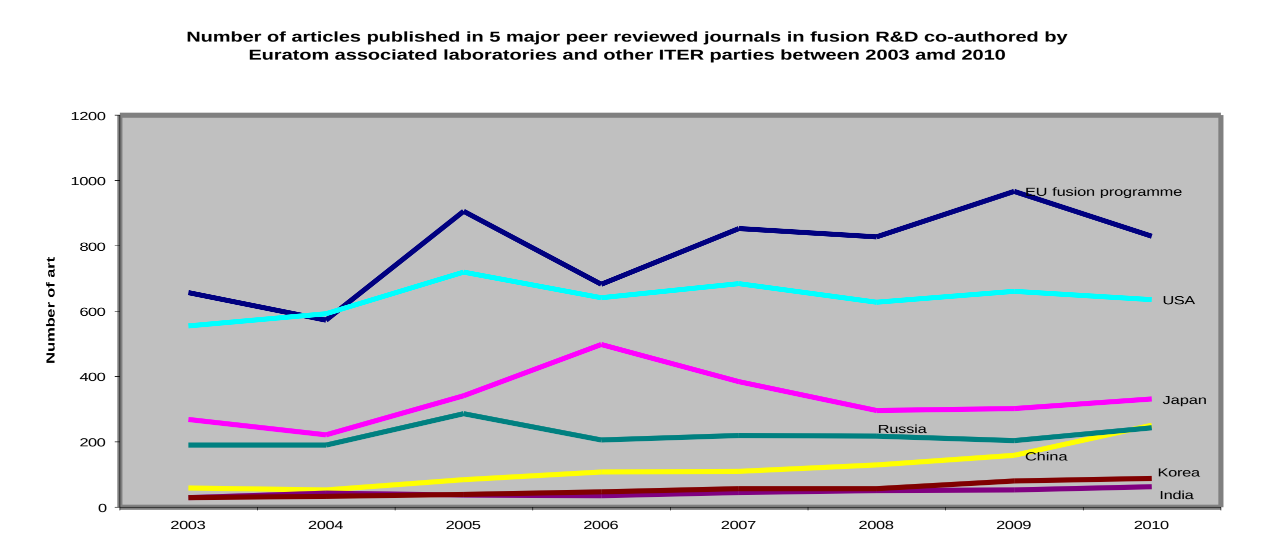
<u>Fusion:</u> Overall, the EU (Member States and Euratom) devotes the largest worldwide budget to fusion research (see table below) and dominates fusion science and technology.

Annual budgets for fusion energy research *estimates in million Euro,*					
	2007	**2008**	**2009**	**2010**	**2011**
EURATOM (1) (including ITER)	271.8	295.9	388.7	438.9	438.0
EU Member States (1)	310.8	311.4	About 300 million euro / year		
Total for Europe (1)	582.6	607.3	About 700 million euro / year		
USA(2)	232.2	215.1	355.4	321.3	307.5
Japan (2) (3)	115.9	150.5	152.7	N/A	N/A

Sources: European Commission, US Department of Energy, IEA
(1) Magnetic confinement R&D only
(2) Includes Magnetic confinement R&D and inertial confinement
(3) May not include all administrative and running costs.

Analysis of peer reviewed journals and citations show a strong leadership of the Europe in fusion R&D. **Europe through its fusion laboratories co-authored the largest number of articles published during the period 2003-10** in five international peer reviewed journals in the field of plasma physics and fusion[63], with an **average number close to 800 articles per year** (see figure below).

Europe's leadership in fusion is further underlined by the fact that **436 of most cited 1000 articles** published in these 5 journals were prepared on the basis of research <u>co-funded by Euratom</u>. **On average each of these 436 articles resulted in 25 citations** (similar to USA, 26, and better than Japan, 21) with the **best article yielding 141 citations.**



Source: Calculated on the basis of Scopus.com

Some countries like Russia and USA have fusion R&D programmes well established since the 1950s, while others such as China, Korea and India have developed more recently (1990s-2000s) in parallel to intensification of the ITER programme. All the ITER partners are pursuing the tokamak approach, but none have facilities comparable to JET. The rate of progression of Asia is fast and impressive and Europe will have to adapt its effort to this evolving situation in order to benefit from its past investments.

Fission: Recent data indicate that Europe spends less on fission R&D than USA and Japan (assuming that expenditure in 2009-2011 has remained at the 2008 level in the table below). The European R&D sector in fission is dominated by France and covers a wide range of activities in all relevant areas, though is particular strong in nuclear safety, geological disposal and radiation protection. Regarding research in advanced systems, the situation is less favourable, even despite projects such as ASTRID and MYRRHA. Annual figures collected by the Generation-IV International Forum (GIF, unpublished) show that Europe is investing similar amounts in pre-conceptual design research on advanced systems as other GIF members, but that Asia is much further advanced regarding development of demonstrator reactors, with high temperature reactors and sodium cooled fast reactors under construction in China, India and Japan, and Russia also advancing rapidly. These countries are also dominating the market for new build of current nuclear technology.

Annual budgets for research in fission and radiation protection
In million EUR

	2005	2006	2007	2008	2009	2010	2011
(1) Euratom budget	49.5	53.1	48.7	49.5	51.7	51.0	52.0
(2) EU Member States	598.8	577.6	585.9	514.0	N/A	N/A	N/A
Europe. Total (1+2)	648.3	630.7	634.6	563.5	N/A	N/A	N/A
USA	379.7	288.0	394.2	489.2	560.7	593.4	N/A
Japan	1981.6	1861.8	1880.4	1868.1	1835.5	N/A	N/A

Source: European Commission. IEA. US Department of Energy

IEA database is incomplete and does not cover all Member States (see footnote no. 33)

Europe's performance in the area of nuclear fission R&D can be measured in patents registered in the European Patent Office[64]. For the period 1990-2008, the European industry and research sector (from 27 Member States) has been granted about 1164 patents (51% of all registered by EPO) in the field of nuclear reactors and nuclear power plants. Other major players are USA and Japan (37% and 11% respectively).

However, the majority of these patent applications concern current not future reactor systems. Without continued efforts in Nuclear Research and Innovation, ranging from present reactors to Generation III and IV, the EU will quickly loose its technological leadership since in other parts of the word, advanced reactor systems are under construction or already in operation.

3. Objectives for the future Euratom Research and Training Programme

In order to tackle the problems identified in section 2, it is important to clarify the objectives of Euratom's actions in the field of nuclear research and training.

The overall objective of the Euratom Research and Training Programme (2014-2018) will be to improve nuclear safety, security and radiation protection, and to contribute to the long term decarbonisation of the energy system in a safe, efficient and secure way. This shall reinforce the three objectives of "Horizon 2020" programme: strengthening excellence in the science base; creating industrial leadership and competitive frameworks; tackling societal challenges.

For the attainment of its objective the Euratom Programme shall strengthen the research and innovation framework in the nuclear field and coordinate Member States' research efforts, thereby avoiding duplication, retaining critical mass in key areas and ensuring that public funding is used in an optimal way. The Programme shall continue to promote the European Research Area and the further integration of new Member States and associated countries.

While it is for each Member State to choose whether or not to make use of nuclear power, the role of the Union is to develop, in the interest of all its Member States, a framework for supporting cutting-edge research on nuclear fission technologies, with special emphasis on safety, security, radiation protection and non-proliferation. In order to maintain the Union's nuclear expertise, the Programme shall further enhance its role in training.

The Commission proposed in a communication "A Budget for Europe 2020" (COM(2011) 500) that for projects such as ITER, where the costs and/or the cost overruns are too large to be borne only by the EU budget, the funding should come from outside the MFF after 2013. This will enable the EU to continue to fully meet its international commitments. Therefore ITER construction and related activities are not subject of the Euratom Research and Training Programme and a separate proposal for a supplementary research programme for ITER construction will be prepared.

<u>In order to achieve the overall objective, the following specific objectives must be attained by **indirect actions:**</u>

a) Support safe operation of nuclear systems;

Research to underpin the safe operation of reactor systems (including fuel cycle facilities) in use in Europe or, to the extent necessary in order to maintain broad nuclear safety expertise in Europe, those reactor types which may be used in the future, focusing exclusively on safety aspects, including all aspects of the fuel cycle such as partitioning and transmutation.

b) Contribute to the development of solutions for the management of ultimate waste;

Research activities on remaining key aspects of geological disposal of spent fuel and long-lived radioactive waste with, as appropriate, demonstration of the technologies and safety, and to underpin development of a common European view on the main issues related to waste management from discharge of fuel to disposal. Research activities related to management of other radioactive waste streams for which industrially mature processes currently do not exist.

c) Develop and maintain nuclear competences;

Promote training and mobility activities between research centres and industry, and support maintaining nuclear competences in order to guarantee the availability of suitably qualified researchers, engineers and employees in the nuclear sector over the longer term.

d) Foster radiation protection

Research will focus in particular on the risks from low doses (from industrial, medical or environmental exposure) and on emergency management in relation to accidents involving radiation, to provide a scientific basis for a robust, equitable and socially acceptable system of protection.

e) Move toward demonstration of feasibility of fusion as a power source by exploiting existing and future fusion facilities

Support common research activities undertaken by members of the European Fusion Development Agreement to ensure the rapid start up of high performance operation of ITER including inter alia, the use of relevant facilities (including JET), integrated modelling using high performance computers, plus training activities to prepare the ITER generation of researchers and engineers.

f) Laying the foundations for future fusion power plants

Support for joint activities undertaken by members of the European Fusion Development Agreement to develop and qualify materials for a demonstration power plant requiring, inter alia, preparatory work for an appropriate material test facility and negotiations for the Union's participation in a suitable international framework for this facility.

Support for joint research activities undertaken by members of the European Fusion Development Agreement that shall address reactor operation issues and shall develop and demonstrate all relevant technologies for a fusion demonstration power plant. Activities include preparation of complete demonstration power plant conceptual design(s) and exploration of the potential of stellarators as a power plant technology.

g) Promote innovation and EU industry competitiveness

Implement or support a knowledge management and technology transfer from the research co-funded by this programme, including ITER, to industry exploiting all innovative aspects of the research. For the longer term, the Programme shall support the preparation and enhancement of a competitive nuclear industry, in particular for fusion through the implementation of a technology road map to a fusion power plant with active industrial involvement in the design and development projects.

h) Ensure availability of research infrastructures

Support construction, the use and continued availability of, appropriate access to, and cooperation between key research infrastructures within the scope of Euratom programme.

Direct actions by the Joint Research Centre will contribute to the Euratom Programme's overall objective by attaining the following specific objectives:

a) Improve nuclear safety including: fuel and reactor safety, waste management and decommission; and emergency preparedness;

b) Improve nuclear security including: nuclear safeguards, non-proliferation, combating illicit trafficking and nuclear forensics;

c) Raise excellence in science base for standardization;

d) Foster knowledge management, education and training

e) Support EU policy and legislation on nuclear safety and security

4. POLICY OPTIONS

The Euratom Research and Training Programme is an integral part of the Commission proposal for 'Horizon 2020' the Framework Programme for Research and Innovation. Therefore an analysis of general policy options presented in the main report on the impact assessment for the 'Horizon 2020' apply also to the Euratom Programme.

The following section provides a supplementary information and analysis of policy options (scenarios) for the fusion research programme.

Scenario 1 aims at the shortest path to demonstrate electricity production from a DEMO fusion reactor by 2040;

Scenario 2 takes full benefit of ITER exploitation but with a slower rate of progress on power plant related activities;

Scenario 3 curtails the research programme, delaying DEMO by more than 10 years and compromising the capability of EU industry to become a main actor in the eventual worldwide fusion energy market.

Evaluation of these scenarios is supplemented by the analysis of risks and benefits of fusion research.

5. ANALYSING THE IMPACTS AND COMPARING OPTIONS

5.1. Analysis of scenarios for fusion research

Given the potential of fusion to satisfy future energy requirements and assuming that it will have to take as soon as possible a substantial share of base-load electricity production in the future, it is appropriate to consider reaching the ultimate objective as quickly as possible with a **first scenario** requiring an increased level of activities and resources. This scenario assumes that an ambitious programme should be put in place to have fusion energy electricity in the grid from a demonstration reactor by 2040 and prototype power plants available by 2050. In-depth assessments by the fusion community have shown that this scenario requires the completion of the ITER construction and achievement of first plasma by 2020, followed by the start of Deuterium and Tritium operation by 2027. DEMO design by industry supported by the fusion community should start as soon as scientific results, materials and engineering data are available from ITER exploitation and from other complementary activities, probably a little before 2030. In addition to the present spectrum of research activities, the early implementation of two other projects with long lead-times is essential if such a rate of progress is to be achieved: the development and testing of "Tritium Breeding Modules" for tritium self-sufficient operation of fusion reactors (a TBM programme was established by the ITER Council in 2009 and TBMs will be tritium-tested in the ITER facility from 2027); and preparation for an ad-hoc fusion specific neutron source so that its construction could start by 2020. The first scenario would require a re-evaluation of current funding schemes and structure of the research programme in Europe and the way it is implemented, especially in order to favour more rapid industrial take-up of the technology

Pros: Demonstrating fusion energy potential to produce electricity by 2040 and putting power plants in the grid by 2050, maintaining EU leadership and optimally positioning EU industry to exploit the commercial potential.

Cons: High cost scenario during the period until 2020.

A second scenario assumes that fusion is less urgently needed to complement/substitute other energy sources. It partially omits / postpones some activities and generally has a lower level of activity during the period 2014-2020, postponing a number of developments beyond 2020 and implying acceptance of a longer timescale. As in first scenario, reassessment of the Euratom funding approach is necessary.

Pros: A level of activities maintaining the overall goal of the research programme, at an average cost until 2020 that may be comparable to the average level in FP7.

Cons: Higher risk than in the first scenario and the pace may be slowed down depending on capacity to address scientific/technical/industrial issues during development, and likely higher total cost to reach the ultimate objective owing to delays.

A third scenario implies a severe curtailment and/or postponement of R&D activities including for ITER systems (e.g. for heating systems, Test Blanket Modules) with the consequent risks and likelihood of delays in ITER construction and a slow start of its operation. In this scenario the EU fusion programme would essentially consist of the EU contribution (subject to separate decision) to the (likely delayed) ITER project accompanied by limited other fusion activities. The EU, which is the major contributor to the ITER project, would not reap the full benefits of its investment and the exploitation of the ITER facility would mainly benefit our international competitors. In addition, the EU's progress towards DEMO and fusion energy would be substantially delayed.

It should be emphasised that the most important part (and corresponding cost) of Europe's efforts to establish feasibility of fusion as a power source during the period covered by the 'Horizon 2020' will be, by far, the EU contribution to ITER construction (subject to separate decision on supplementary research programme). It appears therefore sound, subject to the availability and distribution of resources under Horizon 2020, to opt for the first scenario in order to have fusion energy available as soon as possible.

5.2. Where are the risks and benefits of future EU investments in nuclear research?

The main benefit of the fusion research is, in a very long term, to provide solutions for development of fusion as a viable alternative for a large scale and low carbon base-load energy source. The fusion programme proposed for 2014-18 will bring the following specific benefits:

- **Efficient operation of ITER:** the R&D programme will expand the existing knowledge and prepare staff to ensure that Europe will have the human resources to exploit ITER in an international and competitive environment;
- **Acceleration of development of fusion power plants –** in parallel to R&D for ITER, the programme will lay the foundations for fusion power plants by driving forward the significant physics and technology developments that are required.
- **Contribution to the EU competitiveness** – the body of expertise created in by the fusion research community, will provide immediate technology transfer benefits for industry and services[65].
- **Spin-off benefits of fusion research** – besides the promise of bringing sustainable energy supply in the future, fusion R&D is yielding additional societal benefits which should be taken into account in the allocation of public R&D funds[66]. Fusion research has pushed many of the cutting-edge technologies to new limits and in many cases innovative solutions to challenging problems have found applications far beyond the bounds of fusion (cooled high heat flux components in space applications, improvement of Magnetic Resonance Imaging (MRI), applications in brakes and clutches used in trains and motor racing)[67].
- **Reduction of risks regarding future exploitation of fusion energy** – research can further reduce economic, environmental and social risks (see table on the risks and benefits of fusion).

The main risk for fusion research is that it is still at the experimental stage and it may fail to deliver results i.e. demonstrate the feasibility of fusion as an energy source**.** Such a failure will result in economic loss in term of investments made and lost opportunities for using resources for other purposes.

5.3. Risks and benefits of fusion energy

The table below shows possible benefits and risks related to the eventual exploitation of fusion energy (summary of assessments made in numerous peer review journals and studies).

Risks and benefits of fusion energy	
Benefits	
Economic	– The scale and sustainability of fusion energy production will not be limited by fuels (deuterium and tritium) – High energy density and no major land use; – Possible source of stable base-load energy supply – Preliminary analyses based on set of assumptions indicate competitive costs of electricity from fusion
Environmental	– no CO_2 emissions from fusion operations, very low carbon emissions for the whole life-cycle; – The maximum radiological doses to the public arising from the most severe conceivable accident driven by in-plant energies would be well below the level at which evacuation would be considered and would be comparable to typical annual doses from natural causes. – After a few decades, the total radiotoxic potential of the activated material arising from the operation and decommissioning of the fusion plant will have decreased to a low value. All of this material, after remaining in situ for a few decades, may, if desired, be cleared or recycled, with little, or no, need for repository disposal. – No possibility for runaway reactions or meltdown, and much smaller quantities of highly radioactive material than in fission reactor. A Fukushima-type melt-down accident cannot happen in a fusion reactor. – Fusion has significant proliferation advantages compared to fission. Any illicit use of fusion neutrons for transmutation to produce fissionable materials would be easily detectable.
Social	– Important domestic added value (European technological leadership) – Negligible human health impacts
Risks	
Economic	– Fusion's role in the energy mix is very sensitive to the costs – Availability factor for future power plant – Fusion will be able to enter the market in the second half of the century if environmental constraints are applied consistent with a maximum atmospheric CO_2 concentration in the range of 550 to 650 ppm.
Environmental	The main nuclear risk associated with fusion is the use of tritium as fuel
Social	Need to teach society about new source of energy
Sources*: Final Report of the European Fusion Power Plant Conceptual Study (PPCS)* EFDA 2005; *Study on safety and environmental impact of fusion*, EUR (01) CCE-FU / FTC 8/5, EFDA April 2001; *Power plant conceptual studies in Europe*, D. Maisonnier, D. Campbell, I. Cook, Nucl. Fusion 47 (2007) 1524–1532; *Revised assessments of the economics of fusion power*, W.E. Han, D.J. Ward / Fusion Engineering and Design 84 (2009) 895–898, *Economically competitive fusion*, David J. Ward and Sergei L. Dudarev, December 2008, Materials Today, Vol. 11, No 12,	

6. EVALUATION AND MONITORING

To achieve the objectives set out in Section 3 it is vital to put in place an appropriate system for Euratom's programme evaluation and monitoring. The Euratom programme will follow key principles for the evaluation and monitoring presented in chapter 6 of the main report of the impact assessment of "Horizon 2020" Framework Programme for Research and Innovation.

To monitor progress specific indicators. Separate for direct and indirect actions, will be used.

6.1. Indicators for indirect actions

a) Support safe operation of nuclear systems;

<u>Indicator:</u> Percentage of overall programme funding going on projects likely to lead to a demonstrable improvement in nuclear safety practice in Europe.

Current: XX% (2011); Target: XX% (2018) *Data for this indicator will be provided later*

b) Contribute to the development of solutions for the management of ultimate waste;

Indicator: Number of geological repositories for spent nuclear fuel and/or high-level waste that are planned in Europe and for which a *safety case* has been prepared and construction application made.

Current: 0 (2011); Target: 3 (2018),

c) Develop and maintain nuclear competences;

Indicator: Training through research - number of PhD students and Post-Doc researchers involved in Euratom fission projects

Current: ca. 200 (total for 2006-2011); Target: 300 (total for 2014-2018)

Indicator: Number of fellows and trainees in the fusion programme

Current: on average 27 per year (2011); Target: 40 per year (2018)

d) Foster radiation protection

Indicator: Percentage of funding going on projects likely to have a demonstrable impact on regulatory practice regarding radiation protection.

Current: XX% (2011); Target: XX% (2018) *Data for this indicator will be provided later*

e) Move toward demonstration and feasibility of fusion as a power source by exploiting existing and future fusion facilities

Indicator: Number of publications in high impact journals

Current: ca. 800 (2010); Target: Maintain current levels (2018).

Description of the indicator: Source of data – Scopus database. Please note that with the fusion programme's emphasis shifting from research to technology development this indicator may be lower in the future. Indicator concerns articles where at least one contributing author is from the European fusion laboratory participating in the Euratom Programme. It is calculated on the basis of 5 most important international peer reviewed journals in the field of plasma physics and fusion: *Nuclear Fusion, Plasma Physics and Controlled Fusion, Fusion Engineering and Design, Fusion Science and Technology, Journal of Fusion Energy.*

f) Lay the foundations for future fusion power plants by developing materials, technologies and conceptual design;

Indicator: Percentage of the Fusion Roadmap's milestones established for a period 2014-2018 reached by the Euratom Programme;

Current: new indicator, 0%

Target: 90%, including Report on Fusion Power Plant Conceptual design activities (2018);

Description of the indicator: new indicator which will be based on the roadmap for the fusion programme to be developed before 2014.

g) Boost Europe's industrial leadership in fusion technologies through development of the technology transfer process

Indicator: Number of spin-offs from the fusion research under Euratom Programme

Current: 33% of contracts resulted in spinoffs (2011); Target: 50% (2018)

Description of the indicator: new products or services developed by companies involved in the fusion research.

Indicator: Patents applications generated by European fusion laboratories

Current: 2-3 new patents per year (2011); Target: on average 4-5 new patents per year (2018);

h) Ensure availability of research infrastructures for nuclear research;

Indicator: Number of researchers using fusion research infrastructures through mobility support

Current: ca. 800 (2008), Target: 1200 (2018);

Description of the indicator: mobility scheme under fusion programme supports short term visits of European scientists to the fusion facilities such as JET.

6.2. Indicators for direct actions

a) Improve nuclear safety including, fuel and reactor safety, waste management and decommissioning; and emergency preparedness

Indicator: Scientific Productivity (Number of major JRC annual work programme deliverables: reports and publications to support nuclear fuel and reactor safety, waste management, decommissioning and emergency preparedness)

Current: 45 (2010); Target: 50 (2018)

b) Improve nuclear security including: nuclear safeguards, non-proliferation, combating illicit trafficking and nuclear forensics

Indicator: Scientific Productivity (Number of major JRC annual work programme deliverables: reports and publications to support nuclear safeguards, non-proliferation, combating illicit trafficking and nuclear forensics)

Current: 15 (2010); Target: 20 (2018)

c) Raising excellence in nuclear science base for standardisation

Indicator: Scientific Productivity (Number of major JRC annual work programme deliverables: reports and publications to support EU standardisation.

Current: 30 (2010); Target: 30 (2018)

d) Foster knowledge management, education and training

Indicator: Scientific Productivity (Number of major JRC annual work programme deliverables: reports and training programmes)

Current: 20 (2010); Target: 18(2018)

e) Support to EU policy and evolving legislation on nuclear safety and security

Indicator: Policy support impact (Number of JRC reports used as reference for EU legislation)

Current: 0 (2010); Target: 2 (2018)

Indicator: Policy support productivity (Number of major JRC annual work plan deliverables with tangible impact at the level of nuclear policy makers: reports and training programmes)

Current: 40 (2010); Target: 45(2018)

ANNEX 7: GENERAL BIBLIOGRAPHY

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ANNEX 8: GLOSSARY

Applied research: Original investigation undertaken in order to acquire new knowledge. Contrary to *basic research*, it is directed primarily towards a specific practical aim. The results of applied research are intended to be valid for a single or limited number of products etc. The knowledge or information derived from it is often patented but may also be kept secret.

Basic research: Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view (contrary to *applied research)*. The results of basic research are not generally sold but are usually published in scientific journals. Basic research can be [illegible]: 1) Pure basic research which is carried out for the advancement of knowledge, with no positive efforts being made to apply the results to practical problems. 2) Oriented basic research which is carried out with the expectation that it will produce a broad base of knowledge likely to form the background to the solution of recognised or expected current or future problems or possibilities.

Business As Usual (BAU): In this scenario, the main existing EU sources of funding for research and innovation – the FP, the innovation-related part of the CIP, and the EIT – are simply carried forward into the next Multi-annual Financial Framework as separate instruments, with separate objectives, and in their current formats. In the Business As Usual+ (BAU+) scenario, the FP, the innovation-related part of the CIP, and the EIT remain separate instruments and retain their current formats. However They are put together under a 'common roof', and loose coordination mechanisms are established between them and their objectives are loosely aligned. In addition, the implementing modalities of each individual programme and initiative are simplified. No single set of simplified rules applies across the three programmes.

BRIC-countries: Brazil, Russia, India and China.

Collaborative Projects: Support to Framework Programm funded research projects carried out by consortia with participants from different countries. The size, scope and internal organisation of projects can vary from field to field and from topic to topic. Projects can range from small or medium-scale focused research actions to larger integrating projects which mobilise a significant volume or resources for achieving a defined objective.

Competitiveness and Innovation Framework Programme (CIP): The Competitiveness and Innovation Framework Programme (CIP) supports innovation activities (including eco-innovation), provides better access to finance and delivers business support services in the regions, targetting mainly small and medium-sized enterprises (SMEs).

Common Research Data Warehouse (CORDA): CORDA and E-CORDA (External Common Research Data Warehouse – the analogue destined to external stakeholders) are databases containing data on applicants/proposals and signed grants/beneficiaries with regards to a specific Framework Programme for Research. CORDA is refreshed daily with data coming from a wide variety of systems and applications. It, therefore, contains almost up-to-date information on Framework Programme activities. E-CORDA is a 'snapshot' of CORDA extracted semi-annually, the data of which undergoes further quality controls and interpretation.

CORDIS: The Community Research and Development Information System (CORDIS) is a huge internet information system comprising information on past and on-going projects, calls for proposals, partner search facilities, an electronic proposal submission system (EPSS) and other features.

COST: An intergovernmental framework for European co-operation in the field of S&T, allowing the co-ordination of nationally funded research on a European level. COST actions cover basic and pre-competitive research as well as activities of public utility.

CREST: The Scientific and Technical Research Committee (CREST), composed of representatives of Member States, is a high level advisory board to the Commission and the Council in the field of RTD.

Development of a European Multi-model ensemble system for seasonal to inter-annual prediction (DEMETER): This EU-funded project entitled aims to develop a well-validated European coupled multi-model ensemble forecast system for reliable seasonal to interannual prediction. A fundamental aspect is to establish the practical utility of such a system, particularly to the agriculture and health sectors.

Entrepreneurship and Innovation Programme (EIP): The EIP is one of the specific programmes under the CIP, supporting innovation and SMEs in the EU. It focuses on access to finance for SMEs, business services (Entreprise Europe Network), support for improving innovation policy, eco-innovation, as well as support for innovation and SME policy-making through contracts and grants.

ERA-NET: The principal means for the FP to support the co-ordination of national and regional research programmes.

EU-12: The 12 countries that joined the EU since 2004 (Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia).

EU-15: Before 1 May 2004, the European Union consisted of 15 Member States (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and United Kingdom).

EURATOM: The European Atomic Energy Community (EURATOM) is one of the building blocks of the EU. In relation to Community research policy, the EC Framework Programme is complemented by an EURATOM Framework Programme under the Euratom Treaty which covers training and research activities in the nuclear sector.

EUREKA: A pan-European network for market-oriented, industrial R&D. EUREKA supports the competitiveness of European companies through international collaboration, in creating links and networks of innovation. The objective is to bring high quality research and development efforts to the market and to use the multiplying effects of co-operation.

European Added Value (EAV): EU support to research and innovation is provided only when it can be more effective than national funding. It does this through measures to coordinate national funding, and through implementing collaborative research and mobility actions.

European Higher Education Area (EHEA): The EHEA was launched in March 2010, along with the Bologna Process' decade anniversary, during the Budapest-Vienna Ministerial Conference. As the main objective of the Bologna Process since its inception in 1999, the EHEA was created to ensure more comparable, compatible and coherent systems of higher education in Europe.

European Institute for Innovation and Technology (EIT): The EIT is an institute of the European Union established in March 2008, to increase European sustainable growth and competitiveness by reinforcing the innovation capacity of the Member States and the EU, by developing a new generation of innovators and entrepreneurs. The EIT has created integrated structures, Knowledge Innovation Communities (KICs), which link the higher education, research and business sectors to one another, boosting innovation and entrepreneurship. The KICs focus on priority topics with high societal impact.

European Patent Office (EPO): The European Patent Organisation is an intergovernmental organisation that was set up on 7 October 1977 on the basis of the European Patent Convention (EPC) signed in Munich in 1973. It has two bodies, the European Patent Office and the Administrative Council, which supervises the Office's activities.

European Research Area (ERA): A general concept proposed by the Commission and endorsed by the European Parliament and Council in 2001 to overcome the fragmentation of European research and innovation efforts. The concept comprises organising co-operation at different levels, co-ordinating national or European policies, networking teams and increasing the mobility of individuals and ideas.

European Research Council (ERC): Introduced in FP7, it will be the first pan-European funding agency for *frontier research*. Early stage as well as fully established investigators from across Europe will be able to compete for grants with scientific excellence as the sole criterion for funding. The independent Scientific Council will direct the ERC's scientific operations and ensure that its support is in accordance with the highest standards of science and scholarship.

European Space Agency (ESA): Established in 1975, ESA is an inter-governmental organisation dedicated to the exploration of space, with 17 Member States. Its mission is to shape the development of Europe's space capability. By coordinating the financial and intellectual resources of its members, it can undertake programmes and activities far beyond the scope of any single European country.

European Strategy Forum on Research Infrastructures (ESFRI): ESFRI is a strategic instrument to develop the scientific integration of Europe and to strengthen its international outreach. The competitive and open access to high quality Research Infrastructures supports and benchmarks the quality of the activities of European scientists, and attracts the best researchers from around the world. The mission of ESFRI is to support a coherent and strategy-led approach to policy-making on research infrastructures in Europe, and to facilitate multilateral initiatives leading to the better use and development of research infrastructures, at EU and international level.

European Technology Platform (ETP): ETPs are industry-led stakeholder fora charged with defining research priorities in a broad range of technological areas. They provide a framework for stakeholders, led by industry, to define research priorities and action plans on a number of technological areas where achieving EU growth, competitiveness and sustainability requires major research and technological advances in the medium to long term. Some ETPs are loose networks that come together in annual meetings, but others are establishing legal structures with membership fees.

Framework Programme (FP): Since 1984, research and innovation activities of the EU are grouped in one big multiannual programme, the Framework Programme for Research and Technical Development. While FP1 to FP6 were conceived for a period of 4 years, FP7 is synchronised with the duration of the EU's financial perspective and covers the period 2007-2013. The FPs are elaborated and proposed by the Commission and have to be adopted by the European Parliament and the Council in co-decision.

Future and Emerging Technologies (FET): FET are the incubator and pathfinder for new ideas and themes for long-term research in the area of information and communication technologies, to promote high risk research, offset by potential breakthrough with high technological or societal impact.

Government Budget Appropriations or Outlays on R&D (GBAORD): All appropriations allocated to R&D in central government budgets. Data on government R&D appropriations therefore refer to budget provisions, not to actual expenditure, i.e. GBAORD measures government support for R&D using data collected from budgets.

Gross domestic expenditure on R&D (GERD): Total intramural expenditure on R&D performed on the national territory during a given period. GERD includes R&D performed within a country and funded from abroad but excludes payments made abroad for R&D.

Gross Domestic Product (GDP): This aggregate represents the result of the production activity of resident producer units. It corresponds to the economy's output of goods and services, less intermediate consumption, plus taxes linked to imports. The sum of the regional values of the GDP at market prices might differ from the national values for some countries.

Information and Communication Technologies (ICT): Information and Communication Technologies are critical to improve the competitiveness of European industry and to meet the demands of its society and economy.

Innovation (Oslo Manual): Both OECD and Eurostat refer to the Oslo Manual for measuring innovation, which identifies four types of innovation: product innovation, process innovation, marketing innovation and organisational innovation.

Institute for Prospective Technological Studies (IPTS): The Institute for Prospective Technological Studies is one of the seven scientific institutes of the European Commission's Joint Research Centre (JRC)**.** It promotes and enables a better understanding of the links between technology, economy and society. Its mission is to provide customer-driven support to the EU policy-making process by developing science-based responses to policy challenges that have both a socio-economic as well as a scientific/ technological dimension.

Intellectual Property Rights (IPR): They cover all aspects of owning, protecting and giving access to knowledge and pre-existing know how.

Intelligent Energy Europe Programme (IEE): The Intelligent Energy - Europe programme is the EU's tool for funding action to save energy and encourage the use of renewable energy sources in Europe.

Intergovernmental Panel on Climate Change (IPCC): The IPCC is the leading international scientific body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts.

International Thermonuclear Experimental Reactor (ITER): ITER is an international research and engineering project which is currently building the world's largest and most advanced experimental tokamak nuclear fusion reactor. The ITER project aims to make the transition from experimental studies of plasma physics to full-scale electricity-producing fusion power plants. The project is funded and run by seven members – the EU (which shares 45% of the cost), India, Japan, China, Russia, South Korea and the US (each sharing 9% of the cost).

Joint Research Centre (JRC): As a service of the European Commission, the mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. It functions as a reference centre of science and technology for the Union. The JRC has a network of research institutes in different member countries (Belgium, Germany, Italy, Netherlands, Spain). Its activities are financed by the Framework Programme via the direct actions.

Joint Technology Initiative (JTI): JTIs are a means to implement the Strategic Research Agendas (SRAs) of a limited number of European Technology Platforms (ETPs). In these few ETPs, the scale and scope of the objectives is such that loose co-ordination through ETPs and support through the regular instruments of the Framework Programme for Research and Development are not sufficient. Instead, effective implementation requires a dedicated mechanism that enables the necessary leadership and coordination to achieve the research objectives. To meet the needs of this small number of ETPs, the concept of Joint Technology Initiatives has been developed.

Key Emerging Technologies (KET): KETs are knowledge intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly-skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration. KETs can assist technology leaders in other fields to capitalise on their research efforts.

Marie-Curie Actions: The main objective of the FP's Marie Curie Actions is to strengthen training, the career prospects and mobility of European researchers in order to provide support for the development of world-class human resources.

Multi-annual Financial Framework (MFF): In order to improve the budgetary procedure, the European Parliament, the Council and the Commission conclude, since 1988, interinstitutional agreements covering the budget process and the distribution of the budget. These agreements are established for several years, and are also known as EU "Financial Perspective".

New Econometric Model for Environmental and Sustainable Development and Implementation Strategies (NEMESIS): The NEMESIS-model is a large-scale econometric model at the macro- and sectoral levels, which has been built by a Community funded *consortium* of European research institutes. It comprises roughly 70 000 equations. The model can be used for several purposes, which include the assessment of structural (mainly R&D and environmental) policies, the study of the short- and medium-term consequences of a wide range of economic policies, short- and medium-term forecasting (up to 8 years) at the macro- and sectoral levels, and building long-term baseline scenarios (up to 30 years).

Open method of coordination (OMC): A relatively new and intergovernmental means of governance in the EU, based on the voluntary cooperation of Member States. It rests on soft law mechanisms such as guidelines and indicators, benchmarking and sharing of best practice, not on official sanctions for laggards. Rather, the method's effectiveness relies on a form of peer pressure and naming and shaming, as no Member States wants to be seen as the worst in a given policy area.

Organisation for Economic Development and Cooperation (OECD): The OECD is an international economic organisation of 34 countries founded in 1961 to stimulate economic progress and world trade. It is a forum of countries committed to democracy and the market economy, providing a platform to compare policy experiences, seek answers to common problems, identify good practices, and co-ordinate domestic and international policies of its members.

Patent Cooperation Treaty (PCT): The Patent Cooperation Treaty makes it possible to seek patent protection for an invention simultaneously in each of a large number of countries by filing an international patent application. Such an application may be filed by anyone who is a national or resident of a PCT contracting State. It may generally be filed with the national patent office of the contracting State of which the applicant is a national or resident or, at the applicant's option, with the International Bureau of the World Intellectual Property Organisation in Geneva.

Peer review: The *evaluation* of proposals with the help of independent external experts (peers). For FP6, the procedures for the evaluation of proposals are described in detail in a Commission decision on 'Guidelines on proposal evaluation and selection procedures'.

Public Private Partnership (PPP): Public-private partnerships are forms of cooperation between public authorities and businesses, in general with the aim of carrying out infrastructure projects or providing services for the public. These arrangements have been developed in several areas of the public sector and within the EU are used in particular in the areas of transport, public buildings or environment.

Research and experimental development (R&D): R&D comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications. This term covers three activities: *basic research, applied research* and experimental development.

R&D intensity: Gross Domestic Expenditure on R&D (GERD) expressed as a percentage of Gross Domestic Product (GDP).

Risk-Sharing Finance Facility (RSFF): RSFF is an innovative scheme set up by the European Commission and the European Investment Bank to improve access to debt financing for private companies or public institutions promoting activities in the field of research and innovation.

Rules of Participation for the Framework Programme: They set out the framework that governs the relationship between the Commission and the institutions that participate in the programme, covering aspects such as procedures for calls for proposals, types of grants, levels of financing, consortia composition, the evaluation process, financial management of projects, and dissemination of project results. The Rules of Participation are adopted by the European Parliament and the Council in co-decision upon a proposal from the Commission (art. 167 TEC).

Small and medium-sized enterprises (SMEs): Enterprises having fewer than 250 employees and with either an annual turnover of no more than ECU 40 million or a balance sheet total of no more than ECU 27 million.

Stakeholder: Any person or organisation with an interest in or affected by EU legislation and policymaking is a 'stakeholder' in that process. The European Commission makes a point of consulting as wide a range of stakeholders as possible before proposing new legislation or new policy initiatives.

Strategic Energy Technology Plan (SET Plan): The SET plan, presented by the Commission, aims to help achieve European objectives and face up to the energy challenges, by increasing research to reduce costs and improve performance of existing technologies, and by encouraging the commercial implementation of these technologies in the short term, and in the longer term by supporting development of a new generation of low carbon technologies.

Technology Platforms: Introduced in FP7, they bring together companies, research institutions, the financial world and regulatory authorities at European level to define a common research agenda to mobilise a critical mass of - national and European – public and private resources.

Valley Of Death: The gap between basic knowledge generation and the subsequent commercialisation of knowledge in marketable products, is known in broad terms as the "valley of death" issue.

ANNEX 9: LIST OF ACRONYMS

AGRI (DG)	European Commission Directorate General for Agriculture and Rural Development
BAU	Business As Usual
BRIC	Brazil, Russia, India and China
BUDG (DG)	European Commission Directorate General for Budget
CIP	Competitiveness and Innovation Framework Programme
CIP-PSP	CIP Policy Support Programme
CORDA	Common Research Data Warehouse
CSF	Common Strategic Framework for Research and Innovation
EAC (DG)	European Commission Directorate General for Education and Culture
EAV	European Added Value
ECFIN (DG)	European Commission Directorate General for Economic and Financial Affairs
EHEA	European Higher Education Area
EIB	European Investment Bank
EIP	Entrepreneurship and Innovation Programme
EIT	European Institute of Innovation and Technology
ENER (DG)	European Commission Directorate General for Energy
ENTR (DG)	European Commission Directorate General for Entreprise and Industry
ENV (DG)	European Commission Directorate General for the Environment
EPO	European Patent Office
ERA-NET	European Research Area network
ERC	European Research Council
ESFRI	European Strategy Forum on Research Infrastructures
ESTAT	Statistical Office of the European Union
ETP	European Technology Platform
EU12	The 12 countries that joined the European Union since 2004
EU15	The 15 countries that were members of the EU before the 2004 enlargement
EURATOM	European Atomic Energy Community
FET	Future and Emerging Technologies
FP	Framework Programme for Research and Technological Demonstration
GBOARD	Government Budget Appropriations or Outlays for Research and Development
GDP	Gross Domestic Product
IAB	Impact Assessment Board
IASG	Impact Assessment Steering Group
ICT	Information and Communication Technologies
IEE	Intelligent Energy Europe Programme
IPCC	Intergovernmental Panel on Climate Change
IPTS	Institute for Prospective Technological Studies (DG JRC)
ITER	International Thermonuclear Experimental Reactor
ITRE	European Parliament Committee on Industry, Research and Energy
JRC (DG)	European Commission Joint Research Centre
JTI	Joint Technology Initiative
KET	Key Emerging Technologies
MCA	Marie Curie Actions (DG EAC)
MFF	Multi-Annual Financial Framework
MOVE (DG)	European Commission Directorate General for Mobility and Transport
OECD	Organisation for Economic Development and Cooperation
OMC-NET	Open Method of Coordination network
PCT	Patent Cooperation Treaty
PPP	Public Private Partnership
R&D	Research and Development
REGIO (DG)	European Commission Directorate General for Regional Policy
RSFF	Risk-Sharing Finance Facility
S&T	Science and Technology
SANCO (DG)	European Commission Directorate General for Health and Consumers
SET Plan	Strategic Energy Technology Plan
SMEs	Small and Medim-sized Entreprises

NOTES

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

[2] Out of 34 European companies in the Top 100 R&D investing companies, 31 received FP funding under FP6.

http://webarchive.nationalarchives.gov.uk/20101208170217/http://www.innovation.gov.uk/rd_scoreboard/downloads/2010_RD_Scoreboard_data.pdf

[3] These estimates are based upon GDP growth forecasts made by HSBC (*The World in 2050 – Quantifying the Shift in the Global Economy*, HSBC, 4 January 2011). They assume that G7 R&D spending evolves based on the trend observed during the period 1996-2007. For E7, they assume that R&D expenditure evolves according to the 1996-2007 trend until a country reaches an R&D intensity of 3%, and then after this the annual R&D intensity growth for that country is limited at 1%.

[4] Source Eurostat: Government Budget Appropriations or Outlays on R&D

[5] Bruegel Policy Brief, August 2010, R.Veugelers and M.Cincera.

[6] DG ECFIN 2010

[7] For example, the report of the CREST OMC 3% Working Group on "Promoting the role of R&D in services" 2009.

[8] "Science, Technology and Industry Scoreboard", OECD 2009 (p.86)

[9] *European Innovation Scoreboard*, 2010

[10] *European Innovation Scoreboard*, 2010

[11] *European Innovation Scoreboard* 2010. Data for 2008.

[12] Patent applications under the Patent Cooperation Treaty, at international phase, designating the EPO by country of residence of the inventor. Source OECD.

[13] Source Eurostat.

[14] Source: Science Metrix, Scopus (Elsevier)

[15] According to the latest edition of the Shanghai Ranking,

[16] OECD STI Scoreboard 2009

[17] OECD, 2009

[18] *Measuring Innovation: A New Perspective*, OECD 2010

[19] Source : OECD "STI Scoreboard 2009". Data on medical technology and pharmaceutical patents are PCT filings for the period 2004-2006.

[20] (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). The size of each bubble is proportional to the number of patents by European inventors in the field. (2) The broad technology domains are shown in bold. (3) Data relate to the period 2003-2005.

[21] 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.

[22] Interim Evaluation of the Seventh Framework Programme, report of the Expert group, November 2010.

[23] Physics, Astronomy, Earth sciences and Environmental sciences

[24] That is, the field-normalized impact scores of these disciplines are above 1 (with the exception of Earth sciences and Environmental sciences in Italy).

[25] As of early 2011, 10 research infrastructures of the ESFRI Roadmap are in the implementation phase and 41 in the preparatory phase (including 3 research infrastructures of the European Strategy for Particle Physics, as approved by the CERN Council).

[26] 'Capital expenditure on R&D' includes expenditure on fixed assets used in R&D activities such as land and buildings and also expenditure on equipment, research instruments and computer software. The other category of R&D expenditure, called 'current cost' includes labour costs and the non-capital purchase of materials and supplies (Frascati Manual).

27 Study "Investments in joint and open R&D programmes and analysis of their economic impact" funded by DG Research and Innovation, forthcoming.

28 Recent reviews of R&D programmes in several European countries found that linking national research programmes to EU priorities under the FP, or planning large infrastructures according to EU directions, and using EU-level instruments such as ERA-NETs, are various ways to encourage international collaboration in R&D : (1) *Monitoring progress towards the ERA*, European Commission, ERAWATCH Network, 2009, available at: http://cordis.europa.eu/erawatch/index.cfm?fuseaction=reports.home. (2) National mapping of open R&D programmes in the study "Investments in joint and open R&D programmes and analysis of their economic impact" funded by DG Research, forthcoming.

29 This comprises (i) trans-national public R&D performers located in Europe: CERN, EMBL, ESO, ESRF, ILL, JRC. Future research infrastructures of the ESFRI Roadmap will belong to this category (ii) Europe-wide trans-national public R&D programmes and agencies: ESA, EMBO, ESF, EUREKA, ERA-NET, ERA-NET+, JTIs (public funding part: ENIAC, ARTEMIS), Art. 185 (Europe-Developing Countries Clinical Trials Platform, Eurostars and Ambient assisted living for the elderly). The Joint Programming Initiatives belong to this category (iii) bi- or multi-lateral public R&D programmes established between Member States governments and with candidate countries and EFTA countries.

30 Belgium, Bulgaria, Czech Republic, Finland, France, Germany, Hungary, Netherlands, Romania, Slovakia, Slovenia, Spain, Sweden, UK

31 Prospects for fusion, C. H. Llewellyn Smith, *Nuclear Physics* 751 (2005) 442c–452c; See also The Sustainable Nuclear Energy Technology Platform – A vision Report http://www.snetp.eu/

31bis Final Report of the European Fusion Power Plant Conceptual Study (PPCS), EFDA 2005

32 http://www.iaea.org/newscenter/focus/fukushima/

33 http://ec.europa.eu/energy/nuclear/safety/stress_tests_en.htm

34 Strategic Research Agenda of the Sustainable Nuclear Energy Technology Platform, SNETP 2010

35 Proposal for a Council Directive on the management of spent fuel and radioactive waste, COM(2010)618, 3 November 2010

36 Special Eurobarometer 297: *Attitudes towards radioactive waste*, published in June 2008.

37 See for example: http://ec.europa.eu/research/energy/pdf/euradwaste_08_en.pdf and 'Radioactive waste in perspective', NEA2010

38 Vision Report of the Implementing Geological Disposal of Radioactive Waste Technology Platform, 2010 http://www.igdtp.eu/

39 Nuclear education and training: cause for concern? OECD NEA 2000

40 The need for nuclear education culture have been underlined by the Council of the European Union – see conclusions on the need for skills in the nuclear field, 2891st Competitiveness (Internal Market, Industry and Research) Council meeting, Brussels, 1 and 2 December 2008

41 Uranium 2009: Resources, Production and Demand (‘Red Book’); OECD, IAEA, August 2010

42 Assessment of Nuclear Energy Systems Based on a Closed Nuclear Fuel Cycle with Fast Reactors, IAEA, 2010

43 Generation-IV International Forum 2009 Annual Report (published by the OECD Nuclear Energy Agency) http://www.gen-4.org/PDFs/GIF-2009-Annual-Report.pdf

44 Report of the High Level and Expert Group on European Low Dose Risk Research, Jan. 2009 (http://www.hleg.de/fr.pdf)

45 R&D Investment in the Priority Technologies of the European Strategic Energy Technology Plan, JRC 2007

46 http://iri.jrc.ec.europa.eu/research/scoreboard_2010.htm

47 AREVA, EdF, Vatenfall, Iberdola, EnBW Energie Baden-Wurttemberg, Fortum, CEZ, URENCO

48 Some corporate reports indicate that corporate research priorities cover to some extent the challenges indicated in section 1, in particular: lifetime plant management, improvement of fuel utilisation, development of new LWR reactors (generation III) and waste management. Some companies have also indicated investments in the front and back end of the nuclear fuel cycle. Prepared on the basis of the latest version of annual reports from the following companies: AREVA, EdF, Vatenfall, Fortum

49 Sixth Situation Report on Radioactive Waste and Spent Fuel Management in the European Union, COM(2008)542 final and SEC(2008)2416

50 http://www.gen-4.org/

51 The scientific success of JET, M. Keilhacker *et al* 2001 *Nucear Fusion* 41 1925

52 Article 24 of the Agreement on the Establishment of the ITER International Fusion Energy Organization for the Joint Implementation of the ITER Project, Official Journal of the European Union, L 352762, 16 December 2006

[53] Commission's survey (2009) of companies involved in upgrade and construction projects in fusion

[54] Data from http://wds.iea.org

[55] This estimate is based on IEA data available for some Member States only (Austria (2000-2008), Belgium (2007 only), Czech Republic (2003-2007), Denmark (2000-2007), Finland (2000-2008), France (2000-2008), Germany (2000-2009), Hungary (2000-2009), Italy (2000-2007), Netherlands (2000-2003, 2005-6), Slovak Republic (2002-2004, 2008-9), Spain (2000-2006), Sweden (2003-2009),

[56] R&D Investment in the Priority Technologies of the European Strategic Energy Technology Plan, JRC 2009

[57] For more details see http://ec.europa.eu/research/energy/euratom/fusion/eu-fusion/index_en.htm, also http://www.efda.org/

[58] Source: European Commission

[59] http://eur-lex.europa.eu/en/treaties/index.htm

[60] This is the focus of the NULIFE project (nulife.vtt.fi) and related projects– the NULIFE, when created, will be able to provide a service for industry which will ensure common standards.

[61] See for example conclusions of the Interim Evaluation of Euratom 7th Framework Programme http://ec.europa.eu/research/evaluations/index_en.cfm?pg=fp7-evidence

[62] information available on http://www.irsn.fr/

[63] Journals analysed in Scopus database (www.scopus.com): Nuclear Fusion, Plasma Physics and Controlled Fusion, Fusion Engineering and Design, Fusion Science and Technology, Journal of Fusion Energy.

[64] Calculated on the basis of data from Eurostat

[65] For details see http://ec.europa.eu/research/energy/pdf/200905_fusion_industry.pdf

[66] Estimating Spillover Benefits and Social Rate of Return of Fusion Research, Development, Demonstration and Deployment Program, EFDA Socio-Economic Research on Fusion, Edgard GNANSOUNOU, Denis BEDNYAGIN, EPFL, Switzerland, 2007

[67] For details see http://ec.europa.eu/research/energy/pdf/spin_off_en.pdf