Understanding the Long Term Impact of the Framework Programme

Final Report

To the European Commission

DG Research

Under Framework Contract No.

DG BUDG No BUDG06/PO/01/LOT no.3

ABAC no. ABAC 101908

EPEC

5 December 2011

Erik Arnold, Bea Mahieu, James Stroyan, David Campbell*, Malin Carlberg, Flora Giaracca, Andrej Horvath, Zsusza Jávorka, Paula Knee, Ingeborg Meijer, Sabeen Sidiqi and Caroline Wagner*

Technopolis and Science Metrix*

Contact name and address for this study:

Erik Arnold
3 Pavilion Buildings
Brighton
East Sussex
BN1 1EE, UK
Erik.arnold@technopolis-group.com
Telephone number +44 1273 204320

European Policy Evaluation Consortium (EPEC)
Brussels contact address: 146, rue Royale – B-1000 Brussels
Tel: +32 2 275 0100   Fax: +32 2 275 0109
E-mail: contact@epec.info   URL: www.epec.info

SUMMARY

The Framework Programme has been the subject of various kinds of evaluation since it began in 1984. These have consistently focused on the programme cycle in hand. As a result its longer-term – in an important sense most policy-relevant – impacts have barely been explored. This path-breaking study is intended as an initial exploration of these longer-term impacts and of the usefulness of coupling scientometric techniques with a case-based approach to impact. This volume summarises the project as a whole. A companion volume sets out the cases in more detail. A third volume more fully documents the scientometric work and provides various intermediate outputs of potential interest to others who might wish to explore similar methods. The innovative combination of methods in this project has involved literature and document reviews, co-word analysis of project titles and abstracts in FP4-6, bibliometric analysis, interviews with Commission officials and Framework Programme project participants and six case studies of Framework Programme impacts.

The Framework Programme

The origins of the Framework Programme are in European efforts to close a perceived 'technology gap', first with the USA and later with Japan, and to promote European competitiveness, especially in energy and Information Technology. The changing nature of global competition and the progress of the European project towards closer union has meant that the role of the Framework Programme has evolved. Initially, it was an effort to support European industrial competitiveness in a limited number of sectors by networking together and strengthening European technology development effort. It has evolved to become a larger and more powerful instrument for funding and coordinating scientific research as well as more industry-orientated technology efforts across Europe. Since the launch of the European Research Area (ERA) in 2000, the Framework Programme has been a component in a wider and increasingly well-articulated EU research and innovation policy. Correspondingly, the idea of European Added Value, which has been the policy justification for the Framework Programme, has evolved from adding value to national efforts through scale and networking to recognising a role in coordinating Member State policies and taking wider actions in support of EU-level policy. The scale of the Framework Programme has grown from ECU 2.75 billion in FP1 (1984-88) to €51 billion for FP7 (2007-13). Its thematic scope has widened and its activities now include research-council-style single-investigator awards and a range of 'ERA instruments' that build technology platforms and coordinate RTD activities. Despite these shifts, however, there are important thematic continuities through the life of much of the Framework Programme. Many EU organisations that do significant amounts of RTD are engaged in multiple projects and remain involved with the Framework Programme over many years.

While the political or policy objectives of the Framework Programme are set at the level of the Council of Ministers, much of the detail of the Specific Programmes and their constituent Work Programmes emerge from intense interaction between the Commission and stakeholder groups and are negotiated with the Member States and the European Parliament. In this report we have documented in some detail the 'intervention logic' that links the activities of the Framework Programme with its intended effects. This can only be done in general terms. The intervention logic is in practice implemented at the technical level in different ways by different Specific Programmes. We also constructed a simple typology of intended effects, which we used to structure our data collection.

Evaluation of the Framework Programme

Framework Programme evaluation practice has evolved and improved over time. It has become increasingly independent of the stakeholder communities and attention has shifted from the provision of technical advice to the programmes and towards understanding impacts. It has been closely tied to the programming cycle, with the intention of using experience from

one programming period in order to influence programming in the next. This has meant that impact evaluation is primarily done through interaction with project participants, whose projects often have not finished or have only recently done so and whose ability to perceive or anticipate impacts at the level of their organisation, the market or society more generally is limited. The existing evaluation record therefore tells us too little about wider or longer-term impacts or about the achievement of political and policy objectives.

The existing evaluation record underscores that at its heart, the Framework Programme is a 'precompetitive, collaborative' programme. It follows that most of the time participants do not directly commercialise results from projects. Hence, evaluations show that from the participant perspective *the main outputs are knowledge and networks (including marketing-relevant networks and supply chains)*.

The Framework Programme is an important influence on standards and norms to the extent that these are precompetitive issues. Framework Programme projects normally involve networks. These have to be strong in order to win the competition for funding. There are 'usual suspects' that form key nodes in many networks and that persist through successive FPs. This pattern of established players tending to win in competition may promote conservatism. However, there is a gap in the evaluation record: the small parts of the main Framework Programme that promote 'different', non-consensus ideas – the Future Emerging Technologies (FET) and the former New and Emerging Fields in Science and Technology (NEST) programmes have not been evaluated.

Both the bibliometric evidence and the toughness of the competition show that the research and people involved in the Framework Programme are of high quality. Participants believe that FP participation makes them and their organisations more competitive. *There is a clear 'behavioural additionality' at the point where organisations join the first of a series of FP projects in that their networking behaviour changes to adopt a 'European model of open innovation'* and carry on participating.

Scientometric results from this study

Co-word analysis, involving statistical analysis of the ways in which particular words co-occur in various texts, shows that the work of the Framework Programme can be clustered into major clusters that correspond to areas where it is possible to identify impacts using other techniques. Four of the case study fields identified through co-word analysis in combination with an analysis of the numbers and types of projects of which the Framework Programme is made up, a literature review, and interviews with Commission officials were amenable to further scientometric analysis. We had hoped that co-word analysis would also indicate places where scientific breakthroughs were being made but this analysis was not decisive. We did, however, establish that *FP participants were strongly represented among the top 1% most cited papers in their fields. This is consistent with them having produced highly influential work representing potential breakthroughs*. The bibliometric approach confirmed that the Framework Programme involves a very high proportion of European organisations, which have a strong publication performance on a range of definitions. In real life, this is a strength; analytically, it is a problem because it means there is not much of a control group to whose performance we can compare that of FP participants. At the level of individuals, in three of the four fields analysed, FP participants were strongly represented among the most productive researchers in the world.

Our network analysis focused on centrality, namely the extent to which organisations occupied a central role in their co-publication networks with many connections to others. It showed that *European organisations have indeed become increasingly central and therefore, we infer, more powerful in terms of access to information and in setting agendas and building research cooperations*.

All four fields analysed have been growing during the life of the Framework Programme and are widely recognised as important. *In Quantum Information Processing and Computing*

(QIPC), stratospheric Ozone research and solar energy, the European research community has improved its relative position on a range of measures and is now operating in strength at the scientific frontier. Neurobiotechnology was already a strongly established field at the point where the Framework Programme intervened. While there are points of improvement, overall the main contribution of the FP in neurobiotechnology appears to have been to help the community maintain its position.

Key findings from the case studies

In **QIPC**, the Framework Programme picked up the *emergence of a new field of science and technology, helped it establish scientific and technological agendas, organise and grow in Europe to such an extent that the EU appears fully competitive with the other world R&D leaders.* The field has not yet reached the stage where products and processes are developed, but Europe has the technological basis and has started to develop standards for doing so and therefore for continuing to maintain strong positions in the global computing and communications industries as they go through disruptive changes in the technologies they use to process information.

The Framework Programme has been less decisive in **Brain Research**, which was already well established at the point where FP funding began. It has nonetheless made i*mportant contributions in imaging and helped support and integrate the European research community* in a period when the USA has been investing much more public money in the field than the European Member States have, in sum. Launching the European Brain Council was an important contribution to setting and maintaining a relevant and up to date research agenda in Europe. The FP has been important in keeping Europe 'in the game' in this field.

In **Stratospheric Ozone research**, the Framework Programme has made a major contribution by *growing and helping coordinate the European research community*, not least through organising multinational research campaigns to provide a better evidence base for policy. It has helped the European research community move from lagging far behind the USA to working at the global frontier. Research results have shaped the evolving Montreal Protocol requirements and have been so influential at the policy level that Europe has achieved the Protocol's 2020 targets ten years ahead of schedule.

In **Solar Photovoltaics (PV)** the Framework Programme has *expanded the European research community and enabled it to work at the technological frontier* – not only in first- but also in second- and third-generation Solar PV. Demonstration projects and complementary renewable energy policies have helped develop markets for Solar PV and establish a significant European presence in the supply industry.

In the **Automotive Industry**, *the Framework Programme's role has been to sustain longer-term research and development in areas such as fuel efficiency, emissions and safety that create not only private advantages for the industry but significant public goods*. Exploiting the industry's desire to self-organise to define R&D directions and road maps has been a powerful way to coordinate the longer-term R&D effort and has supported a long series of product and process innovations that help maintain Europe's position among the global leaders in this industry.

The **Manufuture Technology Platform** is of interest more for its potential than for any socio-economic impacts achieved at this point. It underlines the importance of coordination and self-organisation as mechanisms to integrate research. *It has defined a research agenda about which there is broad agreement in manufacturing industry, recruited large numbers of partners and helped define 26 national or regional level platforms and is beginning to influence policymaking* (especially in the area of sustainability) and affect industrial processes.

The most important commonality among these stories is the importance of the FP's role in coordinating research and innovation through the support of stakeholder communities' self-organisation. This is a far cry from the 'technology gap' idea, the associated 'technology push' model and focus on industrial champions that underlay the early FPs. However, it does not follow that the Framework can evolve into an advisory rather than a funding function. The FPs have been influential because they provide resources additional to those of the Member States and have been able to 'leverage' the use of those resources by encouraging coordination.

Next steps

Our case studies identified a number of 'impact mechanisms' that appear to be instrumental in the achievement of longer-term impacts by the Framework Programme. Further progress in understanding longer term impacts of the Framework Programme including, in particular, its success in reaching higher-level policy objectives can be aided by treating some of the impact mechanisms identified here as hypotheses and exploring them in particular instances. These mechanisms are largely not amenable to an aggregate statistical analysis, so we will need bigger, deeper studies of individual examples. Different parts of the Framework Programme work in different ways. Finally, the strong theme running through the casework is the importance of coordination through the empowerment of relevant stakeholder communities. We identified a range of research issues that should be explored in order to deepen our understanding. Especially since the evolution of EC research and innovation policy is towards further coordination, probably the most urgent and important issue to explore now is how this works in practice.

TABLE OF CONTENTS

TABLE OF FIGURES

1 INTRODUCTION AND METHOD

This report presents the findings from a study to evaluate the long-term impacts of the EU Framework Programmes for Research and Technological Development in a number of selected fields. Technopolis Group and Science-Metrix carried out the work on behalf of DG Research and Innovation.

There is a strong history of evaluations of the EU Framework Programmes (FPs), spanning at least 20 years. While these studies have provided a very full account of the activities that have been supported and have provided assessments of the processes and procedures that have been employed, the timing of the evaluations and their focus on recent activities means that the longer-term effects of the FPs have received relatively little attention. At the national level, we produced a novel study of FP impacts in Sweden from FP3 to FP6, but there is little else in the literature that is longitudinal in character. In addition, while many studies have sought to determine the impacts of individual projects, the wider effects of the programmes in terms of agenda setting, capability-building, restructuring of research, and so on, have rarely been investigated and documented. This study was intended to make a first step in addressing that information 'gap', and to confront at least some of the methodological challenges involved in tracing the longer-term effects of the FPs.

1.1 Introduction

Most evaluations at the level of the FP as a whole have been carried out during or shortly after a Framework Programme has completed one of its cycles. Each FP has a fixed duration (before FP7 this was usually 4-5 years) across which a large number of annual work programmes are developed, calls for proposals are issued in different domains, project ideas are assessed and selected, and contracts are issued. However, taking into account the duration of the research project, some of which will be completed after the FP has formally ended, and the fact that impacts will also occur later, the actual lifecycle of each FP extends over a much greater period. This will include network building, knowledge transfer, and exploitation of results continuing for many years following the official end of the programme. The consecutive nature of the FPs' official periods of operation thus mask the true periods of operation of each FP, at least when considering the accrual of impacts.

Because they are most commonly asked to focus on a recently completed period of FP expenditure, FP evaluations typically tackle a range of issues relating to the design and implementation of the programme, the support provided to participants and the immediate or short-term outputs and outcomes as expressed through feedback obtained from FP participants. While instructive in their own right, these studies tend to be carried out too early properly to tackle questions relating to the longer-term impacts of the programmes. They are usually intended to be formative with regards to changes considered desirable for the forthcoming FP, so there is a tendency to carry them out as soon as possible after (and indeed sometimes still during) an FP programming cycle. While this approach has some natural strengths, it does mean that questions about the longer-term impacts of the FPs receive less attention, if they are tackled at all.

The difficulties associated with tracing the impacts of research activities over the longer-term are well documented. The diffuse and varied nature of the impacts arising, a lack of established mechanisms for tracing these over time, and the existence of (and interplay between) multiple support initiatives at local, national and international levels all conspire to make the identification and attribution of impacts difficult. This study was designed to try to overcome some of these challenges and to provide an improved basis for identifying and expressing the impacts that the FPs generate over the longer-term.

1.2 Method

Our approach was, first, to describe the long-term impacts that the FPs are designed to generate, and the routes through which such impacts are expected to occur. Next, a variety of methods were used in combination to select suitable focus areas in which the long-term effects of the FPs could be explored and described. Finally, a combination of network / bibliometric analyses, desk research and interviews were used to describe and dimension the actual effects of the FPs over the longer-term in each of six selected 'case study' areas.

- Quantum information processing and computing (QIPC)
- Brain research
- Stratospheric Ozone research
- Solar Photovoltaics (PV)
- Automotive industry
- The Manufuture Technology Platform

In order to address some of the challenges described above, this study incorporated a number of features that distinguished it from the more traditional evaluation studies that have looked at FP impacts.

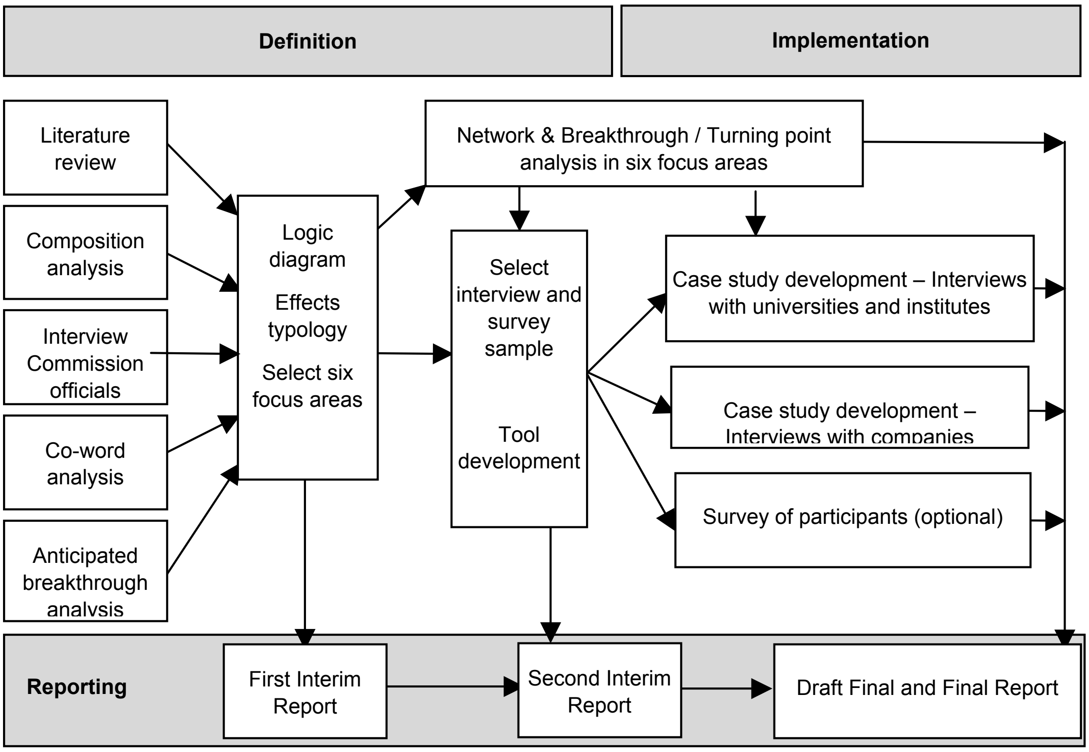
First, we sought to identify impacts that have been generated over the past 15 years, so our search for interesting fields to explore was focused on the activities and initiatives that formed part of FP4 (1994-1998) and FP5 (1998-2002) and that were known to have received continued support from the FPs since those periods. This provided a much-improved chance of identifying the kinds of benefits and impacts that take time to develop and which relate to systems level effects as well as project-specific impacts. These include the impacts of the programmes in (i) restructuring and strengthening European research networks, (ii) contributing to major scientific and technological breakthroughs, (iii) enabling the transfer of knowledge and expertise between the scientific and industrial communities, and (iv) contributing to economic wealth creation and improved quality of life – the ultimate goals of the FPs.

Second, since this study was partly experimental in character, and because of the long-term nature of expected impacts, we sought to integrate methods not normally used in combination and to stretch the repertoire of methods beyond those usually employed. In terms of new approaches, emerging techniques in network analysis and bibliometrics were utilised to try to enhance our understanding of (i) where FP impacts were likely to have occurred; (ii) the role of the FPs in strengthening the position of EU RTD actors within their global knowledge creation networks; and (iii) the FPs' contribution to the major scientific breakthroughs that have taken place during and in the years following the operation of the programmes.

Because some of these newer methods had not been used in exactly this context before, we combined them with more traditional methods (literature review, interviews, surveys), both as a means to manage the risks associated with over-reliance on any single technique, but also so the utility of the newer approaches could be assessed in comparison to the more established ones. The variety of methods used and the reflective nature of the approach meant that we have been able to gain a better understanding of the utility of the individual methods in helping to identify the long-term impacts of the FPs.

We show the approach adopted and the various components of our work plan in Figure 1. The figure shows how the various elements fit together and how each component was designed to feed into subsequent parts of the work.

Figure 1 - Overview of Our Approach



A brief description of each component of the work plan is set out below.

1. A **literature review** to identify (i) the intervention logics of FP4 and FP5 and the full range of impacts that the programmes were designed to generate over the short, medium and longer-term; (ii) pre-existing evidence of the actual impacts of FP4 and FP5 research, as identified through studies carried out previously; and (iii) methods that could be of utility in evaluating the longer-term impacts of RTD programmes
2. A **composition analysis** of FP4 and FP5 projects, in order to establish (i) the expenditure profile of the programmes; (ii) the areas and sub-areas where investments have been made; (iii) the numbers and types of institutions supported; (iv) the most significant actors and their areas, as judged by their level of involvement and the centrality of their role. In particular the composition analysis was used to identify areas where there has been 'continuity' in FP expenditure and institutional participation over the longer-term
3. A programme of **interviews with Commission officials and expert advisors,** who were connected to each of the main FP4/5 thematic priority areas in order to further understand the intervention logics, goals, expected impacts, and areas where those impacts were most likely (or are already known) to have taken place
4. A **co-word 'cluster' analysis** to identify the organising themes that emerge from a meta-analysis of the terms within FP4 and FP5 project titles and abstracts. This explorative technique involved establishing a list of noun-phrases or scientific key words used in FP4 and FP5 project titles and abstracts, which were then analysed to see how these terms (and hence the projects) were clustered together. The hope was that the technique would reveal interesting clusters of projects that were in some way linked but which transcended the established organising structure of the FPs
5. An **anticipated breakthroughs analysis**. The data set produced by the co-word analysis (above) was then analysed further to establish the extent to which the noun phrases and scientific key words revealed anticipated breakthroughs in science or technology. It was hoped that this exploratory technique would help to identify the scientific breakthroughs that were foreseen in the various project clusters. Together with the co-word analysis the findings would be used to help select focus areas that involved 'breakthrough' rather than more incremental research themes

6. A **logic diagram** and associated **effects typology**. This set out the intervention logics of FP4 and FP5 and the planned and known effects of the programmes (based on the literature review and interviews)
7. A **selection process to choose six 'focus areas' for case study**. This drew upon the co-word and anticipated breakthrough analyses, the composition analysis, interviews and literature review. Here we used all of the results from the first phase of the work to determine sub-areas of FP4 and FP5 that appeared to offer high potential as exemplar case studies of the kinds of long-term impacts that the FPs generate
8. **Network** and **breakthrough / turning point analyses** to (i) trace the development of scientific networks within the selected focus areas over time, (ii) identify the main scientific breakthroughs (or intellectual turning points) within those networks since the time of FP4, and (iii) identify the position(s) of the major FP participants in those networks over time and in relation to the identified breakthroughs. This work enabled us to not only *select* those participants who have been most closely associated with the major breakthroughs in their respective fields and that have strengthened their positions most within their knowledge networks, but it also provided the basis for a subsequent programme of interviews aimed at determining the role that the FPs have played in supporting these developments
9. Preparations for the fieldwork. These involved **tool development** and the **selection of interviewees and survey participants**. The logic diagram and effects typology were used to help develop question sets designed to identify aspects of the long-term impacts of the FPs. In addition, the network and breakthrough analyses were used to help to identify FP participants who occupied the strongest and/or most improved roles within their global networks and who have the closest connections to the major scientific breakthroughs in their field
10. **Interviews with universities and institutes:** with the most active in each of the six focus areas and which had participated in the FPs over the long-term (including FP4/5) were then conducted in order to develop a series of six case studies. The interviews were used to investigate the longer-term impacts of the programmes at multiple levels and in relation to the full range of intended impacts of the FPs as set out in the effects typology. Unusually, many of the institutions targeted were selected based on their *known* position in relation to their global knowledge networks, and in some cases also their involvement in the major scientific breakthroughs within their fields. It was intended that this improved targeting of the interviews would enhance the quality of results obtained
11. **Interviews with companies:** with the most active in each of the six focus areas and which have participated in the FPs over the long-term (including FP4/5) were also carried out to compile the case studies. The purpose of these interviews was the same as with the universities and institutes, but the nature of the impacts that we sought to identify were different (i.e. focused on understanding the longer term commercial and industrial impacts that have arisen from the S&T capabilities and new knowledge generated through FP projects)

1.3 Structure of the report

Following this brief introduction, Chapter 2 analyses the Framework Programme and its intended impacts. It describes the policy context of the FP and outlines its history, analysing some aspects of continuity across successive FPs and then using a logic model to describe its apparent 'intervention logic' and to derive a list of types of intended long term impacts. Chapter 3 looks at the history of evaluation of the Framework Programme, discussing what we have and have not learnt from that and the methods that have been used. Chapter 4 describes the results of the scientometric part of this project that have a bearing on impacts. Chapter 5 explains how we chose our six case study examples of FP impacts and summarises what we learnt about impacts. Chapter 1 draws conclusions about impacts and methods and sets out some suggestions for future work.

A companion volume sets out the cases in more detail. A third volume more fully documents the scientometric work and provides various intermediate outputs of potential interest to others who might wish to explore similar methods.

2 THE FRAMEWORK PROGRAMME AND ITS INTENDED IMPACTS

The context of the Framework Programme has shifted as technological development and competition has moved from the national through the European to the global level. EU RTD policy has also evolved as the Union has acquired greater responsibility for research and technological development and set ambitious, continent-wide goals. The principle of European Added Value, which has been the policy justification for the Framework Programme, has evolved from adding value to national efforts through scale and networking to playing a role in coordinating Member State policies and taking wider actions in support of EU-level policy. As the major instrument of EU RTD policy, the Framework Programme has evolved correspondingly, growing both in scale and in scope. There are nonetheless important continuities in thematic focus and participation. We have documented the intervention logic of the Framework Programme in general terms and used this to define both expected impacts and a typology of intended effects.

2.1 Context

The FP has brought together policy strands in innovation and industry policy on the one hand and research policy on the other – starting with the innovation strand and then increasingly incorporating the research dimension.

The Framework Programme has developed and grown in parallel with major changes in the ambitions of industry and innovation policy in Europe and in the rules governing competition and the relation between the state and its industrial suppliers. The technological optimism of the 1960s triggered large, state-led investments in building national technological champions in areas such as transport, energy and computing. Like defence companies, these tended to function in "development pairs"[1] with national agencies or state-owned companies, such as airlines, railways, telephone companies and power generators. With the state as a guaranteed launch customer – and in some cases, also, co-developer – many of these companies were able to produce significant innovations and to build strong international as well as national market positions. The state effectively shared the technological risk of innovation with the producers and reduced the commercial risk, both through buying the first products and by providing 'reference sales' that could be used to persuade subsequent customers of the value and quality of the products.

Successive liberalisations at national and European levels and changes in World Trade Organisation rules meant that it became more and more difficult to operate such development pairs. Liberalisation has meant in many fields a reduced role for the state in developing new generations of technology so that, for example, national telephone companies' R&D departments have shrunk to a minimal size. Breaking the development pairs also meant breaking the link to the national level and diminishing the role for national standards, reducing opportunities to use national idiosyncrasies to protect national suppliers. Formal and de facto standardisation power moved up from the national level through the European level and towards the global level. With globalisation of markets came restructuring of industry. In the case of telecommunications, the Framework Programme was one of the policy ingredients supporting this transition. ESPRIT in FP1 and more especially the RACE programme (later Telematics) in FP2 aimed to set common technology and communications standards. These would encourage the concentration and development of European telecommunications equipment suppliers in the era of liberalisation.

[1] Erik Dahmén, "Entrepreneurial activity and the development of Swedish industry, 1919-1939" *American Economic Association Translation Series*, New York: RD Irwin, 1970

The FP activities were, however, only **part** of the Commission's policy effort in telecommunications, which also involved setting the liberalisation agenda for Europe and playing one of a number of contributory roles to the definition and implementation of the GSM mobile telecommunications standard at European level[2]. (Contributions to subsequent standards were mostly through pre-normalisation and standards-orientated projects within the Framework itself.)

1960s-style 'technology push' efforts focused on national champions eventually fell into disrepute, in part because they became more or less illegal, in part because their ambitions widened from contexts where the state was the major first customer and had considerable monopsonistic power to situations – most notably in computing – where the state had little influence over demand. A lot of the effort in ESPRIT (especially in FP1) went to prop up companies like ICL, BULL and Siemens' mainframe computer division at a point where IBM had almost total dominance of the world mainframe markets – and when the new generation of minicomputer technology was already waiting in the wings, eventually to undermine much of the mainframe market. ESPRIT II and especially III marked a move away from "the failure of an industry policy then aiming to sustain IT manufacturing in Europe"[3] and towards a more all-encompassing and more software- and applications-based idea of 'information society'. 'Rust belt' national industry policies to prop up declining industries such as ship building in different ways tried to work against the logic of markets and were equally unsuccessful.

While many academics like to describe the FP as a 'top down' instrument, in fact it evolved rapidly away from the 'national champions' style into something much more responsive to the needs of wider stakeholder groups. By accident or design, it learnt the lesson that backing a **particular** company (or for that matter research group) is an unnecessary act of hubris. Coordinating and promoting competition within areas, which stakeholders identify as having thematic priority, is a more powerful approach because it harnesses rather than resists market forces.

2.2 EU Research and Innovation Policy

Before 2000, the Framework Programme aimed mainly to network and stimulate activities at the Member State level. The Commission made rather separate efforts in R&D policy on the one hand and innovation policy on the other. In both cases, the over-riding goal was industrial competitiveness. In 2000, building the European Research Area (ERA) and enhancing competitiveness via the Lisbon Agenda and the Open Method of Coordination came onto the agenda. Now, when the Commission is moving towards stronger coordination of research and innovation policy across the Member States but increasingly achieving this coordination by decentralising the initiative to stakeholder communities via the new ERA instruments such as European Technology Platforms and the Joint Programming Initiatives.

European science and technology policies in the 1960s and 1970s were heavily influenced by the idea of a 'technology gap' with the USA[4]. Servan-Schreiber's book *The American Challenge*[5] was emblematic of this concern, which – together with a strong spirit of technological optimism in the 1960s – triggered the creation of a range of institutions and *grands projets* in Europe[6].

---

[2] Herbert Ungerer and Nicholas P Costello, *Télécommunications en Europe*, Luxembourg: Office des Publications Officielles des Communautés Européennes, 1988

[3] Umberto Columbo et al, *Esprit Review Board 1996 Report: Making Progress Happen through Development, Application and Diffusion of Information Technologies*, Luxembourg: Office for Official Publications of the European Communities, 1994

[4] John Peterson, Margaret Sharp, *Technology Policy in the European Union,* MacMillan Press Ltd, 1998

[5] Jean-Jacques Servan-Schreiber, *Le Défi Américain*, Paris: Denoel, 1967

[6] For example the Ministry of Technology in the UK, the first innovation agency in Sweden (the Swedish National Board for technological Development – STU, the Anglo-French supersonic transport project

In 1965, the fledgling European Community of six countries set up a sub-committee of its medium-term economic policy committee to deal with science and technology. This sub-committee – PREST, which became CREST with the enlargement of the Community in 1973 – proposed seven areas for scientific and technological cooperation in 1967. It took a further four years, interrupted by periods when both the Netherlands and France linked the discussions to wider disagreements within the Community, for the Six plus finally a further thirteen non-Community countries and the Community itself to sign a cluster of seven international agreements on European Cooperation on Science and Technology (COST). At the time, COST was seen as potentially fulfilling the task later taken on by the Community's Framework Programme – extending to research funding, not just networking as in COST's current form. However, the Council resolution of 14 January 1974 establishing a Community policy for R&D put an end to the funding ambition. In the following years, the Commission ran a small number of R&D programmes, primarily in energy and data processing.

The FP was launched after a period in which European R&D cooperation had blossomed on a multilateral basis, for example through CERN, EMBL, COST and ESF. Since then, the FP has become increasingly involved in funding aspects of these cooperations. Because the FP exists and is a simpler way to channel money than creating new multilateral organisations, there have been no significant new European R&D cooperations set up since the FP began in which the Commission is not central. There is one historical exception to the Commission's monopoly of European action, namely Eureka, which was in effect Paris' reply to what it saw as a shift of power towards Brussels. But that was in 1985 and even Eureka has now succumbed to the funding logic and taken the Commission's money for the EUROSTARS programme. The FP6 evaluation argued that this concentration of power, and the risk of monopoly of thought that accompanies it, is problematic[7].

The Framework Programmes had roots in earlier activities, for example the Multi-Annual Programme in the field of Data Processing (MAP, running from 1979-83 and subsequently incorporated into the ESPRIT programme, part of FP1). The First Framework Programme was therefore an amalgamation of existing initiatives in an attempt to develop a coherent research and development strategy.[8]

The first Framework Programmes - industry-oriented and very much 'technology-push' - as well as the Single European Act (ratified in 1987) and the Maastricht Treaty (ratified in 1993) need to be understood in the context of the Commission and European governments' desire to bridge the 'technology gap'. The Framework Programmes' initial focus was nuclear energy and IT – actually as part of an OECD-wide push to increase IT research that followed the spectacular successes of Japanese industry in consumer electronics and telecommunications of the latter 1970s. Over time, the Framework Programmes' scope has grown to cover a very wide range of themes and the repertoire of instruments has increased from the early focus on collaborative research to areas like human mobility. Via the CRAFT and BRITE-EURAM programmes, they established an agenda of working with SMEs that continues to this day. The thrust of the Framework Programmes in this period was the desire to achieve economic, impacts. The early efforts in IT and industrial technology exemplify this strand, which was sometimes informally described as 'the Commission's industry policy'.

The European Commission's first innovation programme was launched in 1983 by what is now DG-ENTR, and was renamed SPRINT in 1986. It focused on technology transfer and SMEs, expanding to take on issues such as promoting the science park and venture capital movements

---

Concorde as well as new institutions to study science and technology policy such as the Science Policy Research Unit at Sussex University

[7] Ernst Rietschel et al, *Evaluation of the Sixth Framework Programmes for Research and Technological Development, 2002-2006*, Brussels: European Commission, 2009

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

and establishing Innovation Relay Centres, especially in the 1990s. The VALUE programme (1989-94) focused on disseminating the results of Community-funded research. From the early days, there has been thematic overlap between innovation activities in DG-ENTR and the Commission's work in the DGs for Regional Development and that for Research.

The Maastricht Treaty (1993) gave the Commission the role of leading the coordination of national RTD policies and extended the scope of the FPs – starting with Fourth Framework Programme (1994-1998), which now included basic research, applied research, technology development and the demonstration of new technologies. Industrial policy considerations were more prominent than ever in FP4, and activities were to be geared towards enhancing competitiveness and productivity. Especially in the second half of FP4, research was particularly focusing on applied research, involving a wide range of stakeholders.

A major change in policy thinking was introduced by the Commission's White Paper "Growth, Competitiveness, Employment. The Challenges and Ways Forward into the 21st Century" (1993)[9] followed by the "Green Paper on Innovation" (1995)[10]. In contrast to the previous focus on single industry sectors, these presented a more holistic view of innovation. The White Paper called for action to create jobs, but simultaneously emphasized the need for education, training and job flexibility and stressed the importance of more and better coordinated spending on research and development. It argued that there was a "European paradox", i.e. Europe's "comparatively limited capacity to convert scientific breakthroughs and technological achievements into industrial and commercial successes."

The focus of the debate now shifted to **using** new technologies.[11] Among the follow-ups to the Green Paper was the "First Action Plan for Innovation in Europe" (1997)[12], which identified education and training, financing of new companies, regulation and technology transfer and awareness as the three main areas of action. These shifts in thinking were reflected in the more societal orientation of the Fifth Framework Programme (1998-2002), placed greater emphasis on wider societal benefits, moving beyond the economic-industrial sphere. We can see a continuation of this growing concern with wider societal goals in the more recent discussion of 'grand challenges' as ways to refocus EU research and innovation policy on societal needs and the proposed 'Horizon 2020' Framework Programme for research and innovation[13].

The 2000 Communication on the ERA[14] argued that Europe lagged the USA and Japan in industrial competitiveness and the ability to make social and economic use of research. It proposed a unified research area, comparable with the idea of the EU as a common market for goods and services. Also targeted were increased human mobility and the bringing together of the scientific communities of the new Member States with those of the EU-15, the creation of more opportunities for female and young researchers and steps to make Europe a highly-attractive place to do research based on common ethical values. Two months later, the Lisbon Declaration set Europe "a new strategic goal to become the most competitive and dynamic knowledge-based economy in the world, capable of sustained economic growth with more and better jobs and greater social cohesion". Research and innovation actions building on the idea of the ERA were to be pursued together with improved policies for the Information Society,

---

[9] *Growth, Competitiveness, Employment: The Challenges and Ways Forward into the 21st Century* - White Paper. Parts A and B. COM (93) 700 final/A and B, 5 December 1993. Bulletin of the European Communities, Supplement 6/93

[10] *Green paper on Innovation*, European Commission, COM (95) 688 final

[11] John Peterson, Margaret Sharp, *Technology Policy in the European Union*, MacMillan Press Ltd, 1998

[12] *The First Action Plan for Innovation in Europe*, European Commission, COM (96) 589, 1996

[13] COM(2011) 808 final

[14] Commission of the European Communities, *Towards a European research area*, COM 2000 (6) Final

modernising the 'European social model' and macroeconomic policies. Not long afterwards, the Council set the Barcelona target of spending 3% of EU GDP on R&D.

The idea of ERA has been evolving since it was introduced in 2000. A new Communication in 2002 was clearer about what ERA really meant, namely

- The creation of an 'internal market' for research – an area of free movement of knowledge, researchers and technology, which would contribute to an increasing co-operation, and would stimulate competition and a better allocation of resources
- A restructuring of the European research fabric; in particular by improved co-ordination of national research activities and policies
- The development of a European research policy which would not only address the funding of the research activities, but also all relevant aspects of other EU and national policies[15]

Today it is, in effect, to build a globally competitive research and innovation system optimised at the European level. In 2007, the Green Paper that 're-launched' the ERA[16] described its key features as

- An adequate flow of competent researchers
- World-class research infrastructures
- Excellent research institutions
- Effective knowledge-sharing
- Well-coordinated research programmes and priorities
- A wide opening of the European Research Area to the world

The subsequent debate led to the adoption by the Council of the so-called ERA 2020 vision (2008) stating that "by 2020 all actors should benefit fully from the "Fifth Freedom" across ERA: the free circulation of researchers, knowledge and technology."

DG-ENTR brought its innovation programmes together in the Competitiveness and Innovation Framework Programme (CIP), with a budget of just over €3.6bn for 2007-2013 (equivalent to about 7% of the €51bn budget of FP7 for the same period). It continues activities to promote entrepreneurship, adding the ICT-PSP programme (aiming to demonstrate and create market conditions for the take-up of ICT-based innovations) and the Intelligent Energy Programme. It has been supplemented with six Lead Market Initiatives, where demand-side stakeholders as well as various EU R&D groupings (such as the ETPs) have been consulted about how to create demand conditions that will encourage innovation in areas where Europe has the potential to supply the innovations. These conditions include public procurement. Both ICT-PSP and the Lead Markets Initiative aim to provide links to the Framework Programme. The linkage is not strong but these nonetheless do represent some steps towards the kind of 'holistic' research and innovation policy sought at home by increasing numbers of Member State governments.

Over the years, then the Framework Programme has swung between an industrial focus and more of a social one – though, as we show below, there has also been good degree of underlying consistency in the themes pursued. There has been a distinct shift away from trying to manage markets and national champions and towards promoting and enabling the self-organisation of R&D agendas by beneficiary groups. Recently, there has been a more deliberate attempt to couple research and innovation policy and to recognise that these sometimes cannot be effective without complementary policies (for example on the demand side) being in place.

---

[15] Commission of the European Communities, *The European Research Area: providing New Momentum*, COM (2002) 565 of 16/10/2002, p. 4.

[16] Commission of the European Communities, Green Paper, *European Research Area: New Perspectives*, COM(2007) 161 final, Brussels 4.4.2007

2.3 European Added Value (EAV)

From the start, European Added Value (EAV) – the additional value created compared with action at Member State level – has been at the heart of the actions of the EU and its predecessor Communities. This principle of 'subsidiarity' was clarified in the Maastricht Treaty, which also required that EU interventions should be 'proportional': namely, they should not go beyond what is needed to reach the goals of the Treaty. The Treaty goes on to say that EU action is only justified if

- It has trans-national aspects which cannot be satisfactorily regulated by action by the Member States
- Actions by Member States alone would conflict with the requirements of the Treaty
- Lack of action by the EU would conflict with the requirements of the Treaty
- Action at the level of the EU would produce benefits of a scale or impact that could not be achieved by Member States alone

Council resolutions in 1974 established the legitimacy of the Community developing a science and technology policy. Three years later, the Commission articulated criteria for ensuring that such policy would be consistent with generating EAV. These were

- Efficiency, where community involvement allowed avoidance of duplication and rationalisation of effort (e.g. nuclear fusion)
- Trans-national research, involving issues crossing national boundaries, such as telecommunications and some environmental problems
- The size of the market, where R&D costs were high and potential markets were international
- Common requirements, e.g. international standards[17]

An additional criterion covering the development of scientific and technical potential in Europe was added for FP4: 1994-1998. This justified research actions which contribute to the mobilisation or improvement of European scientific and technical potential and actions which improve co-ordination between national RTD programmes, and between Community programmes and work in other international fora (**S&T potential**).[18]

The Council decision approving FP5 added: making contributions to implementing EU policy; contributing to the achievements of societal objectives (an idea recently reconceptualised as responding to societal 'grand challenges'); and exploiting opportunities for developing new parts of science, technology or industry.

According to the Council "European Added Value is a dynamic concept and should therefore be interpreted in a flexible way."[19] The European Parliament has also protested against "excessively economistic interpretations" of the concept. "The 'cultural value added' should not be forgotten … [and] … the concept of 'European Added Value' must not be limited to advanced cooperation between Member States but should also contain a 'visionary' aspect"[20].

---

[17] Yellow Window, Technofi and Wise Guys, *Identifying the constituent elements of the European Added Value of the EU RTD programmes: conceptual analysis based on practical experience*, study commissioned by DG Research, Antwerp: Yellow Window, 2000

[18] Yellow Window, 2005

[19] C 13/5, OJ 18.1.2003, point 8

[20] *European Parliament resolution on building our common future: policy challenges and budgetary means of the enlarged Union 2002-2013* (COM(2004) 101 – C5-0089/2004 2004/2006(INI)). Ref. P5_TA(2004)0367; cited from Tarscgys, 2005

A little-noticed novelty of FP5 was the 'mainstreaming' of participation in the FP by 'Third Countries', i.e. those that are neither Member nor Associated States. This partly involved bringing in a range of development projects aimed at poor countries and regions outside Europe but – especially in FP6 – it also involved growing participation in mainstream FP projects, not least by Russia and China[21]. FP7 involves a greater degree of what the Commission terms 'internationalisation' (as if the EU were a nation – we should more properly speak of 'globalisation'). The gradual transition towards an interest in globalisation represents a further extension of EAV.

In parallel with the development of FP6, the Commission expanded the definition in another new direction.

> Until now we have defined European Added Value as the collaboration of teams. Now it is time to bring a new definition to European Added Value, one that incorporates the principle of allowing a researcher in any of our member states to compete with all other researchers to win funding. Competition therefore becomes an essential new, forward-looking definition of European Added Value.[22]

This expansion of the concept of EAV was incorporated in the Communication "Europe and Basic Research"[23] in 2004 but did not really become operative until the creation of the European Research Council under FP7.

European Added Value is therefore a dynamic concept, whose meaning evolves along with the development trajectory of the European union itself towards closer integration and eventually federation. It has shifted from having a basis in the logic of independent Member States establishing a common market and doing things together when it makes sense to operate at a larger scale to increasingly providing justifications at the European level. This means that the type of logic used to develop national policy is now also applied at the EU level; that this means 'optimising' things like the structure of the research community and associated infrastructure at the European level; and that there are losers at the national level as well as winners. Overall, there is a shift from networking to increasingly strong forms of coordination.

---

[21] Erik Arnold, Sylvia Schwaag-Serger, Neil Brown and Sophie Bussillet, *Evaluation of Chinese Participation in the EU Framework Programme*, Brighton: Technopolis, 2008

[22] Achilleos Mitsos, Speech at the ELSF-Euroscience Conference of the European Research Centre, Dublin, 21-22 October 2003; quoted from Daniel Tarschys, *The Enigma of European Added Value: Setting Priorities for the European Union*, SIEPS 2005:4, Stockholm: Swedish Institute for European Policy Studies, 2005

[23] Commission of the European Communities, European and Basic Research, COM (2004) 9, final, 14.1.2004

Figure 2 The Evolving Character of 'European Added Value'

Dimensions of European Added Value	FP1	FP2	FP3	FP4	FP5	FP6	FP7
Scale too big for Member States (MS) to handle alone	X	X	X	X	X	X	X
Financial benefits: a joint approach would be advantageous	X	X	X	X	X	X	X
Combines complementary MS efforts to tackle European problems	X	X	X	X	X	X	X
Cohesion	X	X	X	X	X	X	X
Unification of European S&T across borders	X	X	X	X	X	X	X
Promotes uniform laws and standards	X	X	X	X	X	X	X
Mobilising EU potential at European and global level by coordinating national and EU programmes				X	X	X	X
Contributes to implementing EU policy					X	X	X
Contributes to societal objectives (later ‘grand challenges’)					X	X	X
Exploits opportunities for the development of European science, technology and industry					X	X	X
Structures the EU R&D community and ‘fabric’						X	X
Improves quality through exposure to EU-wide competition							X

2.4 The Framework Programme

In more than 25 years of history of the FPs a number of shifts and trends can be observed.

- Thematically: while the first FPs were very much focused on energy and IT the Framework Programmes became more diverse and more ‘horizontal’ themes were introduced. The core of the FPs remained technology focused. The ‘distance-to-market’ varies from programme to programme. As particularly in the early FPs the management of Programmes and sub-themes was quite independent and hardly coordinated, each programme area had it own research culture and character. The ICT programmes managed in a separate DG were generally more focused on reaching socio-economic impact than the programmes of DG Research (or DG XII in early FPs)
- The size of the budget: this showed a constant rise from 3.75 billion ECU (FP1), 5.4 billion ECU (FP2), 6.3 billion ECU (FP3), 13 billion ECU (FP4), 14.96 billion Euro (FP5), to 16,3 billion Euro (FP6). The total €51billion budget of FP7 is for a different time span (7 years for EC and 5 years for Euratom) and is thus difficult to compare, but it would be approximately equivalent to €39 billion for 5 years
- The funding instruments used: while the early Framework programmes were mostly based on collaborative research projects. FP3 introduced the Human Capital and Mobility programme, extending the work of the Framework into human resource development in addition to collaborative research. Major innovations in instruments took place in and around FP6 with the introduction of Research Infrastructures, Networks of Excellence, Technology Platforms (later Joint Technology Initiatives) and the European Research Council. Key to most of these instruments was (a) their much greater project size, with each effectively defining a mini-programme, and (b) the devolution of much of the agenda-setting to the stakeholder groups that became the beneficiaries

2.4.1 Thematic Continuity

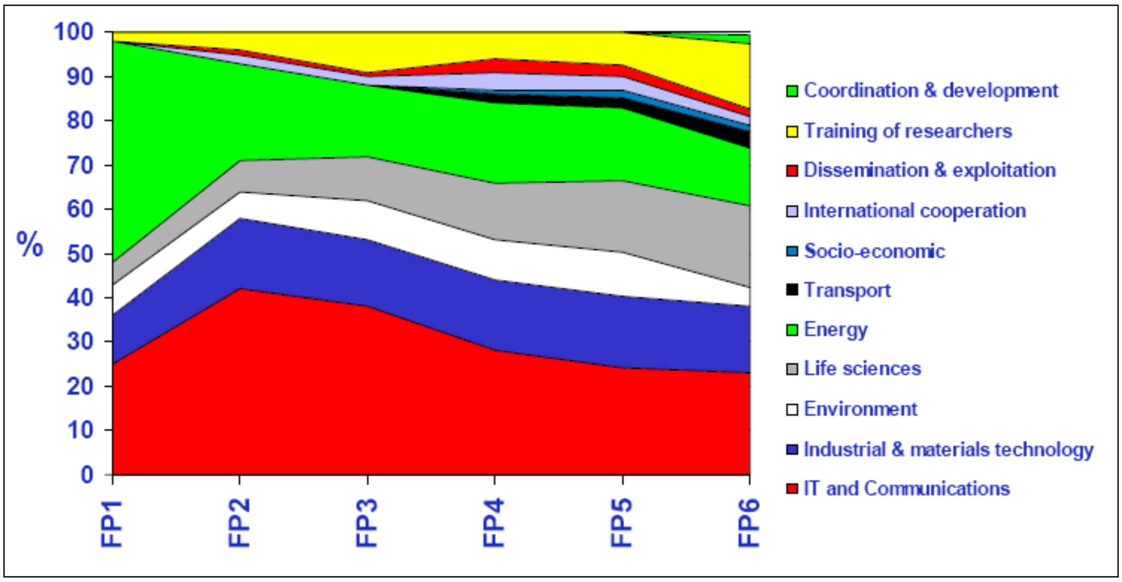
Figure 3 shows how the thematic focus has shifted during FP1-6.

- The key focus for the first 3 FPs was on the strengthening of the competitiveness through IT and Communications and Industrial and Materials Technology, and on socioeconomic objectives of a safe and environmental-friendly energy production. For the latter, a drop in funding can be noticed in FP2, mainly to the benefit of the ICT industry. The mobility and training of researchers became an objective in FP3
- FP4 and especially FP5 were marked by a broadening of the scope of the FPs and an enhanced focus on innovation, illustrated by the inclusion of research in transport

technologies and an increase in funding for knowledge transfer (dissemination), international cooperation, and socio-economic research

- FP6 was characterised by a strong focus on R&D competitiveness, hence the increase in funding for the training of researchers. Coordination and Development became a new strand of funding.

Figure 3 - EU Research: Changing Priorities



Source: EC, 2005[24]

Figure 4 focuses on FP4-6, which are the Framework Programmes whose influence is the focus for this study. It lists all the main programme/priority areas used to structure FP4, FP5 and FP6 and the main lines of continuity over time. The links are based on a simple matching of the titles of priority areas in one FP with the titles of the next, followed by a more in-depth analysis of connections at the level of the sub-programme areas. In addition, information on the CORDIS website describing the evolution of the programme structure has been used to strengthen the analysis.

Despite significant difficulties in matching the programme and sub-programme titles (due to significant fluctuation in the number of categories at both of these levels and the different ways in which they are described) we are confident that the linkages shown in Figure 4 are fairly robust. Based on earlier work[25], we have identified, described and colour coded 14 main thematic areas, roughly half of which are clearly evident in each of the three FPs on which we are focusing.

Figure 5 shows the volume and share of funding within the main FP priority areas identified for FP4-6, respectively – the FPs on which we focus in this study. Within these broad categories we can see the seven areas that have received sustained resources across the successive programmes, as identified in the preceding section above. Looking at the funding patterns we can see the following:

- The most dominant priority area in funding terms has been the **ICT**-related area, which has received a budget allocation of between €3.6-€3.8 billion under each programme. While the

---

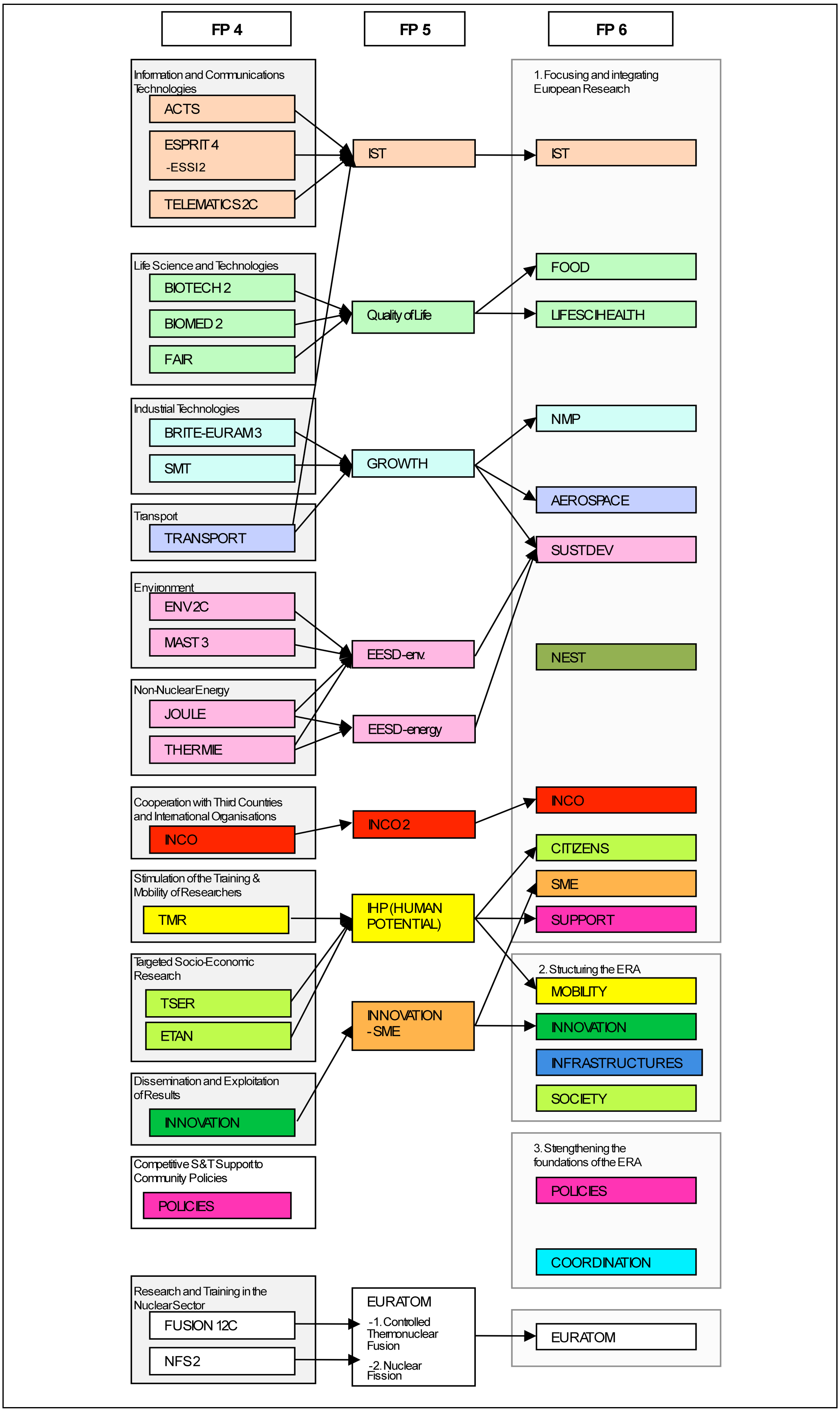
[24] *Towards the Seventh Framework Programme 2007-2013, Building Europe Knowledge*, European Commission, Research DG, April 2005

[25] Erik Arnold, *What the Evaluation record tells us about Framework Programme Performance*, Brussels: European Commission, DG Research, 2005

volume of funding has been fairly consistent, the share of the total budget allocated to this area has been falling across successive FPs

- There has been steady growth in the volume and share of the overall budgets allocated to the **Life sciences, biotechnology, food and health** area over time, reflecting a clear increase in the level of priority attached to this broad area.
- A different pattern can be found in the **materials (including nanotech)** area, with an increase in funding volume and share from FP4 to FP5, followed by a sharp decrease from FP5 to FP6, suggesting that there has been a reduction in support for research in this field in the more recent period
- There has been small growth in the volume of funding allocated to the **environment and sustainable development (inc non-nuclear energy)** area over successive FPs, although the share of the overall FP budgets has remained stable at 14%, suggesting that there has been no marked increase in prioritisation of this broad field
- Support for **International cooperation** has fallen steadily in both absolute and proportionate terms from FP4 to FP6, suggesting again a decrease in the level of priority attached to this area. At the same time, however, it has become easier and more frequent to involve organisations from countries not associated with the Framework Programme to participate in mainstream FP projects, so the global reach of the Framework Programme is increasing rather than decreasing
- Conversely, the **training and mobility of researchers** priority has received increased levels of funding from FP4 to FP6, with increase in both volume terms and in the proportion of the overall budget

Figure 4 Thematic linkages across Framework Programmes



While it is thus possible to see thematic continuities across the Framework Programmes, these tend to be obscured by the very different structure of FP5 compared with FP4 and FP6. Figure 5 uses FP priority area budgets to paint a picture of thematic continuity. However, we believe it understates the degree of continuity because thematic RTD was pursued under other headings in FP5. This is one reason why, in identifying case studies for this study, we sought an alternative approach (co-word analysis) to understanding areas of potential thematic importance in the FP.

Figure 5 - FP4-6 funding in the main priority areas (ECU/Euro)

Broad Areas	*FP4 (m ECU)*		*FP5 (m EUR)*		*FP6 (m EUR)*	
ICT, IST, Telematics and Advanced Communication Technologies	3,646	28%	3,600	24%	3,791	21%
Life sciences, Biotech, Food, Health	1,628	12%	2,413	16%	3,091	17%
Industrial and Material Technologies, including Nanotech	1,921	15%	2,705	18%	1,537	9%
Transport (including Aeronautics and Space)	263	2%	0	0%	1,069	6%
Environment and Sustainable development (including Non-nuclear Energy)	1,856	14%	2,125	14%	2,294	13%
International Cooperation	575	4%	475	3%	351	2%
Encouragement of Participation of SMEs	0	0%	363	2%	484	3%
Training and mobility of researchers	792	6%	1,280	9%	1,686	10%
Science in society (including Knowledge-based Society and Governance)	112	1%	0	0%	322	2%
Research and innovation	312	2%	0	0%	225	1%
Research Infrastructures	0	0%	0	0%	725	4%
Science, Technology (and Research) Policy	136	1%	0	0%	615	3%
Coordination of research	0	0%	0	0%	288	2%
Nuclear fission / fusion (Euratom)	1,017	8%	979	7%	1,230	7%
Total	**12,258**	**100%**	**13,940**	**100%**	**16,664**	**100%**

Source: FP4-FP5 Joan Majó et al, Five-Year Assessment of the European Union Research and Technological Development Programmes, 1995-1999, Brussels: DG Research, 2000; FP6 E-CORDA, 2010

While there are major changes between Framework Programmes in the way the overall priorities are presented, our analysis shows considerable thematic continuity with major themes either flat or growing in budget terms. There are few major visible shifts in budget allocation, as could be expected in response to changes in technological opportunities, changes in the competitive fortunes of European industries or in the overall strategy of the FP. While the ICT spending is declining in relative terms, it remains absolutely large and its character has shifted radically since the ESPRIT programme in response to the changing fortunes of the European ICT industry, not least through a major refocusing from hardware to software and content. Since the content of the FP is largely a result of consultation by the Commission, it may be useful to see the thematic division of the budget as a function of a process of establishing consensus between the Commission and the stakeholders. This brings the strengths of stability, dependability and maintenance of research communities – but also the potential weakness of stasis. The proportion of the FP that fosters radical and disruptive change is very small.

2.4.2 Continuity of FP instruments FP4-6

Having looked at the issue of continuity in the FP priority and sub-programme areas we investigated continuities in the funding instruments (or project types) used to implement the priorities. In order to simplify the analysis we allocated all of the instrument types used in FP4, 5 and 6 to one of four categories – (i) RTD actions, (ii) actions for RTD knowledge transfer, (iii) actions for adoption and innovation, and (iv) actions to support policy-making. Figure 6 shows which FP4, 5 and 6 instruments were assigned to each of the broad categories.

Figure 6 – Categorisation of FP4-6 Instruments

Category	Instrument	Framework programme
RTD actions	Cost-sharing contracts	FP4
	Integrated Project	FP4
	Research grants (individual fellowships)	FP4
	Grants - Subventions	FP5
	Combined Projects	FP5
	Research Projects	FP5
	Integrated Projects	FP6
	Specific Targeted Research Projects	FP6
Actions for RTD knowledge transfer	Coordination action	FP4
	Coordination of research actions	FP4
	Exploratory awards (thematic networks)	FP4
	Marie Curie actions	FP4
	Integrating activities	FP4
	Research network contracts	FP4
	Thematic network contracts	FP4
	Concerted Actions	FP5
	High Level Scientific Conferences	FP5
	INCO - Individual Fellowships for Young Researchers of Developing Countries	FP5
	INCO - Outgoing Fellowships to Japan	FP5
	Marie Curie Fellowships	FP5
	Research Training Network	FP5
	Thematic Network	FP5
	Networks of Excellence	FP6
	Coordination Actions	FP6
	Integrated Infrastructure Initiatives (I3)	FP6
	Marie Curie Actions	FP6
Actions for adoption and innovation	Cooperative research contracts	FP4
	Demonstration contracts	FP4
	Exploratory awards (demonstration)	FP4
	Exploratory awards	FP4
	Access to Research Infrastructures	FP4
	Technology Take Up Measures	FP5
	Cooperative Research	FP5
	Demonstration Projects	FP5
	Exploratory Awards	FP5
	Access to Research Infrastructures	FP5
	Co-operative Research Projects	FP6
	Collective Research Projects	FP6
	Specific Actions to Promote Research Infrastructures	FP6
Actions to support policymaking	Preparatory, accompanying and support measures	FP4
	Study contracts, assessment contracts	FP4
	Classical Accompanying Measures	FP5
	Specific Support Actions	FP6

Source: Technopolis, 2010

Figure 7 presents data on the share of projects and participations allocated to each of the broad instrument categories, in FP4, FP5 and FP6. There is a clear decline in the role of RTD actions as well as actions for adoption and innovation across these three FPs. In contrast, actions to support policymaking and actions for RTD knowledge transfer have grown, suggesting that the character of the FP is changing over time.

Figure 7 - Share of projects by type of instrument, FP4-6

Instrument category	FP4		FP5		FP6	
	Projects	Participations	Projects	Participations	Projects	Participations
RTD actions	67%	73%	45%	57%	30%	53%
Actions for RTD Knowledge transfer	8%	10%	32%	23%	51%	28%
Actions for Adoption and Innovation	18%	13%	15%	13%	6%	8%
Actions to support Policy-making	7%	3%	8%	7%	14%	11%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Source: E-CORDA, 2010

The databases at our disposal only provide funding information for around a third of the FP4 projects, and so it is not possible to calculate the relative shares of the FP4 budget allocated to each of the four main instrument types. Figure 8 shows that from FP5 to FP6 the share of the overall budget allocated to RTD actions and actions for adoption and innovation has fallen slightly, while actions for RTD knowledge transfer have increased significantly. Actions to support policy-making have seen a small increase in terms of their share of the overall budget.

The data also show that FP6 projects were on average just over double the size (in monetary terms) of the FP5 projects. The largest increases have come in the Actions for RTD knowledge transfer category, where FP6 projects were on average nine times the size of those supported under FP5 (€2.8 million as compared to €0.3 million). Actions to support policymaking were on average almost four times as large in FP6 as in FP5, while RTD actions in FP6 were more than twice the scale of those supported under FP5. Actions for adoption and innovation showed an opposite trend, with the FP5 projects being almost three times larger on average than those supported under FP6.

Figure 8 - Share of funding by type of instrument, FP5-6

Instrument category	FP4	FP5	FP6
RTD actions	Not available	74%	67%
Actions for RTD Knowledge transfer	Not available	13%	23%
Actions for Adoption and Innovation	Not available	9%	5%
Actions to support Policy-making	Not available	5%	6%
Total	**Not available**	**100%**	**100%**

Source: E-CORDA, 2010

Despite some variations, the main trend has been for the average size of funding instruments to rise over time, especially in FP6 with the use of Networks of Excellence and Integrated Projects and other instruments that devolve more of the agenda-setting process to the beneficiaries. There has been growing recognition of the importance of knowledge transfer as a complement to knowledge generation.

2.5 Objectives and Intervention Logic of the Framework Programme

The high-level objectives of the Framework Programme have evolved continuously as EU research and innovation policy have evolved. At a more tactical level, changes in knowledge, markets and thematic priorities enforce continuous change. This study has reviewed the major trends in the objectives in the Framework Programmes over time, in order to compile an 'aggregated' intervention logic, which then formed the basis for our search for long-term impacts. Ideally, one would describe a series of evolving intervention logics. Here, we have been forced to simplify and produce a 'logic model' for the Framework Programme as a whole.

2.5.1 The Intervention Logic

The scale and complexity of the Framework Programmes mean that it is extremely challenging to summarise their intervention logic. (By intervention logic, we mean a statement of objectives and a set of expectations about how an intervention will lead to the attainment of those objectives.) This sections aims to provide such a summary, using a logic model.

A logic model describes the intervention logic of a programme, how the programme activities and outputs derive from objectives and influence programme participants, customers and or beneficiaries leading to the achievement of the intended outcomes in the short, medium and longer term. In the logic model the key links from the activity to the long-term objectives are set out, illustrating a "results chain" or "pathway to success", thus identifying key relationships along the chain. The resulting model generally takes the form of a diagram or table with text. In this case, we have one diagram that shows the interrelationship among objectives and a second that describes how the intervention (ie the Framework Programme) is expected to enable the objectives to be reached.

We have distinguished among different types of Framework Programme objectives as follows.

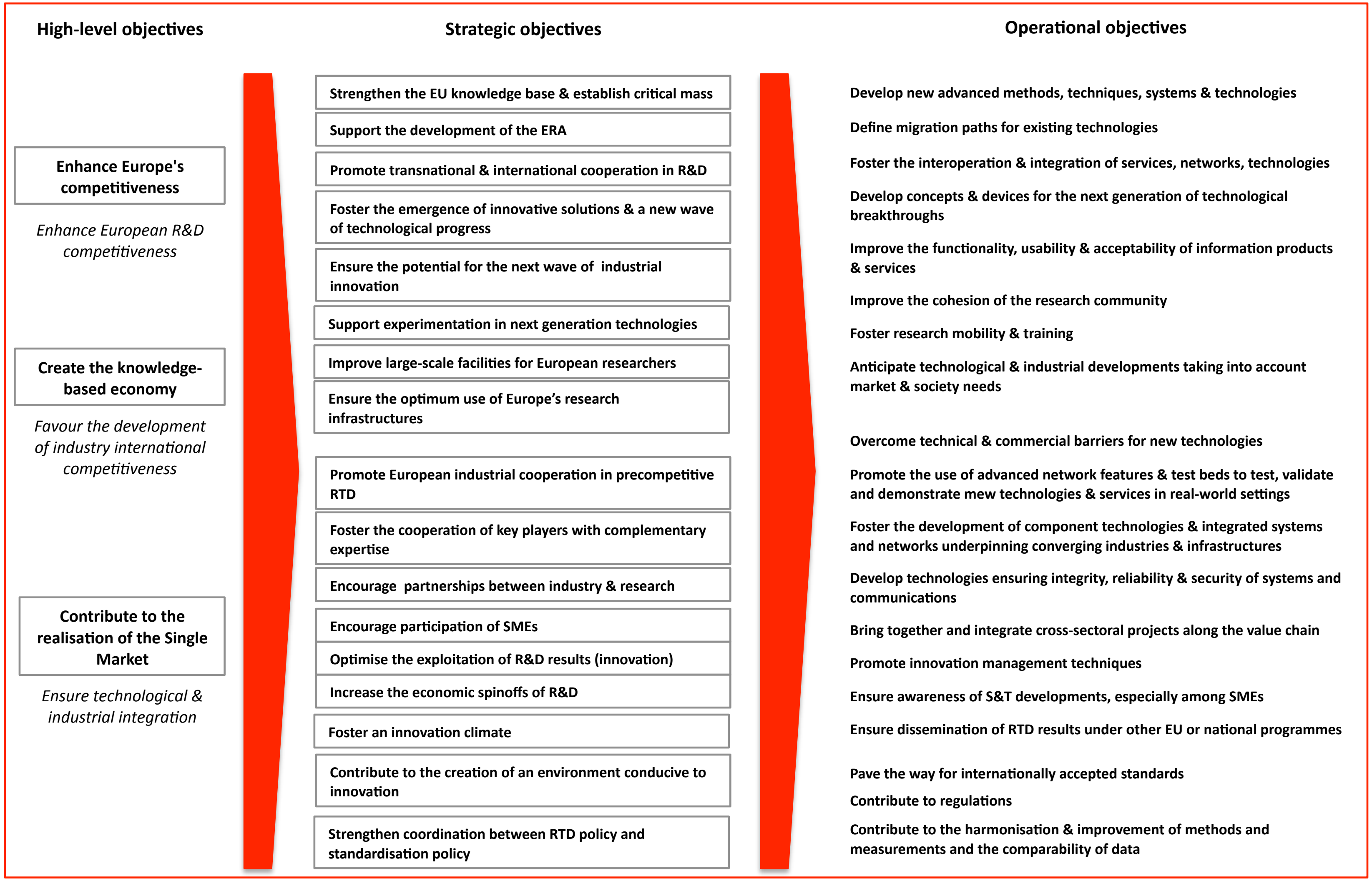
- **High-level objectives**, which relate to those established at the policy level. These objectives correlate well with the intended 'long term impacts' of a Framework Programme or policy strategy. They often relate to broader issues such as economic growth, competitiveness, prosperity etc.
- **Specific or strategic objectives**, which are more programme specific and correlate well with the long-term 'outcomes' of a programme or a strategy (enhanced awareness, coherence in regulations etc).
- **Operational objectives**, which correlate with the 'outputs' and mid-term 'outcomes' resulting from the implementation of the programme - through tools such as instruments or the focus on specific technologies or applications

Operational objectives are set out in the Work Programmes and are closely related to the focus in the programmes on specific thematic priorities and the instruments chosen to implement the activities. The most common of these instruments (in recent FPs also called funding schemes) is collaborative research. As the preceding discussion has shown, both the thematic priorities and the instruments have evolved considerably in recent years.

In order to develop an intervention logic that might serve as a basis for the analysis in this study, we restated the objectives of the various Framework Programmes in more abstract terms (essentially removing the thematic content) and taking especially into consideration those related to the most recent FPs. We focused particularly on the objectives of FP4 and FP5 as these constitute the main sources of our case studies.

When reading this intervention logic, it is important to consider that there are no direct one-to-one links between the objectives at the various levels. High-level objectives are pursued through a **mix** of priorities established at the various programme levels, which were in turn implemented through a **mix** of specific actions and focus points at the specific themes/work programme level.

Figure 9 - Aggregated Intervention Logic



High-level objectives

Ensure sustainable development & economic growth

Achieve an inclusive & user-friendly Information Society

Promote quality of life and health

Ensure social & economic cohesion

Support other Community policies

Ensure a close articulation between research & policy

Strategic objectives

- Support the management and sustainable use of natural resources
- Ensure efficient, clean, safe and environmental-friendly production processes
- Build up or strengthen the knowledge base in identified areas of strategic importance for the future
- Facilitate the development of high-quality innovative products and services meeting the needs of citizen and the market

- Combat social and physical exclusion
- Invest in people & skills
- Increase the competitiveness of the European healthcare sector
- Improve medical knowledge and the health of the European population
- Build up the knowledge base and research networks for comparative European socio-economic research

- Increase synergies between international cooperation in R&D and the Community's external activities
- Help developing S&T innovation and other Community policies
- Improve coordination of EU and national R&D policies

Operational objectives

- Develop applications in agriculture, industry, health, nutrition and the environment to increase productivity in a sustainable fashion
- Develop systems to improve transport efficiency, safety and reliability and reduce congestion and other environmental disbenefits
- Develop innovative technologies and new materials, modes and systems for sustainable and efficient land transport means
- Develop the scientific, technological and socio-economic basis and tools necessary for the study and understanding of changes in the environment
- Reach an improved understanding and resolution of the interrelationships between environmental conditions and objectives, economic vitality, social cohesion and cultural identity
- Investigate cleaner, most notably renewable, energy sources
- Foster a sustainable European capability in operational services for monitoring the Earth from space

- Help improving the quality and user-orientation of services
- Foster the creation of the next generation of interoperable general interest application systems to meet user demands
- Ensure access and accessibility to secure communication networks
- Increase the appreciation and understanding of science, research and technology by the general public

- Consider the ethical and socio-economic implications of R&D
- Promote communication and debate with & between policy makers
- Elucidate decision-making at decentralized, national or Community level
- Enhance the position and role of Community research in the international S&T innovation arena and promote a European S&T innovation culture
- Support national initiatives for innovation

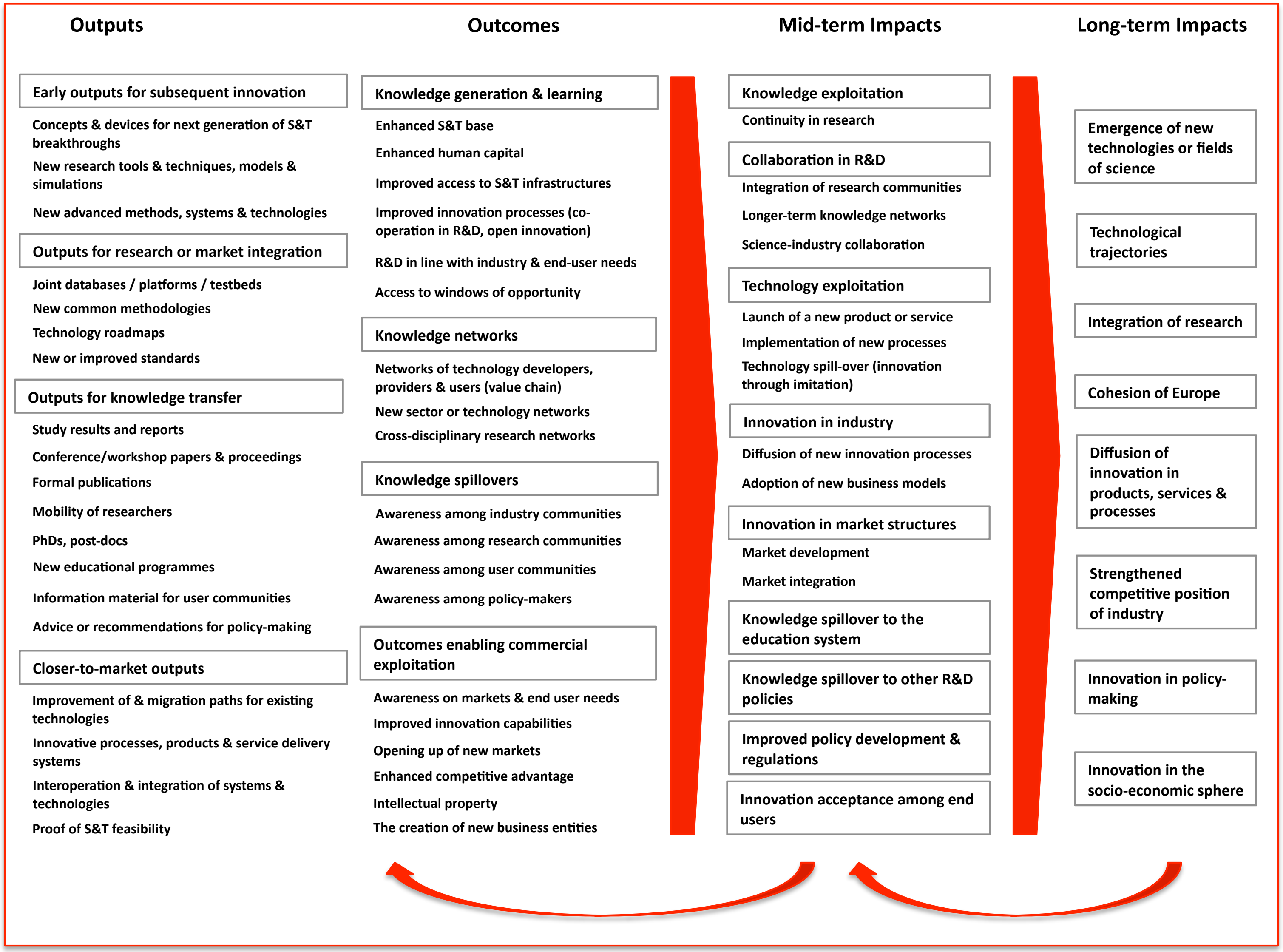
The expected impacts model depicted in Figure 10 shows the results that the Framework Programmes are intended to achieve. It distinguishes between outcomes that relate to *beneficiaries* and impacts that provide *spillovers or externalities to society*. The outputs are the things programme delivery targets, which are produced in order to fulfil the operational objectives. They may take a wide range of forms, such as documented knowledge, facilities, services or information. The 'outcomes' are the benefits, which direct beneficiaries obtain from their participation.

The **impacts**, are the wider effects of the Framework Programme on *society*. Mid-term impacts are inherently linked to the characteristics and stages of development of specific technologies and/or the characteristics and needs of specific industry sectors. Long-term impacts may be the result of co-evolution of technological, industrial, policy and social changes and emerge from a combination of impacts at various levels (technical, knowledge-related, policy-related etc) and at different points in time. They relate to strategic objectives and contribute to the achievement of the high-level policy objectives, depending on the focus of the research activities funded and the industry or public service sectors targeted. More specifically:

- The '*Emergence of new technologies or fields of science'* and '*Technological trajectories'* are both long-term effects in the sphere of scientific and technological research. Whereas the latter is an effect of research aiming at advances along a path defined by an established technological or scientific paradigm, the former is promoted by interventions fostering the search for new S&T paths and the development of new paradigms. Both impacts typically build upon long-term research efforts and consolidated - while sufficiently open - long-term partnerships in research
- '*Integration of research'* and '*Cohesion of Europe'* are expected systemic impacts of the Framework Programmes. 'Integration of research' refers to effects in the sphere of RTD deriving from the creation of effective and long-lasting knowledge networks and linkages between the various actors in research, education, and industry at European level as well as the creation of synergies and complementarities between RTD policies at the European, national and regional levels. 'Cohesion of Europe' covers effects in the economic sphere, deriving from, for example, standardisation efforts and the strengthening of the Single Market or the development of policies and regulations that are coherent at European level
- '*Diffusion of innovation in products, services and processes'* and *'Strengthened competitive position of industry'* indicators cover the 'innovation' effects in the economic sphere. In his 2008 paper on system transitions[26], Könnölä points out that processes of transition are gradual and occur over time along four transition phases. It is only in the 'acceleration' phase, i.e. the third phase following the pre-development and take-off ones, that increasing returns of economies of scales occur which in turn support the diffusion of new solutions and lead to structural change. In this context he also stresses the importance of policy regulations for the creation of market conditions and fostering of both supply and demand, as well as the 'social changes', i.e. the social acceptance of the innovation. The timely diffusion of innovation strengthens the competitive positioning of industry; from a longer-term perspective, a critical factor is also the relevant knowledge capital in society, i.e. the stock of research tools and longer-term knowledge needed for competitiveness and the R&D-skilled human capital and critical mass in areas of relevance to industrial needs.
- '*Innovation in policy-making'* refers to the long-term effects of technological innovation and economic and social changes in society on the focus and processes for development of public policies - at European, national and regional level
- 'Innovation in the socio-economic sphere' specifically focuses on the effects of technological and economic developments on the approach adopted to issues such as quality on life, environmental protection, quality of healthcare, social inclusion, etc.

[26] Totti Könnölä, Javier Carrillo-Hermosilla2 & Robert van der Have, *System Transition - Concepts and Framework for Analysing Energy System Research and Governance*, DIME International Conference "Innovation, sustainability and policy", 11-13 September 2008, GREThA, University Montesquieu Bordeaux IV, France

Figure 10 - Expected impacts of the FPs



2.6 Typologies of Effects Model

In Figure 10 above, the expected mid-term impacts are grouped into nine key 'typologies of effects'. This allows us to develop a matrix identifying which mid-term impacts can be expected to be key for the achievement of the long-term ones – illustrated in Figure 11, below. This matrix was used to focus our analyses in this study.

The table illustrates, for example, that for the achievement of the long-term impact "diffusion of innovation in products, processes or services", effects in the field of technology exploitation, market integration and development, and innovation acceptance among the end users are key determining factors, while effects on collaboration in R&D, innovation in industry, and improved policy development and regulations may also be relevant – depending on the industry sector.

Figure 11 - Matrix of mid-term impacts contributing to long-term impacts

	Mid-term Impacts								
Long-term Impacts	Knowledge exploitation	Collaboration in R&D	Technology exploitation	Innovation in industry	Innovation in market structures	Knowledge spill-over in the education system	Knowledge spill-over to other R&D policies	Improved policy development & regulations	Innovation acceptance among end users
Emergence of new technologies or fields of science	√√	√√					√		
Technological trajectories	√√	√√					√		
Integration of research	√	√√					√√		
Cohesion of Europe		√			√√		√	√√	
Diffusion of innovation in products, processes or services		√	√√	√	√√			√	√√
Strengthened competitive position of industry		√√	√√	√√	√√	√		√	√
Innovation in policy-making		√				√	√√	√√	√
Innovation in the socio-economic sphere			√√	√	√√	√√		√	√√

3 EVALUATION OF THE FRAMEWORK PROGRAMME

The Framework Programme has been subject to evaluation since the outset. Practices have been improving over time. The history of evaluation allows us to describe the impacts of the Framework Programme in the short term, but this short-term focus restricts our vision of both the policy level and longer-term impacts. This short-term perspective has fed through to the evaluation methods used.

3.1 Evaluation History

The Framework has been subject to some degree of evaluation since the start. During FP1, however, it was only evaluated at the level of individual Specific Programmes (SPs – in effect, the sub-programmes of the FP), some of which antedate the Framework. Initially, evaluations tended to be conducted by expert panels, usually with the support of a consultant acting as rapporteur and sometimes providing additional background materials, such as a questionnaire survey of participants. The panels could involve people closely tied to the interventions and tended to provide a mixture of legitimation and broad advice on technological directions. This material is scattered and difficult to overview. The evaluations tended to follow normal scientific and technological panel practice, in part building on a tradition of evaluating programmes within the JRC that appears to have been in place before the Framework Programme. In FP1 as in FP2, some evaluations were rather technically focused, considering the progress and outputs of individual projects[27] within a conceptual framework that paid little attention to assessing outcomes and impacts. Others[28] took more account of the interests of prospective users, and therefore commented on issues such as lack of user involvement and poor dissemination.

The Framework Programme was first evaluated in its entirety in 1992, at the end of FP2 in a Commission Communication that effectively is a meta-evaluation of studies done at the level of Specific Programmes (SPs). The (unnamed) authors struggle bravely to reach conclusions at the level of the Framework as opposed to the individual SPs, They can describe quality and short-term technical effects such as publications and patents, but cannot deal with indirect structural effects in an evidence-based way, even if they claim (based on the concept of European Added Value current at the time) that while "the hard results of the specific programmes in terms of processes, products, standards and patents are still emerging and will continue to emerge over a number of years … the main impact of the second Framework Programme perhaps lies in the structural changes it has induced into the organisation of European R&D" [29]. These structural changes included greater cohesion, in the sense of integrating technologically weaker Member States into the European Research and Innovation System. The Communication stresses on the one hand that it is premature to expect to be able

---

[27] For example, A Gauvenet et al, *Evaluation of the JRC Programme on Safeguards and Fissile Materials Management* (JRC research 1980-1986), Research Evaluation – Report No 26b, Brussels: DG XII, 1986; A Wambersie et al, *Evaluation of the Radiation Protection Research Programme* (1980-1984 and 1985-1989), Research Evaluation report No 37, Brussels: European Commission, 1989

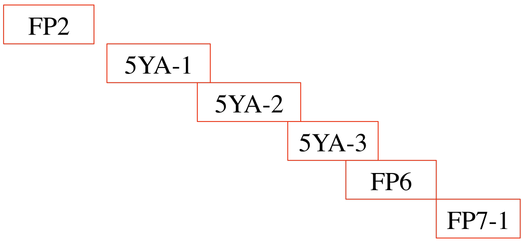
[28] For example, TJ Pect et al, *Evaluation of the Raw Material Research Programmes on Wood and Cork (1982-1985 and 1986-1989),* Research Evaluation Report No 35, Luxembourg: Office for Official Publications of the European Communities, 1989; the later evaluation of JOULE provides evidence that this style of evaluation continued for some time RH Booth et al, *Evaluation of the JOULE Programme (1989-1992)*, Luxembourg: Office for Official Publications of the European Communities, 1994; M Armada et al. Mid-term *Evaluation of the TELEMAN Programme*, Luxembourg: Office for Official Publications of the European Communities, 1994

[29] European Commission, *Evaluation of the Second Framework Programme for Research and Technological Development,* Communication from the Commission, SEC (92) 675 final

to identify significant exploitation impacts given the pre-competitive nature of the FP and on the other hand that take-up and dissemination of results are weak. As a result, FP3 included measures such as CRAFT and VALUE that aimed to improve dissemination – even thought it is far from clear whether FP2's design was faulty in this respect or whether the apparent lack of 'take-up' was the result of a misconceptualisation.

Figure 12 Timing of Framework-Wide Evaluations

FP	1	2	3	4	5	6	7
Dates	84-87	87-90	90-94	94-98	98-02	02-06	07-
B€	3.8	5.4	6.3	13.0	15.0	16.3	39.0*



* 5-year basis

The first Five Year Assessment (5YA) of the period 1992-6[30] involved a new approach to evaluation. Eighteen SP panels (plus one for the JRC) produced evaluations of various parts of the FP, largely based on data made available by the Commission supplemented with interviews and a degree of support from consultants, who prepared background reports. Much of the resulting information had more the character of monitoring than evaluation, in the sense that it could say little about outcomes. As a result, the overall assessment could only say that the SPs appeared to be doing the right things and to echo the traditional complaints about bureaucracy that we associate with every evaluation of the FP. The panel declined to go into the level of detail provided to it, and focused its efforts on making the policy judgement that the FP should shift its focus to become more coherently European and less the sum of individual Member States' needs and desires. This would involve delegating more power over the FP's design to the Commission, whose ideas for FP5 it largely endorsed.

The second 5YA[31] was supported by a similar structure of specific panels and similarly focused its attention on supporting the Commission's ideas for developing the next Framework (FP6 in this case) rather than evaluating the outcomes of the activities it examined. For the third[32] 5YA, the Commission dispensed with the supporting panels (though there was a separate panel evaluation of the IST Programme). Four studies[33] and four analyses by independent experts were commissioned to provide additional inputs to the 5YA panel. These included a meta-

[30] Etienne Davignon et al, *5-Year Assessment of the European Community RTD Framework Programmes*, COM(97)151 final, Brussels: European Commission, 1997

[31] Joan Majó et al, *Five-Year Assessment of the European Union Research and Technological Development Programmes, 1995-1999*, Brussels: DG Research, 2000

[32] Erkki Ormala et al, *Five Year Assessment of the European Union Research Framework Programmes, 1999–2003*, Brussels: European Commission, DG Research, 2004

[33] The specific studies that were implemented to provide input for the Five-Year Assessment (1999-2003) were as follows: a survey-based impact evaluation of Framework Programmes 3 and 4; a similar impact evaluation of Framework Programme 5; a bibliometric study of scientific publishing resulting from Framework Programmes 4 and 5; a study of High Impact Research Activities under Framework Programmes 4 and 5

evaluation of existing FP-relevant work[34]. This was the first time that an FP evaluation had significant numbers of SP- and national-level impact evaluations at its disposal as well as an FP-wide participant survey and studies of specific instruments. Nonetheless, the panel was able to say surprisingly little about outcomes, essentially because the short-term focus of the supporting work provides little evidence about these.

Changes in legislation required that whole FPs be evaluated from FP6 onwards – in fact, given the length of FP7 (7 years) it additionally was required to have an evaluation at mid term. The FP6 evaluation benefited from a large number of externally performed evaluations, not only of individual themes within the FP but also of cross-cutting issues such as the use of new funding instruments, participation by leading researchers, gender, changes in networking behaviour compared with FP5 and also from a growing number of national FP impact studies. It was therefore able to make many more substantial and evidence-based judgements about performance than previous evaluations, in addition to making recommendations for the future policy agenda. As before, however, the short-term focus of all but one of the available studies meant that the overall evaluation had similarly to be focused on the short term.

3.2 What the evaluation record tells us about Framework Programme impacts

Before we look at the longer-tern impacts of the Framework Programme, we here summarise the main elements of what is already known from the existing evaluation record. That record provides information about who participates in the FP, how they work in the Programmes, a little about behavioural changes resulting from participation and some clues about outputs, outcomes and impacts.

In terms of **who participates**, meta-evaluations in 2005 and 2009 suggested that the Framework funded good quality work, in which universities and research institutes played a majority and increasing role. There was scope for greater industrial participation, which could be desirable in order to reach the Barcelona goal of spending 3% of Europe’s GDP on R&D. Studies of the appraisal process[35] and bibliometric studies of FP participants show that winning an FP project is at least as demanding of quality as winning one at national level and that many of the best European researchers participate. However, there is no evidence about whether FP participation **causes** improved research quality or whether at the wider level the FP lifts the quality of research-performing groups, organisations, regions, countries or clusters. FP6 projects have led to increased co-publication activity between project partners[36]; these co-publications have a significantly higher impact (as measured by citation performance) on the scientific field than the world-average (up to twice as great); but it is already well known that international co-publications have on average higher quality than others, so we still miss the causal link here.

The Innovation Impact study[37] makes innovative use of the Community Innovation Survey (CIS) to complement survey and interview-based data on participation in FP5-6 to explore links between the FPs and industrial innovation. It found that compared with the average for their sector, industrial participants tended to be more R&D-intensive, better networked, more orientated to international markets and to patent more. Like many other studies, this one is a reminder that the FP is largely a ‘pre-competitive’ programme, in the original sense of focusing on things about which companies find it unhelpful to compete. Their participations involve less

---

[34] Erik Arnold, *What the Evaluation Record tells us about Framework Programme Performance*, Brussels: European Commission, DG Research, 2005

35 Royal Swedish Academies of Sciences and Engineering, *Qualitative Aspects of Swedish Participation in EU Research Programmes*, Stockholm: Dokumenta report No 66, 1999

[36] AVEDAS AG, NetPact: *Structuring Effects of Community Research – The Impact of the Framework Programme on RTD on Network Formation 2009*, p. 16

[37] Wolfgang Polt, Nick Vonortas and Robbert Fisher, *Innovation Impact, Final report to the European Commission*, Brussels: DG Research, 2008

commercial risk but a longer R&D horizon, more interest in non-core technologies and in exploration of new technological opportunities than in-house projects. In most cases, the FP participation is connected to a larger 'real project'.

In general, it is argued that strong FP participation is possible for those with national strengths on which to build, and that the FP is therefore not generally an appropriate instrument for capacity building in areas where European capabilities are already high. The Quantum Optics case in this study shows, however, that the FP can be used to build common capacity where European capacity starts at a low level. In the past, there have been other capacity-building examples such as the strengthening of computing research capacity in Ireland and Greece during the 1980s and 1990s. Certain fields ignored at the national level have been able to grow in Sweden because of FP support[38]. FP funding appears to have been instrumental in the development of research capacity in Irish universities during the 1990s[39] but to have become much less important following the great increase in national research funding from the start of the 2000s[40].

A study of the research track-record of a sample of lead scientists participating in FP6 projects[41] (as measured by the number of citations their publications receive) demonstrates that these researchers consistently outperform their counterparts publishing in the same field, regardless of factors such as discipline or country. A study[42] of publishing by researchers at five Swedish universities found that FP participants were more successful than non-participants in terms of both citation rates and number of collaborations, already before participating in EU-financed projects. This suggests that one pre-requisite for being successful when applying for EU-funding is already to be an established researcher. Another conclusion is that the general trend towards an increased internationalisation of science has the effect that the differences between participants and non-participants have decreased over time. The traditional effort of the Framework Programme to increase networking in Europe seems to be hitting diminishing marginal returns.

In terms of **how they work** in the Framework Programme, the record shows that while a large number of organisations – especially smaller companies – have a brief flirtation with the FP through one or two participations and then disappear from the record, Framework participation is led by a 'core' of major beneficiaries, who sit at the heart of multiple European RTD networks[43]. Networks evolve relatively slowly over time, with new potential members being tried and tested then gradually admitted to the 'club' while others drop out. Economic theory would suggest that transaction costs decline among experienced network partners at the same time as the risks of

---

[38] Erik Arnold, Tomas Åström, Patries Boekholt, Neil Brown, Barbara Good, Rurik Holmberg, Ingeborg Meijer and Geert van der Veen, *Impacts of the Framework Programme in Sweden*, Stockholm: VINNOVA, 2008

[39] Ken Guy, Jane Tebbutt and James Stroyan, *The Fourth Framework Programme in Ireland: An Evaluation of the Operation and Impacts in Ireland of the EU's Fourth Framework Programme for Research and Development*, report to Forfás by Technopolis, Dublin: Forfás, 2000

[40] Erik Arnold and James Stroyan, *Evaluation of Framework Programme 6 in Ireland*, Dublin: Forfås, 2009

[41] Technopolis, *Bibliometric Profiling of Framework Programme Participants*, Paris: 2009

[42] Johan Fröberg and Staffan Karlsson, *Possible effects of Swedish participation in EU frame programmes 3-6 on bibliometric measures*, Appendix J in Erik Arnold, Tomas Åström, Patries Boekholt, Neil Brown, Barbara Good, Rurik Holmberg, Ingeborg Meijer and Geert van der Veen, *Impacts of the Framework Programme in Sweden*, Stockholm: VINNOVA, 2008

[43] Terttu Luukkonen, Sasu Kalikka, Pirjo Niskanen and Riika Eela, *Finnish Participation in the Fourth Framework Programme*, VTT Technology Studies report 1999/4, Helsinki: TEKES, 1999; Paul Simmonds, James Stroyan, John Clark and Ben Thuriaux, *The Impact of the Framework Programmes in the UK*, London: Office of Science and Technology, 2004; Idea Consult, *Does Europe Change R&D Behaviour? Assessing the Behavioural Additionality of the 6th Framework Programme*

core rigidities and competency traps[44] rises. The creation of such networks was an important early achievement of the FP; this 'nodal' role of key organisations suggests a significant structuring effect – which, however, has not yet been explored outside the FP context, to see whether it is limited only to EC-funded collaboration. Indeed, while the evaluation record provides observations about networking patterns at a few points in time, there is no systematic, micro-level evidence that describes how networks develop and evolve; our interpretation of the available network analyses is essentially based on anecdote.

It seems likely that different network sizes and configurations are useful for different purposes. There is (weak) evidence that small networks are more productive of traditional research outputs (especially publications) than large ones. Social Network Analyses to date describe the network configurations of FP projects and programmes. They show that important R&D-performing organisations are also important nodes in the FP and that they are becoming increasingly dominant. Some static comparisons between network shape and performance are possible, and show for example that being an important hub correlates with having a high propensity to patent[45] but the static nature of the analysis means the direction of causality (if any) is not clear. Often, network analysts are able to confirm that many FP networks have structural characteristics that should in principle enable them to perform certain roles well but are unable to relate these observations to evidence about actual performance.

Building cross-border networking has been an important impact from FP1 on[46] but in FP6 the networks became larger, apparently driven by the use of larger-scale funding instruments. Both interview evidence[47] and subsequent studies[48] have indicated that using bigger instruments does not necessarily increase the amount of collaboration among people who now appear to belong to the same network. Indeed an FP-wide bibliometric analysis found a higher partner co-publication share for smaller teams (maximum 5 members) as well as a stronger increase in partner co-publication share over time[49]. But to the extent that networks have purposes other than producing scientific papers, there are likely to be a range of costs and benefits of alternative network configurations, for example in relation to building supply chains, influencing standards and regulation, coordinating research around a road map etc that is not captured by studies narrowly focused on publication.

In view of the difficulties in measuring the impact of the Framework Programme on commercialisable innovations downstream, an FP-wide study[50] attempted to measure the **impact of programme funding on research behaviour** and strategy. The study aimed to discover whether funding changed the scope, the scale and the speed of the project; whether it changed the nature of the research undertaken; and whether R&D processes have been

---

[44] AVEDAS AG, NetPact: *Structuring Effects of Community Research – The Impact of the Framework Programme on RTD on Network Formation 2009*

[45] Franco Malerba, Nicholas Vonortas, Stefano Breschi and Lorenzo Cassi, *Evaluation of Progress towards a European Research Area for Information Society Technologies*, CESPRI, University Bocconi, 2006

[46] Philippe Laredo, *Structural effects of EC RTD Programmes*, Scientometrics 1995, 34(3), 437-87

[47] For example in Erik Arnold, Tomas Åström, Patries Boekholt, Neil Brown, Barbara Good, Rurik Holmberg, Ingeborg Meijer and Geert van der Veen, *Impacts of the Framework Programme in Sweden*, Stockholm: VINNOVA, 2008; Erik Arnold, Sylvia Schwaag-Serger, Neil Brown and Sophie Bussillet, *Evaluation of Chinese Participation in the EU Framework Programme*, Brighton: Technopolis, 2008

[48] AVEDAS AG, NetPact: *Structuring Effects of Community Research – The Impact of the Framework Programme on RTD on Network Formation 2009*

[49] AVEDAS AG, NetPact: *Structuring Effects of Community Research – The Impact of the Framework Programme on RTD on Network Formation 2009*, p. 18

[50] IDEA Consult, *Does Europe Change R&D Behaviour? Assessing the behavioural additionality of the Sixth Framework Programme*, Brussels: IDEA Consult, 2009

formalised or there have been durable changes in the capability of organisations to manage research. The study found limited evidence for such behavioural changes, particularly amongst the established R&D performers who make up the bulk of FP participants. Strategic or behavioural changes were more evident in small or start-up companies or public research institutions in Candidate Countries for example. Overall, participants reported moderate effects on the time focus, the financial scale and the scope of the research projects. Such effects are lower than those found in national or regional funding programmes, which again reflects the fact that successful FP applicants typically have a strong track-record in attracting funding and that the assembled research consortia build on core long-standing partnerships.

A recent study of behavioural additionality (learning) in the FP[51] notes that at the overall level companies have become more willing to engage in network R&D in recent years. Comparison between accepted and rejected projects found that accepted ones were less risky than rejected ones (in the eyes of the applicants). Big companies were less likely than small ones to abandon a project because it has been rejected by the FP, suggesting either a degree of free riding or that those with a portfolio of projects can afford to pursue much of the portfolio, provided that at least some of the projects are funded. It would be possible to argue that, since money is fungible, it may not actually matter which the funded projects are.

In terms of **outputs outcomes and impacts**, there is, clear evidence that the FP work can influence regulation and practice in new areas where norms are emerging, such as renewable energy or (in the past) new telecommunications standards, such as those emerging from the ACTs programmes FRAMES project and the UMTS multiple access air interface[52].

A consistent finding in Framework evaluations is that projects primarily produce knowledge and networks, strengthening European-level human capital and RTD capabilities across borders. A survey of FP5 participants made a distinction between attaining the respondents' goals (Figure 13) as opposed to those of their organisations but found little difference. This result persists to the present day. Where participants enter projects with a goal of developing products and processes, they tend to be successful in doing so – but only a minority (perhaps one third) has such objectives.

An almost universal finding in the evaluations is that firms believe FP participation has improved their **competitivity**. For example, in the FP-level survey[53] of FP3-4, 26% of industrial participants said their turnover increased as a result of their project; 60% reported increased 'competitiveness'. 'Innovation capability' rather than innovation was the main effect of FP participation by Norwegian companies.[54] In Ireland, the FP was credited[55] with allowing "Irish industry to raise technological capabilities on a broad front, with improved competitiveness a long-term rather than a short-tem consequence."

Some project-level evaluations use 'chain-link' logic to try to follow effects from projects to their outputs and their 'downstream' economic effects. This typically involves trying to assess the effects of projects on the cash flows of participants and the trying to value other effects, such as

---

[51] IDEA Consult, *Does Europe Change R&D Behaviour? Assessing the behavioural additionality of the Sixth Framework Programme*, Brussels: IDEA Consult, 2009

[52] Terttu Luukkonen, *Technology and market orientation in company participation in the EU Framework Programme*, Research Policy, Vol 31, 2002, pp437-455

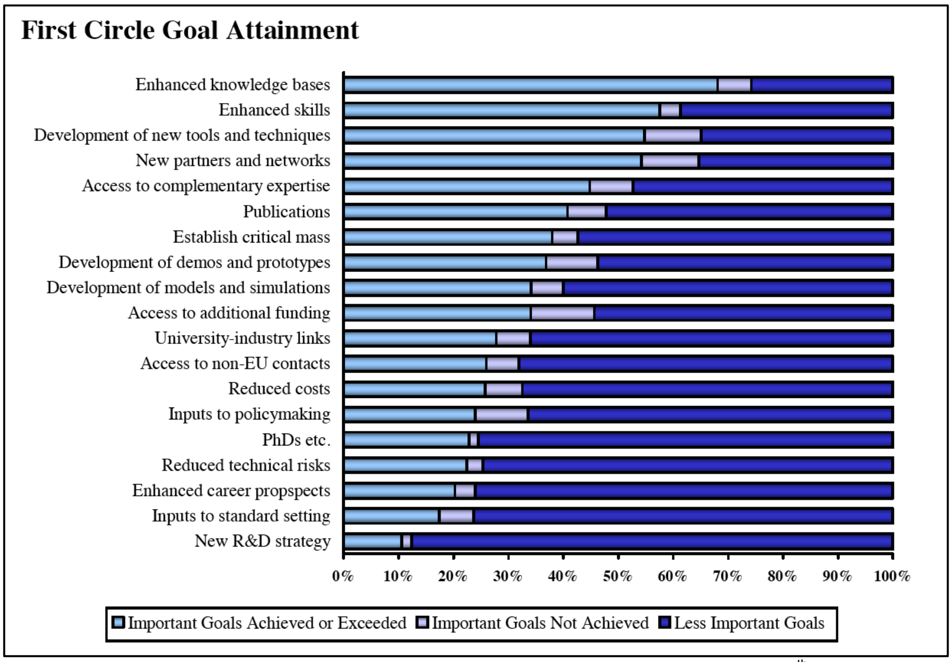
[53] Decisia, HLP Developpement and Euroquality, *Assessment of the Impact of the Actions completed under the 3rd and 4th Community Framework Programmes for Research*, Levallois- Perret: Decisia 2004

[54] NIFU, STEP and Technopolis, *Evaluation of Norway's Participation in the EU's 5th Framework Programme*, Oslo: STEP, 2004

[55] Ken Guy, Jane Tebbutt and James Stroyan, *The Fourth Framework Programme in Ireland: An Evaluation of the Operation and Impacts in Ireland of the EU's Fourth Framework Programme for Research and Development*, report to Forfás by Technopolis, Dublin: Forfás, 2000

estimating the value of networking induced by the projects. As a guide to the absolute size of effects, therefore, such approaches can be misleading[56]. However, when such methods are consistently used across different groups of beneficiaries, they do highlight the importance of 'leverage': the ratio of economic gains to inputs is higher for big companies (and for big countries) than for small ones. Unsurprisingly, the claimed effects of projects on the turnover of large companies are bigger in absolute terms than that on small companies.[57] The third BRITE-EURAM impact study found that while, on average, €1 invested by the EC in R&D support triggered €6.6 in "economic gain,"[58] the gain for large companies was €8.7. A later study associated lower economic returns with CRAFT projects than with others involving larger actors.[59] This finding sits awkwardly with the EC policy desire to integrate SMEs into the Framework Programmes.

Figure 13 Participant Views on Goal Attainment, FP5



Source: Atlantis, Assessment of the Impact of the Actions Completed Under the 5th Community Research Framework Programme – Survey, Brussels, DG Research, European Commission, 2005

There has been increasing effort to count the immediate outputs of FP programmes, for example in terms of patent applications, scientific journal articles, numbers of new participants not previously engaged in RTD activities. For example, NNE produced 400 patent applications, over 800 scientific journal articles, and attracted 1600 new actors not previously engaged in RTD activities. 30% of projects claimed to have made a technological breakthrough while 60%

---

[56] For a detailed critique, see Patries Boekholt, Maureen Lankhuizen, Erik Arnold, John Clark, Jari Kuusisto, Bas de Laat, Paul Simmonds, Susan Cozzens, Gordon Kingsley and Ron Johnston, *An international review of methods to measure relative effectiveness of technology policy instruments*, Report by Technopolis to the Ministry of Economic Affairs, The Hague, Min EZ, 2001

[57] European Commission, *BRITE-EURAM, Making a Lasting Impression on Europe*, Brussels: EC, 2002

[58] This concept is problematic and tends to involve multiple counting of benefits. For a discussion, see Patries Boekholt et al.,2001

[59] GOPA Consortium, *Impact Assessment of Finished Projects of the EC Research Programmes in the Fields Covered by the Present Growth Programme*, Bad Homburg: GOPA, 2003; GOPA Consortium, *Evaluation of Finished Projects in the Fields Covered by the Pesent Growth Programme*, Bad Homburg: GOPA, 2003

resulted in significant technical advances.[60] These kinds of indicator are useful as a 'pulse check': they show that the patient is alive and that some of the right kinds of processes are going on. However, in the absence of meaningful benchmarks or coherent ways of estimating socio-economic effects on the basis of these indicators they tell us little about overall performance, and are probably more useful for monitoring than evaluation purposes.

Thus, while there is quite a rich understanding available of many aspects of the programme, what we can see about outputs, outcomes and impacts is a little limited by the short term perspective of evaluation. The relatively short-term perspective affects the choice of evaluation methods.

3.3 Methods in Framework Programme Evaluation

At the level of individual studies, the methods used in FP evaluation have evolved over the period since FP1. During the early years of the Framework, the EC continued its previous practice of expert group based evaluation, with the group often being supported by a consultant to conduct a questionnaire and/or draft the report. The panel work was based on visits and study of programme and project documentation. Evaluations from this period tend to give detailed advice on scientific and technological relevance, quality and any needed changes in technical direction but pay little attention to the effects of the programmes.

In the late 1980s, the EC funded the SPEAR/MONITOR networks of R&D policymakers and evaluators, which were instrumental in creating today's EU R&D evaluation community and which acted as fora for discussing evaluation methods. We understand this period in the late 1980s and early 1990s as one when a number of research techniques used in research on research and innovation were tested for their applicability in evaluating R&D programmes. A questionnaire-based approach innovated in the evaluation of the UK Alvey Programme[61] spread through these networks to become a mainstay of the evaluation of pre-competitive, collaborative R&D in the FP and in many cases also at national level. One SPEAR/MONITOR study[62] explored the utility of patents as indicators in FP evaluation, concluding that their relevance was limited to testing programme assumptions and assessing the extent to which programmes are basic or applied in nature but that they helped little with evaluating whether programmes reach goals. A SPEAR/MONIOTOR conference on quantitative methods for evaluating FP impacts[63] in 1992 this turned out to have little impact on evaluation practice – essentially because the kind of quantitative economic methods discussed are inappropriate at the level of programme evaluation.

Quantified economic impact analysis has played only a small role in FP evaluation. For a period during the 1990s some evaluative studies were done using the 'Beta Method'. While the authors are careful to stress that this is not a conventional cost/benefit analysis, the Beta method involves estimating the ratio between the subsidy provided to a project and the economic value it creates. This value comprises the direct effects on value-added in the firm (for example as a result of realised and anticipated sales of new products enable by the subsidised R&D project) plus a number of indirect effects such as the acquisition of product and process technologies by

---

[60] GOPA Consortium, *Impact Assessment of Finished Projects of the EC Research Programmes in the Fields Covered by the Present Growth Programme*, Bad Homburg: GOPA, 2003; GOPA Consortium, *Evaluation of Finished Projects in the Fields Covered by the Present Growth Programme*, Bad Homburg: GOPA, 2003

[61] Ken Guy, Luke Georghiou, Paul Quintas, Hugh Cameron, Michael Hobday and Tim Ray, *Evaluation of the Alvey Programme for Advanced Information Technology*, London: HMSO, 1991

[62] Fraunhofer-ISI, *Patents as Indicators of the Utility of European Community R&D Programmes*, Research Evaluation report, EUR 13661 EN, Luxembourg: Commission of the European Communities, 1991

[63] Henri Capron (ed), *Proceedings of the Workshop on Quantitative Evaluation of the Impact of R&D Programmes*, 23-24 January 1992, Luxembourg: Commission of the European Communities, 1992

the firm, reputational effects, growth in the size of the firm's networks and so on. These values are estimated in discussion between an interviewer and a representative of the firm. The method has been used in the BRITE/EURAM and CRAFT programmes, which were closer to market than most of the FP and had explicit aims to contribute to product and process developments. BETA reported that the method could not be applied in EURAM, the predecessor to BRITE, which was a little further from market[64]. The method suffers major weaknesses. In particular, the principles of attribution are unclear and different types of benefits overlap, so that their extent is only limited by the imagination of the interviewers in defining categories to count. It cannot handle situations where multiple projects contribute to benefits and the same benefits can be counted in different evaluations, with the paradoxical result that aggregate benefits increase as a function of the number of evaluations undertaken. It also misses the central point that, in trying to describe the private returns to subsidy, it is measuring precisely the wrong part of the benefits. What matters in the societal calculation are the **societal** returns such as spillovers, not the private returns to beneficiaries. The method appears not to have been used in the FP after about 2000.

In the recent past, quantitative economic analysis has reappeared in the form of macroeconomic models, used **prospectively** at the level of the FP as a whole to estimate anticipated economic and employment effects[65].

Figure 14 analyses the methods used in FP evaluations since FP4. Our coverage of studies is not exhaustive, but we believe we have captured the majority undertaken in the period. Expert panels frequently do evaluations; less frequently do they involve more traditional scientific peer review (where the experts are actually scientifically expert in the field of the programme being evaluated). There is a trend over time away from panels and towards (larger-scale) professionally conducted evaluations and studies. Methods are strongly focused on participant surveys, interviews and analysis of EC-internal databases (notably of FP participants) and documents. These are sometimes supplemented by case studies. Control groups are rarely used. Seldom are FP databases matched to external databases and surveys, such as the Community Innovation Survey or data about regional production, value added or intellectual capital. As the Figure indicates, there has been some broadening of techniques from about 2005, when Social Network Analysis (SNA) and bibliometrics began to be used.

This use of methods is driven in large part by the Commission's evaluation culture and rules, which closely tie evaluation to the programming cycle. Objects of interest are: forthcoming programmes during their planning stage; ongoing programmes at mid-term; and recently completed or soon-to-be-completed programmes at end of term. This impedes analysis of aspects of performance that involve time lags or that are indirect and therefore invisible to participants. Evaluators therefore use techniques that pick up more or less current events and structures: participants' goals and how well they believe they are being realised; the composition of programme and project networks; feedback from participants on programme administration; advice from experts about the technical focus of programmes and their implementation. Because evaluation is done early during the period when programme impacts should occur, evaluators are forced to rely extensively on the opinions of those involved about effects – hence the focus on surveys and interviews. If the periods in scope to evaluations were longer, there would be more opportunity to use techniques that provide harder evidence of effects. The slowly growing use of SNA and bibliometric methods provides different perspectives on the FP, but the short scope of the evaluations means that they can only be used for static analysis. They tell us, for example, that participants are highly networked, that key organisations act as principal nodes

---

[64] BETA, *Economic Effects of the BRITE/EURAM Programmes in European Industry*, Research Evaluation report EUR 15171 EN, Luxembourg: Office for Official Publications of the European Communities, 1993,

[65] For example, Arnaud Fougeyrollas, Pierre Haddad, Boris le Hir, Pierre le Mouêl and Paul Zagamé, DEMETER Project. *R&D Effort During the Crisis and Beyond: Some Insights Provided by the Demeter Model*, report to DG Research, 20/05/2010

in these networks and that projects involve scientists whose publication performance is high. Repeated static analysis shows that FP6 networks are bigger than those in FP5. But, lacking a longer time scale, we cannot tell much about the dynamics of the networks, or whether the involvement of well-published researchers changes over time; we can sometimes correlate but rarely establish causality.

Figure 14 Methods Used in FP Evaluations, FP4 Onwards (See Appendix A for key to studies)

Year	Study	Panel Review	Participant Surveys	Interviews	EC data / document review	Case studies	Other
1999	FP4 Participation Finland				X		
1999	FP4 Quality of Swedish participation		X	X			Non-EC DBs
2000	FP4 Impact NNE	Experts	X	X	X		
2000	FP4 Impact Denmark		+Control	X	X		
2000	FP4 Impact Ireland		X	X	X		
2001	FP5 Impact Gender IST			X	X		
2001	FP4 Impact Austria		+Control	X	X		
2001	FP4 Impact Germany		X	X	X		
2002	FP4 Impact BioMed2	Peers	X		X		
2002	FP4 Impact BRITE-EURAM	Experts	X		X		
2003	FP4 Impact Growth	Experts	X	X	X		
2003	FP4 Impact International RTD Co-operation	Experts	X	X	X		
2003	FP4 Impact Joule/Thermie/NNE	Experts	X	X	X		
2003	FP4 Impact Telematics (TAP-ASSESS)	Experts	X		X		
2003	FP5 Mid-term QoLife Action 6 (Ageing)	Peers		X	X		
2003	FP5 Impact of dissemination in Environment	Peers			X		
2003	FP5 Socio-economic dimension			X	X		
2004	FP3/4 Impact		X				
2004	FP5 Impact		X				
2004	FP5 Impact Genomics	Peers	X	X	X		
2004	FP5 Impact Norway		X	X	X		
2004	FP5 Impact Finland Universities		X	X			
2004	FP4-6 Impact UK		X	X	X		
2005	Marimon Report		X	X	X		
2005	Social and Environmental Impacts						Meta-Evaluation
2005	ERA-Nets' (Network Analysis)						SNA
2005	Marie Curie		X	X	X		
2005	International R&D Cooperation		X	X	X		

Year	Study	Panel Review	Participant Surveys	Interviews	EC data / document review	Case studies	Other
2005	FP6 - TP3 Interim Evaluation	Experts					
2005	WING (10 studies)		X	X	X		Technology/market analysis
2006	ERANET evaluation	Experts		X	X		
2006	EVIMP			X	X	X	
2006	Progress towards ERA in IST			X			SNA
2006	Networks of Innovation in Infosoc			X			SNA
2007	COST FP6	Experts		X	X		
2007	EDCTP Evaluation	Experts		X			
2007	Integration of science issues						Meta-Evaluation
2007	Impact assessment SME R&D Schemes		X			X	
2007	Effectiveness of IST-RTD Networks in the IS				X		SNA, Non-EC DBs, Econometrics, Intellectual capital analysis
2008	INCO in FP6		X		X		
2008	ETP Evaluation		X	X	X	X	
2008	Evaluation of innovation and space	Peers	X	X	X		
2008	Evaluation of Fusion Research			X	X		
2008	Evaluation of JRC	Experts			X		
2008	Evaluation Global Change & Ecosystems	Peers	X	X	X		Bibliometrics
2008	Infosoc (Aho)	Experts		X	X		
2008	Energy Tech Transfer			X	X		Comparative study of national practices
2008	Innovation Impact		X			X	Non-EC DBs, Econometrics
2009	Behavioural Additionality		+Control	X			Literature review
2009	FP6 New Member States			X	X		
2009	FP6 New Instruments		X	X		X	Literature review
2009	FP6 International Standing		+Control	X	X		
2009	FP6 Bibliometric study						Bibliometrics
2009	FP6 Participation Survey		+Control				
2009	NetPact						SNA, Bibliometrics
2009	FP Impact Studies DK, NO, EI, NL, China		X	X	X		
2010	FP Impact AT		Control	X	X	X	

Notes SNA = Social Network Analysis, Non-EC DBs = use of databases other then those describing Framework participations; References to these evaluation studies are reproduced in Appendix 1

4 A SCIENTOMETRIC APPROACH TO IMPACTS

This section briefly summarises the scientometric effort in the project and how we used its results. The appendix volume contains more extensive reports.

A key feature of this study has been the attempt to integrate scientometric approaches (including Social Network Analysis – SNA) with more traditional ways to track effects through the study of documents, analysing FP participations and other databases and interviews. The aims of the scientometric work were to

- Use co-word analysis of project titles and abstracts to delve beneath the shifting sub-programme names and structures of the FP in order to find areas of thematic continuity, which seemed to be promising places to look for long-term impacts. We made the actual choice of fields for case study based on a mixture of scientometric and other criteria
- Use bibliometric techniques to identify areas within some of these where there might be scientific breakthroughs. Typically, research in or near an area of breakthrough is very highly cited, so citation patterns offer clues about breakthroughs
- Understand the influence of FP funding on individual and collective publication performance in these same areas

This section briefly summarises the scientometric work, while the appendix volume contains more extensive reports.

4.1 Using co-word analysis to identify potential impact clusters

Our analysis showed that there is considerable thematic continuity among successive Framework Programmes despite changes in the way themes are described and classified in official programme descriptions (Figure 4). The aim of the co-word analysis was to avoid depending on the somewhat unstable categories used in successive FPs to identify six thematic clusters as the subjects for possible case study work. Overall, we analysed the titles and project abstracts[66] of 31,614 projects across FP4 and FP5, harmonised their use of terminology and identified 3,028 terms that could be used for analysis. Of these terms, 450 were unique, so we could cluster projects around the other 2,578. At the overall level, 5 major clusters of projects emerged[67]. These, of course, were too aggregated to enable case study work so our next step was to dig down to identify 22 sub-fields. We based this analysis on 14,469 projects (46% of the total) because the remainder did not contain enough information to enable us to classify them to both a field and a sub-field. We made the final choice of six case study areas largely from the sub-field list, informed by literature review and discussions with EC officials and other stakeholders, since we needed to find case study topics that were both tractable and that represented a range of different types of experience and impacts. That would allow us to explore impact mechanisms as widely as possible.

4.2 Anticipated breakthroughs

The next stage of analysis was to delve into the case study fields and to try to identify flurries of activity through co-occurrence of words and phrases in the project titles and abstracts. These are typically associated with scientific breakthroughs when observed in the scientific literature. In any kind of research, it may not be clear in advance what a longer-term development or discovery may be, though shorter-term ones tend to be referenced in titles or abstracts. In

---

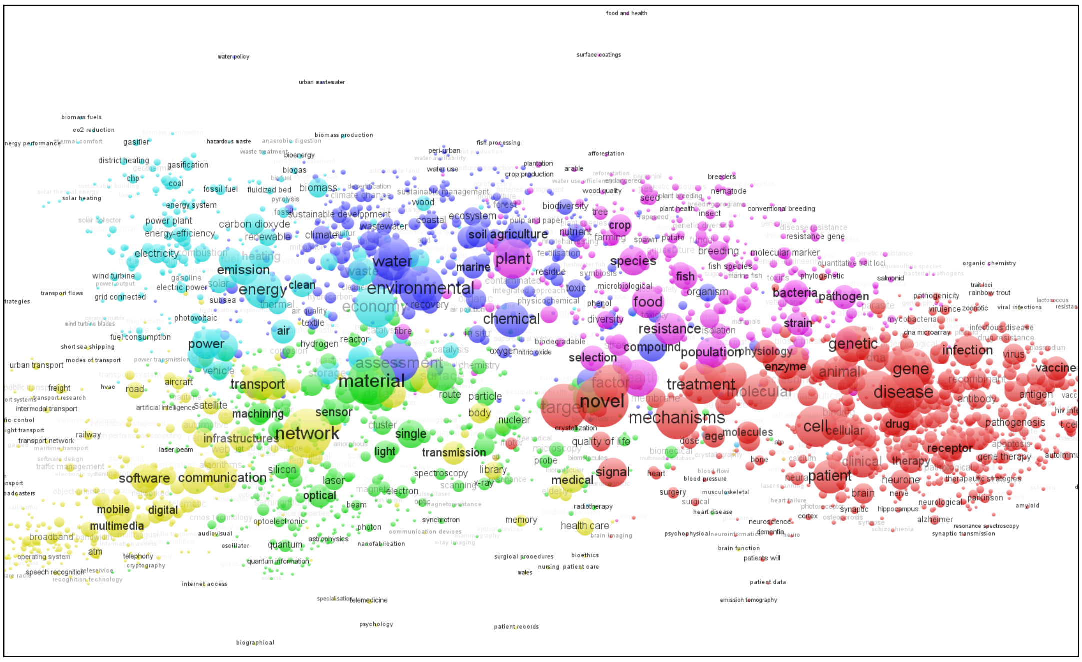
[66] Abstracts were not available for FP4 projects, so we used the projects' objectives instead

[67] Health sciences; biology and environment sciences; energy, ICT and physics

project proposals and scientific papers, researchers identify anticipated breakthroughs in order to attract funding but also to reference related research. Individual breakthroughs may still not be predictable from the literature but the research system enters a state where it is ready to absorb a breakthrough that may come from one of several different lines of enquiry.

We explored the five major project clusters identified in the initial co-word analysis to see whether the project titles and abstracts enabled identification of anticipated breakthroughs.

Figure 15 Co-word map of scientific terms in FP4-5 project titles and abstracts



Source: Produced by Science-Metrix in Vosviewer, using EC data. See separate volume for further details and diagrams

ICT has a distinct cluster around network communications, architecture and mobile telecommunications – all areas of known focus and impact of the FP. There is a second cluster around multimedia, containing topics such as language, database development and knowledge dissemination. These reflect the fact that the focus of FP ICT was shifting from hardware towards software and applications in the period of FP4-5. (Earlier, it was much more hardware focused, especially in the ESPRIT and RACE programmes.) Correspondingly, the anticipated breakthrough analysis shows growing importance for 'user access' – but this is a term that does not map to specific technologies or markets but applies to many, so it is difficult to connect to the case study work.

Health/life sciences contains four major clusters: cell research, which falls close to signal receptors and the more social function of 'regulation'; genetics, especially associated with protein research rather than DNA; virology and immunology, linked to work on vaccines and infectious diseases; and a number of treatment-related clusters. The most important areas of potential breakthrough centre on gene research (especially related to gene expression, methodology, gene identification, disease and vaccines), and plant genetics.

Biology and environmental sciences contains sub-fields such as: agro-forestry and agriculture; climate change and atmospheric sciences; ecology and conservation biology; environmental sciences and sustainable development; and microbiology and food sciences. The co-word clusters split fairly evenly between environmental sciences and plant biology. Fish and species research related to biodiversity is a small cluster that grows through the period of analysis, as is climate change. We can identify activity suggestive of potential breakthroughs in: forest resource management; climate variability and diversity; and breeding crops resistant to climate change.

The **physics, materials and quantum science** cluster sub-fields include astrophysics, astronomy, and high energy and particle physics, as well as materials; quantum physics; imaging; and parts of microelectronics. There is a dominant focus on materials science with associated research in machining, coatings, silicon, and plastic. Optical lasers appear on the landscape in closely related sub-fields, which are also related to semiconductor and nanostructure research. A cluster that could be termed 'photonics' appears around 'light' and 'detection' with satellite terms of 'particle,' 'radiation' and 'x-ray.' We looked separately at anticipated breakthroughs in physics and in materials. There were clearly emerging activities that could be precursors of breakthroughs around electron beam welding, solar energy (especially aspects of photovoltaics) and in the linked areas of quantum physics, quantum theory and information processing. The reach of quantum physics into related clusters suggested developments of real importance were expected here – and is confirmed in the QIPC case study below. Materials science, on the other hand, produced only a number of diffuse and small clusters of activity that could relate to breakthroughs, in: ceramic fibres; low-cost plastic packaging; automotive and food applications of new materials.

Energy contains the sub-fields: fossil fuels, fuel cells, and biofuels; renewable energies; and turbines (wind). Biomass, waste, and gasification form a clear cluster on the landscape close to 'waste.' There are two large clusters. One has several sub-clusters focusing on power generation, heating, and buildings, with a smaller focus on solar energy and renewables. The other has a focus on emissions, the search for clean fuel, and better uses of gas. Anticipated breakthroughs cluster around clean engine technology for automotive applications, partially linked to urban transport. There is a separate area of anticipated breakthrough in wind turbines.

4.3 Bibliometric Approach to Effects of the Framework on Networks and Breakthroughs[68]

We used a bibliometric approach to try to understand influences of the FP on the participants' roles in research networks and in developments within four of the six case study areas chosen. (Neither the Automotive nor the Manufutures case is tractable to such analysis.)

If FP participation increases research-performing institutions' capabilities and competitiveness, then we would expect this to be visible in their network relationships with other similar institutions. Both within Europe and at the global level, we would expect them to acquire more partners, to produce more papers with their partners and to become more central[69] within cooperation networks. Centrality is a measure of the organisation's power relationships relative to other members of the network and the ability of that institution to access important information emerging anywhere within the knowledge system. We used three samples to test this idea in each of the four case study areas.

- The 100 top (ie most-publishing in the period 1996-2009) ERA[70] organisations. A small number of major FP4/5 participants did not appear in the top 100. In addition to looking at the importance of the FP for the top 100, we also analysed a slightly longer list comprising the top 100 plus the additional heavy participants. We refer below to those on this list as the 'selected institutions'
- The 50 top (most-publishing) organisations from the ERA and the 50 top non-ERA (rest of the world) organisations

[68] This work is reported in detail in the Appendix.

[69] There are several different statistical ways to represent centrality – the extent to which one is at the core of a network rather than the periphery. In this study, we used eigenvector centrality, which is less sensitive than other measures to local patterns in the network and therefore less likely to produce misleading information in large networks.

[70] Defined as 35 countries

- At the level of individuals rather than organisations, the 50 top (most-publishing) ERA researchers and the 50 top non-ERA researchers[71]

We used a variety of scientific impact (Average of Relative Citations – ARC; Average of Relative Impact Factors – ARIF) and network (eigenvector centrality) indicators. In order to remove bias from our calculations of network centrality, however, we had to use smaller datasets in comparing ERA and non-ERA organisations. Had we stuck with 50 of each, we would have included a bigger proportion of ERA institutions in the network analysis than there are ERA organisations at the world level. This would have inflated the centrality measure for the ERA organisations. We therefore included in our centrality calculations only those of the top 50 ERA organisations that published at least as much as the poorest-performing non-ERA organisation in the sample.

Separately, we looked at the contribution of the FPs to producing scientific 'breakthroughs', using citation network analysis. This identifies major turning points or 'steps' along the development pathway in each of the focus areas via a main path analysis of the network of citations in the period 1996-2009. The main path is the one through the citation network that has the highest traversal citation weight, which is a measure of the overall scientific impact or merit of the papers it contains. Since scientific papers in which ground breaking discoveries are disclosed usually receive a very large number of citations, the main path is the development 'pathway' that is most likely to contain scientific breakthroughs in the network. This analysis does not 'quantify' the role of the FPs in the production of breakthroughs – other publications not included in the main path will have many citations and will contribute to progress – but it does capture a major source of progress, allowing us to understand the role of the FP in that part of the field. (These detailed analyses are shown in the accompanying volume of case studies.)

We also looked at the top 1% most highly cited papers in the focus areas, which we treat as a proxy for the production of breakthroughs: the more an institution has papers in the top 1%, the more likely it is that it is involved in breakthrough research.

Our analysis confirms that the Framework Programme is involved n many areas of potential breakthrough, including in the areas of Solar PV, QIPC and automotive , which are discussed in our case studies.

4.3.1 Quantum Computing and Information Processing

The FPs have supported most leading research-performing organisations in this field in the 35 'ERA' countries, including those at the core of the research networks who are likely to be among the most powerful research organisations. At the level of individuals, the FP has supported most of the leading researchers in the ERA, whose performance in terms of bibliometric measures of scientific quality is high. The FP has been key in establishing and strengthening this field in Europe.

In the area of quantum computing & information processing, about 24,000 scientific papers were published between 1996 and 2009 at the world level. ERA countries contributed to nearly 41% of these papers. Of the top 100 ERA organisations – selected based on the number of papers they published over this 14-year period – 64% participated in at least one FP4/5 project (Figure 16).

[71] This, however, meant that we had relatively few papers to analyse, so we were unable to obtain meaningful measures of network centrality

Figure 16 Summary of findings for the top (i.e., most-publishing) 100 ERA organisations and the most participating FP organisations in quantum computing & information processing, 1996–2009

	% of ERA organisations who participated in the FP
Within the top 100 ERA organisations for their number of papers	64%
Within selected organisations	66%
Within the top 25 ERA organisations for their ARC*	76%
Within the top 25 ERA organisations for their number of papers in the top 1% most cited papers	88%
Within the top 25 ERA organisations for their centrality in the ERA network*	92%
Within the top 25 ERA organisations for their growth in centrality in the ERA network*	88%

Note: * The results are only valid within the group of selected organisations (108 organisations).
Source: Calculated by Science-Metrix using Scopus

In the ERA, among the selected institutions, the top 25 based on their scientific impact (ARC) include 76% of FP-supported organisations while the proportion of FP-supported organisations within the top 25 for their number of papers within the 1% most cited papers in this area is greater than would be expected (88% versus 68%). However, within the full list of 108 selected institutions, there is not a significant difference between FP-supported and non-FP organisations. This means that the FPs supported most of the leading ERA organisations. They appear in the top 25 and have strong performance, while in the longer list of (108) selected institutions, FP-supported organisations do not differ significantly from those that were not supported. In terms of network centrality, we cannot find evidence that the FPs contributed to improving FP-supported organisations' relative position compared to non-FP ERA organisations. However, they did support most of the players who operate close to the core of the ERA network and those who have increased their centrality the most within that network.

Globally, in terms of their volume of publications in the field, seven of the top 25 organisations in the world are from the ERA, and all of these are FP-supported. Fifteen of the top 25 organisations ranked by scientific impact (ARC) are from the ERA, 80% of them being FP participants,. At the level of the top 101 organisations globally, ERA institutions have marginally higher scientific impact (ARC) and percentage of papers in the most-cited 1% (our proxy for being likely to produce scientific breakthroughs) than non-ERA organisations. ERA institutions tend to have higher than expected network centrality and growth in centrality within the top 25 for each of these indicators.

At the level of individual researchers, 37% of the most-publishing ERA researchers were funded by the FP; 75% of the top 25; and 100% of the top 10. FP-supported ERA researchers have greater network centrality than non-FP supported ones, so the FPs supported most of the leading ERA researchers in terms both of production and network centrality. Looking at the world researcher networks, ERA researchers have much greater network centrality than non-ERA researchers. The quality of ERA participants' output is high: 72% of the top 25 are from the ERA, as against the 50% that would be expected. The scientific impact (ARC) of ERA researchers in the worldwide top 50 is marginally better than that of non-ERA researchers.

Since this was a field that in Europe was initially stimulated and continuously supported by the FP, we can say that establishing and maintaining the European position at the scientific forefront is a major achievement of the programme. The FPs supported most of the leading ERA researchers in the field.

4.3.2 Climate Change and Stratospheric Research

Almost all the top ERA research organisations in this field participated in the Framework Programme, which has enabled the European research community to stay at the front in a fast-moving area of global research. Many of the world's highest-performing researchers are in Europe and most of them have received FP support.

In the area of climate change & stratospheric research, about 115,000 scientific papers were published between 1996 and 2009 at the world level. ERA countries contributed to nearly 44% of these papers. Of the top 100 ERA organisations – selected based on the number of papers they published over this 14-year period – 94% participated in at least one FP4/5 project (Figure 17). The FP therefore involved almost all the significant ERA institutions in the field.

Figure 17 Summary of findings for the top (i.e., most-publishing) 100 ERA organisations and the most participating FP organisations in climate change & stratospheric research, 1996–2009

	% of ERA organisations who participated in the FP
Within the top 100 ERA organisations for their number of papers	94%
Within selected organisations	95%
Within the top 25 ERA organisations for their ARC*	88%
Within the top 25 ERA organisations for their number of papers in the top 1% most cited papers	96%
Within the top 25 ERA organisations for their centrality in the ERA network*	96%
Within the top 25 ERA organisations for their growth in centrality in the ERA network*	92%

Note: * The results are only valid within the group of selected organisations (112 organisations). For example, an organisation outside the top 100 for the number of papers could score a greater ARC than any of the selected organisations. See accompanying Excel databook for detailed statistics.

Source: Calculated by Science-Metrix using Scopus

Within the ERA, among the selected institutions, the FP supported 24 of the top 25, based on their contributions to the top 1% of papers in the field and 23 of the top 25 ranked in order of their growth in network centrality. The fact that almost all the top 100 ERA organisations in this field participated in the FP means it is not possible to compare with non-FP-funded high performers. However, the FP clearly supported the best in the field in the ERA and the importance of these organisations in the field grew during the period examined.

Globally, if we compare the performance of leading ERA organisations with leading non-ERA organisations in the field, it is very similar in terms both of impact factors and share of papers among the top 1% most cited papers worldwide. With the help of the FP (and, of course, other funding sources), the European research community has managed to stay at the front in a fast moving and growing global research field of great societal, political and economic importance. Growing network centrality among leading ERA organisations suggests that their position in the global research community is becoming more important.

At the level of individual researchers, the ERA contains many of the highest-performing individuals in the world. Seven of the top 10 researchers for the size of their scientific production worldwide are from ERA countries and have been supported by the FP. ERA performance among the top 10 researchers is almost as high when measured in terms of scientific impact (ARC) or quality (ARIF) and they have high network centrality within the ERA, suggesting they are key players. If we widen the perspective to the top 25 or top 50 researchers, however, ERA researchers do no better than the non-ERA ones; so the FP and Europe do very well at the highest levels, but the rest of the world does better among those ranked immediately below the top 10.

At the world level, therefore, 56% of the 25 most publishing researchers are from the ERA and 60% of these participated in the FPs. Within the world network, 52% of those who rank among the top 25 for their centrality are from the ERA and nearly half of them participated in the FPs.

Thus, ERA researchers appear to be very well positioned in terms of the size of their scientific production and of their integration within the world network; moreover, about half of these leading ERA researchers are supported by the FPs.

4.3.3 Neurobiotechnology

This field was already well established before the FP became a major funder. The. FP appears to have contributed to maintaining Europe's relative position during a period of considerable growth. Europe's leading research organisations in the field have become more important in research networks. European researchers are productive in terms of the number of papers produced but the volume and quality do not stand out from the world level and the FP has played a more modest role in funding the key researchers than in the other fields considered.

In the area of neurobiotechnology, nearly 190,000 scientific papers were published between 1996 and 2009 at the world level. ERA countries contributed to nearly 42% of these papers. Of the top 100 ERA organisations – selected based on the number of papers they published over this 14-year period – 87% participated in at least one FP4/5 project (Figure 18). The FPs clearly supported most of the organisations that contributed the most to the scientific literature in this area and had the greatest scientific impact (ARC) and quality (ARIF).

Figure 18 Summary of findings for the top (i.e., most-publishing) 100 ERA organisations and the most participating FP organisations in neurobiotechnology, 1996–2009

	% of ERA organisations who participated in the FP
Within the top 100 ERA organisations for their number of papers	87%
Within selected organisations	90%
Within the top 25 ERA organisations for their ARC*	88%
Within the top 25 ERA organisations for their number of papers in the top 1% most cited papers	92%
Within the top 25 ERA organisations for their centrality in the ERA network*	92%
Within the top 25 ERA organisations for their growth in centrality in the ERA network*	88%

Note: * The results are only valid within the group of selected organisations (125 organisations). For example, an organisation outside the top 100 for the number of papers could score a greater ARC than any of the selected organisations.
Source: Calculated by Science-Metrix using Scopus

In the ERA, some 88% of the 25 organisations with the highest network centrality growth in the period were supported by the FP. This is about the same as would be expected considering their proportion within selected institutions for which the indicator could be calculated (90%). Thus, it is difficult to conclude on the impact of the Framework in terms of improving their positions in the wider research community.

Globally, as regards the ERA organisations' standing in the world research community, while the overall scientific impact (ARC) and quality (ARIF) of ERA organisations' publishing are about the same as for non-ERA organisations, at the level of total publications, only 5 of the top 25 institutions are from the ERA. Only 3 ERA organisations make it into the top 25 in terms of scientific impact (ARC) and 6 make it into the top 25 based on their share of the most-cited 1% of papers in the field. There are also slightly fewer ERA organisations (24%) than expected (35%) within the top 25 institutions with the highest centrality within the world network in neurobiotechnology. On the other hand, these institutions appear more frequently (48%) than expected (35%) within the top 25 institutions with the highest centrality growth. So there is a trend towards the top ERA organisations in the field – most of which were supported by the FP – becoming more important in the scientific community over time.

At the level of individual researchers, 25% of ERA's 50 most published authors in the field were supported by the FPs. The presence of FP workers among ERA's top 25 performers (within the selected 50 authors) in terms of scientific impact (ARC), 'quality' (ARIF) or proportion of papers in the 1% most highly cited papers in the field approximately matches their overall presence within the selected groups of the 50 most-publishing ERA researchers. Thus, FP-supported individuals do not stand out among the most-publishing ERA researchers for these aspects of scientific performance. Among the top 10 ERA researchers ranked by network centrality, only the person in 10th place is funded by the FP[72].

At the world level, 56% of the 25 most publishing researchers are from the ERA and 29% of these participated in the FPs. Within the world network (92 researchers), 60% (vs. 46% expected) of those who rank among the top 25 for their centrality are from the ERA and 40% (vs. 29% expected) of these participated in the FPs. In fact, it appears very likely that the centrality of ERA researchers within the world network (composed of 92 researchers) is significantly greater than that of non-ERA researchers; there is only a 12% chance that this conclusion is false (data not shown). Thus, ERA researchers appear to be well positioned at the world level in terms of the size of their scientific production and even more so in terms of their integration within the world network in neurobiotechnology. However, while they have a good presence within the scientific community – and in some cases have made outstanding contributions to science –they did not perform as well internationally for the scientific impact and 'quality' of their papers and for their potential contribution to scientific 'breakthroughs'.

4.3.4 Solar energy

The FP tended to fund a slightly smaller proportion of the top 100 ERA organisations in this field but the ones that were funded occupy more powerful positions in research networks than non-supported ones. More widely, ERA research organisations in this field have increased their network centrality more than non-ERA organisations. Individual ERA researchers perform better than those in the rest of the world in terms of the scientific quality and impact (measured in bibliometric terms).

In the area of solar energy, about 46,000 scientific papers were published between 1996 and 2009 at the world level. ERA countries contributed to nearly 37% of these papers. Of the top 100 ERA organisations – selected based on the number of papers they published over this 14-year period – 71% participated in at least one FP4/5 project (

Figure 19). Thus, compared to the area of climate change & stratospheric research and neurobiotechnology, the FPs did not support as many of the most-publishing ERA organisations in solar energy. Another sample was created (i.e., 'selected institutions') for the analysis, comprising the top 100 ERA organisations as well as other ERA institutions with multiple participations in the FP; 79% of these 141 organisations participated in the FPs.

Figure 19 Summary of findings for the top (i.e., most-publishing) 100 ERA organisations and the most participating FP organisations in solar energy, 1996–2009

	% of ERA organisations who participated in the FP
Within the top 100 ERA organisations for their number of papers	71%
Within selected organisations	79%
Within the top 25 ERA organisations for their ARC*	68%
Within the top 25 ERA organisations for their number of papers in the top 1% most cited papers	81%
Within the top 25 ERA organisations for their centrality in the ERA network*	100%
Within the top 25 ERA organisations for their growth in centrality in the ERA network*	96%

Note: * The results are only valid within the group of selected organisations (141 organisations). For example, an organisation outside the top 100 for the number of papers could score a greater ARC than any of the selected organisations.
Source: Calculated by Science-Metrix using Scopus

There were slightly fewer than expected FP supported organisations in the top 25 ERA organisations for scientific impact and slightly more in the top 25 for highly cited papers. At the

[72] Note that not all individual FP project participants are visible in the FP databases. However, we would expect high performers to be made visible in research proposals

level of the whole list of 141 ERA organisations, there was no significant difference in the contribution to the top 1% most cited papers – our proxy for likelihood of contributing to scientific breakthroughs. However, FP-supported organisations have greater network centrality and appear to have increased their centrality to a greater extent than non-FP supported ERA organisations. It seems likely therefore that the FP has tended to fund researchers whose importance in the research community has risen relative to others – in other words, creating European Added Value through networking.

At world level, 48% (50% expected) of the top 25 organisations among the selected organisations (in terms of volume of papers produced in the field) are ERA organisations, and all of these have had FP support. ERA organisations outperformed non-ERA organisations in the top 100 for both scientific impact and their number of papers in the 1% most highly cited papers. In the world network (which comprises the 75 most-publishing world organisations in solar energy), 33% of institutions are from the ERA, of which 96% have at least one participation in the FPs. Interestingly, ERA organisations have increased their centrality to a statistically significant extent more than non-ERA organisations within the world network. However, it is difficult to assess the extent to which this might be attributed to FP funding.

At the level of individual researchers, 46% of the top 50 ERA researchers in terms of publications participated in the FPs; 48% of the top 25%; and 70% of the top 10. FP-supported individuals do not stand out among the most publishing ERA researchers for their scientific impact and potential contribution to scientific ‘breakthroughs’, but they generally published their papers in journals of higher quality (based on the sampled researchers). Comparing ERA researchers to those in the rest of the world, they performed significantly better internationally for the scientific impact and ‘quality’ of their papers, as well as for their potential contribution to scientific ‘breakthroughs’. Their network centrality was about the same as that of the non-ERA researchers.

4.4 General results

This analysis variously shows or is consistent with some important achievements by the FPs (Figure 20). In each of the four fields considered, the FP has supported at least two thirds (generally a lot more) of the most publishing organisations in the ERA, (ie which are among the 100 most prolific at publishing in the relevant field). The result is similar when the top 100 list is extended to include the small numbers of large-scale FP participants who did not make it into the top 100 in terms of publication volume.

Figure 20 Summary of findings for most prolific ERA organisations and ‘Selected’ organisations, 1996-2009

Percent with FP funding	Quantum Computing and Info Processing	Neuro-biotechn-ology	Climate change, Stratospheric research	Solar energy
Top 100 ERA organisations	64%	87%	94%	71%
Selected organisations	66%	90%	96%	79%
- Top 25 ARC (Average of Relative Citations)	76%	88%	88%	68%
- Top 25 contributors to most-cited 1%	88%	92%	96%	81%
- Top 25 centrality	92%	92%	96%	100%
- Top 25 increase in centrality	88%	88%	92%	96%

The analysis confirms the quality of the participant organisations, showing that the bulk of them make it into the top 25 in the ERA in terms of scientific impact (ARC) and likelihood to produce breakthroughs (contributions to the most-cited 1% of papers in the field). These organisations are almost all very central to research networks in the ERA and their relative importance is growing over time either at the ERA or world level (see appendix volume for more details). The fact that such a large proportion of ERA organisations are supported by the FP makes it hard to test the degree to which the Programme is **causing** good or improved performance. However, the fact that the key supported organisations are improving their network centrality during a period when the FP is the chief network funding instrument available makes it reasonable to attribute at least a part of this effect to the Framework.

All four fields examined here are ones that have been growing in importance and size over the relevant period. The Climate, Quantum and Solar fields are comparatively new, so ERA organisations and researchers' ability to maintain a place at the forefront on a range of performance measures is impressive. Neurobiotechnology is an area where national investments significantly predate those of the Framework Programme; the FP adds topics to the research agenda rather than being an important driver and coordinator of the agenda as a whole. Its influence is correspondingly smaller. But in all four cases, the centrality growth suggests that the importance of the European research community is increasing. To that extent, the FP's ambition to 'structure' the fabric of European research is partly realised.

Looking at individual researcher performance, it is striking that in three of the four cases the best European performances take place at the level of the top 25 or top 10, rather than the level of the top 100. If there is an influence of the FP on relative performance it seems skewed towards the very best – except in the case of neurobiotechnology, where its influence at the very top appears small. At the level of individual researchers, the widespread increases in the network centrality of ERA or FP-participating individuals tends to suggest that the role of European researchers in these fields is becoming more important.

5 IMPACT CASE STUDIES

We selected six case study areas in which to try to understand the long-term impacts of the Framework Programme, based on the scientometric work, discussion with Commission officials desk research as well as a pragmatic view of which areas of potential study were likely to be the most tractable.

- It was believed that long-term impacts could most clearly be detected in fields where there has been continuity of funding since at least FP4. The composition analyses of FPs 4, 5 and 6 investments were therefore used to determine the broad fields and sub-areas that have received sustained attention over time, and to identify areas that have grown in scale and significance both in funding terms and in the range of instruments in place.
- It was important to focus efforts in areas where project officers and other expert staff at the European Commission considered the FPs had been successful in generating significant impacts, and where at least some level of research had already been undertaken to describe impacts.
- It was necessary to select areas that individually and collectively could reveal the full range of medium and long-term impacts identified in the effects typology, which was in turn derived from the intervention logic of the FPs.

Therefore, the selection of the case studies was explicitly made so as to ensure that each provided a different perspective on both how the FPs generate impacts over the longer-term and what kinds of effects they generate.

5.1 Methodology

5.1.1 Interviews with officials

Following a conventional approach for the preparation of the empirical work in the study, it was agreed that as first step we should draw on the experiences of long standing past and current Commission officials who have worked on the Framework Programme. This itself threw up a challenge of who to speak with, since it was also agreed that probably no one had the complete view. As with a complex piece of technology, it is probably beyond the capacity of any one individual to understand fully all the interlocking processes and structures. (and then possibly in a footnote) This idea echoes the thinking of writers on technology such as Brian Loasby who said that, “Nobody knows how a Boeing 737 works.”[73] The same can be said for the Framework Programme. Many people are knowledgeable about individual sub-components; some understand the architecture at various points in time; but no one can offer a complete understanding. In fact, the FP may be harder to understand than the aeroplane because while the 737 is designed top-down and optimised towards a particular purpose, the FP is in no small part self-organising and its purposes evolve over time.

Ten present or former Commission officials who had been involved in FP3 or 4 kindly agreed to be interviewed about their views of the longer-term and ‘horizontal’ trends concerning the FP. Most of our interviewees stressed the critical influence of the FPs in the long run on **‘horizontal’** issues such as the structure of the research community, rather than being related to a specific S&T field.

They especially mentioned the structuring effects of the FPs, both for industry and research communities; impacts on the diffusion of new innovation processes, such as the R&D

---

[73] Brian J Loasby, Making connections, Symposium on Information and Knowledge in Economic, *Econ Journal Watch*, 2 (1), 2005, 56-65

collaboration model and open innovation; and impacts on priority setting and the way national research programmes are run.

In terms of **specific S&T fields** where our interviewees expected long-term impacts to be visible, they were largely unable to say very precisely what these were. Areas mentioned included biotechnology (and more specifically genomes); research on climate change and renewable energy; manufacturing technologies (not further specified); and a wide range of ICT-related research areas, including ICT for transport.

The interviewees also provided us with the following observations.

- The FP has moved over time from micro-management at the level of projects or clusters of projects to macro-management of themes and competences
- Beginning in the 1980s, large companies have been shutting or shrinking their central research laboratories and relying more on the research infrastructure and other firms for their longer-term knowledge needs. The FP fits into this newer style of ‘open innovation’
- The scale and reach of R&D networks has increased substantially through the life of the FP, making innovation processes more open
- At the level of both projects and institutions, research management and execution in Europe have become increasingly international, thanks to the FPs
- The FP appears to have popularised the idea of precompetitive, collaborative programmes at Member State level, since the only earlier model in Europe was the UK Alvey Programme
- The FP involves almost continuous meetings of experts in various fields, in effect making available a higher and more networked level of strategic intelligence – not only to the FP but also to the national level
- FP projects require high levels of both scientific and technological quality and research management competence, so they have served to train a large cadre of people able to manage and deliver major collaborative projects
- Impacts of the FP are often to do with creating readiness, rather than making a direct link to commercialisation of new knowledge. FP projects provide knowledge and resources that participants later re-use in different combinations for research, development and innovation
- At the level of individuals, studies of the Marie Curie programme indicate that long-lasting personal networks are created, which can have profound effects over people’s careers
- In come cases (eg IMEC and LETI in microelectronics) the FP has been instrumental in strengthening research institutions to such a degree that their reach becomes international and they become ‘players’ on the world stage
- Even prior to developing the European Technology Platform as an instrument the FP created a number of de facto platforms (especially in the area of ICT) that created communities of interest that agreed technical directions and helped define standards in ways advantageous to European interests
- While the bulk of FP activity focuses on building and exploiting consensus, there are also examples where it has triggered the development of new fields in Europe, such as Quantum Computing and Microsensors – both of which originated in the FET programme
- The scale and transnationality of FP programmes and projects has raised standards of programme design by engaging experts from several countries in the design process
- Where there are national programmes (as, for example, in Sweden and Germany for the automotive industry) a division of labour emerges between the national and European levels. In the absence of national strategy, the synergies can be less clear
- Member States are now coordinating their planning of research infrastructure and becoming more efficient by sharing that infrastructure

5.1.2 Case selection

Based on our analysis of continuities in the FP, the co-word analysis that identified clusters of activity coinciding with potential scientific breakthroughs, the views of officials and the availability of relevant literature, we drew up a 'long-list' of ten potential case study areas. Based on our knowledge prior to doing the detailed work for the case studies, we classified each according to the impact typology set out in Figure 11. We looked for adequate coverage of the various impact areas and – after discussion with DG Research officials – opted to do the six cases highlighted in Figure 21. The choice represents a judgement about tractability and coverage – the chosen cases are not in any other sense necessarily the 'best'. They are not intended to be representative: our aim was to understand impact, so we have looked in places where we had reason to believe we would find it. During the course of the fieldwork, we have in some cases narrowed the scope of the cases.

Figure 21 Long- and Short-list of Case Study Areas

Impact type	Field
Emergence of new technologies or fields of science	Quantum physics/computing
Technological trajectories	Healthcare biotechnology
Integration of research	Manufacturing technologies
Cohesion of Europe	Audiovisual systems
Diffusion of innovation in products, processes or services	Solar photovoltaics
Diffusion of innovation in products, processes or services	Open innovation / Living labs
Strengthened competitive position of industry	The automotive industry
Strengthened competitive position of industry	The semiconductor industry
Innovation in the socio-economic sphere	Semantic technologies
Innovation in policy-making	Climate change / stratosphere

5.2 Quantum information Processing and Communication

Quantum Information Processing Computing (QIPC) is a new scientific field that has the potential to generate disruptive technologies in the field of information processing, radically changing the way we communicate and compute. The Framework Programme has helped build a world-class European research community, building larger-scale collaborations than could have been generated from the national level. It enabled the community to set the scientific and technological agenda and brought the physics community into contact with other disciplines needed for the science to move into applications. It drew industry in at an early stage and established a standardisation activity within ETSI – essential prerequisites for the valorisation of Europe's position among the global research leaders in the field. As a result, Europe has the basis for competing successfully in the computing and communications industries as they shift to a new technological paradigm.

5.2.1 Context

The current technology trajectory for ICT, based on semi-conductors, has provided steady performance improvement through increasing miniaturisation during the last 60 years. However, it will reach its limits by around 2020[74]. Already today, quantum effects begin to affect performance. The need for technological alternatives has driven research in a number of fields, including Quantum Information Processing and Communications - QIPC. By harnessing quantum phenomena such as *superposition, entanglement* and *coherence* to encode, process and

[74] Source: http://www.intel.com/technology/mooreslaw/index.htm

transfer information, QIPC will radically increase the speed of calculations and provide communications that are inherently secure.

Physicists and computer scientists in Europe and the USA, driven by a desire to understand the physical limits of computation, developed the early theoretical concepts of QIPC in the 1980s. In 1982, Richard Feynman of CalTech proposed a model for a quantum system to conduct quantum computations. Paul Benioff at Argone National Laboratory (1981) and David Deustch at the university of Oxford (1984) proposed models for a quantum computer and Deustch showed that quantum processing gates could function in the same way as binary logic gates in classical digital computing. Charles Bennett of IBM Research developed the first quantum cryptography protocol in 1984 with Gilles Brassard of the University of Montreal. However the quantum computer remained a largely hypothetical concept until Peter Shor at Bell Labs developed the first quantum computing algorithmin 1994. The theoretical concepts of QIPC moved towards physical realisation of a quantum computer with the publication in 1995 of a proposal for a making a quantum logic gate (based on trapped ions) by Peter Zoller at the University of Innsbruck in Austria and Ignacio Cirac at the University of Castilla-La Mancha in Spain. Scientists at NIST realised a physical implementation the same year. Others in both the UK and USA proposed error-correction schemes for quantum processing systems.[75]

From this point on, interest and activity levels in QIPC research grew rapidly, as may be seen from the significant increases in the funding of quantum information technology in the last decade; in particular in the United States, Canada, Australia and in some countries in Asia. [76]

Quantum cryptography has a slightly longer history than the wider field of QIPC, dating back to independent definitions of two different quantum cryptography protocols in the USA/Canada in 1984 (Bennett and Brassard) and in Europe in 1991 (Ekert). Both protocols built on the theoretical work of Stephen Wiesner which was done in the early 1970s but not published until 1983.[77,78] However, until the early 1990's, there were very few people involved in quantum cryptographic research. QKD is mre mature than the wider QIPC field, not simply due to its longer research history, but because it requires a less complex system based on a sub-set of (optical) QIPC technologies - it essentially only requires devices to create, communicate and receive quantum states.

Europe has played a leading role in the development of QIPC, enabling it to evolve and develop from a niche area within physics and theoretical information science into a research field in its own right. The European QIPC research community is at the forefront of the field, recognised by its international peers as comprising world leaders.

5.2.2 The Framework Programmes

The Framework Programmes have supported QIPC from the outset – initially through bottom-up research grants for **frontier research** in the ESPRIT programmes in FP2, FP3 and FP4 and subsequently under the FET programme. Since FP6, research in Quantum Cryptography, having reached maturity, was funded under the strategic objective “Towards a global dependability and security framework”.

---

[75] Amit Hagar, Quantum Computing, *The Stanford Encyclopedia of Philosophy (Spring 2011 Edition),* Edward N. Zalta (ed.),

[76] European Commission, *Quantum Information Processing and Communication in Europe - Strategic report on current status, visions and goals for research in Europe*, QIST ERA – pilot project, DG Information Society & Media, 2005

[77] The Bennett-Brassard Protocol (BB84) developed by Bennett at IBM and Brassard at the University of Montreal; Ekert Prtotocl (E91) developed by Ekert at the University of Oxford

[78] S. Wiesner, Conjugate Coding, *SIGACT News*, 15:1 pp. 78-88, 1983

The technical content of the FP-funded work has evolved. FP2 and 3 concentrated on understanding quantum effects in traditional computing devices but the focus of the work shifted towards quantum information processing during FP4. FP5 broadened the scope, mostly experimenting with ways to realise quantum devices, tackling aspects of the underlying physics but also information processing architectures and quantum imaging. FP6 work integrated other disciplines with QIPC – a necessary precursor to building devices, standards and systems. FP7 projects aim both to develop computing and communications modes that go beyond pre-quantum architectures and to make further progress towards reliability, scalability and interconnection of components.

The Framework Programme – and more specifically the FET initiative - has had a very strong and successful **unifying and structuring role**. In **FP3,** a small number of RTD projects were funded under the Esprit Programme, addressing issues in the quantum limits of 'classical' components, while others specifically addressed QIPC.

FP4 funded seven fairly small research projects in the electronics/microelectronics areas of the ESPRIT programme, supporting around 35-40 researchers in 29 organisations. At least as important, FP4 funded a working group known as the Quantum Computing in Europe Pathfinder Project (QCEPP) to map the field of research and the competences in Europe as well as five training and mobility projects enabling researchers to travel, exchange ideas and train PhD students – the QIPC researchers of the future.

The 1998 FET 'pathfinder' project mapped the field, research competences in Europe and defined the research agenda. As a result, the EC launched the FP5 FET QIPC Proactive Initiative under **FP5**. This involved the key European "fathers" of quantum computing and included a major public event where more than 100 scientists contributed to shaping its long-term objectives. The FET Proactive initiative was the world's first substantial research programme dedicated to QIPC. DARPA in the USA launched a similar programme about two years later. The thematic network **QUIPROCONE** (2000-2003) acted as the starting point for the creation of a community of researchers, from a variety of different institutions and research fields, working in the new field of QIPC. It instigated an annual review meeting and workshop for all PI and FET Open QIPC projects to review QIPC research as a group but also physically to bring project participants together. This coordination continued in FP6 in the **QUROPE** project and in FP7 in **QUIE2T**. The Proactive Initiative continued throughout FP6 and FP7 funding research and coordination activities and acting as the focal point for QIPC research in Europe.

In **FP6**, in total 3 IPs and 8 STREPs were funded. The Commission continued to view co-ordination as extremely important and funded the QUROPE co-ordinating action and the QIST ERA-pilot which brought national research funding agencies together to review the state-of-the-art, identify potential for co-operation make recommendations to funding-institutions on the national and European level for future research and funding policy, and propose clustering in the form of regional or thematic centres of excellence. A further output was the QIST roadmap, providing also a review of QIPC research in Europe and internationally.

In 2010, under FP7, the **CHIST-ERA** EraNet project was launched to coordinate national funding agencies and develop research calls in areas of long-term research important to FET. The themes selected for the calls in this project include Quantum Information Foundations and Technologies (QIFT), in part thanks to the preparatory work conducted under the ERA-Pilot QIST and the existence of the QIPC roadmap developed under the FP coordination actions. At the end of 2010, a €7.9 million joint call in QIFT was launched involving nine national research agencies. A further €14 million joint call in QIPC is expected under the ERANET-Plus scheme, included in the FET work programme for 2011/2012.

The themes of the large IPs under FP6 were continued in the **FP7** projects AQUTE, Q-ESSENCE and SOLID (3 IPs). To date, FP7 has funded 17 QIPC projects under FET Open and the central co-ordinating action QUIE2T project (Quantum information entanglement-enabled technologies), as well as the CHISTERA projects (European coordinated research on long-term challenges in information & communication sciences and technologies).

Research in *Quantum Cryptography,* having reached maturity, was (also) funded in the 'mainstream' IST programme under the strategic objective "Towards a global dependability and security framework"; this included the IP SECOQC**,** receiving an EC funding of €11.3m. The FP7 objective on critical infrastructure protection was successfully launched jointly with the FP7 Security Theme. As a result of the Joint Call on the subject, nine new ICT projects were launched in 2008. [79] Research on *quantum repeaters* has also moved to 'mainstream' ICT and is currently taken up by the Photonics Unit of the DG Information Society and Media.

5.2.3 Impacts

European scientists have been at the forefront of QIPC research since the beginning and the FET programme has been successful in attracting to the IST program the best QIPC research teams in Europe and a high number of world-renowned scientists. Starting in FP5, industry also became involved in QIPC research, including technology suppliers as well as intermediate-users.

The bibliometric and network analyses performed in this study confirm that the Framework Programmes supported most of the key research institutions in Europe, strengthening their positions. The major centres in Austria, Belgium, Denmark, France, Germany, Netherlands, Poland, Spain, UK, and Switzerland formed the core of the EU networks involved in the FP-funded research. The Framework supported all the Top-10 most prolific publishing scientists in the world and most of the leading European scientists in the field.

The FET initiative integrated previously fragmented research groups and national programmes – often focused on only one specific sub-field of QIPC research - and provided a platform for knowledge networks and cross-fertilisation among experts in different sub-fields, creating critical mass and research mobility but also facilitating insights through greater inter-disciplinarity. It now acts as the focal point for the QIPC research community in Europe which in the course of 10 to 15 years time, has grown into including 158 research groups, of which about 120 have their central activities in QIPC, spread over more than 30 countries. It acted as a reference point for national research programmes and throughout successive FPs, provided the opportunity for these national activities to start to connect together at the European level, ultimately resulting in the launch of joint calls. It also promoted the elaboration of a common European research strategy in the field, fostering the development and constant updating of a scientific and technological roadmap as a steering device for both the Commission work programmes and the future research activities of the research community itself.

Over the last ten years, the research efforts have led to remarkable results, developing the most secure methods of communication (quantum cryptography) and building the basic building blocks of quantum computation on a range of hardware platforms.

QIPC research is now entering a new phase where a family of highly promising potentially disruptive technologies is being explored further, speeding up the process of bringing them from the lab to the real world. Potential areas of application for QIPC technologies are manifold and range from entanglement assisted sensors and metrology for biomedical imaging, the exploration of environmental hazards or the search for mineral resources; quantum simulators allowing for testing and commercialisation of new drugs, new energy efficient materials, or accelerating the transition toward renewable energy sources; quantum computers opening up a viable route to provide the next generation of scalable processors beyond micro- and nano-electronics, etc. Major industry sectors that will profoundly be affected by the developments in this field include the telecommunications sector, the consumer electronics sector, the IT sector, and the semiconductor industry. As an indication of the dimension these impacts may have, in 2008 the semiconductor industry in Europe generated revenues of € 29 billion and about 215,000 jobs were directly connected to chip making.

---

[79] European Commission, *Directorate F Management Report 2008*, DG INFSO F - Emerging Technologies and Infrastructures, 2009

Thanks to the ongoing support and the agenda-setting role of the FP, through the last two decades, Europe is at the forefront of the international competition for this new phase and both its well-structured and collaborative research and industry community has the needed critical mass to reap the benefits.

5.3 Brain Research

Diseases of the brain cause increasing human suffering and economic cost as Europe's population ages. In this area, and in pharmaceuticals more generally, Europe is losing ground to the USA both in terms of public investment in research and in overall share of the drugs market. The Framework Programme has added significantly to the research investment, in part targeting more unusual diseases that are uneconomic to tackle at the level of a single Member State. It has reinforced the position of the European research community and helped it to set agendas by, inter alia, launching the European Brain Council. It has succeeded in increasing industry participation in collaborative research, despite pharmaceutical companies' historical reluctance to do so. (They normally maintain bilateral relationships with research-performing organisations.) With the launch of the first Joint Programming initiative on Alzheimer's disease, the Framework has decisively increased its agenda-setting role, leveraging large amounts of money and effort at the Member State level.

5.3.1 Context

Brain research encompasses a wide range of disciplines researching the brain, the spinal cord and the peripheral nerves. It ranges from basic neuroscience to applied clinical research. Brain diseases include both neurological and "mental disorders". Depression, schizophrenia, panic disorder, drug dependence and insomnia are examples of "mental disorders", while dementia, epilepsy and multiple sclerosis exemplify neurological disorders. In this study we especially covered the research focusing on neurodegenerative diseases, which constituted the core of research funding under the Framework Programmes in this field. These include diseases such as Alzheimer's, Parkinson's and Multiple Sclerosis.

Policy driving forces behind the European effort in neuroscience research are the desire to gain new insights into mental processes in general and the need to develop new and better means for diagnosis and treatment of neurological and psychiatric disorders and diseases.

Brain diseases currently constitute a high burden and costs on individuals and society as a whole and pose a major challenge to European health care systems. A recent report based on a World Health Organisation (WHO) study revealed that the burden of brain diseases (neurological, neurosurgical and psychiatric) accounts for about 35% of all diseases in Europe, affecting millions of Europeans. Some of these diseases are connected to brain development (and therefore concern mainly children), the most severe effects of brain diseases such as dementia or Parkinson's are related to ageing.

Currently, an estimated 8.6 million people in Europe suffer from neurodegenerative diseases, with Alzheimer's disease in the lead representing about 70% of the cases of dementia and affecting an estimated number of 7 million individuals.

The 2011 'Cost of Disorders of the Brain' study[80] is a starting point for understanding the economic impact of brain disorders on European society. The study showed that in 2010, 179 million Europeans (on a total population of 514 million people including the new member states) suffer from brain disorders, at an estimated cost of €798 billion.

The pharmaceutical industry makes an important contribution to Europe's and the world's well-being. Data from the 2009 EU Industrial R&D Investment Scoreboard[81] indicate that the

---

[80] Gustavsson, A., et al., Cost of disorders of the brain in Europe 2010, *Eur. Neuropsychopharmacol.* (2011), doi:10.1016/j.euroneuro.2011.08.008

[81] The 2009 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG Research

European pharmaceutical industry is one of the few remaining leading **high technology** industries in Europe, accounting for about 3.5% of EU manufacturing value added. It employs approximately 630,000 workers, 18% in R&D facilities. At European level, the pharmaceutical industry is the leading high-technology sector in terms of trade surplus. The European Commission informs that overall, in 2007 EU-27 production of pharmaceuticals was estimated at €190 billion with exports equivalent to €210 billion and imports accounting for €161 billion (a positive trade balance of €49 billion). Globally, the pharmaceutical industry sector is characterised by fierce competition. It is a **highly research-intensive** industry sector: as a whole, the pharmaceutical industry accounts for 17.0% of the EU business R&D expenditure and invests about 18% of its sales into R&D in Europe (2010 data).

As recently as 1997, 70% of all medicines were developed in Europe. However, The period 1995-2005 saw an increasingly **strong US market dominance**, marked by a significant shift of economic and pharmaceutical research activity towards the US. Over the period 2005-2009, US companies launched 45.2% of the new chemical and biological entities compared with 35.6% for European companies. In 2010, with an estimated share of 38.1% of the world pharmaceutical production, the USA still is the primary manufacturing centre for medicines in the world, just ahead of Europe (35%) and Japan. Together, these three regions account for the bulk (approximately 82%) of the world pharmaceutical production.

In other words, *Europe is lagging behind the USA in its ability to generate, organize and sustain pharmaceutical innovation*. A report issued in 2000 'Global Competitiveness in Pharmaceuticals: A European Perspective' considered that the competitiveness of the European pharmaceutical industry was inhibited by domestic and fragmented markets and research systems.

The industry began a fundamental technological shift from chemical- to biologically based medicines. From the 1980s, new medicines tended to have a basis in biotechnology. Success in the industry is very skewed. It takes 10-13 years for a compound to move from laboratory to clinical practice. Of 5,000 molecules tested, typically 250 make it into preclinical testing. Of these 10 will enter clinical development and one will survive regulatory approval to make it onto the market[82]. About 30% of medicines marketed recoup their R&D costs before their patents expire.

At the end of the 1990s, the European research community was fragmented, both geographically and among the different scientific subfields, and the US was a leading actor in the global research community, predominantly thanks to high public R&D funding in the field.

Studies conducted in the mid 2000s[83] identified a number of obstacles for European brain research to regain its competitive edge globally. These included insufficient research funding – especially public funding for brain research; an uneven distribution of the funding over the various brain disorders leading to a limited capacity to fill in 'pharmaceutical gaps'; a lack of collaboration and coherence among national research programmes; and a general lack of 'visibility' of brain research, largely attributed to the fragmentation of the European research community.

There is a **growing gap in R&D investment** in the field of neuroscience between Europe and the US. Until some 20 years ago, Europe led the world in brain research funding; since the 1990s, the US has overtaken Europe and in 2003, the gap was even widening. A consequence of this higher level of research funding has been a brain drain from Europe to the US, leading to a shortage of highly competent scientists in Europe.

---

[82] Source: EFPIA website – European Federation of Pharmaceutical industries and associations

[83] Unless otherwise indicated, data in this sector derive from: P. Sobocki, I. Lekander, S. Berwick, J. Olesen and B. Jonsson, Resource allocation to brain research in Europe – a full report *European Journal of Neuroscience*, pp. 1–24, 2006

Compared to the US, data point at an underinvestment in brain research especially by the government and charity sectors. In 2005, the total funding of brain research in Europe was estimated at €4.1 billion, of which the public sector contributed €855 million (20%) and industry €3.25, i.e. approximately *80% of the total funding*. In contrast, in the US, about €6.1 billion came from public sources (93.5% government and 6.5% charities) and €8.4 billion from industry funding, i.e. *58% of the total funding*. R&D funding is also **unevenly distributed** over the various brain disorders.

There are important policy implications to this uneven distribution of R&D investments over the brain disorders: experts point out that although mental disorders account for two-thirds of the total cost of brain disorders, in 2005 they only received one-third of the total investment in brain research. A 2004 WHO report[84] also pointed at the consequences in terms of Europe's funding of research to fill pharmaceutical gaps, defined as **"**those diseases of public health importance for which pharmaceutical treatments either do not exist (lack of basic scientific knowledge or market failure) or are inadequate (lack of efficacy or safety concerns or because the delivery mechanism or formulation is not appropriate for the target patient group)". A high burden diseases in Europe for which the currently available treatment is inadequate is Alzheimer's disease.

There were large **disparities between countries** both in the level of their public research funding and the focus of the research. A 2001 WHO report data attributed these low levels of public funding to the fact that "mental disorders have long been stigmatized and hence **'invisible'**, receiving little acknowledgement from healthcare providers and society in general." Experts also considered the fact that those working in the field of mental disorders have been little successful in bundling their efforts and form lobbying forces to influence the research agenda of government agencies. The lack of European coherence, the visibility of the research and the general public awareness of its importance and implications for health were indicated as a 'failure' for brain research in general.

A key issue in this context was the **fragmentation of the research community**, due to the broad range of scientific fields involved in neuroscience research. Neuroscience is a scientific field involving a broad range of scientific and technological disciplines involved.

5.3.2 The Framework Programme

In 2003, the European Commission took the initiative of organising a conference bringing together European research societies and associations active in the field. The – intended – outcome of this conference was the creation of the **European Brain Council.** In 2006, the EBC published the first version of the **Consensus document on European brain research** and according to the EBC, "The explicit wording on brain diseases in the European Commission's Seventh Framework Programme (FP7) Cooperation Work Programme is based on this document and has resulted in a significant increase in funding of brain research under the first three calls of FP7, compared with FP6". The Consensus document is currently being revised and updated by the EBC, taking into account the changes in research priorities and advances in brain research that have taken place since 2006. Written by multinational and multidisciplinary teams, the Consensus document will outline the priorities to be achieved based on the current strengths in European research, with equal importance attached to basic and clinical research. [85]

The European Commission has supported neurological and brain-related research since the early Framework Programmes. In FP3 and 4, brain research was funded under the BIOTECH 1

---

[84] Warren Kaplan, Richard Laing, *Priority Medicines for Europe and the World*, World Health Organization, Department of Essential Drugs and Medicines Policy, 2004

[85] Monica DiLuca, University of Milano, European neuroscience research: the road ahead, *European Journal of Neuroscience*, Volume 33, Issue 5, page 767, March 2011

and BIOMED 1 programmes. Up to this point, the FP largely funded rather basic research, contributing to the Human Genome Project during FP4 and 5.

FP5 (1998–2002) identified ageing as a mega-trend. Funding for brain-related research was organised primarily under the 'Neurosciences' sub-area of the 'Quality of Life' (QoL) programme. A significant body of related research that addressed issues relating to brain functioning and brain-related diseases was also carried out within other parts of FP5, amongst others the Marie Curie programme and the research topic "Nervous system, including Alzheimer's disease and Parkinson's disease" under Key Action 6 "The Ageing Population and Disabilities". FP5 emhasised more interdisciplinary work and strengthening of research capacity.

Under FP6 (2002-2006), brain research was mainly funded through 'Priority I – Life Sciences', in the sub-priority area 'Advanced genomics and its applications for health'. Research in the application of informatics and imaging technologies was funded also in the Health action line in the IST programme – more specifically through the Virtual Physiological Human initiative; biomedical Informatics (BMI) was specifically addressed in the FP6 IST Call 4 "Integrated Biomedical Information for Better Health". Within FP6, focus was on the **integration of postgenomic research**, and on the **"translational" approach** (bringing basic knowledge through to the application stage). The main objective was to support more ambitious European activities. This meant concentrating pan-European efforts on larger-scale collaborative research projects exploring those topics that could be most effectively handled, with the most value-added, at EU level. Both basic and clinical research was covered, including identification of genes and molecules playing a role in brain diseases, physiopathology of diseases, development of new therapies and diagnostic tools as well as diseases prevention.[86] Considerable efforts were made also in the field of biomedical informatics, expanding the focus of the research to the development and use of computational tools for biological interpretation of large amounts of data and the integration of multi-level data for the modeling and simulation of human functions[87]

Brain research in the Seventh Framework Programme (FP7; 2007-2013) includes an activity on 'Research on the brain and related diseases, human development and ageing', under the Health Theme. The Virtual Physiological Human is one of the three objectives of the IST programme Challenge 5 'Towards sustainable and personalised healthcare'.

The funding instruments used for brain research have evolved in line with the overall pattern in the FP. Some 5-7% of the projects in FP4-6 were networked and coordination actions, rather than research or human resource projects. In the early part of this period, these actions coordinated across the FP; in FP6, Networks of Excellence –ie research networks, played a bigger role. In FP6, too, brain research became the subject of an ERA-Net (NEURON, which continues as a coordination action under FP7) and was involved in the Innovative Medicines Initiative (IMI Technology Platform, led by the pharmaceutical industry. Alzheimer's was the subject of the first Joint Programming initiative, so the coordinating role of the FP has evolved from coordination within the research community, through agenda setting via the European Brain Council to coordination of national efforts and closer engagement of industry.

FP brain research was fundamental up to FP5, but then and thereafter was refocused onto more translational and interdisciplinary activities. FP5 indentified 'ageing of the population' as a mega-trend. While earlier FP brain research interconnected existing members of the European research community, FP5 and FP6 directed considerable efforts into human resource actions, building capacity.

During FP4, the main participants in FP brain research were 'core' institutions with nationally established strength in the field such as Karolinska Institutet, CNRS, INSERM and University College London. By FP6, the number of participating institutions had doubled to 450 while the

---

[86] Brain research - EU Funding (2002-2009), European Commission, 2009

[87] Virtual Physiological Human – project portfolio, EC, DG INFSO, May 2001

number of participations of the leading institutions fell between successive FPs, so participation widened to new participants rather than existing players deepening their involvement. Industrial participation rose from 3% to 16%, which is an important achievement in an area where industry traditionally prefers bilateral rather than network relations with universities and institutes. Europe's best research performing institutions and researchers were represented in the FP but it did not attract a greater proportion of the world's best researchers than would have been expected. Nonetheless, there are many well-respected and published authors among the FP participants, whose work is associated with areas of potential breakthrough.

5.3.3 Impacts

So far, the long-term impact of the FP has been mainly to allow the European research community to keep pace with international developments, broadening academic and industrial participation and building network relationships conducive to application as well to fundamental research. The European Commission has supported brain research since the early Framework Programmes – until recently predominantly through the funding of basic research. The research activities led to numerous high-quality publications, and sometimes to groundbreaking discoveries, thanks to the FP involving the best European researchers. The FP acted as an additional source of funding, next to national programme and university funding. Its major added value was in ensuring continuity of research whenever research priorities changed in the national programmes and in providing a European platform for research covering large pools of patients, generating data for diseases that are not so frequent, or requiring multidisciplinary expertise.

Our bibliometric analysis shows that while the Framework Programme has supported many of the world's top researchers and it is probable that European researchers' positions in scientific networks have become stronger during the period of the Framework Programme, the European research community was already sufficiently well established on the basis of prior national funding that the intervention of the Framework was not decisive in building the community.

Throughout the last decades, the Framework programme also set the building blocks for a recovery of Europe's competitive positioning in the field. It contributed to the worldwide efforts in gathering data on the human genome and invested significantly in those technologies that would provide the basis for future scientific advances such as biotechnology and biomedicine - including neuro-informatics and neuro-imaging. Europe is considered among the leaders in these application fields of IT.

At the turn of the century, the moment was ideal for a convergence of science and technology: the technology had grown more mature and large data sets had become available. A major turnover in the field of neuroscience occurred.

This was also the time when the 'ageing' of Europe came on the foreground as a societal challenge and brain research found itself the object of a progressive policy pull. Starting in FP5 and especially in FP6, the Commission tackled the systemic barriers hindering progress in this scientific field such as the limited public funding, fragmentation of the research communities, little science-industry collaboration, and the lack of coordination among national research programmes.

The enhanced science-technology integration together with the 'momentum' of brain research from a policy point of view spurred a broad range of research activities and initiatives in the field, funded and promoted by the Framework Programme and for which the European research community could build upon the knowledge, expertise, and networks developed in the preceding decade. Expected outcomes and impacts of these activities consist in an improved early diagnosis as well as treatment and prevention of mental and behavioural disorders or diseases. The importance for Europe's nearby future from a socio-economic point of view is apparent when considering that currently 8.6 million people in Europe suffer from neurodegenerative diseases and that this figure is expected to double by 2020 as the European population ages further.

5.4 Stratospheric Ozone Research

Damage to the Ozone layer, which protects us from excessive ultraviolet light and from some of the heating effect of solar radiation on the atmosphere poses a major risk to life. When the Montreal Protocol (the first international treaty aiming to mitigate damage to the Ozone layer) was signed in 1987, European research on stratospheric Ozone lay far behind that in the USA. From 1989, the Framework Programme not only funded research in the area but also established mechanisms through which the research community could set agendas and actively coordinate national efforts. A key contribution was to organise a series of research campaigns involving hundreds of scientists across many countries in simultaneously collecting data at a scale much bigger than would have been possible at national level. The European research community has grown to achieve comparable scale and quality to that in the USA. Knowledge generated in the Framework Programme has been instrumental in refining the targets set under the Protocol and Europe has met its 2020 targets ten years early.

5.4.1 Context

Ozone (O_3) occurs naturally in the stratosphere, about 10-45 km above the Earth's surface; it is beneficial to life on earth because it blocks much of the dangerous ultraviolet light (UV-B) radiated by the sun. Stratospheric ozone is broken down by chlorofluorocarbons (CFCs) and by nitrogen oxides (NO and NO_2). While nitrogen oxides are by-products of combustion CFCs are man-made chemicals used in refrigeration systems, air conditioners, aerosols and solvents and in the production of some types of packaging. Depletion of the ozone layer is a threat to both human health and the environment. Negative economic effects include both increased healthcare and other costs associated with climate change, since ozone depletion promotes global warming.

Stratospheric ozone research - or atmospheric chemistry – is a highly multidisciplinary research field, gaining much information from both high-tech and sophisticated instrumentation, and theoretical and computational approaches. In the last decades, research in this field provided data and information on the level of ozone depletion in the stratosphere and on its underlying causes. Major current challenges include forecasting global climate change and understanding the link between air quality, atmospheric chemistry and climate.

The science tied to this case study can be said to start in the early part of the 1970s when a small number of scientists started research around the possible effects on the atmosphere of CFCs and halons – more specifically chlorine and bromine.[88] A major milestone occurred in 1985 when the ozone hole over the Antarctic was first reported. A team from the British Antarctic Survey (BAS) reported that losses in total ozone of more than 50 per cent had occurred in the Antarctic spring in the previous few years, and have continued to occur each year since. The BAS finding caused considerable interest among scientists as it had not been predicted by existing models of atmospheric chemistry. The finding also attributed the ozone depletion to man-made causes.

Although there were pockets of eminent research groups in European countries – in particular in the UK, Germany and France - the scientific superpower in the 1970s and 1980s was without doubt the United States.

NASA and other US federal agencies were major funders of stratospheric ozone research early on; other notable funders of the effects of CFCs on stratospheric ozone in the 1970s and 1980s included European countries, particularly the UK's Department of Environment and French agencies (e.g. CNRS). According to anecdotal evidence, by the end of the 1980s, the largest

---

[88] The information in this section is predominantly based on the document: G. T. Amanatidis and H. Ott, *European Commission Research on Stratospheric Ozone Depletion,* European Commission, Directorate General DGXII Science, Research and Development, Phys. Chem. Earth, Vol. 20, No. 1, pp. 13-19, 1995. Copyright © 1995 Elsevier Science Ltd Printed in Great Britain.

research programme in Europe was the German ozone initiative. At an EU level, COST Actions were established as early as the 1970s to foster collaboration between European scientists in the field.

An important channel for **early stage European research collaboration** in atmospheric science (tropospheric research) was the Eureka initiative **EUROTRAC** (The European Experiment on the Transport and Transformation of Environmentally Relevant Trace Constituents over Europe), partly funded by the European Commission. This was established in 1986 to tackle the scientific problems and combine the expertise, knowledge and resources produced a large number of new researchers in the field. Supporting young talent was an important part of the collaboration, and it is believed that the cooperation helped slow down a trend which saw students in the field moving away from Europe to the United States.

5.4.2 The Framework Programme

EC environmental policymaking has been cemented in Environmental Actions Plans (EAPs) since 1973. Initial limitations on the production and use of CFCs were imposed at the end of the 1970s by a smaller group of countries that included Canada, Denmark, the Netherlands, Norway, Sweden, West Germany and the US. The EEC agreed less ambitious regulations. The big policy breakthrough on the ozone issue came instead with the signing of the **Montreal Protocol** in 1987.This was the first international treaty for mitigating a global atmospheric problem before serious environmental impacts have been conclusively detected[89]. The agreement was in many ways the beginning rather than conclusion of the issue of ozone - partly because the Montreal Protocol had to be actually implemented and partly because it opened up new scientific issues. It has been reworked and amended several times as a result of new scientific findings.

COST Actions related to ozone were established in the 1970s and environmental research was incorporated in Framework Programmes since the 1980s. Consultations undertaken for this case study have confirmed there were some scientific activities related to ozone depletion in DG Research's Environment Division in the first half of the 1980s, that is, even prior to the British Antarctic Survey findings. Nevertheless, proper coordination of European science in this field was to happen only in the same year the original Montreal Protocol was ratified – i.e. in 1989, with the creation of the Atmospheric Sciences Programme in the second Framework Programme.

The 1980s ended with the establishment of the European (Framework Programme) atmospheric science programme, which was a joint achievement championed by both DG Research and scientists in Europe who, in a statement to the European Commission, underlined the "**increasing gap in stratospheric science between Europe and the US**", and the "inadequate funding and unavailability of satellites and state-of-the-art instruments". European scientists were concerned that the continent was unable to respond to the chemical changes that had occurred in the ozone layer. Environmental issues have been reflected in the Framework Programmes ever since and became a thematic priority in FP6 (2002- 2006). FPs 4-7 funded a succession of projects related to stratospheric ozone. FP managers not only funded projects but encouraged a **strong collaboration with the national funding agencies and the research community** as a whole. Up to the first phase of FP5, the strategy of the European Commission was to develop a *pan-European programme of atmospheric chemistry research,* support through funding from both the Commission and the Member States.

The science community argued there was a need for an independent science panel and coordination unit. The EC strongly encouraged such coordination and offered significant and strategic financial incentives to support scientific collaboration. The chosen vehicle was the **European Advisory Science Panel on Stratospheric Ozone,** an independent 15-person panel

[89] Peter M Morrisette *The Evolution of Policy Responses to Stratospheric Ozone Depletion*, Available at www.ciesin.org/docs/003-006/003-006.html

that up to the 6th Framework Programme provided advice to the EC regarding future direction and priorities of atmospheric research. This empowered the research to set the agenda. To support the Science Panel, DG Research helped create a Coordination Unit – EORCU (the **European Ozone Research Coordinating Unit**) to review and liaise with existing European national programmes and research funders, prepare research plans and provide advice to the broader European network, supported by the EC and the then UK Department of Environment[90] and funded through smaller contributions by other stratospheric ozone FP projects. The work of the Unit was inclusive, supporting small as well as large groups in Europe and providing continuity across several FPs. The Coordination Unit (co-)organised regular **European Workshops on Polar Stratospheric Ozone Research.** In addition, national research funders and policy-makers were kept informed through four-year **scientific assessments of European research**. Once assessments had concluded what advancements were made for particular scientific questions and what fields and issues remained – or had opened up as new – obstacles to understanding the science behind ozone depletion, the Framework Programme was used as an instrument to stimulate further scientific research in the field.

Over time the function of the EORCU changed: in the 5th Framework programme, it was responsible (also) for the co-ordination of research clusters formed in the course of the programme, while it served as the project office/co-ordination unit of the SCOUT-O3 IP funded under the 6th Framework Programme. Since 2004, changes in the structure of EC funded European Ozone Research has resulted in the funding of large integrated projects which coordinate atmospheric science within specific themes. As such the need for the Science Panel fell away, and EORCU now coordinates the Stratospheric-Climate Links with Emphasis on the Upper Troposphere and Lower Stratosphere (SCOUT-O3) Integrated Project. [91]

To be mentioned are especially the **research campaigns** organised under FP3, FP4, FP5 and FP6 carried out under the direction of the Science Panel and EORCU. The 1991-2 campaign involved over 250 researchers from 18 countries – predominantly European; over 300 scientists from 21 countries took part in the 1994-5 campaign. The scale and breadth of expertise needed in the campaigns meant they could not be done by one country or region, as they involved a large number of experts, some in niche scientific fields, whose competence one would not be able to access in a single country alone.

In line with the developments of the field and the need for information by policy-makers, the **focus of the research** funded under the FPs gradually changed, evolving from research exclusively focused on ozone depletion to research increasingly addressing the ozone depletion-climate change interlinkages. [92]

Also the **policy objectives** underlying the funding of the research evolved: research in the first FPs was predominantly focused on advising policy-makers in the context of the Montreal protocol and its amendments. Under FP5 stronger parallels were drawn with other European policies such as the 5th EAP as well as with other international environmental conventions such as the United Nations Convention on Climate Change, the Kyoto Protocol, and the Biodiversity Convention. Key objective was to establish a *solid basis of information on which European environmental legislation could be build* and to support international commitments such as the Montreal Protocol. A similar policy focus was maintained and even enhanced under FP6 and FP7.

---

[90] Study consultations estimate that the UK Department funded 2/3 of the costs of the Unit for a decade, much thanks to the dedication of the Thatcher government, who was very vocal about the ozone issue.

[91] Source: http://www.ozone-sec.ch.cam.ac.uk/EORCU/background.html

[92] Information in this section is based on various Reports of the existing and planned ozone research activities of the European Union, prepared by the European Commission for the annual meetings of the WMO/UNEP Ozone Research Managers

Work in FP1-3 therefore focused on understanding the causes and consequences of ozone depletion. In FP4, the focus shifted towards understanding the processes involved in depletion while FP5 work involved understanding, quantifying and predicting stratospheric changes. FP6 and FP7 carried on this thrust, looking further at the links among different parts of the atmosphere and the interaction with climate change. In the period of FP5-7, the projects became increasingly interdisciplinary.

5.4.3 Impacts

Over the last 20 years, atmospheric chemistry research in Europe has become more than competitive with that in other parts of the world, including the United States. Europe now has a leadership role in the field. The Framework Programmes are unanimously considered a major facilitator for this success, fostering scientific understanding in the field and the development of a truly European community of researchers on atmospheric ozone and UV- radiation.

The Framework Programmes played a key role in the strengthening of Europe's positioning in stratospheric science by ensuring the development of a balanced programme of research, creating synergies with the national research programmes, and integrating and expanding the European scientific community, thus creating 'critical mass'.

They also provided effective co-ordination mechanisms to jointly use European research facilities, promoted integrated interdisciplinary research thereby addressing the scientific problems in a more holistic way, and set the base for the creation of new knowledge, to the benefit of the European and international communities.

The bibliometric and network analyses performed in the context of this study indicated that the Framework Programmes succeeded in involving the leading European research organisations in the field of climate change & stratospheric research. Seven of the top-10 most prolific authors in the field were supported by the Framework Programme.

A critical element of this success was the **co-ordination of the research** at a European level, leading to the development of a pan-European research programme in atmospheric chemistry that built upon a **strong co-operation with the national research programmes** and capitalised existing strengths in the national research communities. Equally important was the fact that the content and direction of this scientific programme was based upon a **widespread consensus** of the scientific community; to a certain extent, the programme was even a bottom-up initiative. The Framework Programmes have ensured **continuity in funding**, even at times when national sources have tended to dry up during economic recessions – especially for international activities not deemed to be core national priorities.

Although the projects supported through the Framework Programme have focused on scientific progress, **instrumentation** has nevertheless been central. The campaigns facilitated the improvement and modification of specific instruments developed in various Member States which formed the foundation for scientific breakthroughs.

The Framework Programme has been key from this perspective. Initially, it predominantly acted as a **platform for the coordination of national activities**. The European dimension was advantageous and even critical due to the broad range of data needed; it also allowed for a sharing of the research infrastructure and equipment and led to a standardisation of instruments, data collection methods and timing, modalities for data storage etc.

Another key added value of the support provided by the Framework Programme is related to the approach adopted for the implementation of the research programme, strongly based upon involvement of the national research programmes and consensus-building within the research community – ultimately leading to integration of the policy-making and research communities. The FP also 'imposed' the policy concepts of cohesion and integration during the implementation of the programme, and helped build capacity in peripheral countries and minor universities or research institutes as well as in established research communities. . It also increasingly promoted the development of multidisciplinary research teams across Europe. In other words, the Framework Programme strongly fostered the **integration and expansion of a transnational, multidisciplinary knowledge base** in the field.

Finally, the Framework Programme has helped European scientists to make major advances to the understanding of the stratospheric ozone and UVB issue. The scientific and technological impact was particularly high, illustrated in the creation of new knowledge and large number of publications in high-level journals.

As a conclusion we can state that the Framework Programme has provided the conditions for the vital contributions made by European science to international assessments on ozone depletion and climate change.

Direct impacts are related to an informed European and international policy-making, with important indirect impacts in the health and environmental sphere. Europe is a recognised world leader in complying with the Montreal protocol and is already now in line with the targets set for 2020. The effects on the health of the European citizen - in terms of, for example, a diminished risk of skin cancer - are of obvious importance.

5.5 Research in the field of Solar Photovoltaics

Shifting energy supply towards renewable sources involves not only new knowledge but also making big changes to energy systems and policy. Solar Photovoltaics (PV) makes up a small but rapidly growing part of the energy system. The Framework Programme has supported technological development and demonstration in the area since the 1980s. The Framework Programme has expanded the research community in Europe and enabled it to work at the global research frontier. The Commission's role in developing energy policy has increased since the 1980s. PV-friendly policies have meant that the industry is now demand-led. With a 15% share of world production, Europe maintains a strategic position in an important and rapidly growing industry that supports a large number of small and large firms and well over 100,000 jobs. By establishing road maps, funding a range of PV technologies at different levels of maturity and linking through demonstration to policy, the Framework Programme has enabled Europe to build a strong position in current and future PV markets, easing a transition towards renewables.

5.5.1 Context

Since the signing of the Euratom Treaty in 1957, the concept of **energy security** has been a driving force for EU energy policy, along with the need to ensure the **competitiveness** of Europe's energy sector and industry as a whole. Since the energy White Paper[93] in 1995, there has been especially strong and growing emphasis on renewables in EU energy policy. The Commission set targets for renewables in each member country in 2001 and in 2007 proposed an integrated climate and energy package, which is partly implemented by the Strategic Energy Technology Plan (SET-Plan). Solar Photovoltaic technologies can play one part in the overall strategy of moving towards renewable energy sources.

The Solar Photovoltaics industry sector is an 'emerging industry'; it is characterised by strong technological uncertainty, strategic uncertainty, high initial costs but steep cost reduction through production scale[94], many embryonic companies and spin-offs, first time uninformed buyers, state intervention (subsidy, etc.). As in all renewable energy sectors, both technology push and regulatory pull are necessary components for market development. The development of the solar PV sector is hampered by the fact that existing power systems are designed for large-scale central power generation and distribution, so the design of technology and tariffs that encourage

---

[93] European Commission, *An Energy Policy for the EU*, Brussels, 2005

[94] Gregory F. Nemet, Beyond the learning curve: factors influencing cost reductions in photovoltaics, *Energy Policy* 34, no. 17, 2006: 3218-3232.

comparatively small PV installations either to stand alone or to feed into existing distribution grids are comparatively recent.

While PV provided only just over 0.1% of European electricity supply in 2008[95], it is the fastest-growing segment. The **European Union is leading in PV installations worldwide,** with a little more than 70% of worldwide installed capacity. The 2007 SET-Plan set a target of 3GW solar electricity to be developed in the EU by 2010. This target was exceeded nine fold: by 2010 solar PV had reached the target set for 2030. [96]

Photovoltaic module production capacity increased by more than 50% to 11.5 GW during 2009. **PR China and Taiwan** are growing fastest and together account for about 50 % of world-wide capacity. If current trends continue, by 2015, China will have 34.7% of worldwide production capacity, and Europe will have 14.6% - an important strategic position in the international market.

From the very early days of the PV industry, the market leader was '**first generation**' crystalline wafer silicon due to its high level of efficiency, and this continues to be the case, with around 80% market share in 2009. The '**second generation**' thin-film technology, however, saw a sharp increase in its market share in the last years, i.e. from 6 % in 2005 to 10 % in 2007 and 16 – 20 % in 2009. [97] While early installations were stand-alone (with an expensive PV solution being chosen in order to involve the costs of connecting to the grid), since 1990, the main growth has been in grid-connected systems. Concentrating Photovoltaics (CPV) is an emerging **'third generation'** technology, which is growing fast from a low starting point. This uses lenses and other arrangements to increase the amount of light falling on the PV surface.

The employment figures in photovoltaics for the European Union was estimated to be well above 100,000 in 2009. For 2010, direct employment in photovoltaics for the European Union are estimated to be in the range of 120,000 to 150,000. If jobs in the equipment manufacturing industry and along the supply chain are added, EPIA estimated about 300,000 European jobs for 2009 and 400,000 jobs for 2010. [98]

In the last decade, the photovoltaic market has changed **from a supply- to a demand-driven market**. PV production is based on technologies and capacities developed in the semiconductor industry. Like semiconductor production, its economics are highly scale driven with increases in scale leading to sharply declining unit costs. A combination of scale economies and production overcapacity in the past two years has led to a 50% reduction in unit prices for crystalline PV. The industry structure is nonetheless fragmented, suggesting that consolidation is imminent.

A key economic goal is to reach 'grid parity', ie the point at which the generation cost of electricity produced by PV systems equals the retail price of electricity from the grid. PV firms especially focus on bringing down costs, while government-funded research continues to support technological foundations.

---

[95] European Commission, *Europe's Energy Position markets and supply,* Market Observatory for Energy, *2009*

[96] Arnulf Jager-Waldau, *PV Status Report 2010 - Research, Solar Cell Production and Market Implementation of Photovoltaics*, Institute for Energy, Renewable Energy Unit, European Commission, DG Joint Research Centre

[97] B. Brown, C. Hendry, Public demonstration projects and field trials: Accelerating commercialisation of sustainable technology in solar photovoltaics, *Energy Policy 37*, 2009, 2560–2573

[98] Arnulf Jager-Waldau, *PV Status Report 2010 - Research, Solar Cell Production and Market Implementation of Photovoltaics*, Institute for Energy, Renewable Energy Unit, European Commission, DG Joint Research Centre

In a 2008 Impact Assessment[99], the Commission described a range of **market and policy failures** that explained the less-than-desired rate of investment in installing PV.

- High investment costs, greater per unit of electricity than existing large-scale technologies
- Large incumbents still dominated most national energy markets and these have "no incentive to encourage the uptake of small scale or off-grid technologies that reduce their energy sales" and are even likely to create barriers
- Information failure. Significant information failure was perceived, related to end-users slowing down public acceptance
- Financial short-sightedness. For most of the technologies, initial investment costs are substantially higher than fossil fuel alternatives, requiring a long-term perspective

5.5.2 The Framework Programme

The Framework Programmes started supporting research in the field of photovoltaics already in the 1980s. On our estimate, the Commission invested some €335m in PV across FP4-6[100]. In FP4 the work was mostly supported in the Non-Nuclear Energy programme (in sub-programmes JOULE for research and THERMIE for demonstration) and focused on reducing wafer production costs and generating new hybrid technologies. At that point, there was little effort on second-generation PV. In FP5 PV was funded under the Energy, Environment and Sustainable Development programme. Projects focused on scaling up crustalline technology for production and, increasingly, on developing second-generation technology. In FP6, the Sustainable Development, Global Change and Ecosystems programme funded PV , working to optimise crystalline PV but increasingly attention switched to thin film technology. FP7 does comparatively little on crystalline PV, which is now the province of company R&D departments, and the main focus has shifted to second-generation technologies.

Recognising the importance of overcoming systemic lock-ins and obstacles to the take-up of PV, the FP has funded a significant amount of demonstration effort (Figure 22) to raise awareness and confidence in PV generators and stimulate larger markets for PV deployment in both the EU and in developing countries. It also involved significant efforts to network stakeholders and policymakers, creating the consensus on the technological road map and links to complementary policies needed be effective.

- *PV-NET - Network for the development of a road map for PV R&D* (2001 – 2003) involved representatives of all relevant R&D and production areas in photovoltaics. For the first time it brought together basically all major players in European PV to formulate a comprehensive strategy for research and industry. It developed a roadmap for PV R&D across the whole range from materials to systems
- *PV-EC-NET - Network for the co-ordination of European and national RTD programmes for PV Solar Energy* (2002 – 2004) had as main goal to increase the effectiveness and coherence of the PV RTD Programmes and developed a commonly accepted European PV RTD roadmap
- The FP6 *PV-NAS-NET* (2003 – 2005) was the network of the representatives of ten Newly Associated States, four EU Member States and Switzerland. It was a complementary network to the PV-EC-NET

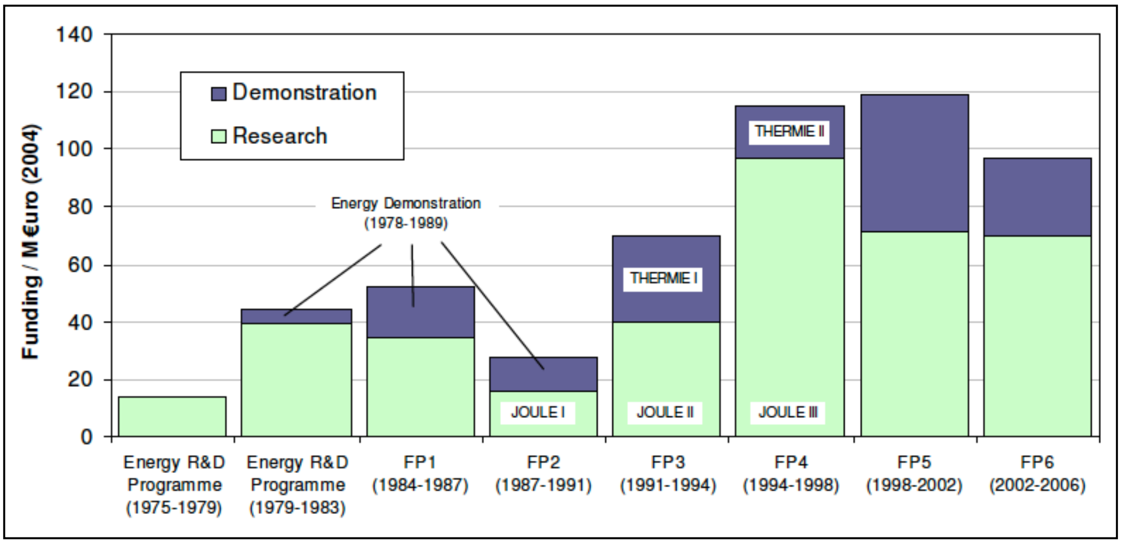
---

[99] European Commission, *Annex to the Impact Assessment – Document accompanying the Package of Implementation measures for the EU's objectives on climate change and renewable energy for 2020*, Commission Staff Working Document, SEC (2008) 85, Vol. II

[100] Our co-word analysis enabled us to identify about €24m in Commission contribution not evident from the official programme and project lists

- The FP6 *ORGAPVNET* project established a common understanding for future investments and strategies concerning organic photovoltaics. It allowed for closer relations between the various organisations of scientific and technological cooperation in the two largest organic solar cell communities in Europe; facilitated the transfer of results from European research to the European PV industry, and fostered measurement standards and prediction of the performance of organic PV cells and modules. [101]

Figure 22: Demonstration and Research Funding for Solar Photovoltaics in Framework Programmes (1975-2006)



Source: European Commission, 2006[102]

Previous analyses[103] as well as the analyses performed in the context of the study indicate that the Framework Programme succeeded in attracting all main European universities and research institutes in the field of solar energy. EU institutions ranked among the top 25 world leading institutions in solar energy - in terms of number of papers published as well as the inclusion of their research papers among the 1% most cited papers - all had participated in the FPs.

Throughout the Framework Programmes, there was growth in the 'core network' of research organisations participating. New universities and institutes became involved and with the emerging of new concepts to produce PV cells and the need for analysis and modelling during FP5 and especially FP6, research groups from other disciplines like physics or chemistry that have no direct history in semiconductor or PV related research were also attracted.

A major added value of the support provided by the Framework Programme was its capacity to act as a platform for the creation and strengthening of long-term knowledge networks that involved research and industry key players across Europe. In a research field and market characterised by strong geographical divergences in the importance attributed to solar PV, the Framework Programme played a fundamental role in ensuring continuity in R&D funding beyond the geographical boundaries and succeeded in promoting expansion of the existing core network

---

[101] European Communities, *Renewable Energy Technologies Long Term Research in the 6th Framework Programme 2002 I 2006*, 2007

[102] Isolde Arzberger, Presentation: Technical Status of EU-funded PV Projects, General Assembly Photovoltaic Technology Platform, 19 May 2006, Brussels

[103] European Commission, *Evaluation and Impact Assessment of the European Non Nuclear Energy RTD Programme – Area 1: Solar Energy*, EPEC - Technopolis, 2009

of FP participants. Such expansion regarded the geographical dimension, leading to a growth of the solar PV market also in 'non-core' countries, as well as the scientific and technological expertise of the research community, involving research groups and institutes with different scientific and technological backgrounds, thus allowing for the exploration and development of new and emerging concepts.

A major characteristic of the Framework Programme was also the breadth of the research focus, covering all generations of technology, combined with a close alignment of the policy instruments adopted to promote technology or market readiness. Projects demonstrating the reliability and feasibility of the first generation technology contributed to market readiness and innovation take-up; the promotion of technological variety in the early stages of R&D prevented premature lock-in to a specific technology and facilitated first mover advantages for European companies and spin-offs exploiting, for example, the second generation thin-film technologies; research in novel technologies is currently setting the base for future R&D and economic competitiveness. Finally, for future developments in this field, Europe can build upon a structured and coordinated research community in this field and an industry that has accumulated considerable experience.

5.5.3 Impacts

The FP has had significant impacts in solar PV but these have only been possible because of complementary policies, especially to stimulate demand. The German feed-in tariff, for example, was an important driver for PV technologies, creating a market for PV in Germany and stimulating the demand in the whole of Europe.

Underlying the FP's capacity to react to market conditions and technological developments was the fact that it generated the early research roadmaps in this field. Already in the beginning of the 2000s (FP5), these roadmaps, based upon consensus-building efforts involving all stakeholders, were of critical value for the Commission, the research and industry communities for the steering of research agendas.

FP-funded research contributed to the achievement of incremental technological advances improving, for example, cell efficiency and lowering production costs. These advances contributed to the significant growth in the solar PV market and the launch of multiple successful spin-off companies in the field that have achieved a competitive positioning in the world market. For example, the project Crystal Clear in FP6 addressed the whole supply chain in crystalline PV enabling a 40-50% improvement in efficiency[104]. At the same time it has explored second- and third-generation technologies, creating the basis for subsequent generations of technology and products, in FP6 projects such as Larcis and Metaflex. By promoting technological variety, the FP has helped prevent premature lock-in and created innovation opportunities in newer PV technologies.

The FP established larger knowledge networks than would have been possible without it and drew new countries into PV research and production. The Framework Programme funded almost half (46%) of the Top-50 most prolific European researchers in the field – and 7 of the top 10. The European research community publishes in higher-quality journals than others and makes a bigger contribution to the 1% of most highly cited articles than would be expected, given its size.

In the field of solar PV, a close alignment of R&D and demonstration projects and their continuous intertwining is of critical importance, especially in the first stages of the market development: there was an ongoing need for R&D to improve electrical efficiencies and

[104] Beaucarne, G. et al., others, 2008. Solar cell process development in the European Integrated Project CrystalClear. in *Proceedings of the Twenty-Third European Photovoltaic Solar Energy Conference*.

manufacturing costs, while demonstration projects were important to bridge the gap between the R&D phase and the full commercialisation of products. Experts in the field[105] state,

> *Parallel and iterative funding of R&D and Demonstration projects (DTs) has been a feature in the long-term effort to reduce costs—in PV through material development. This complex engagement with public programmes of (sometimes separately funded) R&D and DTs is seen in many large firms. BP Solar, one of the world leaders in PV, for example had 39 EU DT projects and 20 R&D-related over a 15-year period.* [106]

FP projects contributed to lowering production costs and reducing development times for PV products. Considerable numbers of start-ups and spin-offs were triggered by FP-supported research. However, the importance on non-R&D activities in the success of the FP in solar PV cannot be exaggerated. Not only the FP demonstration projects but also the wider activities of the Commission in setting the agenda for European energy policy and influencing national energy policies have been essential preconditions for the creation of solar PV markets. It is noteworthy that President Obama has recently launched a major programme in the USA aiming to reduce PV unit costs and following the European lead in promoting PV-based renewable energy.

Overall, Europe enjoys R&D and economic competitiveness in the field of solar PV and the Framework Programme is overall acknowledged as a major facilitator for this positioning of the European research and industry communities. Indirectly, the support of the Framework Programme therefore contributed to the development of one of the most dynamic sectors globally, which in 2009 provided employment in Europe to approximately 100,000 people, growing to 120–150,000 in 2010.

5.6 Research Sustaining R&D in the Automotive Industry

The Automotive Industry is one of Europe's most globally competitive sectors, contributing 3% of GDP and accounting for 6% of total manufacturing employment and is a sector where policy-push in the form of regulations and directives is an important driver for innovation. FP-funded research had a very significant effect on the competitive position of the European car manufacturing industry, tackling longer-term high-risk research. Involving the industry in setting the agenda for parts of the FP has allowed the vehicle manufacturers to define road maps and build capabilities subsequently to be exploited via in-house development. In recent decades, the Framework Programme has contributed to technological breakthroughs strengthening the competitive positioning of the European car manufacturing industry - notably in areas of European technological strengths such as engine technology, combustion, catalysis, safety and Intelligent Transport Systems. FP-funded research has focused on and contributed to technological developments with a direct environmental or social benefit to the citizen, including research for the improvement of fuel consumption, reduction of CO2, elimination of exhaust pollutants, and countless improvements of driver safety. A long series of these product innovations can be traced back to individual FP-funded projects. An example is the effective significant reduction of air pollution thanks to the introduction of catalytic converters on passenger cars in Europe at the beginning of the 1990s.

---

[105] European Commission, *Clean, Safe and Efficient Energy for Europe - Impact assessment of non-nuclear energy projects implemented under the Fourth Framework Programme*, Thematic Report, 1998

[106] Chris Hendry, Paul Harborne, James Brown, So what do innovating companies really get from publicly funded demonstration projects and trials? Innovation lessons from solar photovoltaics and wind, *Energy Policy* 38 (2010) 4507–4519

5.6.1 Context

The Automotive Industry is one of the most globalised industry sectors in the world and the European Automotive Sector has a strong global competitiveness, with about a quarter of the global market share (or more like 30% if European MNCs' production outside Europe is included). It is one of Europe's key sectors contributing 3% of GDP and accounting for 6% of total manufacturing employment as well as 6% of Europe's exports. The EU-25 Automotive Sector is characterized by the presence of a few globally active Automotive producers (Original Equipment Manufacturers, OEM), large international suppliers and a substantial number of SMEs among the component suppliers. The OEM's spend about 4% of sales – over €20bn per year – on R&D. The sector is both oligopolistic and well organised at the European level via the European Automotive Manufacturers' Association ACEA, in which the US Ford and General Motors companies are prominent players. Its **EUCAR** offshoot was set up in 1994 specifically in order to lobby the European Commission on research for the automotive industry and as a vehicle for its members to organise collaborative projects with EU subsidy. All of the 84 of the world's most prominent suppliers of car parts, systems and modules and 26 National trade associations and European sector associations are members of the European Association of Automotive Suppliers - CLEPA.

Established in 2003, the European Road Transport Research Advisory Council - **ERTRAC** brings together the European-owned automotive OEMs, the EU trade associations, member-state ministries and the European Commission to discuss and establish visions and roadmaps for European automotive R&D. A further forum for coordination is **ERTICO** – the European Road Transport Telematics Implementation Co-ordination Organisation. It comprises industry, ministries, infrastructure organisations and users of Intelligent Transport Systems (ITS) and provides a forum for coordinating ITS policies, databases and standards.

Policy push in the form of regulations and directives is an important driver for innovation in the automotive industry. International harmonisation efforts in the framework of the UN Economic Commission for Europe have strongly influenced safety and environmental standards and the ACEA have also imposed voluntary standards, notably on emissions. EU-wide standards on emissions have been in place since 1970 and their successive tightening has forced the industry almost to eliminate so-called 'harmful' (ie poisonous) emissions and dramatically reduce CO_2. The hunt for increase fuel efficiency and therefore reduced CO2 emissions goes well beyond combustion and catalysis to weight reduction, increased design effort on producing light but strong structures, use of new materials and manufacturing techniques. Recyclability requirements and eco-labelling have induced further technological changes.

Broadly, those States with significant OEMs or component clusters (such as Austria and Norway) also have national automotive R&D support programmes.

Because it produces high-value goods in large volumes, the automotive industry is extremely risk-averse, despite its heavy reliance on technological development for product performance and differentiation. There have been dramatic reductions in harmful emissions including diesel particulates, noise and CO2 from vehicles in use, and also in their manufacture (especially in areas like painting). Vehicle life has increased dramatically. Partly to meet emissions requirements but also to improve performance, safety (eg ABS braking, traction control) and add features, the share of a vehicle's value made up by electronics has risen from about 22% in 1997 to 33-40% today. Huge amounts of effort have been expended to improve combustion and catalysis and a significant effort is being made to change the driveline: eventually abandoning conventional internal combustion engines in favour of hybrid drives, fuel cells and fully electric vehicles. There have been great advances in passive safety (seat belts, air bags, neck restraints, crumple zones, side impact protection, etc) and the focus has increasingly shifted towards active safety, using electronic control to intervene to prevent a crash or to reduce its likelihood.

Active safety increasingly intersects with a separate, long-running effort variously known as Road Transport Informatics (RTI), Intelligent Highway Vehicle Systems (IVHS) or Intelligent Transport Systems (ITS). These systems generally involve electronic communication between the vehicle and infrastructure (highways for paying tolls, communications, navigation and traffic information, active safety systems such as cruise controls that keep a safe distance behind the vehicle in front, potentially in the future means to organise cooperative driving through communication with other vehicles and the roadside).

Innovation in the automotive sector involves maintaining a balance between satisfying common (often regulation-induced) needs and product differentiation. There is close cooperation between OEMs and component manufacturers. Increased electronic content also means that standards are growing in importance. ERTICO, in particular, has put a lot of effort into supporting industry-wide standards to allow component interoperability. The intent was to prevent component makers like Bosch from imposing de facto standards and acquiring a Microsoft-like grip on their customers.

5.6.2 The Framework Programme

The history of significant involvement by the vehicles industry in European Research actually begins with the EUREKA Prometheus project, which started on the initiative of Daimler-Benz in 1986 and ran to 1994. with a total budget of over 70m ECU per year. It comprised research projects and ten 'Common European Demonstrators'.[107] These substantially defined the research agenda in Intelligent Transport Systems up to the present time.

The DRIVE programme in FP2 (1987-1991) duplicated much of this activity but was nonetheless attractive because, not being an industry initiative, it was able to get greater participation from the public authorities. Thus, Prometheus focused more on in-vehicle technologies while DRIVE put more emphasis on the infrastructure.

Since then, research activities of interest to the car manufacturing industry have been funded across various research programmes. Three major strands are visible in the FPs (Figure 23). One follows the RTI/IVHS/ITS trajectory that started in Prometheus. A second is a changing mix of activities focused on engineering production that at some times is specifically focused on road vehicles but at others is more generic. The third is a stream of energy research dealing with emissions and new and alternative vehicle fuels[108].

[107] Common European Demonstrators were: Vision Enhancement, Proper Vehicle Operation, Collision Avoidance, Cooperative Driving, Autonomous Intelligent Cruise Control, Emergency Systems, Commercial Fleet Management, Test Sites for Traffic Management, Dual Mode Route Guidance, Travel Information Services

[108] Impacts of the Framework Programmes in Sweden, Technopolis, 2008

Figure 23 Vehicles-orientated parts of the Framework Programmes

	RTI/ITS	Vehicle Engineering	Energy and Fuels
FP2	[Prometheus] DRIVE	BRITE/EURAM	JOULE
FP3	Telematics / • DRIVE2	BRITE/EURAM II	JOULE2
FP4	Telematics / • Telematics for Transport	BRITE/EURAM III - Materials and Technologies for Product Innovation / Technologies for Means of Transport	JOULE
FP5	IST / Systems and Services for Transport & Tourism	GROWTH - Key actions (products, mobility, transport, aeronautics) / RTD (materials and their technologies; steel)	Sustainable Development / Sustainable Energy Systems
FP6	IST / eSafety	SUSTDEV / Sustainable surface transport	SUSTDEV / Long-term impact
FP7	Information and communication technologies	Transport (incl. aeronautics)	Environment (incl. climate change) / Energy

Source: Impacts of the Framework Programmes in Sweden, Technopolis, 2008

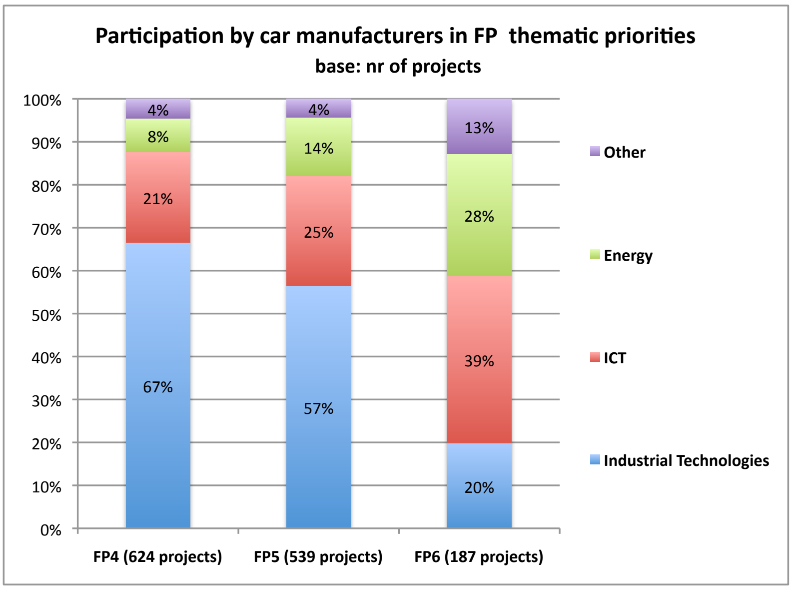
EUCAR has been a vital forum for obtaining consensus in R&D needs among the OEMs (recently including truck as well as car makers) and communicating with the EC. The ETP on road transport – ERTRAC – has played a similar role in relation to transport, mobility and logistics – taking a more societal focus than EUCAR. Joint Technology Initiatives under FP7 (especially Fuel Cells and Hydrogen and the ARTEMIS embedded systems JTI) have provide new ways to coordinate and to look for synergies with R&D needs of other sectors. The EU's Intelligent Car Initiative, launched in 2006 as one of the i2010 Flagship Initiatives, aims to accelerate the introduction of safety-related technologies in new cars. As part of its European Economic Recovery programme, the European Commission recently launched the PPP European Green Cars Initiative to promote research across the technologies and smart energy infrastructures that will be essential for a breakthrough in the use of renewable and non-polluting energy sources. It will have a combined budget of at least €5 billion and the Framework Programme (FP7) is expected to offer research grants with a €1 billion budget, funded equally by the European Commission and the transport industry.

In terms of **programmes and initiatives**, participation by car manufacturers in FP-funded research was focused on three areas:

- In the Industrial technologies theme (BRITE-EURAM in FP4 and Sustainable Growth in FP5), automotive manufacturers predominantly participated in research on new production technologies in the broadest sense – from design techniques, quality and other business processes to new materials and a wide range of new and improved manufacturing technologies and techniques
- In ICT research under various sub-themes within the ESPRIT (FP4) and IST (FP5) Programmes. In ESPRIT participation was pronounced especially in research related to Information Technologies for Product & Process Data Modelling
- Energy research within NNE-JOULE C (FP4) and Environment and Sustainable Development (EESD-ENERGY, FP5)

Figure 24 illustrates the trend in participation pattern for the care manufacturing OEMs. It especially depicts the increasing importance of ICT for innovation in this industry sector.

Figure 24: Participation by car manufacturers in the FP thematic priorities, nr. of projects



Source: Technopolis, based on E-Corda, 2011

All the major European automotive manufacturers participated in the FPs, with Fiat being the most frequent participant followed by Daimler and Volvo. Their main motives were:

- Reduced opportunities for national and regional funding in some European countries (especially Italy and to a certain extent France – with the exception of electric vehicles that received substantial funding).
- A need for large-scale research projects that cannot be funded nationally.
- Limited clarity in objectives of national and regional programmes compared to European programmes.
- Opportunity to test competing technologies, compare them in a common environment with a working legal framework with established rules on IPR.

In FP4, automotive manufacturers participated especially in research in the field of **production and manufacturing**. The relevance of this research line has gradually declined over the FPs, reflecting the maturity of the technologies. Research in **Emissions & combustion** also became less important in FP6, while it constituted a major research line in FP5 (1998-2002). However, research in **Communication technologies**, including human-vehicle interaction and intelligent transport systems as well as research on **Software, integrated systems and sensors**, grew, pointing at an increasing interest in passive and active safety and mobility topics as well as the increasing importance of electronic embedded systems. **Alternative drivetrains** (including research into hybrid and fully electric vehicles and alternative fuels) saw a steady increase in number of projects across the FPs.

5.6.3 Impacts

Direct attribution of technological developments to research conducted in the Framework Programmes is a difficult task in the case of the Automotive Industry where innovation is foremost based on internal knowledge stock and dependent on long-term developments and testing because of the high risk factor. Furthermore, the FP contribution to research in the relevant areas constitute only a limited fraction of the overall R&D investments by industry, being this a high-intensive R&D sector. And also national R&D programmes contribute to automotive-related technology developments.

Nevertheless, all interviewees in our study – as well as other studies – stressed the importance of European FP-supported research for the actors in this sector. The Framework Programmes were considered to have a very significant effect on the level of cooperation with and within the European automotive industry, on its development and ultimately on its competitive position in the global market. The following major facilitators for impact achievement by FP-funded research activities emerged.

The long-term funding by the Framework programmes and the continuity in the thematic priorities allowed for an **incremental innovation** of technologies that often had 10 to 15 years time-to-market. In some cases this was due to the dependence on the maturity of other technologies (e.g. the research on *spark-ignition engines*); in other cases the cause was to be found in the high level of technological challenges (e.g. the research related to the *treatment of exhaust gases*). In many cases several competing technologies were funded to achieve one objective, for example it funded intelligent transport systems using terrestrial as well as satellite communication technologies; both spark ignition and diesel engines research projects etc. The involvement of the OEMs since the very start of these research lines allowed these companies to build up the needed capabilities and **internal knowledge stock** in order to then take up the final stages of the technological development in-house.

The European dimension of the Framework Programmes as well as the pre-competitive character of the research was of particular importance. It allowed the FP to act as a platform for 'open innovation', involving several - if not all - car manufacturing OEMs. In some cases these projects allowed for an evaluation and comparison of competing systems, **reducing the risk element** to innovation in this sector and thus **shortening time-to-market** as well as providing a platform for **standardisation** across several areas. In other cases, the Framework Programme allowed for joint exploratory research where the companies could build upon each other's knowledge stock, leading to **cross-fertilisation** and directing corporate research lines. The FPs have been often used for benchmarking and scanning of the current research landscape and competitors' capabilities in emerging technologies as well as for identification of future trends. In many research lines – and especially in exploratory research – the involvement of companies or research institutes with **complementary expertise** resulted critical for the achievement of the desired research results.

Last but not least, the Framework Programmes strengthened and expanded the **collaboration networks in R&D** between the OEMS and their supply chain on the one hand and the OEMs and research institutions on the other.

FP-funded research had a very significant effect on the competitive position of the European car manufacturing industry. In comparison to many nationally funded research programmes or in-house R&D, its major added value was in its capacity to act as a platform for **longer-term high-risk research**, involving the best in Europe while covering full value chains, and offering the opportunity for low-risk knowledge- and experience-sharing among competing OEMs. At the roots of its successful contribution to this industry's competitiveness was the alignment of both the focus of the research and the mix of instruments adopted with the industry needs, the technological advances and opportunities, and the market- and industry-specific dynamics for innovation.

It allowed for an incremental innovation of technologies that often had 10 to 15 years time-to-market; benchmarking and scanning of the current research landscape and competitors' capabilities in emerging technologies as well as identification of future trends; joint exploratory research, leading to cross-fertilisation and directing corporate research lines; a contemporaneous development of several competing technologies to achieve one objective (for example, both spark ignition and diesel engines research projects). In some cases these projects enabled the development of industry standards; in others it allowed for evaluation and comparison of competing systems, reducing the risk of innovation and thus shortening the decision-making process and ultimately time-to-market. Particularly important from that perspective were also the FP-funded activities that allowed for the testing and demonstration of the feasibility and reliability of innovative technologies and systems.

Involvement in the early stages of the research and the continuity in thematic priorities allowed the OEMs to build up the needed capabilities and **internal knowledge stock,** in order then to take up the final stages of the technological development in-house. Especially in the case of research related to the integration and embedding of electrical and electronic components, participation in FP-funded research also allowed them to build up sufficient know-how for an informed management of the relationship with their suppliers.

Benefits for the research organisations included the opportunity to work on technological issues determined by industry needs, testing simulation platforms, making conjoint decisions on new concepts and designs and testing and proving their ability to construct demonstrators. Participation in FP research allowed them to increase their scale of operations and networks that kept them up-to-date with the leading research questions in their fields, often resulting in **knowledge spill-over** in their national or regional environment.

Over the last decades, the Framework Programme has contributed to major technological breakthroughs sustaining and strengthening the competitive position of the European car manufacturing industry - notably in areas of key European technological strengths such as combustion, catalysis and safety/ITS. The FP was instrumental in the development of the 'common rail' technology, which enabled the transition from first- to second-generation diesel engines with better-controlled combustion, fewer emissions and power characteristics much closer to those of a petrol (Otto) engine. This underpinned Europe's continuing technical lead in diesel technology and enabled, for example, Mercedes Benz to be the first manufacturer selling diesel-powered cars in the US and meeting the toughest Californian emission standards. FP-funded research gave Daimler the opportunity to gain basic understanding of new materials, which then resulted in the development of new exhaust after-treatment technologies and supported Fiat in its R&D efforts leading to the introduction on the market worldwide of an electro-hydraulic variable valve actuation technology controlling air intake in 2009.

In the majority of cases, FP-funded research focused on and contributed to technological developments with a direct environmental or social benefit to the citizen, including research for the improvement of fuel consumption, reduction of CO2, elimination of exhaust pollutants, and countless improvements of driver safety, ITS systems for improved mobility. A long series of these product innovations can be traced back to individual FP-funded projects. The results of these developments are visible especially in the sphere of energy efficiency and environmental protection where product innovations reaching market penetration have led to important impacts. An example is the effective significant reduction of air pollution thanks to the introduction of catalytic converters on passenger cars in Europe at the beginning of the 1990s.

5.7 Expanding the FP Structural Effects – the Case of the ManuFuture ETP

The Framework programme plays an increasingly catalytic role in integrating and strengthening the European research infrastructure, impacting industry and research communities. Structural effects promoted by the Framework Programme include the creation or strengthening of knowledge networks often evolving into long-term strategic alliances; the integration of research and industry communities – cross-sectoral, interdisciplinary or transnational; and collaboration networks between and among European and national R&D policy-makers, in a growing number of cases resulting in joint-programming of research.

At the base of the ‘knowledge networking’ impact is the collaborative R&D model that has been adopted in the Framework Programmes since its very outset. Through the life of the Framework Programme, the collaborative research model evolved into a European ‘open research and innovation’ model and many consider this to be its major long-term effect. We note the sequential building-up and expansion of these structural impacts, with current structuring activities building upon the results of preceding ones. The ManuFuture ETP is a example of such incremental structuring of a research and industry community: the platform itself as well as its strategic input in terms of the research agenda are deeply rooted in preceding activities promoted by the European Commission. It responds to the need for a ‘horizontal’ technology platform related to the manufacturing industry, with particularly high expectations in relation to its future economic impacts.

5.7.1 Context

Manufacturing accounts for a quarter of EU employment and 37% of GDP as well as three quarters of exports[109]. Maintaining competitiveness in the face of globalisation is clearly important. In the context of the Lisbon agenda, industry as well as European policy-makers considered that in order to sustain and strengthen global competitiveness, European manufacturing needed to **radically transform** its base and turn from a resource-intensive into a knowledge-intensive sector. Manufacturing enterprises were to progress towards "customer-responsive enterprises, totally connected, reconfigurable and efficient, based on knowledge and technology innovation".[110]

Experts considered that the economic context and the shift in business paradigms in manufacturing required a new vision of manufacturing based on research-based knowledge creation and added value. A European manufacturing strategy was to be created, and the European Technology Platforms were expected to play a considerable role in this process, providing input on research agendas and roadmaps reflecting industry needs. A number of 'vertical' action plans and Technology Platforms (TPs) had already been set up or were in the course of development, tackling manufacturing issues in various technology- or sector-specific contexts.

However, there had been little concerted effort to address technology requirements and associated barriers that cut across multiple sectors. Manufuture was to address these underlying 'horizontal' approaches, applicable across a broad spectrum of industries. Adaptable and reconfigurable manufacturing systems, information and communication technologies, and modelling and simulation, for example, were indicated as three key enabling technologies research areas that address several manufacturing challenges.[111] Environmental and social targets were expected to dictate new paradigms that reflect the long-term needs for a more sustainable way of manufacturing.[112]

The ManuFuture ETP was expected to support the development of an interdisciplinary manufacturing research and development programme by creating an integrated knowledge community, bringing together multi-sectoral interests across a broad spectrum of manufacturing interests. [113]

5.7.2 The Framework Programme

The Framework Programme has a supported manufacturing since the outset. (Figure 25 shows the key programmes involved. These have primarily been small-company focused, though the Growth and NMP programmes have increasingly welcomed larger participants. Many other projects in other parts of the FP have tackled manufacturing issues relevant to particular

---

109 Janez Potočnik, *Towards resource-efficient growth – the role of manufacturing*, speech at European Forum for Manufacturing Round Table, European Parliament, Brussels 29 November 2010

110 José Sá da Costa, *Manufacturing - Background paper for the European Commission's High Level Group on Key Technologies for Europe*, European Commission, July 2005

111 European Commission, *The long-term impact of industrial research - European industrial research, evolution and impacts,* EIR - European Industrial Research, March 2006

112 José Sá da Costa, *Manufacturing - Background paper for the European Commission's High Level Group on Key Technologies for Europe*, European Commission, July 2005

113 José Sá da Costa, *Manufacturing - Background paper for the European Commission's High Level Group on Key Technologies for Europe*, European Commission, July 2005

technologies, industrial or other societal priorities. However, there was no Framework-wide or industry-wide approach.

Figure 25 Manufacturing Technology Programmes in FP1-6

FP	Period	Programme	Budget (€m)
FP1	1984-1987	BRITE	185
FP2	1988-1991	BRITE-EURAM I	620
FP3	1991-1994	BRITE-EURAM II	748
FP4	1995-1998	BRITE-EURAM III	1617
FP5	1999-2002	Growth	2700
FP6	2003-1906	NMP	1300

Globally, the Intelligent Manufacturing Systems (IMS) grew from an initiative by the President of the University of Tokyo in 1989, finally being launched in 1995 by Australia, Canada, the EU and Norway, Japan and the USA. It provides a platform for establishing collaborative R&D projects in manufacturing wholly funded by industry (although the Commission acts as the secretariat for the European part of IMS). This is probably the most important precursor of Manufuture and is an important indicator of movement towards a more open innovation models among large, global manufacturers.

ManuFuture is a European Technology Platform, designed to underpin a competitive, sustainable and job-creating EU manufacturing sector in the years ahead. It was launched in 2004 as the result of a set of activities, launched or promoted by the European Commission and all aiming at creating a platform and infrastructure for an improved definition of European manufacturing strategy.

At the beginning of the 2000s, the European Commission started its activities for the development of the Manufacturing Technology Action Plan. Among these activities was therefore a range of foresight and road mapping exercises, implemented in the context of 'support actions' such as FUTMAN and INFORMAN. In the summer of 2003, DG Research established an Expert Group, which was to discuss the future of manufacturing in Europe in a series of workshops. Its recommendations then constituted a working document for the conference 'European Manufacturing of the Future: role of Research and Education for European World Leadership' (Manufuture), held in Milan in December 2003.[114]

At that conference, Commissioner Busquin proposed to create a High Level Group (HLG) on Manufacturing to develop long-term visions for research and innovation actions at EU level. The conference resulted in the establishment of a High-Level Group that showed a balanced representation covering industry, research and education, trade associations and other stakeholders. Workshops were held around Europe in mid 2004, culminating in "Manufuture, A vision for 2020 – Assuring the Future of Manufacturing in Europe', presented in the Netherlands in December 2004. At the end of this exercise, representatives of four major stakeholders confirmed their support for an ETP on manufacturing and in 2005 work began on a Strategic Research Agenda.

In December 2007, the Council and the European Commission encouraged the MANUFUTURE community to take the next step and to explore the feasibility of launching a Joint Technology Initiative. Throughout the year 2008, MANUFUTURE developed a concept for a public-private partnership with the European Commission, including the establishment of a joint undertaking pursuant to article 171 of the EC Treaty. In November 2008, the European Commission proposed the Factories of the Future Initiative with an estimated envelope of €1.2 billion up to

[114] European Commission, *Improving European Competitiveness*, European Industrial Research, 2003

2013. In March 2009, the MANUFUTURE High-Level Group decided to create the special purpose association EFFRA.

5.7.3 Impacts

The ManuFuture ETP is a example of such incremental structuring of a research and industry community: the platform itself as well as its strategic input in terms of the research agenda are deeply rooted in preceding activities promoted by the European Commission. It also responds to the need for a ‘horizontal’ technology platform, focusing on trans-sectoral challenges for the manufacturing industry; launching a public/private partnership funding applied research explicitly focused on these challenges; acting as a platform for the collaboration and integration of other technology platforms; and creating spill-over structural effects in the national landscapes.

So far, the ManuFuture ETP has successfully acted as a platform facilitating an enhanced collaboration between cross-sectoral research and industry communities and ETPs. Its activities have resulted in an expansion of its membership base and thus of the community directly or indirectly involved in FP-funded research. It created a leveraging effect also at the national level by the launch of several mirror NTPs, contemporaneously contributing to an improved coherence with and among the national public research agendas. Its key role, however, is in the integration of research activities concerning the manufacturing industry – at both the European and national level. It has set up a trans-sectoral technology roadmap tackling common barriers and pitfalls, organises annual conferences, and strengthened its sustainability and its impact on European R&D in manufacturing technologies through the successful launch of the PPP Factories of the Future.

Concretely, major achievements of the Manufuture ETP have been:

- The expansion of the membership base and consolidation of the ETP. From the initial core group of FP participants, in 5 years time the membership base of the platform has expanded to including 1,700 registered members among which 1,300 SMEs, 230 large companies, 120 research institutes, 20 associations and 30 governmental bodies.
- The development and implementation of the Strategic Research Agenda, effectively creating a roadmap for R&D across manufacturing
- The establishment of 26 mirror National/Regional Technology Platforms involving 2,000 direct members
- Joint activities with other European initiatives and ETPs
- The set-up and launch of the Factories of the Future PPP, with a €1.2 bn budget

At this stage, the longer-term effects of Manufuture are far from clear – and understanding them will pose a significant challenge for evaluators. However, the Platform is an important instance of the shaping and structuring that appears to be one of the Framework Programme’s most powerful impact mechanisms. Already at this stage it is clear that its influence is enormously far-reaching.

6 CONCLUSIONS

This report tells the story of one of a significant attempt to catalogue and investigate the long-term impacts of the framework programme through a number of selected areas. This has involved not only the analysis of what has emerged from the programme, itself a very challenging task given the complexity and diversity of the research activities which are covered, but also an attempt to unravel what were the structures and inputs against which impacts have been achieved. Indeed it is only through such a process, essentially reconstructing what the programme has done before saying what it has produced, that we can begin to understand longer-term impacts.

The Framework programme has played an increasingly catalytic role in integrating and strengthening the European research fabric, impacting industry and research communities. Structural effects promoted by the Framework Programme include the creation or strengthening of knowledge networks often evolving into long-term strategic alliances; the integration of research and industry communities – cross-sectoral, interdisciplinary or transnational – that took up the task of developing research roadmaps and providing strategic input for the research agendas of public agencies and private enterprises; collaboration networks between and among European and national R&D policy-makers, now in many cases resulting in joint-programming of research.

The Framework programme has, in effect, undertaken quite a long journey from its early days of introducing the idea of collaborative research to often-suspicious stakeholders, slowly legitimising a more open model of innovation. With increased openness, it has become increasingly possible to coordinate. Crucially, that coordination is not top-down but works by enabling, channelling and supporting the self-organisation of the industrial and research communities involved, eventually (through joint programming) also influencing Member State policies and priorities. The next challenge for evaluation and for the provision of strategic intelligence about and for the Framework Programme is to understand more about how these high-level and inherently rather long-term mechanisms operate and can be improved. This will involve both new methodologies and new perspectives on evaluation that are less rigidly attached to the programming cycle than is the case today.

6.1 What the existing evaluation record tells us about Impacts

The existing evaluation record paints a picture of the Framework Programme that is by now rather familiar.

At its heart, the Framework Programme is a ‘precompetitive, collaborative’ programme. That is, it involves cooperating about R&D issues where it is in participants’ interest to cooperate. For academic researchers, this covers most kinds of research, since they are rarely involved in commercialisation. For companies, this is normally about things where it makes no sense to compete, such as technologies that will be applied in the medium-long term or aspects of technology that confer no competitive advantage (for example, where everyone has to comply with regulation). It follows that most of the time participants do not directly commercialise results from FP projects. Hence, evaluations show that from the participant perspective the main outputs of the FP are knowledge and networks (including marketing-relevant networks and supply chains).

The FP is an important influence on standards and norms to the extent that these are precompetitive issues. Standards reduce uncertainty, so companies have a common interest in agreeing them, even with their competitor. In some cases, the FP allows a European ‘bloc’ to organise and to compete with others.

FP projects normally involve networks. These have to be strong in order to win in the competition for funding. They tend to evolve slowly with new members being tested and admitted only once they have built trust and old members sometimes falling off the train. We know that there are ‘usual suspects’ – often Research and Technology Organisations or applied industrial research institutes like the Fraunhofer Societybut also certain companies and university groups – that form key nodes in many networks and that persist through successive FPs, though we know nothing about their behaviour at the micro level that would explain why they do this and whether the FP could make better use of this role. Evolving networks tend to be conservative, so they may reinforce the conservatism of the consensus-based FP – but we have no evidence about this.

For the most part, the FP reinforces the strength of those who already strong. You have to build strength at the national level before you can win the competition for FP funds, so the consistent winners in the FP are the strong universities and RTOs and the bigger firms. This further promotes conservatism. But there are also cases where the FP promotes the creation of new things (see the QIPC case in this study). Here there is a gap in the evaluation record: the small parts of the main Framework Programme that promote ‘different’ ideas (FET, the former NEST) have not been evaluated. (The ERC has no thematic relationship with the rest of the FP so its role in relation to the main FP agenda is presumably similar to that of national research councils.)

Both the bibliometric evidence and the toughness of the competition show that the research and at least some of the people involved in the FP are of high quality. Participants believe that FP participation makes them and their organisations more competitive.

There is a clear ‘behavioural additionality’ at the point where organisations join the first of a series of FP projects in that their networking behaviour changes to fit the FP. We like to say that they then adopt a ‘European model of open innovation’ and carry on participating – so there is no further behavioural additionality. Again we lack micro-studies that explain their strategies and behaviour. Thus, for example, we do not know whether over time participation ‘crowds out’ internal research in companies, or whether large participants can rely on a stream of income from the FP that frees up internal resources that can be applied to activities not eligible for FP funding.

Most of what we understand about the FP is seen through the eyes of the participants, who kindly cooperate in our surveys and interviews but who have little idea about the overall effects of participation on their organisation or the economy. It does appear that larger participants reap larger benefits than smaller ones – and it is correspondingly likely that they also tend to drive larger social and economic effects than small ones.

6.2 What the scientometrics tells us about impacts

Co-word analysis shows that the work of the Framework Programme can be clustered into major clusters that correspond to areas where it is possible to identify impacts using other techniques. We had hoped that co-word analysis would also indicate places where scientific breakthroughs were being made but this analysis was not decisive. We did, however, establish that FP participants were strongly represented among the top 1% most cited papers in their fields. This is consistent with them contributing to breakthrough but does not allow us to be certain that they themselves made the breakthroughs or to identify such breakthroughs.

The bibliometric approach confirmed that the Framework Programme involves a very high proportion of all significant European organisations, including those with strong publication performance on a range of definitions. In real life, this is a strength; analytically, it is a problem because it means there is not much of a control group to whose performance we can compare that of FP participants. At the level of individuals, in three of the four fields analysed, FP participants were strongly represented among the most productive researchers in the world.

The network analysis focused on centrality, namely the extent to which organisations occupied a central role in their co-publication networks with many connections to others. It showed that European organisations have indeed become increasingly central and therefore, we infer, more powerful in terms of access to information and in setting agendas and building research cooperations.

All four fields analysed have been growing during the life of the Framework Programme and are widely recognised as important. In QIPC, stratospheric Ozone research and solar energy, the European research community has improved its relative position on a range of measures and is now operating in strength at the scientific frontier. Neurobiotechnology was already a strongly established field at the point where the Framework Programme intervened. While there are points of improvement, overall the main contribution of the FP in neurobiotechnology appears to have been to help the European research community to maintain its relative position.

6.3 What the cases tell us about impacts

Figure 26 uses the long-term impact categories we defined in the analysis of the Framework Programme's intervention logic (see Figure 10). In generalising, of course, we lose the subtlety of the individual case stories but it is interesting to see that there is a diversity of impact patterns.

Figure 26 Long term impacts of the Framework Programmes

Long-term impacts	QIPC	Brain Research	O_3	Solar PV	Auto-motive	Manu-future
Emergence of new technologies or fields of science	X	X		X		
Technological trajectories	X			X	X	
Integration of research	X	X	X	X	X	X
Cohesion of Europe			X	X		X
Diffusion of innovation in products, processes or services				X		
Strengthened competitive position of industry				X	X	
Innovation in policy-making			X			X
Innovation in the economic sphere				X	X	X

In QIPC, the Framework Programme picked up the emergence of a new field of science and technology, helped it establish scientific and technological agendas, organise and grow in Europe to such an extent that the EU appears fully competitive with the other world R&D leaders. The field has not yet reached the stage where products and processes are developed, but Europe has the technological basis and has started to develop standards for doing so and therefore for continuing to maintain strong positions in the global computing and communications industries as they go through a paradigm shift in how they process information.

The Framework Programme has been less decisive in Brain Research, which was already well established at the point where FP funding began. It has nonetheless made important contributions in imaging and helped support and integrate the European research community in a period when the USA has been investing much more public money in the field than the European Member States have, in sum. Launching the European Brain Council was an important contribution to setting and maintaining a relevant and up to date research agenda in Europe. The FP has been important in keeping Europe 'in the game' in this field.

In Stratospheric Ozone research, the Framework Programme has made a major contribution by growing and helping coordinate the European research community, not least through organising multinational research campaigns to provide a better evidence base for policy. It has helped the European research community move from lagging far behind the USA to working at the global frontier. Research results have shaped the evolving Montreal Protocol requirements and have been so influential at the policy level that Europe has achieved the Protocol's 2020 targets ten years ahead of schedule.

In Solar PV the Framework Programme has expanded the European research community and enabled it to work at the technological frontier – not only in first- but also in second- and third-generation Solar PV. Demonstration projects and complementary renewable energy policies have helped develop markets for Solar PV and establish a significant European presence in the supply industry.

In automotive, the Framework Programme's role has been to sustain longer-term research and research in areas such as fuel efficiency, emissions and safety that create not only private advantages for the industry but significant public goods. Exploiting the industry's desire to self-organise to define R&D directions and road maps has been a powerful way to coordinate the longer-term R&D effort and has supported a long series of product and process innovations that help maintain Europe's position among the global leaders in this industry.

The Manufuture Technology Platform is of interest more for its potential than for any socio-economic impacts achieved at this point. It underlines the importance of coordination and self-organisation as mechanisms to integrate research. It has defined a research agenda about which there is broad agreement in manufacturing industry, recruited large numbers of partners and helped define 26 national or regional level platforms and is beginning to influence policymaking (especially in the area of sustainability) and affect industrial processes.

The most important commonality among these stories is to do with coordination by enabling self-organisation. This is a far cry from the 'technology gap' idea and the associated 'technology push' model that underlay the early FPs. That does not mean that the Framework can evolve into an advisory rather than a funding function. If there are no resources there is nothing to coordinate or organise. The farmer does not listen to the agricultural extension worker because he is wise. The farmer listens to the agricultural extension worker because he is wise and brings the subsidy cheque.

6.4 Impact mechanisms

Our earlier analysis on the Framework Programme's intervention logic tries to describe intended causal links: what causes what. Figure 27 (which is undoubtedly not exhaustive) tries to explain **how** such links are made, based on what is visible in the six case studies.

We can see that the scientifically focused cases contain elements of discovery. The Framework is funding serious science and this leads in some cases to progress at a quite fundamental or basic level. Of course, discovery alone is not all that useful. To have societal effects, it must be placed in a wider system that connects it with needs, opportunities, production and eventually markets or other competitive arenas such as policymaking. In four of the cases, the FP made a clear contribution by increasing the volume of knowledge production, especially in relation to applications. This can involve 'translational research' (which 'pushes' fundamental knowledge towards applications) but perhaps more fundamentally makes connections with potential uses and users, often making the mix of work more interdisciplinary, since it is usually the case that the closer research gets to solving real-life problems the more disciplines need to be involved. In one case (QIPC) the Framework Programme appears to have made a decisive contribution to the development of a new discipline.

Figure 27 Impact Mechanisms in the Case Study Areas

Impact mechanisms	QIPC	Brain Research	O_3	Solar PV	Auto-motive	Manu-future
Discovery	X	X	X	X		
Creating new knowledge outputs, more generally, especially moving towards applications	X	X	X	X	X	
Discipline development	X					
Focusing device in relation to innovation				X	X	X
Agenda-setting	X	X	X	X	X	X
Promoting self-organisation of stakeholder communities	X	X	X	X	X	X
Influencing regulations or standards	X		X	X	X	
Coordinating or influencing policy		X	X	X	X	X
Strengthening networks, Knowledge Value Collectives; defragmenting the research community	X		X	X	X	X
Changing research network shapes: putting Europe in the centre	X	X	X	X	N.A.	N.A.
Levering funding for R&D	X	X	X			X
Mobility and development of human capital	X	X	X	X	X	
Research infrastructure (Grids, test-beds, etc)						
Behavioural additionality: learning a 'new' innovation model		X			X	X
Speeding up industry' entry into new technologies	X					
Tackling problems too big for an individual Member State	X	X	X			X
Addressing areas of major socio-economic importance for the EU	X	X	X	X	X	X

Three of the impact mechanisms are examples of 'arenas', with the FP providing the virtual place in which ideas are interchanged: focusing devices; agenda setting; and coordinating or influencing policy.

Nathan Rosenberg coined the term "focusing device"[115] for phenomena in industrial innovation that focus the attention of innovators on problems that they could solve, thereby triggering innovation. We have used the term[116] in a more specialised way to refer to interactions that draw the attention of the research and/or policy communities to innovation opportunities that depend on the conduct of research. In effect, industry signals 'there is something here that we need to understand better in order to be able to innovate'. We can see examples of this happening in the Framework Programme in the three cases where there are reasonably well-developed markets

All the cases involve agenda setting, typically by creating scientific research agendas or technological road maps. These focus the effort and increase stakeholders' willingness to do

---

[115] Nathan Rosenberg, *Perspectives on Technology*, Cambridge University Press, 1976

[116] Erik Arnold, Barbara Good and Henrik Segerpalm, *Effects of research on Swedish Mobile Telephone Developments: The GSM Story*, VA 2008:04, Stockholm, VINNOVA, 2008

work and invest by reducing uncertainties. In principle, this activity can be risky. What if we set the wrong agenda? In practice, these things are regularly discussed, revisited and modified. In the case of technology road maps, there are often several adequate potential solutions and a large part of the value of the road map is that it represents an agreement that everyone will work on one of them. Of prime importance is that the coordination is not done by the Commission but by the stakeholder communities themselves. The value added of the FP is encouraging and providing a setting in which that self-organisation can happen.

A similar logic applies to influencing regulation or standards, which is a mechanism also visible among the cases. These help define how markets work, so naturally industry tends to be especially interested in this impact mechanism.

There is also a strong bidirectional link between the FP and policy. This can involve research results influencing policy, as is especially clear in the Ozone case, or policy influencing research, as with emissions requirements for vehicles. In the detail, even these apparently one-way flows are in fact two-way. Emissions policy is constrained by what is technically possible just as the problems of incrementally improving the Montreal Protocol raise research questions.

Strengthening networks has been recognised as a key function of the Framework Programme since the beginning. The scientific cases show that this is especially important in newer fields and that it is correspondingly harder to make a difference in established ones, even though there may still be good reasons for investing in such established areas. Network relations can be commercial as well as technical. One of the most important aspects is the creation of a large cadre of people in industry and in the knowledge infrastructure who understand and work with a body of knwoledge – what Bozeman and Rogers[117] call a Knowledge Value Collective. By this they mean a social configuration able to produce knowledge value. Conventionally, we try to count the benefits of an intervention such as a research programme in the industrial world by looking at its effects on institutions. But to a considerable extent, the community of people who work with a technology persists more strongly than institutions, especially companies. Thus, when Digital and Apple left Ireland to move computer production to the Far East, they left behind a population of people, some of whom migrated to other companies and others of whom set up their own businesses, using their knowledge of computer design and production. The effects of the Knowledge Value Collective persisted longer than the particular companies in which some of its members had worked.

The scientometric work strongly suggested that the Framework Programme has enabled European actors to become more central and therefore influential and powerful in R&D networks. This can be expected both to create advantage and to move the European research fabric towards the ERA vision.

Networking is conventionally seen as a way to defragment the research community in Europe, building up 'critical mass' more successfully to compete in the global arena. Implicit in the ERA vision is the idea that individual research groups grow in size to become globally competitive. IMEC and LETI are well-know examples of this happening with strong FP support. It is a question for policy as much as for evaluation how Europe can achieve further successes in this style.

With most FP projects involving cost sharing, the Framework Programme rests heavily on the idea of using EU money to 'leverage' contributions from project participants. However, well before the attempts to coordinate or leverage national money via the ERA-NETs and more recently the Joint Programming Initiatives, our cases show that the FP was aligning funding and activity at national level.

---

[117] Barry Bozeman and Juan Rogers, 'A churn model of scientific knowledge value: Internet researchers as a knowledge value collective,' Research Policy, (31), 2002, pp 769-794

Mobility and the role of the FP as a 'training school' for the research community are impact mechanisms that for accidental reasons are not much in focus in our case studies but whose importance is well understood, even if their longer-term effects are not well explored.

From time to time, there have been important examples of the Framework Programme organising test beds and other shared facilities that generate European Added Value. There are old examples in ESPRIT and RACE as well as new ones in Grid Computing and ESFRI. In our cases, this dimension did not often appear – the main example being the coordination of infrastructure in the stratospheric Ozone field, especially in connection with the large data collection campaigns. The importance of infrastructure as an impact mechanism should nonetheless not be neglected.

Especially in industry, the Framework Programme appears to have been instrumental in achieving change through the use of a more 'open' model of innovation. Once the tradition of collaboration is established, coordination and self-organisation through activities like road mapping become easier. This openness appears to have been important in introducing QIPC research to industrial partners at a very early stage, both so that they cold learn and because this would provide focus to the research, which was ultimately aimed at applications in computing and communications.

In at least four of our cases, the Framework Programme partly achieved its impact because it was uniquely positioned to do the job: the problems at hand were simply to big to be tackled at the national level. In all the cases, we would argue that a key reason that the Framework Programme was able to be influential was a widespread recognition of the socio-economic importance of the field.

6.5 Overall findings

This study has confirmed that the Framework Programme is a strong force acting on European competitiveness in research and innovation, not only in the short- but also in the longer term. It funds leading individuals and organisations in European R&D communities. Its influence is so widespread that few leading organisations do not participate.

The Framework Programme is necessarily complex, addressing changing needs in different parts of the European research and innovation system in ways that vary according to the requirements and maturity of individual fields and thematic areas. The overriding influence that becomes visible when looking at long-term effects is its role in **structuring** the research and innovation system. This role is becoming increasingly explicit through the use of the 'ERA instruments' such as European technology Platforms Joint Technology Initiatives and Joint Programming but it appears that the Framework programme was already exerting a significant structuring influence before these instruments were developed.

- **Structuring to improve the competitiveness of research**
  - Creating and strengthening research networks, increasing the centrality of European actors in global networks, creating critical mass
  - Supporting the creation of new disciplines fields and communities
  - Working in areas of actual or likely breakthrough and discovery
- **Structuring industrial and technological development**
  - Through agenda-setting, road mapping and other forms of building consensus
  - Creating longer-term technological opportunities
  - Focusing research and industrial attention on relevant problems, whose solution create opportunities for research and innovation
  - Building European advantage and accelerating developments through pre-normalisation and standards-related R&D
- **Structuring policy**
  - Via coordinating R&D, support to the definition and resolution of technological and societal challenges

A key common thread in these processes is the support and empowerment of stakeholder groups within and across research and industry to define consensus-based agendas.

Examples of these influences from the present study include

- Supporting the creation of a globally competitive European research and innovation community in QPIC
- Expanding the European solar PV R&D community and supporting the development of wide technology options and capabilities that underpin its continuing importance, especially in newer generations of photovoltaics
- Addressing environmental and industrial challenges in the European automotive industry, supporting both competitive advantage and the creation of significant public goods
- Growing and helping organise a European stratospheric Ozone research community, influencing the development of world norms for combating Ozone depletion and enabling Europe to lead the way in their implementation

The study clearly points to the existence of a range of longer term impacts of the Framework Programme that need to be understood in greater depth, in parallel with standard evaluation, in order to explore more policy options and allow the development of policies that are effective over the longer term. This will require continued experimentation and increased diversity in methods: first, because existing methodologies are not always able to address the different impact mechanisms involved in the longer term; and, second, because of the longer time constants involved. The complexity of the Framework means that a single set of methods or a single pan-Framework study will not produce a simple, overall 'answer'. Rather, we need to explore the individual impact mechanisms in turn. Only when this has been done can we create a synthetic understanding of the Programme as a whole.

6.6 What next?

Broadly, we can conclude that the traditional evaluation record tells us little about the achievement of high-level (policy) objectives, some things about specific or strategic objectives and quite a lot about operational objectives. Our hypothesis is that, if we can identify and understand more about impact mechanisms, it will be easier to trace not only the longer term but also the higher-level performance of the Framework Programme.

Looking at the past Framework Programme evaluation process and methods, it is clear that these determine many aspects of what we can and cannot see when we try to understand FP impacts. Especially since the Commission management reforms in 2000, much evaluation is closely tied to the programming cycle. Combined with the tradition of methods use in R&D evaluation, this means that we can largely see what the current participants can see – and this may be rather a small part of the picture. Certainly, it excludes any longer term effects.

The growing professionalisation of evaluation has contributed to making it more systematic – but has probably reinforced the tendency of New Public Management-style close-coupling of evaluation to the programming cycle to abstract from the technical content of the FP. As a result, we say a lot about the generalities ("knowledge and networks") but lose sight of the specific technical achievements and how these relate to movements in the technology frontier and changes in markets.

The low rate of methodological innovation in the evaluation record is striking. On one level, this should not be a surprise. Evaluation is a profession more than a research discipline and professionals win the contest for work by offering tried and tested formulae while evaluation customers have good organisational reasons for being risk-averse. The close link between the timing of evaluation and the programming cycle means that evaluators' attention is effectively directed towards short-term phenomena – some of which are still in process. This in turn forces the use of participant perception as the 'lens' through which to evaluate and excludes the use of many other techniques that would be relevant with a longer term perspective. Where new approaches have been tried, the returns have not always been very good. Social Network Analysis is increasingly used to describe the FP but has yet to yield many results that tell us how it works – either in terms of relating network shapes and behaviours to performance or in terms of linking them to strategy and micro-descriptions of how networks work. Central findings on changes in network size and the importance of key organisations as nodes in multiple networks are obvious to anyone with a four-function calculator.

Linking FP data to other datasets – scientometric databases and the Community Innovation Survey – appears promising because aspects of these external databases tell us about **performance**. We can therefore find out more about causality. However, such approaches require a radical increase in the 'cleanliness' and inclusivity of FP databases. In some cases they can run into data protection problems because they involve using data for purposes other than those for which they were collected.

As regards this study, case studies provide a rich way to get a qualitative understanding of FP impacts. They require some understanding of the fields they address and the ability for the researcher to move with the twists and turns of emerging evidence rather than solely relying on standardised techniques like surveys. The stories they generate can be confirmed by having participants and observers validate them but they are inevitably stories, lacking the satisfactory solid feel that numbers give. With better, cleaner data about the FP (and a deal more time), it would have been possible to dig a lot deeper into the participation record and follow events at the level of sub-themes and individual network constellations. The quantitative support given by the scientometric work to the case studies covered a small part of the overall story but has undoubtedly contributed to their robustness. Other kinds of non-FP data could undoubtedly contribute to case-based work. For example, automotive industry data is a potential source of information about innovation that could be exploited in a larger-scale automotive study.

Mixing scientometric and qualitative techniques turns out to be quite difficult. A key issue is matching the level of granularity. Cluster analysis proved unable to identify a level that made cognitive sense (ie one at which you can understand and tell stories) while the level of historical logic visible in the cases could not accurately be reflected in the scientometric work. Thus the match between the scope of the bibliometrics and the case studies is approximate. Bibliometric artefacts such as the main path analyses do not have cognitive counterparts, so scientists we interviewed did not recognise them as meaningful accounts. The scientometrics, of course, focuses only on a small part of the innovation process so it must necessarily be complemented by other techniques in order to understand impacts. A particular issue with the co-word analysis technique we used was that while it seems to work well in science, the different ways in which FP projects are entitled and described introduces a lot of 'noise' and makes meaningful patterns much harder to see.

Further progress in understanding longer term impacts of the Framework Programme including, in particular, its success in reaching higher-level policy objectives can be aided by treating some of the impact mechanisms identified here as hypotheses and exploring them in particular instances. These mechanisms are largely not amenable to an aggregate statistical analysis, so we will need bigger, deeper studies of individual examples. Different parts of the Framework Programme work in different ways – large-scale surveys that ignore this fact will not help us learn much more.

Some of the specific research issues emerging from this study are listed here.

- What are the longer term impacts of the Framework Programme in the area of mobility and individual careers?
- Micro-level studies of network evolution, including the role of key 'nodes'
- Micro-level studies of the role of the FPs in organisational development (universities, companies, RTOs)

- More detailed study of network behaviour and evolution, linking social network analysis with micro-level strategy and behaviour
- Studies of the possible Disadvantages of networks: lock-ins, conservatism in network practice and the trade-off with trust and uncertainty reduction
- Quality: does FP participation cause quality or does quality lead to participation?
- More detailed studies of individual fields in the FP over time
- Exploring the role of the 'non-consensus' elements of the FP such as NEST and FET
- Big effort on data cleaning and completeness
- Policy-level evaluations
- Moving to a human capital approach to complement the existing focus on 'research impacts'. This is notably important in relation to exploring the role of the FP in developing and sustaining Knowledge Value Collectives
- What does defragmenting the research community really mean? An exploration of whether networking actually leads to stronger research groups, or whether policy needs to refocus on building individual institutions at the cost of others

Finally, the strong theme running through the casework is the importance of coordination through the empowerment of relevant stakeholder communities. Especially since the evolution of EC research and innovation policy is towards further coordination, probably the most urgent and important issue to explore now is how this works in practice.

Appendix: References to FP Evaluations

Year	Study	
1999	FP4 Participation Finland	Terttu Luukkonen, Sasu Kalikka, Pirjo Niskanen and Riika Eela, *Finnish Participation in the Fourth Framework Programme*, VTT Technology Studies report 1999/4, Helsinki: TEKES, 1999
1999	FP4 Quality of Swedish participation	NIFU, STEP and Technopolis, *Evaluation of Norway's Participation in the EU's 5th Framework Programme*, Oslo: STEP, 2004
2000	FP4 Impact NNE	The European Commission, *Impact assessment of non-nuclear energy projects implemented under the Fourth Framework Programme*, 2000
2000	FP4 Impact Denmark	Ebbe K Graversen and Karen Siune, *Danish Research Co-operation in EU: Extent, Return and Participation, An analysis of co-operation in the 4th EU Framework Programme*, Report 2000/7, Århus: Danish Institute for Studies in Research and Research Policy, 2000
2000	FP4 Impact Ireland	Ken Guy, Jane Tebbutt and James Stroyan, *The Fourth Framework Programme in Ireland: An Evaluation of the Operation and Impacts in Ireland of the EU's Fourth Framework Programme for Research and Development*, report to Forfás by Technopolis, Dublin: Forfás, 2000
2001	FP5 Impact Gender IST	European Commission, *Gender Impact Assessment of the Specific Programmes of Framework Programme 5: User-Friendly Information Society (IST)*, Brussels: European Commission, 2001
2001	FP4 Impact Austria	Andreas Schibany, Leonhard Joerg, Helmut Gassler, Katharina Warta, Dorothea Sturn, Wolfgang Polt, Gerhard Streicher, Terttu Luukkonen and Erik Arnold, *Evaluation of Austrian Participation in the 4th EU Framework Programme*, Technopolis Ltd, Joanneum Research and VTT, Vienna: BMVIT, 2001
2001	FP4 Impact Germany	ISG, *Europäische Forschungsrahmenprogramme in Deutschland*, Köln: 2001
2002	FP4 Impact BioMed2	EC, *Impact Assessment of the Biomedical and Health Research Programme BIOMED2* (1994- 98), Brussels: EC, 2002
2002	FP4 Impact BRITE-EURAM	EC, *BRITE-EURAM, Making a Lasting Impression on Europe*, Brussels: EC, 2002
2003	FP4 Impact Growth	GOPA Consortium, *Impact Assessment of Finished Projects of the EC Research Programmes in the Fields Covered by the Present Growth Programme*, Bad Homburg: GOPA, 2003; GOPA Consortium, Evaluation of Finished Projects in the Fields Covered by the Pesent Growth Programme, Bad Homburg: GOPA, 2003
2003	FP4 Impact International RTD Co-operation	EC, *Impact Assessment Report on the Specific Programme: International RTD Co-operation, 4the Framework Programme (1994-1998)*, Brussels: 2003
2003	FP4 Impact Joule/Thermie/NNE	EC, Clean, *Safe and Efficient Energy for Europe, Impact Assessment of Non-Nuclear Energy Projects Implemented under the Fourth framework Programme, Synthesis Report*, EUR 20876/2, Brussels: EC, 2003. This summarised impact studies in the area, whose contents we also include under this reference
2003	FP4 Impact Telematics (TAP-ASSESS)	Gabriella Cattaneo TAP-ASSESS Consortium, *Telematics Projects Socio-Economic Impact Assessment: Conclusions and Recommendations*, presentation to the EC, Brussels, 2000
2003	FP5 Mid-term QoLife Action 6 (Ageing)	EC, Mid-Term *Assessment Report, Key Action 6, The Ageing Population and Disabilities, 1999-2002*, Brussels: EC, 2003
2003	FP5 Impact of dissemination in Environment	EC, *Impact Study of Result Dissemination in the Field of Environment and Sustainable Development, Brussels*: EC D-G Research, 2003
2003	FP5 Socio-economic dimension	EC, *The Overall Socio-Economic Dimension of Community Research in the Fifth European Framework Programme*, Brussels: EC, 2003

Year	Study	
2004	FP3/4 Impact	Decisia, HLP Developpement and Euroquality, *Assessment of the Impact of the Actions completed under the 3rd and 4th Community Framework Programmes for Research*, Levallois- Perret: Decisia 2004
2004	FP5 Impact	Atlantis, Wise Guys and Joanneum Research, *Assessment of the Impact of the Actions completed under the 5th Community Research Framework Programme (1999-2003),* Survey, EC: 2005
2004	FP5 Impact Genomics	EC, *Analysis of genomic research supported under FP5, Quality of life and management of living resources (1998-2002)*, EUR 20811, Brussels: DG-Research, 2004
2004	FP5 Impact Norway	NIFU, STEP and Technopolis, *Evaluation of Norway's Participation in the EU's 5th Framework Programme*, Oslo: STEP, 2004
2004	FP5 Impact Finland	Marjo Uotila, Pirjo Kutinlahti, Soile Kuitinen and Torsti Loikkanen, *Finnish Participation in the EU Fifth Framework Programme and Beyond*, VTT Technology Studies, Helsinki: Finnish Secretariat for EU R&D, 2004
2004	FP4-6 Impact UK	Paul Simmonds, James Stroyan, John Clark and Ben Thuriaux, *The Impact of the Framework Programmes in the UK*, London: Office of Science and Technology, 2004
2005	Marimon Report	*Evaluation of the Effectiveness of the New Instruments of Framework VI*, Report of a High- Level Expert Panel chaired by Ramon Marimon, Brussels: EC, 2004
2005	Social and Environmental Impacts	*Assessing the Social and Environmental Impacts of European Research*: Report to The European Commission, 2005
2005	ERA-Nets' (Network Analysis)	Caroline S Wagner, Jonathan Cave, Tom Tesch, Verna Allee, Robert Thomson, Loet Leydesdorff and Marteen Botterman, *ERAnets: Evaluation of NETworks of Collaboration Among Participants in IST Research and their Evolution to Collaborations in the European Research Area (ERA)*, 2005
2005	Marie Curie	Daphne van de Sande, Helen Louise Ackers, Bryony Gill, *Impact assessment of the Marie Curie fellowships under the 4th and 5th Framework Programmes of Research and Technological Development of the EU (1994-2002), EC:* June 2005
2005	International R&D Cooperation	The Evaluation Partnership, *Impact Assessment Report on the Specific Programme: International RTD Co-operation, 5th Framework Programme (1998-2002)*, Brussels: 2005
2005	FP6 - TP3 Interim Evaluation	Expert Advisory Group, Sixth Framework Programme (2002-2006) Thematic Priority 3, *Mid term assessment FP6-TP3: Nanotechnolgy and Nanosciences, Knowledge-based Multifunctional Materials, New production Processes and Devices*, 2005
2005	WING IST Impact Analysis - 20 'domain' studies, with FP5 and FP6 aggregate reports	Ken Guy, WING Consortium, *Impact Assessment of FP5 IST Projects*, European Commission, DG Information Society, 2008 Bea Mahieu, Erik Arnold, WING Consortium, *FP6 IST Impact Analysis Study*, European Commission, DG Information Society, 2009
2006	ERANET evaluation	The Expert Review Group, *ERA-NET Review 2006*
2006	EVIMP2	Deloitte, *EVIMP-2: Evaluation of the results and anticipated socio-economic impact of completed projects of the Growth Programme*, 2006
2006	Progress towards ERA in IST	Franco Malerba, Nicholas Vonortas, Stefano Breschi and Lorenzo Cassi (CESPRI, Bocconi University), *Evaluation of progress towards a European Research Area for Information Society Technologies*, 2006
2006	Networks of Innovation in Infosoc	Franco Malerba, Nicholas Vonortas, Lorenzo Cassi, Nicoletta Corrocher and Caroline Wagner (CESPRI, Bocconi University), *Networks of Innovation in Information Society: Development and Deployment in Europe*, 2006
2007	COST FP6	*Final Review of COST in the Sixth Framework Programme*, Panel Report, 2007
2007	EDCTP Evaluation	IER/EDCTP Panel, *Independent External Review Report: European and Developing Countries Clinical Trials Partnership (EDCTP Programme),* 2007
2007	Integration of science issues	Mary Braithwaite (Tacitus sprl) et al., *Final Report of the Study on the Integration of Science and Society Issues in the Sixth Framework Programme*, 2007
2007	Impact assessment SME R&D Schemes	The European Commission, *SMEs and Research: An Impact Assessment of R&D Funding Schemes*, 2007
2007	Effectiveness of IST-RTD Networks in the IS	Edna Pasher Ph.D & Associates with Altec, *Effectiveness of ICT RTD Impacts on the EU Innovation System*, 2007

Year	Study	
2008	INCO in FP6	Ramboll Management, *Evaluation of FP6 INCO Programme*, 2008
2008	ETP Evaluation	IDEA Consult nv, *Evalutaion of the European Technology Platforms* (ETPs), 2008
2008	Evaluation of innovation and space	GHK Consulting and Technopolis, *Ex-post Evaluation of the Activities carried out by DG Enterprise and Industry under the Sixth Framework Programme for Research, Technological Development and Demonstration Activities*, 2008
2008	Evaluation of Fusion Research	Jørgen K. Kjems, *Ex-post Evaluation of the European Fusion Energy Research Programme of the 6th Research Framework Programme (EURATOM),* 2008
2008	Evaluation of JRC	JRC/European Commission, *Ex-post Evaluation Joint Research Centre Direct Actions in the 6th Framework Programmes 2002-2006*, 2008
2008	Evaluation Global Change & Ecosystems	European Policy Evaluation Consortium (EPEC), *Ex-post Impact Assessment FP6 sub-priority "Global Chage and Ecosystems"*, 2008
2008	Infosoc (Aho)	*Evaluation of the effectiveness of Information Society Research in the 6th Framework Programme 2003-2006*, 2008
2008	Energy Tech Transfer	Strategy and Policy Unit of Directorate J, Research Directorate-General of the European Commission, *Innovation and Transfer of Results of Energy RTD in National and European Community Programmes*, 2008
2008	Innovation Impact	Wolfgang Polt, Nick Vonortas, Robert Fisher et al., *Innovation Impact Final Report*, 2008
2009	Behavioural Additionality	IDEA Consult nv, *Does Europe change R&D behaviour? Assessing the behavioural additionality of the Sixth Framework Programme*, 2009
2009	FP6 New Member States	COWI A/S, *Assessment of the Impact of the 6th Framework Programme on new Member States*, 2009
2009	FP6 New Instruments	European Policy Evaluation Consortium (EPEC), *Assessment of the impact of the new instruments introduced in FP6*, 2009
2009	FP6 International Standing	IDEA Consult nv, *Assessment of the international standing of the 6th Framework Programme*, 2009
2009	FP6 Bibliometric study	European Policy Evaluation Consortium (EPEC), *Bibliometric profiling of Framework Programme participants*, 2009
2009	FP6 Participation Survey	IDEA Consult nv, *Participation survey and assessment of the impact of the actions completed under the 6th Framework Programme*, 2009
2009	NetPact	AVEDAS AG et al., *Structuring Effects of Community Research – The impact of the Framework Programme on Research and Technological Development (RTD) on Network Formation*, 2009
2009	FP Impact Studies DK, NO, EI, NL, China	Technopolis, *Evaluation of Danish Participation in the 6th Framework Programmes*, 2009 Helge Godø, Liv Langfeldt, Aris Kaloudis, et al. (NIFU STEP), *In Need of a Better Framework for Success: An evaluation of the Norwegian participation in the EU 6th Framework Programme (2003-2006) and the first part of the EU 7th Framework Programme (2007-2008)*, 2009 Technopolis, *Evaluation of Framework Programme 6 in Ireland*, 2009 Technopolis, *Impact Europese Kaderprogramma's in Nederland*, 2009 Erik Arnold, Sylvia Schwaag Serger, Sophie Bussillet, Neil Brown, EPEC, *Evaluation of Chinese participation in the EU Framework Programme*, February 2009
2010	FP Impact AT	Technopolis, *Evaluation of Austrian Support Structures for FP 7 & Eureka and Impact Analysis of EU Research Initiatives on the Austrian Research & Innovation System*, 2010