July 10, 2014

Evaluation of Pertinence and Impact of Research Infrastructure Activity in FP7 - EPIRIA

Final report

technopolis |group|

in consortium with

empirica

Evaluation of pertinence and impact of research infrastructure activity in FP7

Draft final report

July 2014

Bea Mahieu, Erik Arnold, Xavier Potau (Technopolis Group)

Reinhard Hammerschmidt, Karl Stroetman (empirica)

For the study team:

Jelena Angelis, Strahil Birov, Christien Enzing, Paula Knee, Paresa Markianidou

Bastian Mostert Anke Nooijen, Martijn Poel, Viola Peter Lorena Rivera

Joost van Barneveld, Geert van der Veen, Wieneke Vullings, Uta Wallosek, Frank Zuijdam

Table of Contents

Table of Exhibits

List of cases

Executive Summary

This study analyses the relevance, efficiency and effectiveness of the Research Infrastructures (RI) component of the Seventh Framework Programme (FP7), assesses its European Added Value and suggests options for future Community RI actions.

A key part of our approach has been to categorise the FP7 RI activities into 'Thematic Areas', classifying the projects by the scientific field in which the **users** of the RIs funded are active, irrespective of the support scheme under which they received funding. Five of the resulting categories cover specific disciplines: life sciences (LS), energy, earth & environmental sciences (EEES), material sciences & analytical facilities (MS&AF), physics & astronomy (P&A), and social sciences & humanities (SSH). Projects that cut across individual disciplines are classified into one of two 'horizontal' areas: horizontal e-Infrastructure services; and policy development & coordination support.

The study was launched in January 2013 and covers in its quantitative analyses the contracts signed under the FP7 RI programme before the end of 2012. A total of 313 projects are in scope, with total EC funding of €1,357m, and 4649 participations. Close to 1,600 organisations were involved. About half of the projects had finished at the time of this study.

Main findings

The key added value of the FP7 RI programme was to strengthen the European dimension in RI policies, activities and services.

Its **relevance** is high, in the sense that its objectives correspond to policy needs and that the projects funded are largely consistent with meeting those objectives as well as with the RI users' needs. This means that the programme has been quite well designed. Limitations were that the programme allocated too few resources to innovation and there was too little effort devoted to improving skills in the management of RIs. There was also little funding for infrastructural support to research in the social sciences.

The FP7 RI programme clearly succeeded in involving leading organisations in the different fields and made good use of the mix of funding instruments at its disposal However, the continuing increase in the numbers of funding schemes and focus areas now risks fragmenting the Commission's RI funding. The separation between funding schemes for research infrastructures and e-Infrastructures is becoming increasingly artificial in a time where e-Infrastructures are basic components of any research infrastructure.

The Programme fulfilled its **primary function** of supporting the development of *networks* of research infrastructures in Europe and improving the way research infrastructures *operate, evolve and interact* with similar infrastructures and with their users – at European and global levels.

The EC increased the cohesiveness of the European RI landscape by interlinking research facilities and data infrastructures, the harmonisation, standardisation and interoperability of methodologies and tools, the delivery of transnational access, increasing connectivity and ease of access. Innovation in the tools and methods for the collection, processing and analysis of RI resources and the use of the facilities, including visualisation and simulation techniques and scientific instruments led to a considerable improvement in the delivery of RI services. The shift to a more service-oriented approach in the e-infrastructure ecosystem was a particularly important contribution.

The FP7 RI Programme has been very successful in increasing the value of research infrastructure as a **tool for Science**. The networking and integration of the research infrastructures helped improve the structure and cohesiveness of the European research community, enhancing European and international cooperation in research. It fostered the creation and increase of critical mass in research and generated strong spillover potential to research and education. Funding for transnational access was especially important for small and newer Member States.

The Programme also facilitated the development and use of new and improved research methods and technologies. The eScience paradigm shift is an important development, which is changing the nature of the research process in some fields. The ability of the e-Infrastructure communities to deliver user-tailored services and the development of a multilayer e-Infrastructure ecosystem have been key in helping European researchers to stay at the forefront of scientific developments.

The FP7 RI programme has made an important contribution to increasing **international collaboration** in Research Infrastructure and opening up of the European RIs to the world, to the mutual benefit of the European and international research communities. It reinforced cooperation with countries such as the United States, Japan, Australia and Canada, and was particularly active - and successful - in enhancing collaboration with emerging economies such as Latin America, Africa, China, India and the Middle East. These intercontinental RI partnerships provide important opportunities to broaden the European knowledge base.

As a founding member of the international Research Data Alliance, Europe has gained a strong positioning in the global data standardisation efforts, an asset that can be expected to create significant economic returns in the future.

The FP7 RI programme has shown that there is potential for impacts on industrial **innovation** by fostering capacity building and knowledge transfer but has so far had little impact on industrial innovation. One reason for this may be that little time has elapsed since the projects were undertaken. There are in fact early examples of product innovation resulting from the involvement of industry in the RI projects, both as suppliers or users of the RIs and via the exploitation of research results. However, inconsistencies between the legal framework and industrial needs (notably in relation to IPR and open access) are important barriers to increased industrial engagement.

The programme addressed the fragmentation of RI policies at national and European level and was successful in improving **coherence of RI policy making** based on the ESFRI roadmap and projects. However, the Commission needs to go beyond the ESFRI roadmap to develop a wider and more holistic research infrastructure strategy connected to European visions expressed in Horizon 2020 and its wider strategic context.

The FP7 RI programme has met with little success in **optimising the RI funding landscape** through pooling resources across national RI policies and the Structural Funds. RIs funded by the Structural Funds focus on regional priorities and are planned in processes that are hard for short-lived individual European programmes to address. This also explains why individual pan-European RIs struggled to obtain complementary funding from Structural Funds.

The **sustainability** of the integrated research infrastructures is a major issue. The FP7 RI programme succeeded only to a limited extent in alleviating the tension between the priorities and governance responsibilities of the national policy makers and the policies at the European level.

European Added Value in the form of transnational access and integration of RI facilities is fragile for all forms of RI but in particular for the distributed and virtual research infrastructures. Stronger and more permanent EU-level incentives may be needed to maintain a shared infrastructure optimised at the European level.

Conclusions and recommendations

The FP7 RI programme has made a significant step forward in the efficiency and effectiveness of its support to the European research infrastructure compared to the programme in FP6.

An important facilitator for this highly positive evolution was the more coordinated approach to the funding of existing and new distributed research infrastructures or networks of research infrastructures in Europe, based on the ESFRI roadmap. The shift in focus towards the delivery of user-tailored e-Infrastructure services and the development of a multi-layer e-Infrastructure ecosystem resulted crucial for the creation of the globally connected European Research Area in Research Infrastructure.

The Programme has brought e-Science into the European research system, helping researchers and engineers to stay at the forefront.

There is nonetheless room for improvement. The most important needs are

- Greater focus on exploiting the innovation potential of the Research Infrastructures
- Even though progress has been made compared to FP6, the coherence of European RI policy making – and especially RI funding – needs to be improved and refocused on developing an holistic European vision
- Stronger cooperation between the scientific and e-Infrastructure communities is crucial to strengthen Europe's capacities in e-Science and Europe's competitive positioning in research at the global level
- Reducing the tendency to funding fragmentation at the EC level
- There is a need for a strategic vision for Europe
- The sustainability of the European Added Value is a major issue.

Our recommendations are:

- Tackle the sustainability issue through new funding and/or governance models
- Promote a more holistic and comprehensive view on research infrastructure among national policy makers. This involves both developing a European vision and connecting it with the role of national and regional planners in using the Structural Funds, so it will involve not only funding programmes but also wider coordination activities
- Consider whether it is satisfactory that the ESFRI roadmap should be the sole driver of EC RI funding priorities
- Further strengthen the cooperation between ESFRI and eIRG and the scientific/e-Infrastructures communities as a whole
- Improve the coordination of RI strategy among DGs
- Improve synergies with other EC services/initiatives – beyond the Structural Funds
- Support the development of distributed RI in Social Sciences
- Strengthen the innovation element in the RI, e.g. through financial incentives for SME use of RI, stronger emphasis on economic impact and user-orientation as selection criterion, revision of regulations and access rules in line with industry needs, …

1. Introduction

In this chapter of the report we give a brief overview of the objectives and scope of the study, the methodological background, and the structure of the report.

1.1 Objectives and scope of the study

The objectives of this study are set out in the terms of reference (ToR) and are

- To analyse the pertinence and effectiveness of the schemes used under the Seventh Framework Programme. (FP7) to support Research Infrastructures (RI) for the European Research Area (ERA)
- To analyse the impact that the Research Infrastructure activities have had on scientific communities, research policy, innovation and society at large
- To assess the efficiency and European added value of these European Community (EC) activities.
- To suggest options for further Community actions and focus areas regarding RI support schemes

The results will be used to inform the Directorate-General Communication networks, Content and Technology (DG Connect) and the Directorate-General Research and Innovation (DG Research) on the pertinence, impacts and efficiency of the implementation of their activities regarding research infrastructures. The results will also contribute to the Commission's overall ex-post evaluation of the Seventh Framework Programme. (FP7).

The study was launched in January 2013.

1.2 Methodological background

This evaluation applies the programme logic-based evaluation model, in line with the specifications in the ToR. This approach assumes that there is a logical chain between a set of needs, problems or issues, a policy intervention with corresponding change objectives, a set of resources (not only financial) applied to some activities which lead to a set of outputs that will lead to the desired changes either in the relatively short-term (outcomes) or in the long term (impacts). The basis for this **'intervention logic'** approach to evaluation is the hierarchy of objectives, i.e. the link between objectives at high policy, strategic and 'specific' level. In the case of the FP7 RI programme, this relates to links between objectives of the higher-level EC policies, the programme, and the support schemes.

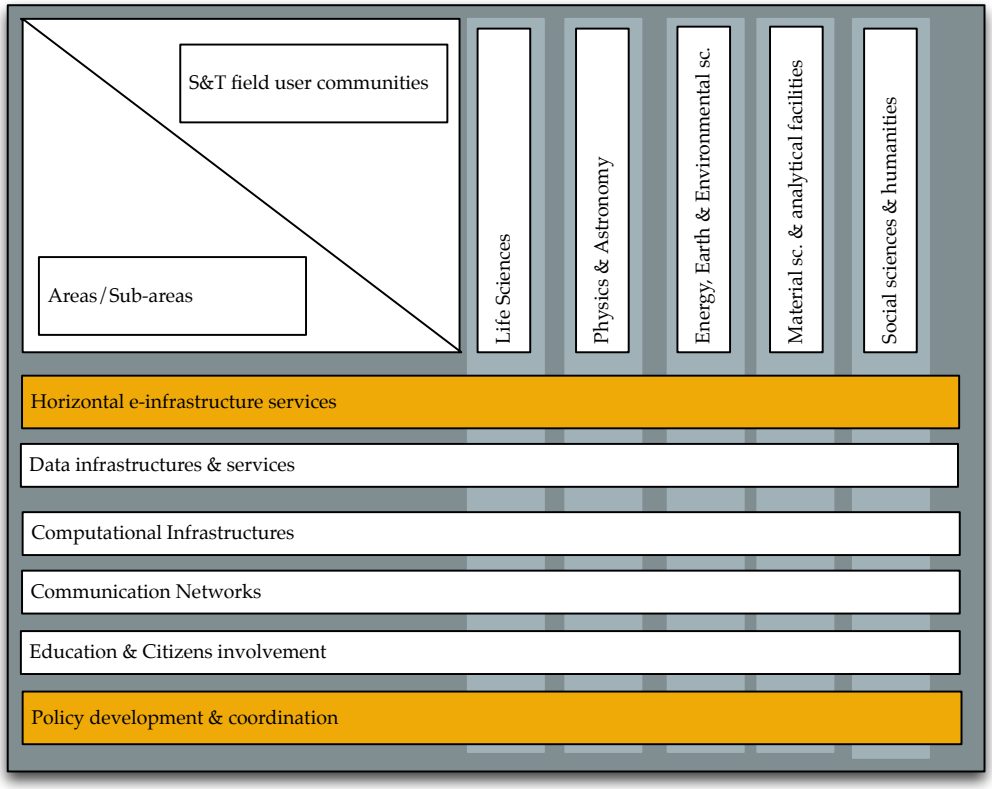
We took a holistic approach to the programme for this evaluation. The key objective was to set the activities of the FP7 Programme as a whole within the context of the overall RI landscape and the communities involved. For this purpose, we grouped all projects into **'Thematic Areas'**, surpassing the organisational structure of the programme in schemes and sub-schemes, research infrastructures and e-infrastructures.

- A first set of projects was grouped according to the scientific field in which the **users** of the supported research infrastructures (RIs) are active. This led to the collocation of the projects into 5 S&T-specific thematic areas: life sciences (LS), energy, earth & environmental sciences (EEES), material sciences & analytical facilities (MS&AF), physics & astronomy (P&A), and social sciences & humanities (SSH).
- Secondly, 2 'horizontal' thematic areas were defined, grouping the programme activities that provided support for RIs cutting-across S&T disciplinary domains:

the horizontal e-Infrastructure services thematic area and the policy development & coordination support one.

This categorisation of the FP7 RI activities provided the opportunity better to identify effects, relevance and efficiency of the programme for the different user communities, as well as the role and value of the different support schemes for programme success.

Exhibit 1 The Thematic Areas



The evaluation is based on a **mix of multiple methods** to collect quantitative and qualitative data and information. The quantitative data analyses were limited to contracts signed before the end of 2012. Quantitative methods used were

- The Logical Framework Analysis, based on FP7 RI programme documentation
- The portfolio and composition analysis of the FP7 RI programme and its participants' base, on the basis of the eCorda database
- An analysis of the data in the RI users' database, which was derived from an aggregation of the information provided by the Integration activities projects in the context of their annual reports
- Statistical analysis of the responses to a questionnaire survey, covering all FP7 RI participants in the covered time period. A return rate of 17% was reached (based on unique participants) and the responses cover 50% of the FP7 RI projects. The sample of survey respondents is representative for the overall sample of participants in the programme in terms of and stakeholder categories (research, private sector, public administration) as well as participation in the support schemes. Responses were analysed against a set of key dimensions, i.e. support schemes, thematic areas, stakeholder categories, geographical location, and type of RI
- Bibliometric analyses, investigating the participants' level of scientific excellence (based upon the eCorda database) and measuring the potential of spillover effects

to research by participants and RI 'external users (based upon the OpenAire database and the Integrating activities' RI users databases, respectively)

- Social Network Analysis, mapping the networks of participants and RI users (on the basis of the eCorda database and the RI users databases)
- A cost-benefit analysis, conducted through 8 case studies

The qualitative analyses covered topics referring to the entire FP7 period and consisted in

- Desk research, including the documentation of all projects (technical annexes, final reports etc), relevant studies and policy documents. The most important of these studies are listed in the bibliography in Appendix A to this report
- An analysis at thematic area level, on the basis of 33 case studies and 110 interviews and supported by 15 field-specific experts
- An analysis of the potential for industry spill-over, by means of interviews
- Experts consultation for the finalisation of the methodology, the validation of the findings related to the thematic areas, and the validation of the programme evaluation preliminary findings – the latter by means of a workshop

This approach allowed for thorough **triangulation** of the findings in the different analytical phases, i.e. the confirmation of data collected through one methodological tool by means of others, ensuring sound evaluative judgements.

Participants in the FP7 RI programme and other thematic and/or scientific experts have constituted an important source of information for this study. In total close to 150 participants and experts have been involved. They are listed in Appendix B to this report.

1.3 The structure of this report

This report is structured as follows:

- We set out by describing the background to this study, i.e. the policy context and the characteristics of the FP7 RI programme, including the developments since FP6 as well as a description of the funding and project distributions (Chapter 2)
- The relevance and efficiency of the FP7 RI programme is the topic of Chapter 3
- In Chapter 4 we report on our main findings related to the impacts of the FP7 RI programme, achieved or expected. We also cover the European Added Value of the programme and the sustainability of its effects.
- In Chapter 5 we draw our conclusions and give recommendations.

2. The background

This section sets the basis for this study. It gives an overview of the policy context to the FP7 RI programme (Section 2.1) and describes its main characteristics (Section 2.2).

2.1 The policy context

The Seventh Framework Programme sets the RI activity in the context of the needs of both the research communities and the private sector. It states as overall policy objective of the RI programme "to optimise the use and development of the best research infrastructures existing in Europe, and help creating in all fields of science and technology new research infrastructures of pan-European interest, needed by the European scientific community to remain at the forefront of the advancement of research, and able to help industry to strengthen its base of knowledge and its technological know-how."[1]

The Commission strategy sets support to Research Infrastructures firmly within the context of the development of the **European Research Area** (ERA). The idea of European Research Areas has been evolving since it was introduced in 2000. In 2007, the Green Paper that 're-launched' the ERA described its key features as:

- *An adequate flow of competent researchers* with high levels of mobility between institutions, disciplines, sectors and countries
- *World-class research infrastructures*, integrated, networked and accessible to research teams from across Europe and the world, notably thanks to new generations of electronic communication infrastructures
- *Excellent research institutions* engaged in effective public-private cooperation and partnerships, forming the core of research and innovation 'clusters' including 'virtual research communities', mostly specialised in interdisciplinary areas and attracting a critical mass of human and financial resources
- *Effective knowledge-sharing* notably between public research and industry, as well as with the public at large
- *Well-coordinated research programmes and priorities*, including a significant volume of jointly-programmed public research investment at European level involving common priorities, coordinated implementation and joint evaluation
- *A wide opening of the European Research Area to the world* with special emphasis on neighbouring countries and a strong commitment to addressing global challenges with Europe's partners

Today its aim, in effect, is to build a *globally competitive research and innovation system* optimised at the European level. The ERA concept is defined in the European Council Communication of July 2012[2] as:

> *"A unified research area open to the world based on the Internal Market, in which researchers, scientific knowledge and technology circulate freely and through which the Union and its Member States strengthen their scientific and technological bases, their competitiveness and their capacity to collectively address grand challenges".*

The FP7 RI programme contributes also to the implementation of **Europe 2020** strategy, which was launched in 2010. It is considered a key tool in implementing the

[1] Decision No 1982/2006/EC of the European Parliament and of the Council of 18 December 2006 concerning the Seventh Framework Programme of the European Community for research, technological development and demonstration activities (2007-2013)

[2] COM(2012) 392 final, A reinforced European Research Area partnership for excellence and growth, 2012

Innovation Union flagship initiative, which addresses the science and innovation system of Europe including the European Research Area (ERA), and supports also key actions of the *Digital Agenda for Europe* initiative.

- The Communication on the *Innovation Union Flagship initiative*[3] specified:
  - Resources to build and operate RI must be pooled across Europe and in some cases globally. In the context of scarce public resources, these investments should be given political priority and new funding mechanisms developed
  - Research infrastructures should continue their opening to, and partnership with, industrial researchers to help address societal challenges and to support EU competitiveness
  - By 2015, Member States together with the Commission should have completed or launched the construction of 60% of the priority European research infrastructures identified by the European Strategy Forum for Research Infrastructures (ESFRI)
  - The potential for innovation of these (and ICT and other) infrastructures should be increased. The Member States are invited to review their Operational Programmes to facilitate the use of cohesion policy money for this purpose.

In relation to the objectives of the Digital Agenda flagship, the programme is intended to contribute especially to the attainment of the objectives in Pillar V–Research and Innovation, and in particular

- Reinforce the *coordination and pooling of resources with Member States and industry*, and put greater focus on *demand- and user-driven partnerships* in EU support to ICT (Information and Communication Technologies) research and innovation (Action 51)
- Ensure sufficient financial support to *joint ICT (Information and Communication technology) research infrastructures and innovation clusters*, develop further *e-Infrastructures* and establish an EU strategy for cloud computing notably for government and science (Action 53)

2.2 The FP7 Research Infrastructures (RI) Programme (2006-2013)

The EU Framework programmes for RTD have supported research infrastructures for many years, starting from the "Large Installations Plan" in FP2 in 1989. Over the years, the funding for RI support activities has seen a constant growth, reaching the sum of about 1.7 m€ under FP7 for the years 2007-2013. [4]

Two European Commission Directorate Generals are delivering support for RI: DG Research and Innovation and DG CONNECT. Up to FP5 (included), the support activities were provided in the two DGs separately. This changed in FP6 with the launch of a single RI programme, involving both DGs.

2.2.1 Trend in EC support for research infrastructures – FP6 versus FP7

The launch of FP7 in 2006 coincided with the publication of the European Strategic Forum for Research Infrastructures (ESFRI) roadmap, published for the first time in 2006 with updates in 2008 and 2010. Based upon a peer review-based selection process, this roadmap identified a set of 48 new pan-European Research Infrastructures or major up-grades to existing ones, corresponding to the needs of

[3] COM(2010) 546 final, Europe 2020 Flagship Initiative - Innovation Union, SEC(2010)

[4] Fotakis, C., *FP7 Interim Evaluation: Analyses of FP7 supported Research Infrastructures initiatives in the context of the European Research Area*, European Commission, 2010

European research communities in the next 10 to 20 years. The roadmap includes also an additional set of 3 projects deriving from the CERN Council strategic roadmap for particle physics (see further in Section 4.6.2 in this report). The intention is to construct these new pan-European RI by 2015-2020.

The ESFRI roadmap triggered a major change in the focus and process for EC support to the European Research Infrastructure compared to the practice in FP6. It allowed the European Commission to take a more **coordinated approach** to the funding of existing European networks of research infrastructures and distributed research infrastructures as well as for the development of new pan-European research infrastructures, in contrast to the bottom-up approach in FP6. These changes in implementation regarded in particular the activities funded by DG Research.

In a first instance, it led to an increase in support for the development of new pan-European RI. The FP6 'Construction of New Infrastructures' scheme was substituted by 2 new schemes reflecting the stages for development of new RI (preparation and implementation), in addition to the Design scheme.

As of 2010, the ESFRI roadmap also guided the funding for the existing networks and distributed research infrastructures through the I3 Integrating Activities. Instead of the previous bottom-up approach, the funding focus was now on research infrastructures that interfaced with those identified in the roadmap.

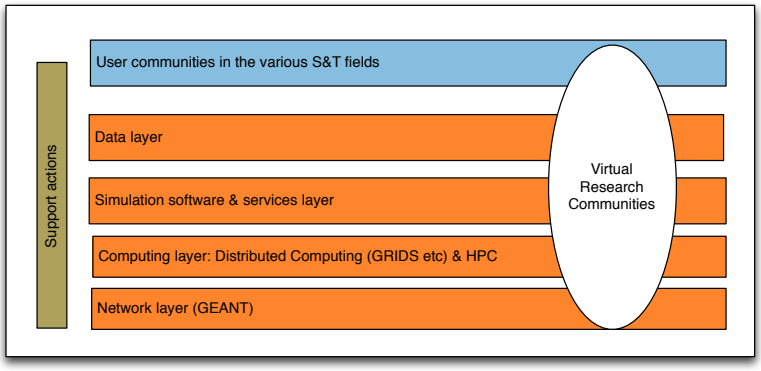
Partly thanks to technological developments, there was a major change also in focus and approach in the e-infrastructures component of the programme, leading to an **expansion of scope**. The evolution was from the technology- and product-orientation in the previous FPs to a more pronounced focus on the delivery of user-tailored services and the development of a multi-layer e-Infrastructure ecosystem that would constitute a reliable basis for the conduct of e-Science.

In FP6 the e-infrastructure projects focused on the communication network, i.e. GEANT, and the further development of the Enabling Grids for E-sciencE (EGEE), continuing the work that was initiated under FP5 in the physics community led by CERN. In its FP6 Self-assessment report[5], the Commission also highlights the establishment of the High Performance Computing (HPC) in Europe Taskforce and indicated the emergence of the concept of Global Virtual Research Communities (VRC).

Building upon these achievements, activities in FP7 supported developments in the different components of the e-Infrastructure (Exhibit 2), i.e. the communication network (GÉANT); the computing infrastructures including 'grids' of high-throughput computing (HTC) resources, high-performance computing e-Infrastructures (HPC), desktop grids and cloud infrastructures; software and service infrastructures for visualisation and simulation; and last but not least, scientific data infrastructures and global Virtual Research Communities.

[5] Self-Assessment of the Effectiveness of IST-RTD in the 6th FP - Ex-post Evaluation of the IST Research in FP6, European Commission, DG Information Society, 2007

Exhibit 2 FP7 e-Infrastructure layers



2.2.2 Distribution of funding and projects

At the end of 2012[6], the total EC funding was €1,357m, distributed over 313 projects and involving close to 1,600 organisations, for a total of 4649 participations. DG Research took charge of 62% of the FP7 RI budget (845 m€), distributed over 172 projects; funding by DG CNECT amounted at 511.7 m€, covering 141 projects.

The support schemes

The FP7 RI programme was implemented along three lines of actions:

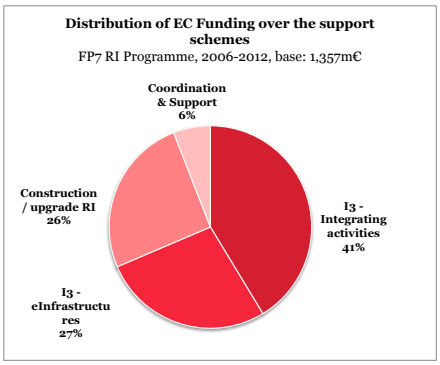
- The optimal performance and use of *existing RIs*, supported through the I3 schemes *Integrating Activities* and *eInfrastructures*
- The development (or major upgrading) of *new RIs* of pan-European interest, supported through schemes that reflected the stages of RI development (design, preparation and implementation)
- *Specific coordination and support actions* supported research infrastructures and their communities, in Europe and worldwide, as well as policy-makers at the European and national levels

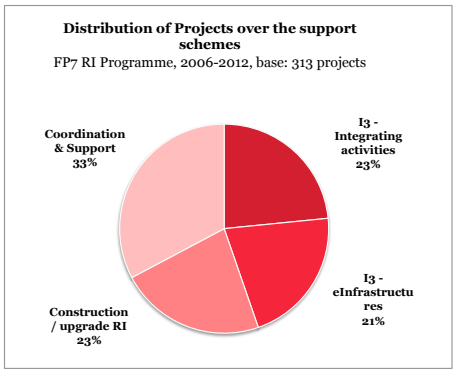
The programme focused in particular on supporting **networks of existing research infrastructures**. This action line accounted for ~70% of the funding and for 45% of the projects (Exhibit 3).

The construction of new RI and major upgrade of existing RI accounted for ~30% of the funding (~25% of the projects). The remaining 6% of the FP7 RI programme budget was allocated to the Policy/RI coordination and support actions, which accounted for 33% of the projects.

[6] The scope of the quantitative analyses in this study is limited to contracts signed in the time period 2006-2012. Contracts signed in 2013 could not be included

Exhibit 3 Distribution of projects and EC funding over the FP7 RI support schemes (portfolio analysis, 2006-2012)



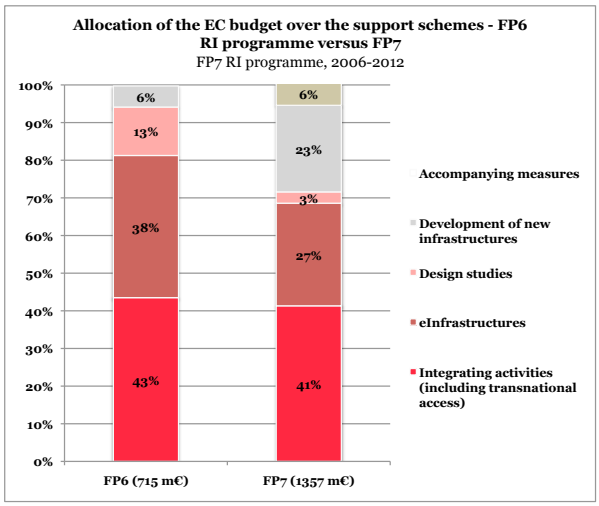


Source: eCorda database, 2006-2012

Despite this pronounced focus on the funding of existing pan-European RI, compared to FP6 there was a clear shift in funding focus. The share of funding for the development of new infrastructures increased from 19% to 26% of the EC budget in FP7 (Exhibit 4). This was a direct result of the ESFRI roadmap implementation.

It should be noted that this did not imply a reduction of funding for the e-Infrastructures component of the programme. The overall budget for support to RI close to doubled from FP6 to FP7.

Exhibit 4 Trend in allocation of the RI budget over the support schemes – FP6 versus FP7 (portfolio analysis, 2006-2012)

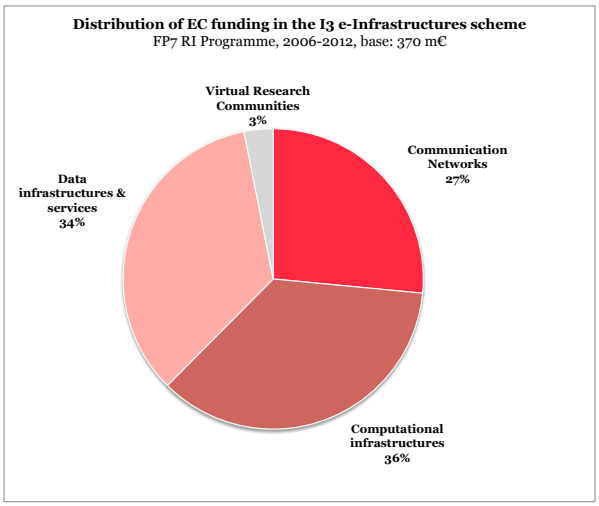


Source of FP6 data: Court of Auditors[7], EC website FP6

In the FP7 I3 e-Infrastructure scheme, ~35% of the EC budget was allocated to the development of **computational infrastructures** (Exhibit 5). The Data infrastructures and services sub-scheme accounted for a similar share of the EC funding.

[7] The effectiveness of the Design studies and Construction of new infrastructures support schemes under the Sixth Framework Programme for Research, Special report, Court of Auditors, 2010

Exhibit 5 Distribution of EC funding in the FP7 I3 e-Infrastructure scheme (portfolio analysis, 2006-2012)



Source: eCorda database, 2006-2012

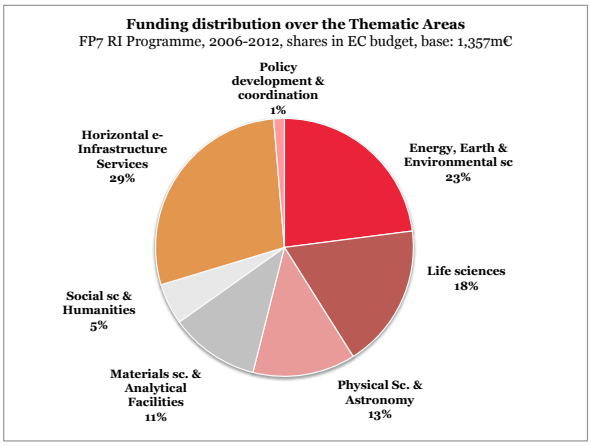
The thematic areas

Close to 70% of the EC funding in the FP7 RI programme was dedicated to RI supporting on **specific S&T fields** (in total 70% of the funding – see Exhibit 6).

The distribution of the funding over the Thematic Areas indicates a strong focus on support for research in scientific fields that are key for the tackling of the Grand Challenges. Particular focus was set on RI supporting research in the field of energy, earth & environmental services and life sciences (accounting respectively for 23% and 18% of the programme budget).

However, little funding was foreseen for support to research in the Social Sciences, a field that provides strategic information for policy making on more general societal challenges and where significant new opportunities arise from the Big Data phenomenon. Funding for RI in the social sciences & humanities thematic area accounted for 5% of the budget.

Exhibit 6 Allocation of EC funding over the thematic areas (portfolio analysis, 2006-2012)



Source: eCorda database, 2006-2012

3. Relevance and efficiency of the FP7 RI programme

The issue of relevance consists of examining whether the objectives of the FP7 RI programme and its activities reflected and responded to the needs, problems and issues it was intended to address. It is closely interlinked to the topic of efficiency and sets the basis for the assessment of the effectiveness and European added value. It informs on the *plausibility* and *possibility* for expected impacts to occur thanks to the programme design and implementation processes.

In this chapter, we first analyse the relevance of the supported activities against the two dimensions that were indicated in the ToR, i.e.

- The policy objectives of the FP7 RI programme and the European Research Area (ERA) (Section 3.1)
- The needs of the RI user communities – from a scientific and technological perspective (Section 3.2)

The next two sections focus on the efficiency of the programme in terms of involvement of the appropriate stakeholders (Section 3.3) and the efficiency of the programme implementation process (Section 3.4).

3.1 Relevance for the FP7 RI programme and the ERA

In this section we first describe the ERA and FP7 RI programme objectives, to then describe also the objectives of the different support schemes.

In the FP7 RI programme the objectives of the supported activities had a strong alignment with the programme's higher-level policy objectives and the objectives of the ERA. In essence, this indicates a high quality in the programme design.

3.1.1 The ERA and FP7 RI programme objectives

The *fragmentation of RI programmes and policies* at national and regional level was a clearly identified systemic failure that the FP7 RI programme was expected to address, in addition to the *limited international cooperation* of the RI.

The explicit inclusion of the research infrastructures theme in the ERA objectives needs to be set in this context; it illustrates the particular structuring effect that research infrastructures are expected to have on the European research system.

The **ERA priorities** can be summarised as follows:

- A single market for knowledge research and innovation
- More effective national research systems
- Optimal transnational co-operation and competition
- An open labour market for researchers
- Gender equality and gender mainstreaming in research
- Optimal circulation, access to and transfer of scientific knowledge including via digital ERA

In the context of FP7, the **RI Programme** was intended to play a catalysing and leveraging role by helping to ensure wider and more efficient access to and use of the infrastructures existing in the different Member States. The EU actions should also stimulate the coordinated development, deployment and networking of these infrastructures, and foster the emergence of new research infrastructures of pan-European interest.

3.1.2 Objectives and expected impacts of the support schemes

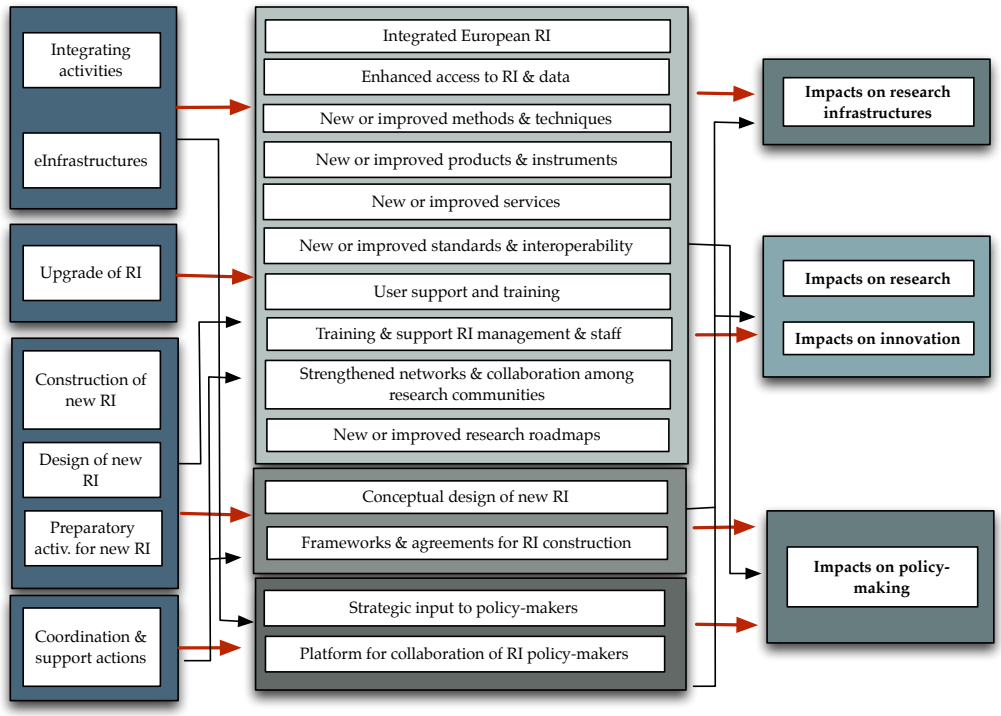
As mentioned in the previous section, the FP7 RI Programme was implemented by means of a set of schemes and sub-schemes, listed in Exhibit 7, below.

Exhibit 7 Support schemes & sub-schemes

Support Schemes	Support Sub-schemes
Support for existing research infrastructures	
I3 - Integrating activities	
I3 - eInfrastructures	Data infrastructures & services
	Virtual Research Communities
	Computational infrastructures
	Communication Networks
Support for the development of new research infrastructures	
Construction / upgrade RI	RI - Design phase
	RI - Preparatory phase
	Implementation
Coordination & Support	

These support schemes were intended to contribute **jointly** to the achievement of the FP7 RI programme and the ERA objectives. In Exhibit 8, below, we illustrate this concept by mapping the categories of expected outputs and outcomes of the support schemes against the major categories of impacts. We indicate with a red arrow the *primary categories* of outputs and outcomes that were expected from the specific support schemes. These outputs and outcomes are described at a conceptual level in order to allow for aggregation.

Exhibit 8 Contributions of the support schemes to the higher-level objectives



Objectives of the FP7 RI support schemes in detail

The **I3 Integrating Activities** projects had as primary objective to open up key national RIs to all European researchers and to ensure their optimal use and joint development. They included a set of three activities: transnational and virtual access activities, networking activities to foster a culture of cooperation, and joint research activities to improve the services provided by the infrastructures.

The aim of the **I3 – eInfrastructures** scheme was to strengthen research by fostering the further development and evolution and global connectivity of high-capacity and high-performance communication and grid infrastructures. They were expected

- To empower researchers with an *easy and controlled online access* to facilities, resources and collaboration tools
- To foster the *emergence of new working methods*, based on the shared use of resources across different disciplines and technology domains, reinforcing European computing capabilities

In the Communication Networks sub-scheme, the main objective was to further deploy and evolve the pan-European high-capacity and high-performance communication network GÉANT, which constitutes a core part of the e-Infrastructures in Europe, provides Europe with a gateway for global collaboration, supporting the needs of the research and education communities.

Projects in the Computational infrastructures sub-scheme focused in particular on the further deployment of grid-empowered e-Infrastructures. Expected outputs and outcomes are the continuation of the world-class performance of the European Grid infrastructures and their ongoing global relevance; the availability of repositories of easy-to-install middleware components, combined with consistent training and education programmes; improved access to RI; and a broader interdisciplinary scientific collaboration. Projects focusing on high-performance computing (HPC) address the growing computational and simulation requirements of the European scientific communities and industry.

Another field of action are software and simulation tools, which are a key enabler of e-Science. eScience software environment projects focus on the development, deployment and evolution of scientific application software and simulation infrastructures and services. This includes the development of models, tools, algorithms, and simulation and visualisation techniques. The goal is to replace traditional experimentation for "*in silico*" experimentation in order to address major scientific, industrial and social challenges. The overall aim is the integration of scientific software applications to enable the full and timely exploitation of high-performance and distributed computing capabilities.

The expected outcomes and impacts of the data infrastructures & services sub-scheme are an increase in the scale of federation and interoperation of data infrastructures; better exploitation of synergies with the underlying e-Infrastructures; reduction of costs; increase of the user base and bridging across disciplines; enablement of cross-fertilisation of scientific results and favouring of innovation.

Projects in the Virtual Research Communities sub-scheme aim at developing global communities or e-Science environments – through the development of collaborative platforms for the recording, sharing and use of global data resources. The main goal is to help users access and effectively use the e-Infrastructure for global, cross-disciplinary research.

The three schemes for the **construction of new European research infrastructures** or major upgrade of existing ones had the following objectives and expected outputs/outcomes:

- *Design studies* focus on the technical preparatory work and the development of new equipment.

- *Support for the preparatory phase/major upgrades projects* facilitate the achievement of financial and fiscal agreements between the funding countries to set up the new facility
- *Support for the implementation phase projects* were funded for 2 categories of activities:
  - The development of clusters in specific S&T fields, creating long-term synergies between existing research infrastructures that face substantial challenges. Expected outputs include standards, common technical solutions, common e-science components and services
  - The creation of the new PRACE infrastructure, which is expected to act as a permanent pan-European High Performance Computing service

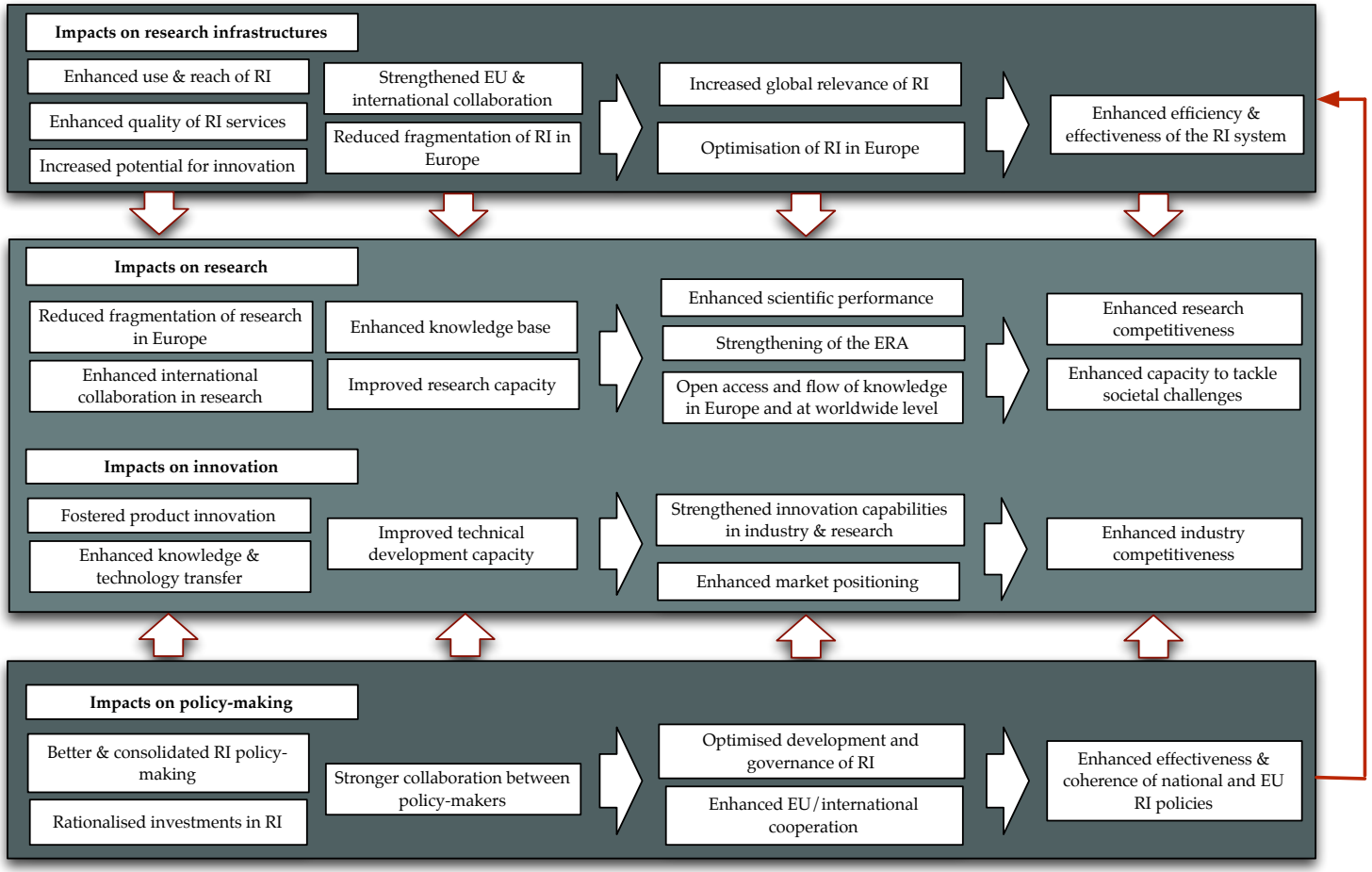
The overall objectives of the **Coordination and Support actions** were to provide support for policy development and programme implementation. A broad range of activities was funded. Expected outcomes were improved co-operation among national policy-makers, National Contact Points, and established RIs, as well as an enhanced international cooperation and establishment of global RIs, through, e.g., the development of long-term sustainable framework (common data policies and standards, approaches for infrastructures, IPR).

Alignment with the ERTA and Framework Programme objectives

Building upon the description of the FP7 RI support schemes' objectives in the programme documentation, Exhibit 9, below, maps the aggregated outcomes of these activities (the column to the left) against the expected mid-to-long-term impacts of the FP7 RI programme and contributions to the ERA (columns to the right).

It shows the strong alignment of the objectives of the FP7 RI programme and its schemes and sub-schemes with the high policy objectives of the Framework Programme and the European Reasearch Area strategy.

Exhibit 9 Expected outcomes and mid-to-long-term impacts of the FP7 RI supported activities



3.2 Relevance for the S&T user communities

This section focuses on the relevance of the FP7 RI activities for the research user communities from a thematic and systemic perspective. It considers the alignment of the policy mix with the users' needs in terms of scientific focus (Section 3.2.1) and more general needs for development (Section 3.2.2).

Overall, the focus of the programme and the use of the different schemes in the various thematic areas responded to the needs in the various scientific fields that the RIs serve. This included the high focus on integrating activities in areas where research communities are still rather fragmented or where inter-disciplinary research is key (e.g. social sciences & humanities and life sciences), as well as the support for research infrastructures in areas that are facing the big data challenge or where access to global data is mandatory (e.g. energy, earth & environmental sciences).

The analysis also confirmed the importance of an improved flow of knowledge, in particular for users located in the newer EU Member States, and highlighted the need for closer collaborations between scientists and ICT developers (e.g. in the energy, earth & environmental sciences). Industry participants stressed the importance of research-industry collaboration.

The analysis suggests two major gaps, i.e. the improvement of RI management capabilities and support for innovation.

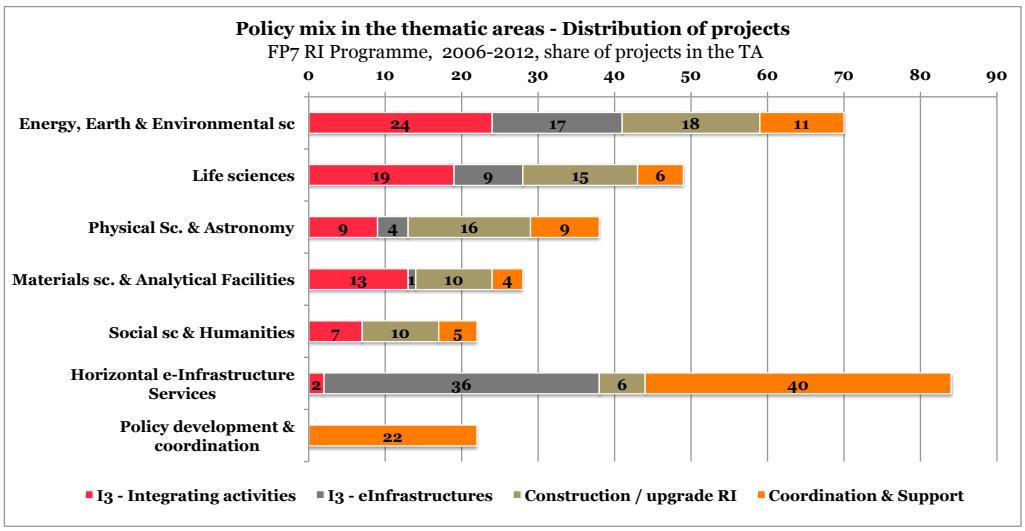
3.2.1 Thematic focus of the support

Exhibit 10, below, shows the distribution of the support schemes in the different thematic areas.

The FP7 RI programme had a pronounced focus on RI serving the research communities in **energy, earth and environmental sciences** – for both existing and new networks or integrated RI, followed by the support for pan-European RI in the **life sciences**.

This is partly thanks to the fact that the 2008 and 2010 updates to the ESFRI roadmap were mainly related to RI in the fields of environment, energy and life sciences.

Exhibit 10 Policy mix in the thematic areas: distribution of the projects (portfolio analysis, 2006-2012)



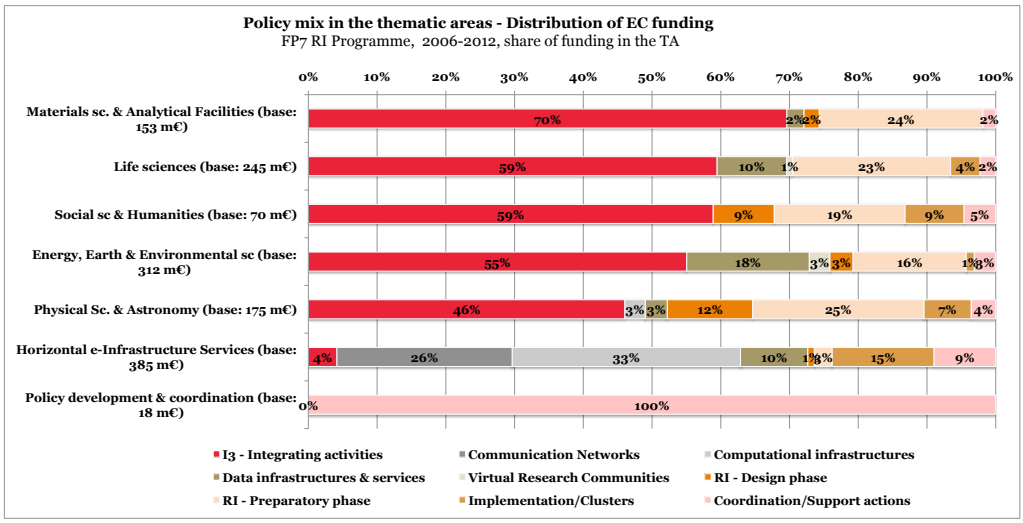
The relatively high level of support to RI in the **physical sciences & astronomy** thematic area is to be noted, in particular in the number of projects supporting the construction of new RI networks. The ESFRI roadmap played a limited role from this

perspective: six out of these 16 projects were design studies, so not included in the ESFRI roadmap. In a 2013 paper[8], researchers at Fraunhofer ISI considered that the focus of funding in the FP7 RI programme does not match the "factual" pattern of the RI landscape in Europe. They indicated in particular an over-representation of RI in the field of (nuclear) physics and astronomy. According to the authors, this was due to the traditional focus on these fields in FP RI funding.

Finally, the **social sciences & humanities** (SSH) thematic area has the lowest number of projects supported, in particular for the networking of existing RI. The Fraunhofer ISI researchers mentioned above recognised the improvement compared to FP6 related to the funding of RI in the field of SSH and the important role of the ESFRI roadmap to bring these RI to the attention of the national policy makers. Nevertheless, they considered that RI in this field of science are still underrepresented in the RI programme. Participants in a workshop organised by the Meril project broadly agreed with this observation and attributed this situation to the characteristics of RI in SSH, mainly digital infrastructures, and the poor understanding of digital infrastructures and their value among national policymakers.

An analysis of the policy mix in terms of distribution of funding gives a better view on the **effects of the ESFRI roadmap** on the focus of the funding and its implications in terms of budget for RI in the thematic areas. (Exhibit 11)

Exhibit 11 Support schemes in the Thematic Areas – share of EC funding (portfolio analysis)



We note the following:

- Close to 70% of the funding in the material sciences & analytical facilities thematic area was allocated to the I3 – Integrating activities scheme
- Data infrastructures & services projects were funded in particular in the energy, earth & environmental sciences and life sciences thematic areas; these areas were also the only ones were support was given for the development of Virtual Research Communities. This is in line with the importance of international cooperation and access to RI at the global level for these fields of science

[8] Stahlecker, T., Kroll, H., *Policies to build RI in Europe – Following traditions or building new momentum?,* Fraunhofer ISI Working Paper, R4/2013

- The computational infrastructures sub-scheme especially supported RI in the physical sciences & astronomy field, in addition to the work in the horizontal e-Infrastructure services thematic area
- Preparatory phase projects were funded in particular in the areas of physical sciences & astronomy, material sciences & analytical facilities, and life sciences
- Design studies were funded especially in the areas of physical sciences & astronomy and social sciences & humanities
- Implementation of new RI – in the form of cluster projects – were funded in all S&T-specific thematic areas, with the exclusion of material sc. & analytical facilities

3.2.2 The user needs for further development

Survey respondents mapped as shown in Exhibit 12, below, their current needs for further developments that would allow them to reach or however maintain a global competitive positioning in their fields of activity.

Top on the list are the financial support for RI design and an improved synergy in RI funding and coherence in policy-making between the EC and the national authorities. Key topics are also technical support for the improvement of RI services, capacity building in the use of advance tools & methodologies, more interdisciplinary research, and access to large data infrastructures.

Exhibit 12 Needs for development versus objectives of the support schemes (based on survey responses)

	Needs for development	Objectives of the support schemes					
		Integrating activities	e-Infrastructures	Design activities	Preparatory activities	Implementation activities	Coordination/ support
Research Infrastructures							
Financial support for RI design	72%			XX			X
Technical support for RI services improvement	64%	XX	XX				
More access to large data infrastructures	61%	X	XX		X	XX	
Research-ICT experts collaboration	58%	X	XX				
More access to advanced scientific instruments	58%	XX	XX		X		
More access to large research facilities	57%	XX	XX		X		
Multidisciplinary scientific data infrastructures	55%	X	XX		X	XX	
Support for improvement RI management capabilities	52%	X					X
More access for industry to international RI	48%	X	X				
More access to state-of-the-art simulation & visualisation tools	47%		XX				
Research							
Interdisciplinary collaboration in research	68%	XX	XX		X	XX	
Capacity building in use of advanced tools & methodologies	63%	XX	XX				
Research-industry collaboration	55%	X	X				
Open access to publications & research results	54%		XX				
Common EU research methodologies & tools	53%	XX	XX				X
Common global research methodologies & tools	47%	XX	XX				X

	Needs for development	Objectives of the support schemes					
		Integrating activities	e-Infrastructures	Design activities	Preparatory activities	Implementation activities	Coordination/ support
Policy							
EU/national funding synergies	77%				XX	XX	XX
Coherence EU/national policies	68%	X	X		XX	X	XX
Transnational collaboration policy-makers	62%					XX	XX

Some significant differences in the responses were noted, depending on the scientific and technological fields and organisational profile of the respondents (research versus industry) and their geographical location:

- Researchers located in the newer EU Member States indicated a high need for an improved **flow of knowledge** among researchers, facilitated by more open access to S&T publications and research results, an improved collaboration between scientists and computing and communication technology developers, and improvement of access to advanced scientific instruments
- Industry actors highlighted the importance of improved **research-industry** collaboration Improved access to state-of-the-art simulation & visualisation tools
- An enhanced development of common research methodologies and tools at the **global level** was an important factor for researchers in the energy, earth and environmental sciences. These researchers valued also open access to S&T publications and research results
- Researchers in the life sciences highlighted the need for more capacity building in the use of **advanced tools & methodologies** and for a closer collaboration between scientists and computing and communication technology developers
- Researchers in the social sciences & humanities attributed more than average importance to a closer collaboration between **scientists and computing and communication technology developers** and highlighted the importance of open access to S&T publications and research results
- An improved access to **state-of-the-art simulation or visualisation tools** was a development need that was felt in particular by respondents involved in the Horizontal e-infrastructure services thematic area (58%)

Exhibit 12, above, indicates which support schemes can be expected to respond to these needs, based on their objective descriptions. It shows that all needs for development are covered to a substantial level by at least one of the support schemes. Exceptions to the rule are indicators related to RI management and industry innovation, such as access for industry to international RI, and research-industry collaboration.

3.3 Efficiency in stakeholder involvement

The objectives that have been set for the FP7 RI programme imply the need for involvement of a broad range of stakeholder communities, including the research community, the private sector and public administration. In Section 3.3.1 we consider to what extent the programme was efficient from this perspective.

The extent to which the participants in the programme are also leaders in their communities influences the potential for spill-over effects. We consider this aspect in Section 3.3.2. Finally, the ERA-related objectives require an appropriate geographical distribution of the programme participants. We cover this in Section 3.3.3.

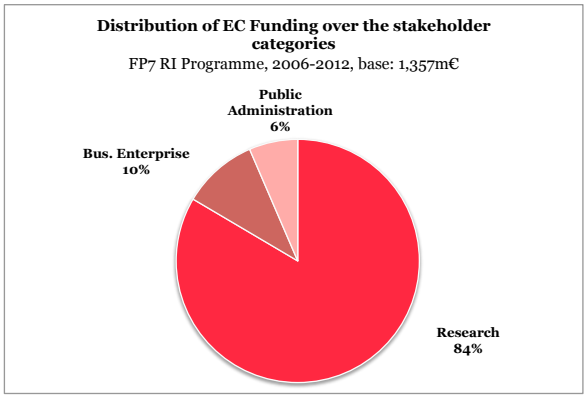
The analysis reported in this section shows the high involvement of the research communities in the programme. This is fully in line with the primary function of research infrastructures. In contrast, there was little participation by actors in the private sector, suggesting a limited focus on innovation in the RI projects.

The FP7 RI programme clearly succeeded in involving the best of organisations in the different fields. Positive is also the relatively high participation and funding rate of organisations located in smaller EU15 and newer EU member states, setting the base for a strong effect on European cohesion.

3.3.1 Involvement of the stakeholder categories

The **research community** was the major beneficiary of the funding in the FP7 RI programme (84% - see Exhibit 13). Research institutes were the most funded actors in this stakeholder category (~45% of the total budget); higher education institutions accounted for approximately 35% of the budget, setting the basis for a potentially considerable knowledge spillover into the educational sector. Public Service agencies that perform research (such as government labs, meteorological institutes, libraries, space agencies etc) received 4%.

Exhibit 13 Distribution of EC funding over the stakeholder categories (composition analysis, 2006-2012)



Source: eCorda database, 2006-2012

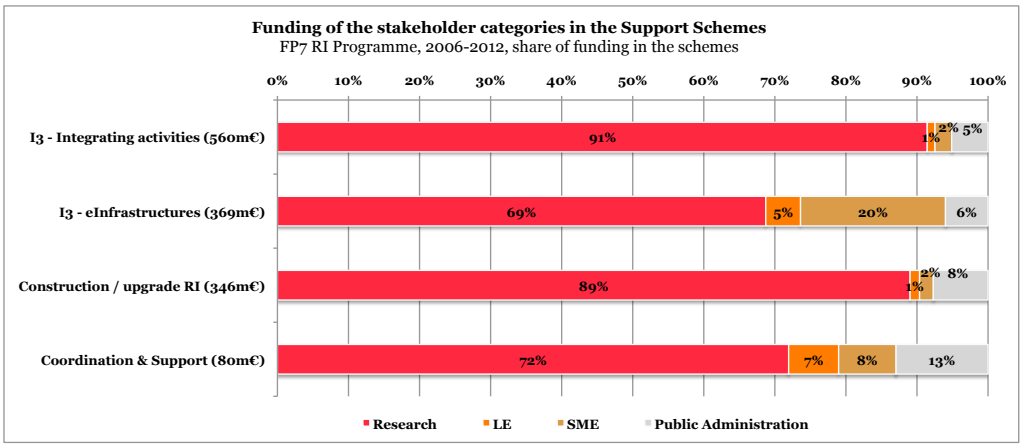
The level of funding for the **public administration sector** illustrates the efforts made in the programme also for an improved coordination of national policy-makers: public administration participants accounted for 6% of the overall EC funding, but for about 8% in schemes supporting the development of new RIs and for 13% in the coordination/support schemes (Exhibit 11).

While the participation and in particular funding levels for the research and public administration actors can be considered in line with the expectations, involvement of the **private sector** was limited, ~10% of the FP7 RI budget. Beneficiaries were predominantly SMEs (8% of the budget) rather than Large Enterprises.

The share in EC funding was low especially in the I3 – Integrating activities and the Construction/Upgrade RI schemes (3%). In the I3-eInfrastructures scheme, ~25% of

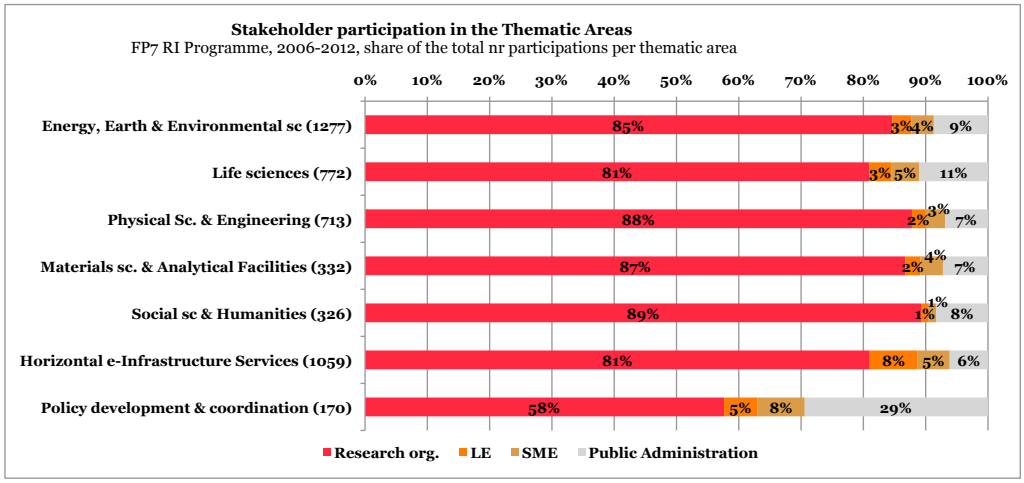
the budget was allocated to industry. However, this was predominantly to the benefit of DANTE, the organisation responsible for the GEANT network, which accounted for 17% of the total funding in the e-Infrastructures scheme. Other private sector actors accounted for 8% of the budget.

Exhibit 14 Funding of the stakeholder communities in the support schemes (composition analysis)



Involvement of industry is determined, amongst other factors, by the characteristics of the science field that the RI serves. However, Exhibit 15, below, shows that even in more applied research or technology-oriented thematic areas, participation by industry was very limited. This included ~7% in the energy, earth & environmental sciences (EEES), and life sciences, and 6% in the materials sciences & analytical facilities.

Exhibit 15 Stakeholder participation in the thematic areas (composition analysis)



In the thematic area horizontal e-infrastructure services, industry participation had an overall share of 13%. In this area, industry participants were predominantly suppliers, i.e. software and middleware systems developers, in addition to telecommunication companies. In the EEES and Life sciences thematic areas, the industry sector was involved also as user of the RI, including enterprises in the aeronautics industry, the energy sector, and the medical sector.

3.3.2 Positioning of the research teams in their environment

The majority of the survey respondents (more than 80%) considered their organisation to be a lead player or however highly important in their areas of work at the national level, half of them considered a similar positioning of their organisation

also at European level. For ~40%, the participating organisation was a lead or highly important player also at the global level.

Interesting is the difference in responses among stakeholders involved in different support schemes: ~40% of the participants involved in the I3 Integrating activities and the Preparatory phase actions considered their organisations to be important players at the global level, compared to ~30% of respondents involved in the I3–e-Infrastructure scheme.

The higher share of 'new entrants' at global level among the participants in e-infrastructures schemes suggests a higher capacity of the e-infrastructure support scheme to involve new emerging actors. The breakdown of these data shows that the involvement of new entrants regarded especially the 'data infrastructures and services' projects and more in general, the industry stakeholders (large enterprises as well as SMEs, but particularly the latter).

Exhibit 16 Positioning of the participants' organisations in their area of work at global level (survey respondents)

	Leading/high importance	Moderate/minor importance	A new entrant	Don't know/Not applicable	Base
I3 - Integrating activities	42%	51%	2.9%	4.1%	172
I3 - eInfrastructures	28%	59%	8%	5%	111
Construction / upgrade RI	47%	47%	2%	4%	104
Coordination & Support	27%	54%	5.8%	13.5%	52

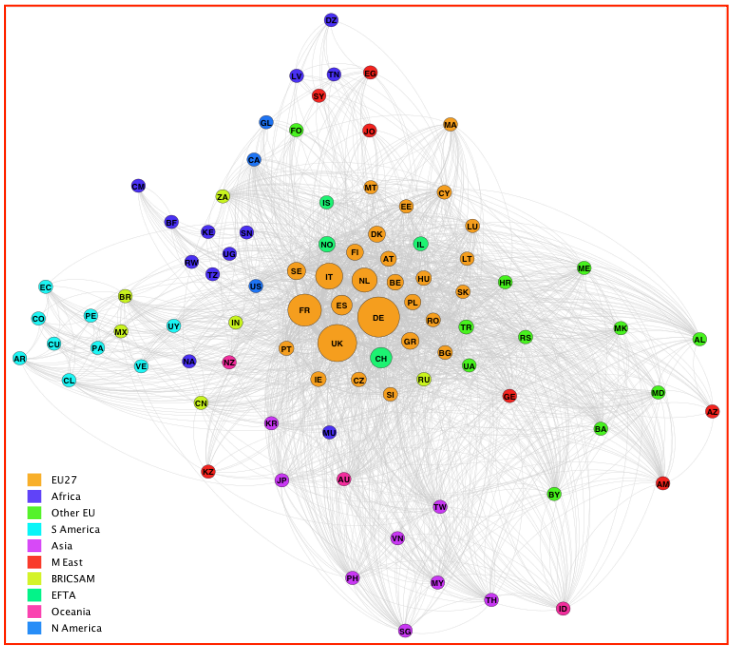
The **bibliometrics data** confirmed this picture of competitive strength in the FP7 RI programme constituency from a research perspective. The analysis looked into the publication history of 200 FP7 RI participants, covering their articles and reviews for the five years preceding the FP7 project. This regarded participants in research infrastructure and e-infrastructure projects. Our finding was that in general, programme participants have better publication histories than their peers in the respective fields. They publish more in high quality journals, have higher-than-average citation rates, and have a high share of international co-publications.

3.3.3 Geographical location of the FP7 RI participants

EC funding in support of research infrastructures was predominantly to the benefit of organisations located in the EU Member States (90%) and the EFTA countries (7%).

The FP7 RI network is built around **5 core Western European countries**, i.e. Germany, the United Kingdom, France, Italy and the Netherlands (Exhibit 17). Together organisations in these five countries received more than 65% of the total EC contribution. Organisations based in these top 6 EU Member States accounted for about 70% of EC funding in the I3 schemes and the design and preparatory phase schemes.

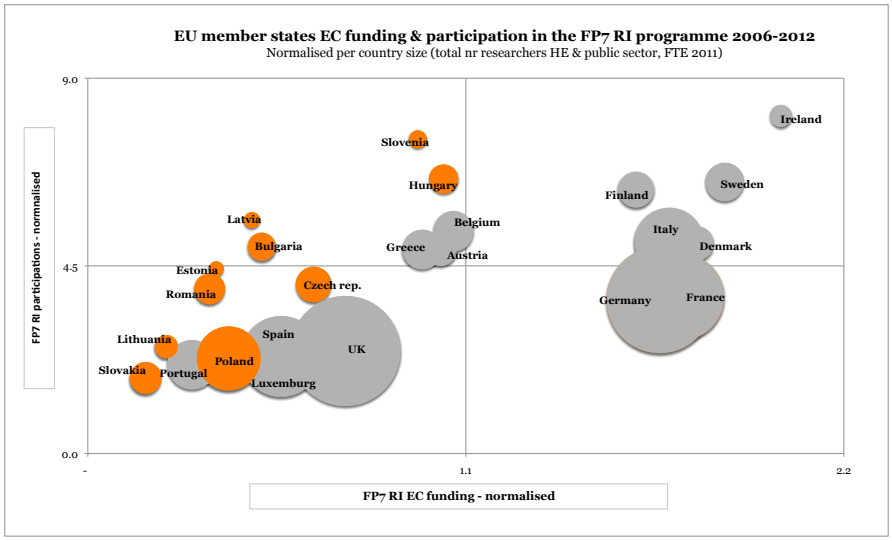
Exhibit 17 The FP7 RI programme network – geographical location (social network analysis, 2006-2012)



Source: eCorda database, 2006-2012

However, normalised data on EC funding and participations, based on the size of the country (in terms of researcher base), highlight the value of the programme in particular for **small and newer EU member states** (Exhibit 18). Especially smaller EU15 member states (Ireland, Sweden, Finland, Denmark, Belgium, Austria and Greece) and newer member states such as Slovenia, Hungary, Bulgaria and Latvia had higher than average normalised funding and/or participation profiles.

Exhibit 18 Geographical distribution of funding and participations – normalised per country size (composition analysis, 2006-2012)



Notes: Size of bubbles = Total nr researchers HE & public sector, FTE 2011 (source: Eurostat)

3.4 Efficiency of the programme implementation

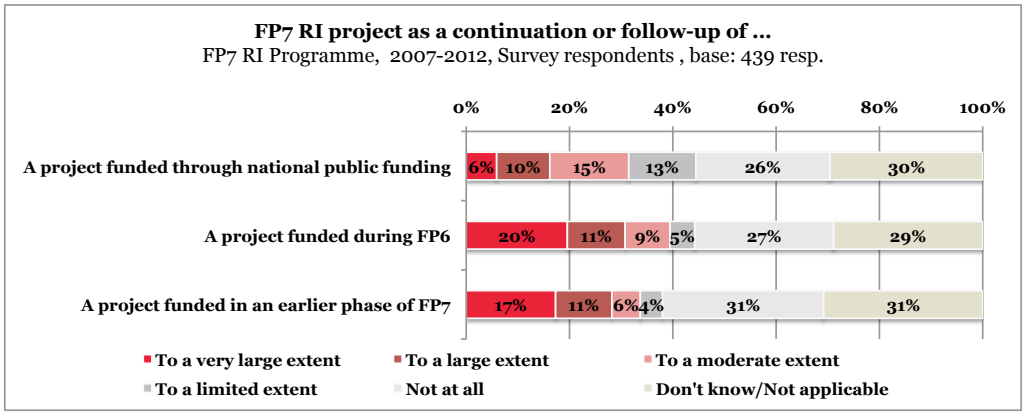
We assessed the efficiency of the programme implementation in terms of the appropriate use of the support schemes over time and the general characteristics of the approach taken.

The two DGs involved adopted a different strategy from this perspective, appropriately taking into consideration the historical background and different nature of their support. However, the continuous increase in focus areas, in particular in recent FPs, raises questions on the level of funding dispersion.

3.4.1 The use of the policy mix

A considerable number of FP7 RI projects were a continuation or follow-up of projects previously funded under FP6 or in an earlier phase of FP7. Approximately 30% of the survey respondents stated that their projects was a continuation or follow-up of indicated of projects funded under FP6 and/or in an earlier phase of FP7 (Exhibit 19). It is interesting to note that only ~15% of respondents indicated a previous project funded at the national level.

Exhibit 19 FP7 RI projects as a continuation or follow-up of previous publicly funded projects – overall (survey responses)



Several of the current research infrastructures find their roots in the integrating and networking activities that were launched in the Integrating Activities scheme under FP6. Interviewees in our case studies considered that these FP6 activities were a critical first step for the creation of the research infrastructure, in particular in the case of data infrastructures. In many cases, the major outcome of these projects was the creation of an integrated research community; follow-up support under FP7 was then focused on strengthening and expanding the community as well as improving the RI services.

Data suggest a **different strategic approach** in the two DGs involved in the FP7 RI programme, due to the nature of the support they provide as well as the focus of funding in FP6.

There are considerable differences in the responses of participants involved in the different support schemes: ~40% of respondents indicated for the Integrating Activities a project funded under FP6, whereas ~40% of those involved in the e-Infrastructures scheme indicated previous FP7 funding (Exhibit 20).

Exhibit 20 FP7 RI projects as a continuation or follow-up of previous publicly funded projects – the support schemes (survey responses)

	National funding	FP6 funding	Previous FP7 funding
I3 - Integrating activities (172 resp.)	11%	39%	21%
I3 – e-Infrastructures (101 resp.)	12%	27%	38%
Construction / upgrade RI (104 resp.)	22%	23%	24%
Coordination/Support actions (52 resp.)	15%	27%	40%

There are substantial differences also in the size and duration of the projects: I3 Integrating activities tend to be large projects and have an average funding of 7.6 m€, with an average duration of 46 months. E-Infrastructure projects, instead, receive an average funding of 5.5 m€, ranging from 5.3 m€ for computational infrastructure projects to 3.6 m€ for data infrastructure & services and 2.9 m€ for the virtual research infrastructure ones. They also have a shorter average duration, i.e. 33 months

Participants consulted in the case studies pointed out that the funding approach in the e-Infrastructures scheme forces the researchers to break the problem down into different steps, to be executed as separate projects. Even though this approach may cause some extra management overhead, it was generally considered as positive because of the flexibility that it offers.

3.4.2 Dispersion of the funding?

The European Commission support to research infrastructures dates back to the first FPs. Over these last decades, there has been an ever-increasing level of expectations and focus areas for the support to be provided (Exhibit 21). This was especially the case in the most recent FPs, in line with the increasing importance attributed to research infrastructures in the context of the development of the European Research Area. In FP7, a major influencing factor was the implementation of the ESFRI roadmap.

An inevitable question that emerges in this context is whether this increase in focus areas implied a **dispersion of the EC funding** such to set the efficiency and effectiveness of the RI programme at risk.

Exhibit 21 Objectives of FP-funded activities in support of the RIs

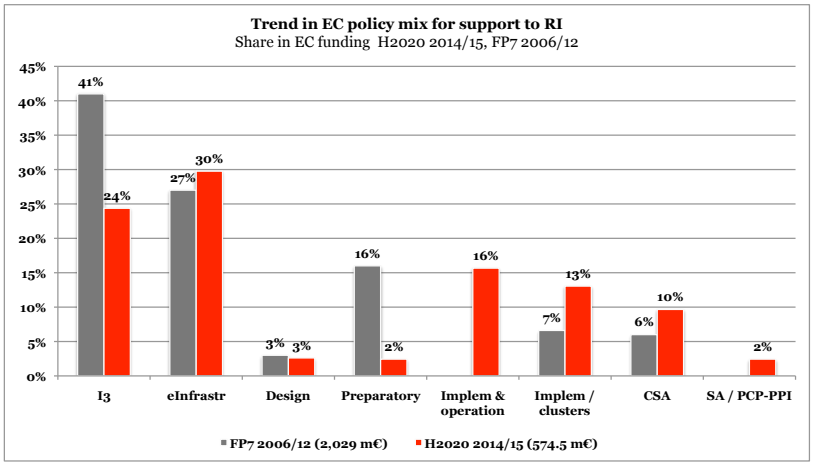
	FP2 – FP4	**FP5**	**FP6**	**FP7**	**FP8**
Trans-national access to research facilities	√	√	√	√	√
Advanced network & computational technologies		√	√	√	√
RI cooperation networks & integrated existing RI		√	√	√	√
Improved quantity & quality of RI services			√	√	√
New scientific equipment			√	√	√
Supported design of new RIs			√	√	√
Supported construction of new RIs			√	√	√
Supported development of data infrastructures				√	√
Reinforced national & EU policy cooperation				√	√
Facilitated international cooperation				√	√
Supported development of Virtual Research Communities				√	√
Supported development of Regional Partner Facilities in synergy with DG REGIO actions					√
Supported operation phase of new RIs					√
Fostered innovation potential of RIs					√
Strengthened human capital of RI					√

The FP7 Interim Evaluation report[9] stated, "Maintaining the level of funding per year at the present level (or even worse decreasing it further), while simultaneously expanding the range of scientific domains served by RIs, may lead to the imposition of upper funding thresholds as has happened in recent calls. Such thresholds are rather arbitrary and may impinge on the optimal impact of the RIs programme."

A similar opinion was voiced in conclusion of a European Association of National Research Facilities -ERF seminar[10]: "EU Transnational Access funding has had major impact in FP6 but has been dramatically under-developed during the FP7. It needs to be largely amplified and targeted on new users from new countries."

The general fear is that the funding for the development of the new research infrastructures will imply a reduction of the funding for the existing ones. The budget allocation in the first H2020 Workprogramme (budget 2014/15) suggests that these fears are justified (Exhibit 22).

Exhibit 22 Trends in funding allocation – FP7 RI 2006/12 versus H2020 WP2014/15



[9] Fotakis, C., FP7 Interim Evaluation: Analyses of FP7 supported Research Infrastructures initiatives in the context of the European Research Area, European Commission, 2010

[10] Findings of the ERF Seminar on Future Access to European Research Infrastructures, Lund, October 2009

4. Impacts of the FP7 RI programme – achieved or expected

In this chapter we report on our findings related to the effectiveness of the FP7 RI programme in reaching its expected outcomes and impacts, in addition to the European Added Value (EAV) of its support and the sustainability of its results.

Wherever appropriate, we looked into the role and value of the different support schemes, the effects on the S&T research fields, and the barriers for impact achievement.

The structure is:

- Impacts on the European Research Infrastructure - Chapter 4.1
- Impacts on research – Chapter 4.2
- Impacts on the internationalisation of RI and research – Chapter 4.3
- Impacts on industrial innovation – Chapter 4.4
- Impacts on national and EU RI policy making – Chapter 4.6
- Socio-economic impacts – Chapter 4.5
- Impacts on RI policy making and funding – Chapter 4.6
- European Added Value of the FP7 RI Programme – Chapter 4.7
- Sustainability of the FP7 RI Programme results – Chapter 4.8

4.1 Impacts on the European Research Infrastructure

The enhancement of the efficiency and effectiveness of the European RI system was the primary objective of the FP7 RI programme. This included the optimisation of the research infrastructures landscape in Europe and the services that they offer, and the strengthening of their global relevance.

In the sections below, we illustrate the performance of the FP7 RI programme against these objectives. Section 4.1.1 sets out the main findings; in Section 4.1.2 we highlight the role and value of the different support schemes.

The programme reached significant effects on an improved cohesion of the European RI landscape and on the breadth and quality of the RI services. All support schemes contributed to these achievements; however, the impacts were reached in particular through their combined efforts and the appropriate use of the policy mix. An important factor is the growing synergy and complementary role of the research infrastructure and e-infrastructure activities.

4.1.1 Overview of the main findings

The range of research infrastructures that was supported in the FP7 RI programme is very diverse, and reflects the new opportunities that digital, and communication technologies offer in terms of designing big science research. They include centralised (single site) facilities such as particle accelerators, telescopes, central laboratories and research ships, as well as physically distributed resources for research, such as computing networks, and large collections of data or physical objects. In fact, they cover major equipment or sets of instruments, in addition to knowledge-containing resources such as collections, archives and data banks, and 'facilities that facilitate research facilities', such as GRIDS and Supercomputers.

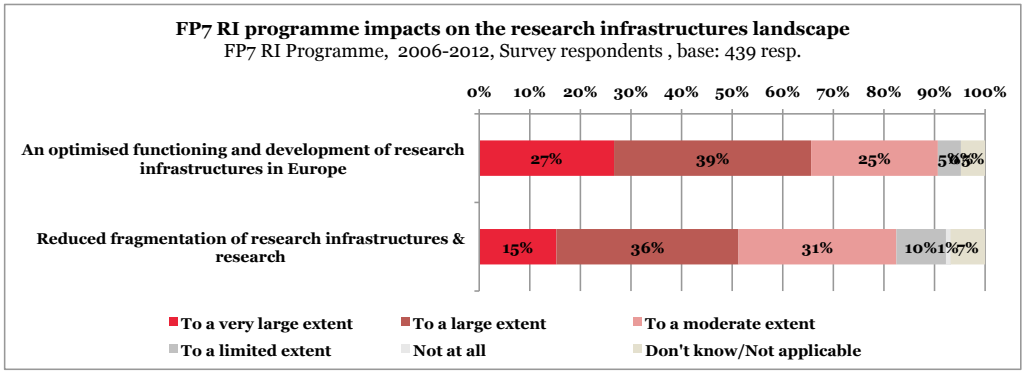
The overall objective of the FP7 RI programme was

- To develop a *networked fabric* of research infrastructures in Europe and
- Improve the way research infrastructures *operate, evolve and interact* with similar infrastructures and with their users – at a European and global scale

The Programme has performed particularly well against these objectives.

There was a general high appreciation among our interviewees, confirmed by the majority of survey respondents. Approximately 65% of these participants stated an impact of the Programme on an optimised functioning and development of research infrastructures in Europe, ~50% half of them indicated an impact on a reduced fragmentation (Exhibit 23).

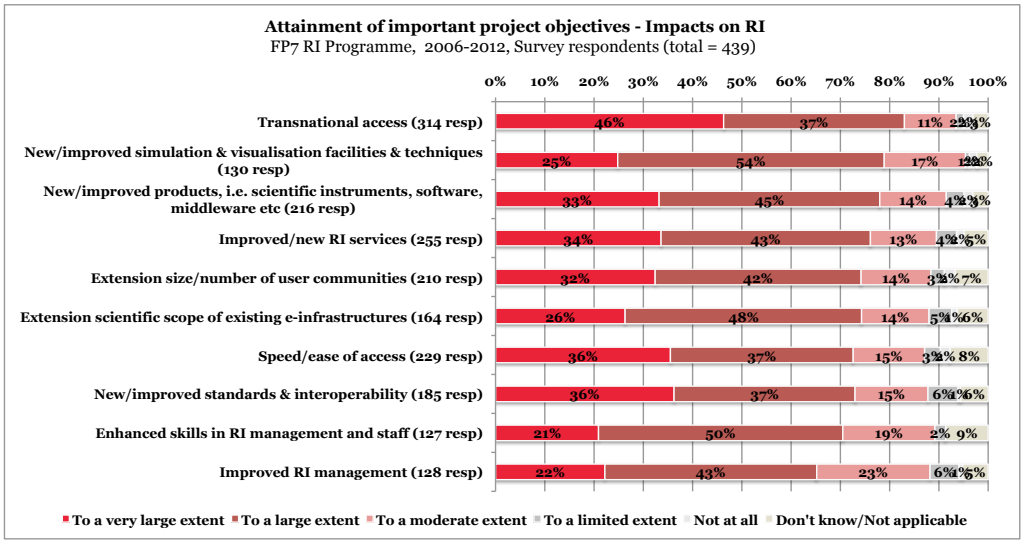
Exhibit 23 FP7 RI programme impacts on the research infrastructures landscape



According to the survey respondents (Exhibit 24), major outputs and outcomes of the FP7 RI projects were

- An improved transnational access (~80% of respondents)
- New or improved products in terms of scientific instruments, software, middleware, etc. (~80% of respondents)
- New or improved simulation & visualisation facilities and techniques (~80% of respondents)
- Extension of the RI users base, from a scientific and/or research community perspective (~75% of the respondents)
- New or improved RI services in general (~75% of respondents)

Exhibit 24 Attainment of important project objectives – impacts on RI (survey respondents)



Notes: Attainment of project objectives that were indicated of (very) high importance

The FP7 RI projects contributed to impacts in this sphere by a broad range of actions:

An **enhanced cohesion in the European RI landscape** was reached thanks to the interlinking of research facilities and data infrastructures; the harmonisation, standardisation and interoperability of methodologies and tools; the delivery of transnational access; and an increasing connectivity and ease of access.

- The FP7 RI programme has played a crucial role for the development of a more coherent European RI ecosystem in particular by fostering the harmonisation and standardisation of procedures, methodologies, work practices or workflows, and principles for data management and sharing, as well as the delivery of standardised services and the interoperability of technical equipment, software, data sets etc.

  Common standards and definitions and harmonised rules are essential for the functioning and use of distributed research infrastructures. Many FP7 RI projects contributed to standardisation and harmonisation and the added value of European efforts in this area is significant.

- The projects that supported the construction of RI clusters in specific S&T fields of research aimed at implementing common and efficient solutions on issues ranging from architecture of distributed infrastructures to distributed access management, from development of critical components to new/revised data acquisition, access and deposit policies.

  The policy objective was to foster harmonisation, cost-efficiency and interoperability. In most cases they promoted *synergies among initiatives i*n the same field and the implementation of common solutions to respond to common needs. They also enabled large-scale technical and policy coordination.

- In several scientific fields, the FP7 RI activities have led to an expansion of the research infrastructures' scale, scope and reach in the user communities. This was achieved through a linking and opening up of research infrastructures, by fostering transnational access to the RI networks, and by scaling up the speed and ease for access in the more mature infrastructures thanks to the advances in the network and computational infrastructure technologies.

  The eInfrastructures GÉANT, PRACE and EGI give access to innovative infrastructures that offer *high capacity services* not matched by any commercial or national offer. The services offered are not affordable for most individual member states or for most big companies and are completely out of reach for the budget of SMEs.

- By facilitating and maximising access to RI, the Programme allowed for expansion of the RI user communities, geographically spread and often active in different scientific disciplines or sub-disciplines.

  An example in the physics & astronomy thematic area is the NEXPRES e-infrastructure project, contributing to the enhancement of the data services in the Square Kilometre Array (SKA) research infrastructure, a global distributed facility in the field of radio astronomy, as well as extending the platform to a large number of researchers.

Improvement of the RI services was attained thanks to innovation in the tools and methodologies for the collection, processing and analysis of the resources, visualisation and simulation techniques, scientific instruments etc.

The shift to a more service-oriented approach in the e-infrastructure ecosystem constituted an important development in this context. Work in FP7 has led to an improved response to the researchers' need for enhanced data collection, handling, storage and sharing.

The networking effects (i.e. the volume of the data collected and shared) has led to optimised models and new and enhanced data analysis tools, and in some cases also the data quality (samples, images. Often, the integration of different data sources also enhanced their statistical significance.

The development and improvement of tools and scientific instruments was a typical focus of the Joint Research Activities in the I3 schemes. Several of the I3 integration projects in particle physics, for example, supported the upgrading of key facilities including CERN. In fact, these projects were almost entirely focused on the R&D required to develop the next generation detector and accelerator technologies for RIs.

Below we provide another example, in the field of seismic engineering.

Case 1 SERIES (Impacts on RI - EEES)

Seismic Engineering Research Infrastructures For European Synergies – SERIES is an I3 - Integrating activities project. The consortium comprised 23 participants from 10 countries in the EU27 and two other countries in the European continent (Turkey and Macedonia). The main aim of the SERIES project was to bridge the gap between Europe and US/Japan in experimental seismic engineering, via the integration of its infrastructures and research teams.

The SERIES project developed a very large virtual European research laboratory that allows for telepresence and geographically distributed concurrent testing at the participating research infrastructures. In addition, it promoted wider sharing of data and knowledge across the field of earthquake engineering through the project's web portal and the creation of a distributed database of test results, pooling data from the beneficiary research infrastructures and others, accessible and maintained by a virtual research community after the project's end.

The joint research activities focused on the development and improvement of concepts, technical requirements and prototyping for new-generation electro-dynamic actuators (including coupling with hydraulic ones) for high-performance, enhanced-quality real-time testing; new instrumentation and sensor techniques for improved sensing and test control, including dedicated software for data processing and virtual models; and new capabilities and techniques for experimental study of soil-structure-interaction and seismic wave propagation phenomena.

Input for policy-makers was provided through the development of and enhancement of standards, protocols and criteria for qualification of RTD infrastructures in earthquake engineering.

4.1.2 The value and complementary role of the support schemes

The impacts mentioned above were reached through the combined efforts of the various support schemes. Major facilitators were the projects in the I3 schemes. These projects were expected to implement a mix of 3 activities: transnational access (TA), joint research activities (JRA) and transnational networking activities (TNA).

In the sections below we highlight some specific outputs and outcomes of the two I3 schemes, i.e. I3 – Integrating Activities and I3 – eInfrastructures.

However, we note a **growing synergy and complementary** role of the Programme 'research infrastructure' and 'e-infrastructure' activities, in particular in those cases where integrating activities and e-Infrastructures that develop services related to large datasets of measurement co-exist to support a same community or groups of largely overlapping communities.

An implication of the eScience paradigm shift is that the distinction between 'research infrastructures' and 'e-infrastructures' is increasingly blurring. The 2010 ESFRI roadmap[11] stated:

[11] Strategy Report on Research Infrastructures, ESFRI Roadmap 2010

> *Across all research areas, e-Infrastructures are playing an ever increasing role in data acquisition and management, digital repositories, access to standardised, calibrated and inter-operable data, data curation, the mining of archived data and its release for broad access. Research Infrastructures ranging from Human and Social Science libraries and surveys, to interconnected Biomedical Sciences laboratories, Environmental Sciences observational networks, Physical, Materials, Astronomical and Engineering Sciences accelerators, synchrotrons, observatories and energy demonstrators are all dependent upon e-Infrastructures.*

Research Infrastructures are increasingly interconnected and supported by e-Infrastructures. The e-infrastructure projects need large datasets of measurements to begin with. In order to obtain these datasets there has to be a coordinated data gathering effort with interoperability at the single facility level. Depending on the maturity of the research community and its network, the path towards harmonisation and standardisation can be long and difficult. In that case, the integration of facilities and the discussions between researchers about the best way to represent data for a specific scientific discipline is usually carried out at the level of Integrating Activity projects. Once consensus on the basic features is reached and set in operation, an overarching e-Infrastructure 'layer' allows for the development of a distributed RI with European scope for its service provision.

The value and success of the e-Infrastructure, however, depends on the critical mass that the communities have been able to achieve. In turn, successful e-Infrastructures provide the user-base that is needed for the tools that are to be developed and help in the dissemination of the service catalogue.

In this process, the **close interaction between scientists** in the specific field and **computational scientists or ICT engineers** is of crucial importance. The development of user-focused services is challenging and depends critically upon understanding user needs (from the side of the computational experts) and awareness among the scientists of the opportunities that e-infrastructures can provide.

There seems to be room for improvement from this perspective in the RI programme. The 2010 ESFRI roadmap admits: "Data taking and data management is something that is often overlooked at the beginning of a Research Infrastructure project, as is the financing of the necessary e-Infrastructures."

The I3 – Integrating Activities

Overall the I3 – Integrating Activities showed a high level of effectiveness, achieving the expected outputs and outcomes. **Transnational access** and new or improved **research methods and techniques** were major outputs of these projects: achievements 'to a (very) large extent' were indicated respectively by ~75% and ~60% of respondents.

The analyses at thematic area level showed the importance of the thematic context in which the supported RIs operate; this is particularly the case for the transnational access activities, which can be expected to have direct effects on the research communities involved. Influencing factors appear to be the characteristics of the research as well as the maturity of the RI in the fields.

Stakeholders active in the physics & astronomy thematic area particularly highlighted the relevance of the Joint Research components in the I3 – Integrating Activities for the research infrastructures in this area. Several of the I3 integration projects in particle physics, for example, supported the upgrading of key facilities including CERN. In fact, these projects were almost entirely focused on the R&D required to develop the next generation detector and accelerator technologies for RIs with very limited support for transnational access compared to typical I3 projects.

The provision of transnational access was an important component of the I3 – Integrating Activities in the fields of material sciences & analytical facilities (M&A) and specifically the field of laser research. It positively affected the quality of the

research in countries where cutting-edge instrumentation for material science and large-scale analytical facilities are scarcely or not at all available.

We cover the Programme's value in facilitating transnational access in Chapter 4.2, below.

The I3 – e-Infrastructures

Also the I3-eInfrastructure projects showed a high level of effectiveness in achieving the expected outputs and outcomes. High effects on the research infrastructures' efficiency, global relevance, usage levels and innovation potential were indicated or expected by 50% to 60% of the respondents. Major outputs were in the technical spheres and related to new or improved software, middleware, and scientific instruments (achievement indicated by 50% of respondents) and new or improved standards & interoperability (~45%).

GÉANT proved its ongoing importance in acting as a gateway for global collaboration and providing seamless access to knowledge, improving its connectivity capacities. The GN2 and GN3 projects have included ongoing programmes of development of technology and services which have had a direct impact on the advanced services made available to research communities in Europe. In GN3, the focus was on increasing resilience and reaching technology upgrades that would enable new services and direct peering possibilities, building upon the achievements of the previous project where the focus was on cross-border dark fibre links.

eVLBI would not have been possible without the development of lambda/lightpath services and the development of the networking infrastructure to support the movement of data from the LHC experiment at CERN. The support for other research infrastructures such as the PRACE HPC infrastructure would have been much more costly if GÉANT did not exist.

GÉANT has successfully deployed several services, most of them for managing the network but also some end user services. An example of the latter is EduRoam, developed by the NRENs, allowing for seamless access to federated wifi campus infrastructure.

The **GRID projects** brought forward knowledge on grid computing and the European gLite infrastructure was implemented widely. They were successful in serving the communities that they were specified for and raised awareness of the benefits deriving from distributed computing and the interconnection of European resources. Repositories of easy-to-install middleware components were developed, combined with consistent training and education programmes, and enhanced capacities for broader interdisciplinary scientific collaboration. e-Science Grids have emerged that allow sharing and combining the power of computers and sophisticated, often unique scientific instruments. In climate application of Grids computing there are some good examples where the Grid projects fostered international climate research.

For the data and computational infrastructure layers in the e-infrastructure ecosystem, the trend is towards developing multi-purpose e-infrastructures that can serve several communities and thus reduce the need for dedicated community services. This would foster cost-efficiency and interoperability, enabling interdisciplinary research. Critical from this perspective is the development and deployment of standardised services as well as the harmonisation of operational and security procedures.

The EGI-Inspire project has picked up the challenge of anticipating these trends and adapting the GRID and computational models to the needs of multiple research communities. *Close collaboration between ICT experts and the scientists* was critical for success: when the two communities were working productively together, dramatic progress was achieved. In this context, the challenge for policy is to devise measures and incentives for transferring the knowledge gained from implementing the Grids to new user communities with different, but complementary requirements. Incentives for

the current grid providers and major users, i.e. the high-energy physics community, to share their knowledge would alleviate the apparent current lock-in and avoid under-exploitation of an important European resource.

Europe shares the idea that **high performance computing** is essential for European competitiveness and innovation as has been expressed in the European Council decision from 2013. Access across country borders is important for European cohesion, as the tier-0 systems are too expensive for small or less resourced states such as Finland or Sweden and the newer EU Member states. This has clearly been achieved with PRACE, which addressed the growing computational and simulation requirements in the scientific and industrial communities. The HPC infrastructure PRACE allows the most powerful users of simulation technology to gain access to several powerful machines and supported world-class science. The European projects funded in FP7 attempt to unify access to HPC resources by developing a joined application process, storage, transmission services and protocols. Another important component is training, which becomes easier the more similar the systems are. Training is important, as knowledge on how to programme HPC systems needs to increase across the user community. According to some interviewees, there is a need for further harmonisation of the PRACE systems and a closer coordination of their procurement.

Scientific data infrastructures add value to existing research infrastructures as an overarching infrastructure, enhancing and facilitating access to the RI and enabling inter-disciplinary coverage and internationalisation. This implies the need for standard development and enforcement on a global level. Within the S&T thematic areas, e-Infrastructure projects supported research infrastructures in particular in the energy, environment & earth Sciences (EEES) and the life sciences areas, according to the survey respondents with considerable success.

A major impact of the **Virtual Research Communities** (VRCs) projects was in the enhancement of transnational collaboration across Europe. They have contributed to bridging the gaps amongst different sub-disciplines of a research field by providing a common, standardised, interoperable and multidisciplinary infrastructure, which is still capable to address the specific needs of the single disciplines. As a result, they are making possible the establishment of international research workflows. VRCs were funded in all S&T thematic areas.

The coordination & support actions

The complementary role of the coordination and support actions should be noted. These projects were critical in facilitating the development of integrated research infrastructures. Support consisted in providing platforms for strategy development, roadmapping and policy coordination, the development of interoperability frameworks (common data policies and standards, approaches for infrastructures, IPR) and models facilitating cooperation and the establishment of global RIs, virtual observatories such as the European Virtual Observatory in the field of Astronomy, etc, They also included projects developing and deploying computational infrastructures at a regional level or in the context of development aid.

Case 2 The NEUGRID chain of projects (Impacts on RI - LS)

In the FP7 RI programme, four different projects were funded focusing on the development of imaging facilities for the subareas of Biology and Medical Science. The projects were all I3-e-Infrastructure activities, except for OUTGRID, a coordinating action.

NEUGRID started as a direct follow-up of ENIR (European Neuroimage Repository), a small early-stage feasibility project in FP6, funded by DG Research. After NEUGRID, funding was made available for *coordinating internationally* with OUTGRID and in parallel funding was awarded to develop the *platform closer to the clinical community* (DECIDE).

With N4U the funding has been used to *complete the user interface* and develop *more accessible tools*.

In this case, the Coordination and Support action outGRID has helped generate additional buy-in of the research infrastructures developed under the I3- eInfrastructure at an international scale. In addition, it has allowed for the necessary relations to establish interoperability at a global level. In turn, the e-Infrastructures DECIDE and N4U have built upon the coordination and support action by incorporating the partners from outside the EU into the activities for developing the follow-ups of the initial project NEUGRID.

4.2 Impacts on research

The FP7 RI Programme has been particularly successful in enhancing the value of research infrastructure as a tool for Science.

In the sections below we highlight and illustrate the effects reached by the FP7 RI programme on an **improved structuring** of the European research base (Section 4.2.1)

Section 4.2.2 describes the value of the programme for the conduct of scientific research and its effects on the **advancement of knowledge** and **knowledge flow**, within the research as well as educational components of the European knowledge society.

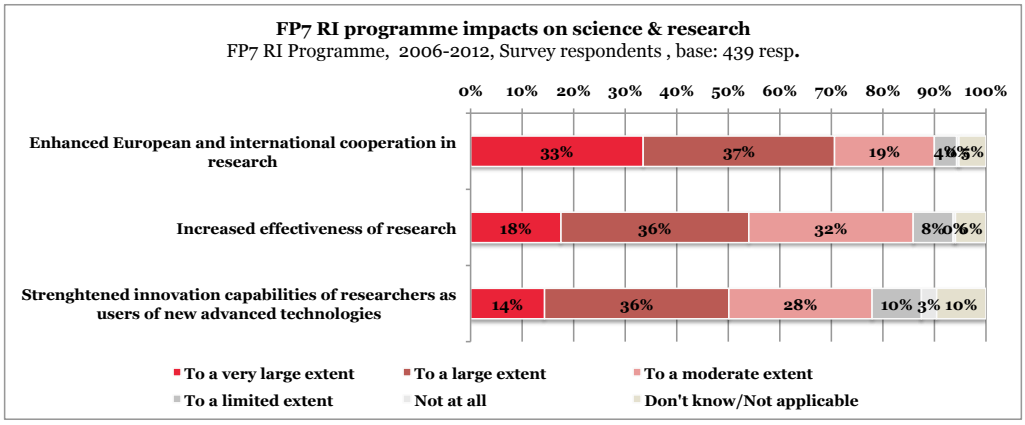
In Section 4.2.3 we highlight the value of the programme activities for the **building of capacity** in the use of advanced research tools and technologies and the development and implementation of new research methods. An important evolution in this context is the **eScience** paradigm shift.

4.2.1 Structuring the European research base

The FP7 RI programme fostered and accelerated an improved structuring of the European research base and considerably enhanced European and international cooperation in research.

Impacts from this perspective were indicated by 70% of the survey respondents and overall confirmed in the case studies and interviews (Exhibit 25).

Exhibit 25 FP7 RI programme impacts on science & research (survey respondents)



Continuity in the focus on the integration of Europe's research infrastructures over the FPs and in particular in FP7 has allowed the RI programme to reach significant structuring effects on numerous research communities (see the example of ETSF, below)

Work in the RI projects helped creating and strengthening research communities in various scientific fields as well as across disciplines, in Europe and beyond. It has led to the shared development of research strategies, investment and cooperation in experimentation, which forced the community to develop scientific priorities, shaping its work. It can even determine the direction of scientific progress.

Case 3 ETSF (Impacts on research - MS&AF)

In the thematic area of MS&AF, the Seventh Framework Programme (FP7) supported one large Research Infrastructure in the field of materials sciences: the project European Theoretical Spectroscopy Facility (ETSF). It received 3.8M€ subsidy for the period 2008-2010. As such, support for ETSF accounted for 7% of FP7 support for Research Infrastructures in the thematic area of MSAF. European Support was provided under the I3 eInfrastructures scheme.

In the context of ETSF (a RI with emphasis on theory), involvement of the main research groups is easier but nonetheless relevant than in the case of involving all relevant (physical) facilities. Interviewees stress that ETSF is unique in Europe and that 68 research groups are involved (November 2013). This includes two groups from the US. From the start of the Nanoquanta research network (2004), at least 10 research groups took the lead, while committing a larger number of groups from Western Europe and Slovakia. ETSF was a truly joint effort. The same picture emerged from analysing project documentation.

As a consequence of training provided to (young) researchers from across Europe, of ETSF networking initiatives (workshops, meetings etc.) and of collaborative research projects, a **European ETSF community** has emerged. This has been important for creating a new generation of researchers, e.g. first taking up positions as visiting researchers at ETSF partners in other countries, later becoming guest lecturers and building the relations and trust that are needed for writing new FP7 proposals together, preparing for Horizon 2020, etc.

4.2.2 The advancement of knowledge and the knowledge flow

Supporting excellence in science

The FP7 RI programme facilitated a more effective use of the research potential that the RI offer and developed infrastructures that could act as a vehicle for multi-disciplinary research. It has set the basis for an accelerated advancement of knowledge.

From the scientific perspective, in some fields large infrastructures are **preconditions** for doing leading-edge research, timely research or even research at all – whether by providing experimental equipment and databases on which to experiment or 'platforms' such as vehicles or computers upon which to mount experiments. Some infrastructures enable experimental work to be done quickly, others support interdisciplinary work or enable large numbers of researchers to operate in a coordinated way. By collaborating together in the development of RI and taking advantage of the transnational access, research groups have been able to obtain significant efficiency gains through scale.

In the physics & astronomy thematic area, the development and use of new cutting-edge RIs is essential to research and the programme is supporting the development of improved capabilities in fundamental science that will, once operational, lead to enhanced scientific performance.

The R&D that was conducted to support the development of the new RI also contributes to Europe's **leading-edge science and technology outputs**. In astronomy, advances have already been made in adaptive optics, novel photonics and robotics, and in particle physics, funded in part by I3 projects,. I3 projects are supporting R&D in, for example, highly sensitive detectors, vertically integrated electronics and micro-machining. In some cases the small companies that form the RI supply chain are already working with their counterparts in the research community.

Communication networks, computing, and data infrastructures are important underpinning services for researchers in all scientific domains. Developments in ICT mean that high-performance computers and communications networks can act as infrastructures in their own right; they also have increasing uses in linking other physical infrastructures together not only for exchange of data but sometimes also to conduct larger-scale experiments, for example connecting radio telescopes together to create a larger, virtual telescope. All these technologies, including visualisation technologies, have an increasingly important role as **enablers for research**, forming the backbone for all phases of the scientific process and facilitating interdisciplinary

research and research cooperation in general. In many cases, researchers have seamless access to the resources required for their research and are not even aware of the communication and computing technologies through which the resource provisioning is managed. The benefit of the incremental updates that have been made to the RI will filter down to all of its user community.

An example of such project is the SCIence Data Infrastructure for Preservation – Earth Science (SCIDIP-ES) project, contributing to the set-up of a European Framework for the long term preservation of Earth Science (ES) data through the definition of common preservation policies, the harmonization of metadata and semantics and the deployment of the generic infrastructure services in the ES domain. Another example are the infrastructures in the field of environmental sciences, deployed for atmospheric or earth observations, that make use of satellites, sensors or radars, the technologies for which were optimised in projects funded in the context of other thematic areas.

The case of SERIES, below, illustrates the contribution of the FP7 RI programme to an improved use of the RI base in Europe by the seismic engineering community.

Case 4 SERIES (Enhancing scientific performance - EEES)

Seismic Engineering Research Infrastructures For European Synergies – SERIES is an I3 - Integrating activities project. The scope of the project covers integration of infrastructures needed in all aspects of seismic engineering testing, from eight Reaction Wall Pseudodynamic (PsD) facilities and ten Shake Table labs, to EU's unique Tester of Bearings or Isolators, its two major Centrifuges and an instrumented Site for wave propagation studies. In addition, it fosters co-operation of the largest earthquake engineering labs in Europe and of close to all the active research groups in European earthquake engineering.

Despite large investments over the past decades, European seismic engineering research suffers from extreme fragmentation, inefficiency and sub-optimal use of RI between countries. In addition, there has historically been a lack of access to these infrastructures by the scientific and technological community of earthquake engineering, especially that of Europe's most seismic regions.

A curious paradox is found in this field: the need for these research infrastructures, as well as the expertise and interest of researchers in the field is mostly in South and Eastern Europe, where there are very few seismic research infrastructures. By contrast, the largest infrastructures are currently concentrated in the UK, France and Northern of Italy, where there is little seismic activity. Currently, none of Europe's research infrastructures has the critical mass of people and the broad range of experimental capability or expertise needed for major breakthroughs in the state-of-the-art in this field.

The coordination at European level has allowed to balance and leverage on the strengths of each participant country. The activities in the SERIES project help up-and-coming new research infrastructures, especially in highly seismic but less technologically advanced areas, emerge in the medium to long term as earthquake engineering RI of pan-European interest. The project has successfully integrated most of the entire European research community in earthquake engineering.

The impacts of the SERIES project on science and research have been achieved thanks to the integration in a short term of the European Research Area in earthquake engineering and to the optimisation in the use and development of the best European research infrastructures in the field.

Transnational access to the benefit of small and newer EU Member States

Data on the use of the EC-supported RI show that in particular researchers located in the small and newer EU Member States drew benefit from the opportunity offered for transnational access by the I3 Integrating activities schemes.

In the I3 - Integrating activities scheme data on 'external' RI users are collected on an annual basis by the RI supported as part of their annual reporting. The aggregated database of these data allowed us to identify a total of *8,239 unique users from 55 countries*, accounting for a total of 11,252 visits to the RI. These included repeated

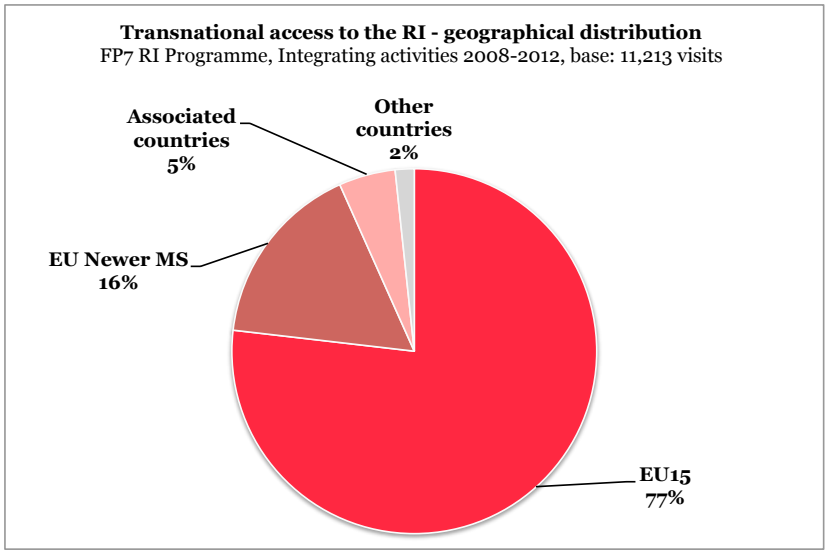
visits to the same RI and visits to different RI. It should be considered that the RI users database of which we disposed entailed information from only 47 out of the 74 RI Integrating Activities projects, i.e. those launched between 2007 and 2011, and covered data from 2008 to 2012.

The thematic area materials sciences & analytical facilities was responsible for the largest number of unique users (~2500), followed by the energy, earth & environmental services and physics & astronomy ones (~1700 each), and the life sciences TA (~1200). In the M&A thematic area, and specifically the field of laser research, it positively affected the quality of the research in countries where cutting-edge instrumentation for material science and large-scale analytical facilities are scarcely or not at all available.

Users of the research infrastructures were coming close to exclusively from the public research sector, i.e. universities and research institutes. Private research organisations and SMEs accounted only for approximately 1% of the access.

Exhibit 26, below, presents the geographical distribution of the users in terms of their total number of visits. Close to 80% of the visits were made by users based in the EU15, ~15% by users from the newer EU member states.

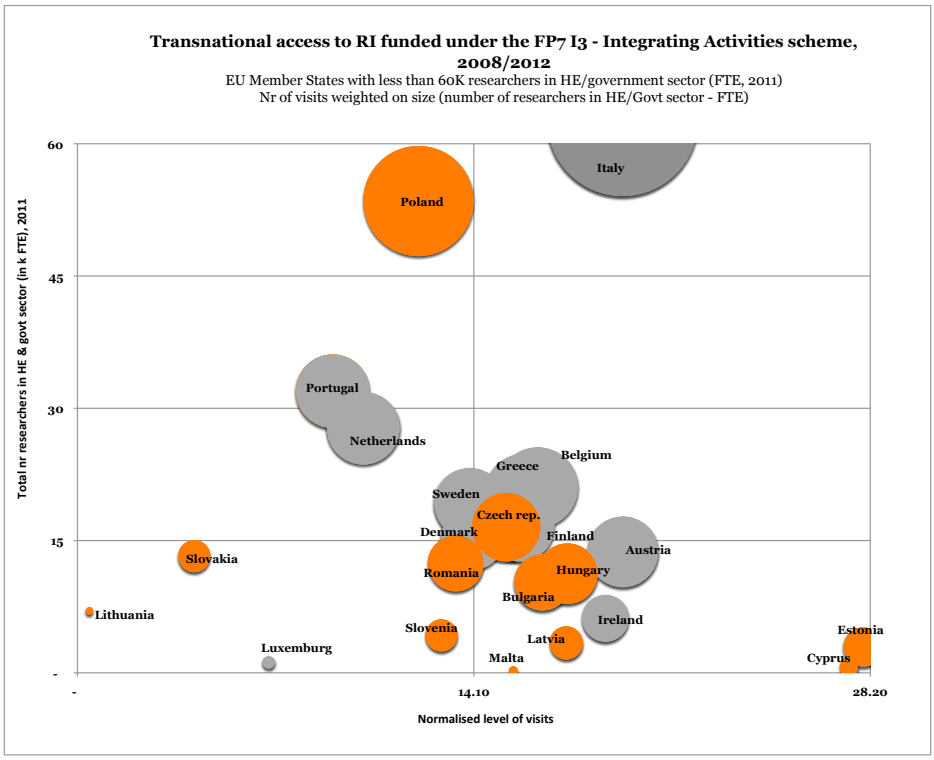
Exhibit 26 Geographical distribution of the RI users (nr of visits) (RI users database)



In absolute numbers, researchers located in Germany, Italy, the UK and Spain accounted for the highest shares in visits among the EU member states (resp. 16%, 11%, 9% and 8%). However, if we normalise the figures with the size of the countries (in terms of total number of researchers in HE and the public sector), it appears that countries that benefit most from the EC support for transnational access to RI are the **smaller EU15 Member States** such as Austria, Ireland, Belgium, Finland and Greece, and **newer Member States** such as Hungary, Latvia, Bulgaria and the Czech Republic.

Participants from newer EU Member States stress that collaboration due to transnational access has been very beneficial for them. Participation in I3 projects has helped them raising the bar and contributed to increasing catch-up in terms of research capacity and quality. In addition, Transnational Access activities have given a broader perspective to scientists with fewer opportunities to travel and have helped building networks between established and newer research groups. There is a general consensus that collaboration between newer and old Member States in the programme is essential and has been beneficial for everyone.

Exhibit 27 Transnational access to RI – geographical distribution based on normalised data (RI users database)



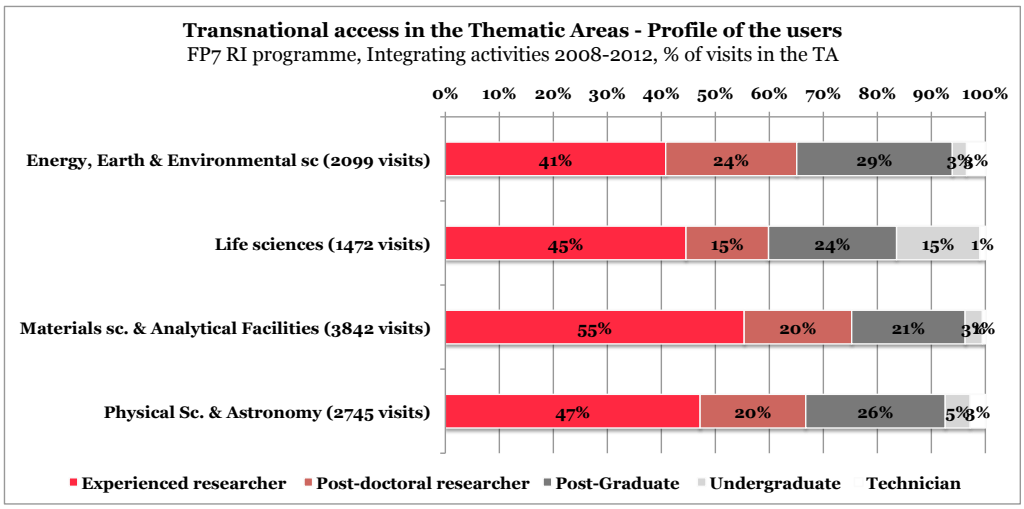
Notes: Size of bubbles = total nr visits; countries with more than 60K researchers (France, Germany, UK and Spain) all scored below average in terms of normalised visits (i.e. less than 14)

Spill-over effects

The FP7 RI programme has also set the basis for a range of knowledge spill-over effects, to the **educational sector** as well as the broader **research communities**.

Data on the users of the supported RI indicate also that young researchers (PhDs and post-doctoral researchers) accounted for 44% of the visits to RIs, and in the energy, earth and environmental sciences even for more than 50%.

Exhibit 28 Transnational access – profile of the users (RI user database)



Spillover effects in the **research sector** occur through strategic partnerships and co-operation networks, mobility of knowledgeable individuals, and by transferring knowledge through publications.

The extent to which spillovers were realised through the use of the RI can only be guessed at this point in time because of the short time lapse between the end of the projects and this evaluation exercise. However, the results of the bibliometric analysis on publications by participants show that there is a **high potential for knowledge spill-over** to occur to the other research communities. Programme participants as well as external users publish their papers in above average quality journals, i.e. journals with high citation rates. In the scientific world, high citation is equivalent to high scientific impact. RI programme participants also published in high quality journals within the various fields and have a high share of co-publications, which is a factor influencing their higher-than-average citation impacts.

We conducted bibliometric analysis on a sample of 300 publications by e-Infrastructure participants (during project time, as registered in the OpenAire database) and on a sample of 200 publications by 'external users' of the integrated RI, as indicated in the Integrating activities users database. These publications are directly attributable to the FP7 RI programme and in the case of the external users, to the

The bibliometric data for the 'external' users of the RI show that, if we compare the normalised citation impact of the papers for the four main fields, the RI 'external' users published in journals far above the field average (Exhibit 29). There are marked differences in terms of range of outreach, though. In four fields (SSH, Health sciences, Energy and Environmental sciences), the choice of publication means is more limited than in the other fields, suggesting a more reduced potential spill-over effect.

Exhibit 29 Citation impact of RI users versus field averages based on SNIP 2011 (bibliometrics)

Scopus fields	Field average	RI users	Numbers of journals
Health sciences (main field level)	0.637	1.148	5
Social Sciences (main field level)	0.702	5.468	2
Life sciences (main field level)	0.759	1.059	35
Physical sciences (main field level)	0.776	1.193	87
• **Material sciences**	0.741	1.368	22
• **Energy**	0.609	1.780	2
• **Earth & Planetary sciences**	0.715	1.145	10
• **Environmental sciences**	0.741	1.382	2
• **Physics and astronomy**	0.782	1.153	56
• **Engineering**	0.705	1.359	12

Source: Technopolis. Data: Scopus

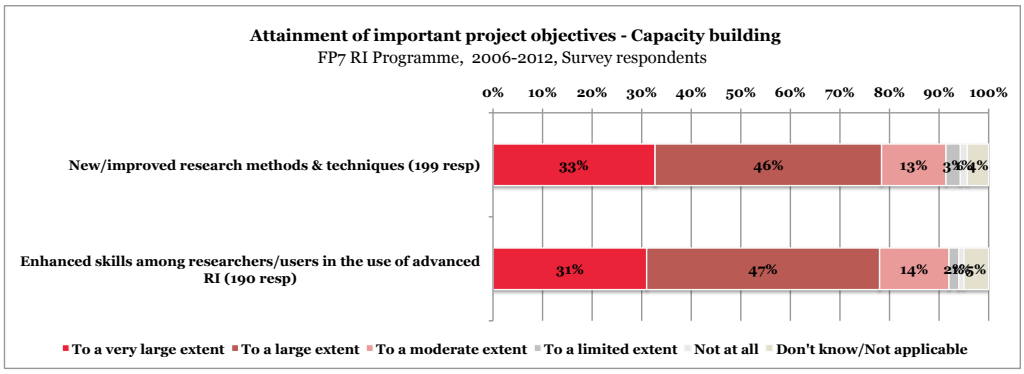
For the e-infrastructures participants we also notice high co-publication patterns. Two-third of the publications (199) are international co-publications, i.e., involving authors from at least two countries.

In terms of potential reach and intensity, the work by programme participants gets published in above average quality journals, a fact that is defined by high citation rates. In the scientific world, high citation is equivalent to high scientific impact.

4.2.3 New research methods and capacity building

Capacity building in the use of advanced research tools and technologies contributes to the deployment of state-of-the-art research processes and ultimately, an enhancement of the **efficiency** of research. The majority of the survey respondents stated positive results against these topics (80% - see Exhibit 30).

Exhibit 30 Attainment of important project objectives – impacts on capacity building (survey respondents)



The Programme also facilitated the development and use of new and improved research methods and technologies. An important evolution in this context is the **eScience** paradigm shift, which constitutes a significant change in the research process.

Capacity building & critical mass

Through the inclusion of a training component in the I3 Integration Activities schemes, the FP7 RI programme has facilitated and fostered important capacity building in the use of advanced technologies and tools.

In some cases such as laser science, the programme contributed to the diffusion of technology also to other application areas (see the case on LLE, below).

Examples of projects in the sphere of life sciences are EATRIS, which organised training on GMP and TRANSVAC, which offered workshops on the use of animal models and vaccine development. BioMedBridges also offered a training package (i.e. ontology in terms of data sharing; high-throughput screening for pharmacological research; data security; programming with JAVA; data uses of databases of individual RIs).

Most of the I3 integrating activities aimed at increasing the efficiency of research by improving S&T capabilities and were successful in doing so. This was addressed in WPs directed at, for example, developing new tools (molecular monitoring tools: NADIR), improving animal models (TRANSVAC; NADIR), improving the use of assays, reagents (TRANSVAC). These trainings also serve as a useful tool for building collaborations as these trainings encourage personal interactions.

Examples of considerable efforts in other thematic areas are PRACE and LASERLAB EUROPE.

Case 5 PRACE (Capacity building - Horizontal e-infrastructure services)

Training is important, as knowledge on how to programme HPC systems needs to increase across the user community While the investment in the hardware and maintenance costs are paid for by the providing HPC centres the focus of the FP7 projects in that area was on establishing a user and provider community, operation software, grid connection and most importantly training and education. In essence the FP7 projects lower the boarder of accessing HPC resources.

PRACE created 6 training centres with 3000 participants up to know; 112 events with PhD students and researchers have taken place; 5 industrial seminars (1 per year) with 400 participants; it achieved that 600 people are working together in the HPC community; it issued 139 white papers on how to use and optimise programming the HPC infrastructure. A preparatory access programme of 2-6 month access is part of the training. It allows researcher to scale applications and test them. A single peer review system created allow European researcher to get access with one application.

Case 6 LASERLAB EUROPE – LLE (Capacity building - MS&AF)

LASERLAB EUROPE (LLE) is a consortium with one of the main distributed laser facilities in Europe. Today, the chain of LLE projects that have been funded by the EC has grown into a partnership of 30 leading laser research groups from 16 different European countries. LLE also is directly linked to the new pan-European projects HiPER (mainly Fusion and Laboratory Astrophysics) and ELI (mainly Secondary Sources and Harmonics).

When looking at the figures, it can be concluded that LLE has been very successful in educating the laser user community in Europe. From 2004 to mid-2012, access to LLE facilities has been granted to over 1,000 scientists (mid 2013 this figure was raised to about 1,200) from institutions outside LLE to perform 575 research projects. The LLE users come from all over Europe. Even though still almost 56% are from laboratories located in just 4 countries (France, Germany, Great Britain, and Italy) the LLE policy towards integration of its new partners in Southwest and Eastern Europe shows an increase in the proportion of users based in these countries from 14% (2004-2008) to 16.5% (2009-2012).

One of the main effects is also that when the LLE consortium increased - in LLI participants from nine European Member States and in II and II already from 16 - this included also research groups from East-European countries that were not strong yet in laser researcher. However they have developed very fast and now even some of these countries participate in the ELI project.

Facilitating the conduct of e-Science

The 2009 international panel for the review of the UK e-Science Programme defined e-Science as "research done through distributed global collaborations enabled by the Internet, using very large data collections, terascale computing resources and high performance visualisation."[12]

The panel considered that e-Science includes

- Systems - shared software with interfaces and a variety of extensions features
- Organisational structures - formal and informal groups that provide very important e-Science services
- Human capital - build-up of knowledge and experience that makes it much easier to adapt and adopt technologies, and
- Data and information resources - systems that support the increasingly data-intensive nature of research)

In the European RI system, eScience research consists of the backbone GÉANT network; distributed storage & computing infrastructure - European Grid Initiative (EGI); and the PRACE initiative providing tier-0 High Performance Computing (HPC) infrastructure.

Several projects in the e-Infrastructure scheme are taking this approach, resulting in an improvement of the effectiveness and efficiency of doing research. Activities that a few years ago would involve a large group of researchers, can now, or in the near future, be done with a small team or even with a single researcher using computers and working with specialised databases. For example, the project transPLANT plays a role in making that possible for the plant science community. Also, the project chain on NMR has shown that providing a large number of dedicated, state-of-the-art instruments adapted to different applications in a grid of research infrastructures is the technologically most advanced and at the same time the most cost-effective way of access provision.

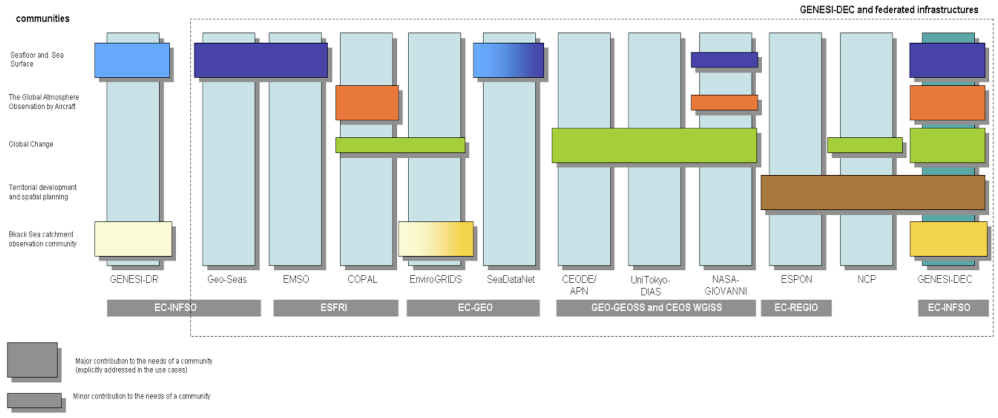
[12] RCUK Review of e-Science 2009 – Building a UK foundation for the transformative enhancement of research and innovation, Report of the International Panel for the 2009 Review of the UK Research Councils e-Science Programme, 2009

The case of GENESI-DEC, below, illustrates the development of e-Science facilities for the Earth Science community

Case 7 GENESI-DEC (Impact on research – EEES)

During the last two decades, the Earth Science community has received a large boost from the progress made in the remote sensing domain, which has been afforded by in part by space and other technologies for mass data collection. At present time, a large number of Earth observation missions and large-scale data acquisition initiatives are in place. While usually these activities enjoy from very good cooperation amongst the facilities undertaking them they do not take advantage of the present ICT infrastructure capabilities that have been set up at a European level. In addition, all specialised environmental and territorial data such as seismology data, marine data, seafloor data, geo-economics data, are scattered among several digital repositories, as shown in the diagram below.

Framework Programme 7 (2007-2013) Research infrastructures projects



The GENESI projects, with special emphasis on the GENESI-DEC project, provided a platform for federation of these digital repositories and a virtual community for scientists to use the data in them and engage in collaborative research workflows. These developments contribute to an optimised use and development of the data sources currently in Europe, in addition to generating critical mass.

GENESI-DEC was coordinated by ESA and participated by the JRC. In addition, five participants from the private sector were present (two SMEs and three large companies). GENESI-DEC aggregates the community of GENESI-DR and others through a federated environment of digital repositories and also contains the aspect of stimulating, educating and supporting the creation of a virtual research community.

4.3 Impacts on the internationalisation of RI and research

In this section we look into the contributions of the FP7 RI programme for the enhancement of international cooperation and collaboration and highlight the role and value of the different support schemes in this context (Section 4.3.1). Section 4.3.2 reports on the importance of a major effect of RI internationalisation – as well as enabling factor and driver, i.e. the creation of global standards and harmonisation. In Section 4.3.3 we illustrate the efforts made and its benefits and value in relation to specific scientific areas and geographical regions.

The FP7 RI Programme has considerably contributed to opening up pan-European large research infrastructures on a global scale These span over all thematic areas and include especially the Virtual Research Communities.. The programme has therefore provided a positive response to one of the major market failures that were identified at the launch of FP7, i.e. the lack of international cooperation in the European RI landscape.

The mechanisms of cooperation range from bilateral or multilateral international agreements (e.g. the Eastern Europe Partnership – EAP), international participation in project, international connectivity projects and peering of major computing infrastructures such as EGI and DEISA, to Joint Calls for proposals and contributions to international standards.

In the preceding chapters we have provided several examples of the value and benefits deriving from these internationalisation efforts. Participants indicate that the programme activities have allowed to

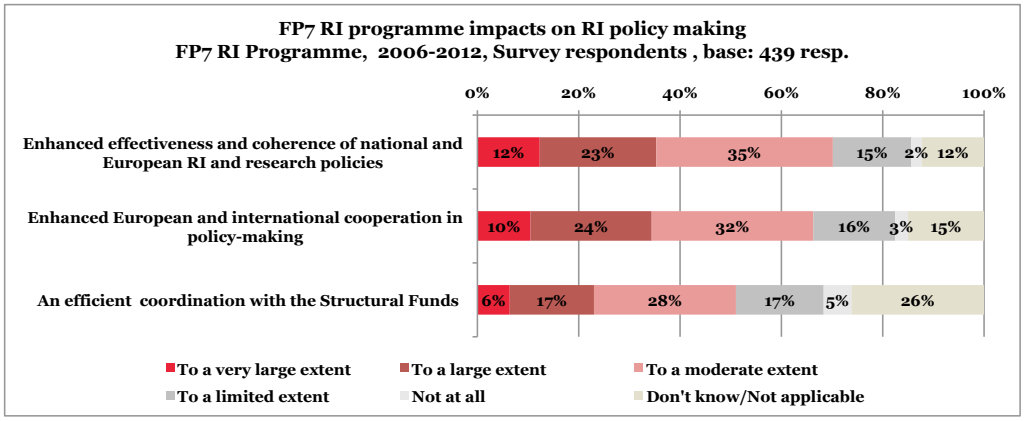
- Improve global interoperability and increase awareness around it (harmonisation in metadata, data formats and semantics)
- Contribute towards the development of a global research community
- Acquire skills in design and organisation to establish and promote global research infrastructures
- Increase interconnection of ESFRI listed infrastructures with each other and global initiatives

4.3.1 The international co-operation activities

The FP7 RI programme has made considerable efforts to facilitate and enhance the international collaboration of European RI. This was an achievement especially of the coordination and support actions and the I3-eInfrastructure schemes.

In the opinion of the survey respondents, the FP7 RI programme made a moderate contribution to the enhancement of cooperation in policy making at European and international level. Only ~35% of the survey respondents considered such a programme outcome (Exhibit 36). However, participants in the coordination & support actions scheme had a significantly more positive view: ~50% of respondents agreed to a (very) large extent that the programme had reached effects in this field.

Exhibit 31 FP7 RI programme impacts on RI policy making (survey responses)



More than **one third of the 313 projects** (38%) included participation from an organisation that was not located in a EU Member State or EFTA country. Non-European countries were involved especially in the I3-eInfrastructures scheme (35% of participations in that scheme) and the Coordination/Support actions (26%).

Participation in the I3-eInfrastructures scheme was high for organisations located in South-America, while the Coordination/Support Actions involved in particular the **BRICSAM countries** (Brazil, Russia, India, China, South Africa and Mexico). The latter were the most frequent non-European participants also in the I3-Integrating Activities scheme and in the preparatory activities for the construction of new RI. Overall, they accounted for 0.4% of EC funding. Other world regions such as South America, the rest of Africa, North America, the Middle East, Asia and Oceania had a combined share of 0.6%.

Ten per cent of the projects funded had an **explicit** focus on fostering international cooperation. These projects were funded especially in the Horizontal e-infrastructure services thematic area and in the Policy development and coordination one (Exhibit 32).

Exhibit 32 Number of projects with explicit geographical focus (portfolio analysis)

	EU-Africa	EU-Latin America	EU-Asia (China, India)	EU-US	Bordering regions (Baltics, Caucasus, CESE, EU-MED, SEE)	EU	Total projects
Energy, Earth & Environmental sc				3%	1%	96%	70
Life sciences						100%	49
Materials sc. & Analytical Facilities						100%	28
Social sc & Humanities					9%	91%	22
Physical Sc. & Astronomy		3%				97%	38
Horizontal e-Infrastructure Services	2%	5%	5%		10%	79%	84
Policy development & coordination	14%				5%	82%	22
Grand Total	2%	2%	1%	1%	4%	91%	313

With regard to **sustainability** of these activities, participants stress that there is a need for a more coordinated investment in inter-continental links. They pointed out that some of these funding initiatives currently overlap or leave gaps where funding is not available. They also stressed that governance at the national level for these projects causes national interests to dominate, which can harm intercontinental activities. This is an issue that is shared by many EC-supported RI. We cover it more in detail in Chapter 4.8, below.

The projects funded in the different support schemes showed different focus areas for their activities:

- Some of the projects funded by the EC have focused on organising and delivering a continuous improvement to the underlying basic infrastructure in the other regions in terms of **communication networks**. The essential backbone of the research and education network in the EU, GEANT, has extensive links to other world regions such as North and Latin America, the Balkans, the Mediterranean, Black Sea, South Africa, Central and Eastern Asia.
- The activities in the **computational infrastructures** sub-scheme were fundamental for the empowerment of integrated research infrastructures and the construction of extended grid infrastructures and international collaboration. The current European Grid Initiative (EGI) consolidates ten years of research and development that was achieved by the EGEE series of European projects. It includes a network of 340 Compute and Storage Resource Centres across the globe to which it arranges general access and sharing of services.
- There were also several projects involving several world regions with the specific focus to train and build a user community of Grid computing and establish a **production quality GRID infrastructure**. Efforts in this direction have been made to the benefit of many neighboring regions to Europe as well as in Latin America, China, India, and Africa.

  The sustainability of the international GRID production projects is unclear. On the one hand the projects were successful in establishing a trained user community and production state infrastructure. On the other hand the maintenance now belongs to the international partners. The GISELA business plan, for example, proposed to give the management to RedCLARA, the Latin American Cooperation of Advanced Networks. Whether the infrastructure is still in place was unclear at the time of the interviews.
- **Coordination and support actions** have played a critical role in facilitating the development of international collaborations; they have enhanced the ability for European researchers and policy-makers to speak with a single voice in international discussions and negotiations.

4.3.2 Harmonisation and standardisation at the global level

Investments in research infrastructure and their internationalisation need to be set in the context of the intensification of international cooperation in science and research. Research groups all over the world are increasingly working in a network context and are internationally mobile. As a consequence, research infrastructures are increasingly networked – and expected to be networked – at a global level. This implies that standards need to be developed and enforced on a global level.

The RDA-Europe project responded to this need in its role as a founding member of the international Research Data Alliance. It succeeded in positioning Europe as a significant partner in the growing consciousness that data sharing is a global issue and that global, networked, distributed solutions must be imagined. It ensured that Europe would be considered as a serious partner by the US, thus allowing Europe to influence the general process of coordination and protocol-setting that will gradually emerge in the coming decade or more. Being in this position is a strong asset for the EU, but also an obligation that is backed by high quality research.

It is useful to set these standardisation efforts in the context of **innovation**. A core instrument of industrial policy is to promote international *standards*, and also through active international RI cooperation to build on the EU's role as a de facto standard setter and to take a leading role in reinforcing the international standardisation system. Standards can play a strong role in integrating European firms more firmly into global value chains, and is well-designed European standards will accelerate the diffusion of industrial innovations. Or as an industrial leader recently stated: "If global industrial standards are to continue to come from Europe, we need to think on a larger scale and cooperate on a European level. It is only then that we can achieve the critical mass with which we not only serve markets but can define them as well." He pointed out that this had, for instance, worked in the past with the mobile radio standard GSM[13]. It is to be expected that in times of Big Data, Big Science and global RTD infrastructure cooperation such standard setting will significantly increase in importance, and that it could lead to considerable economic spillover benefits.

The EarthServer/rasdaman case is a good example to illustrate how RIs can contribute and get involved in such global standardisation activities leading to significant spillovers for industry.

Case 8 EarthServer/rasdaman (Knowledge and technology transfer for innovation – EEES)

The core technical idea of the case is to use database query languages as client/server interface to achieve barrier-free mix & match access to multi-source, any-size, multi-dimensional spatio-temporal data -- in short: "Big Earth Data Analytics" -- based on the open standards of OGC. EarthServer/rasdaman very actively participates in this Open Geospatial Consortium (OGC), an international industry consortium of presently 471 companies, government agencies and universities participating in a consensus process to develop publicly available interface standards. OGC Standards support interoperable solutions that "geo-enable" the Web, wireless and location-based services and mainstream IT. The standards empower technology developers, consultancy companies and data users to make complex spatial information and services accessible and useful with all kinds of scientific as well as commercial applications.

OGC standards are developed in a unique consensus process supported by the OGC's industry, government and academic members to enable geoprocessing technologies to interoperate, or "plug and play". It should be obvious that participation in such global endeavours will be mandatory in future to sustain the excellence and competitive position of European RI actors and the industry which will strongly benefit from it – which may even simply have to involve itself to not lose competitive advantage.

4.3.3 The scientific and geographical focus of the supported global RI networks

It is clear that the need and importance of global cooperation between RI is **scientific discipline dependant**.

Exhibit 32, above, shows that projects with an explicit global cooperation focus were funded in particular in the energy, earth & environmental sciences, physical sciences & astronomy, and the horizontal e-infrastructure services thematic areas.

In thematic areas such as Physics and Astronomy, collaboration at the EU level provides the platform to engage in a structured manner with international organisations such as ESO, NASA and ESA. These partnerships are needed, for example, to interface with telescopes worldwide, which are increasingly located in more remote locations such as the Atacama Desert in Chile, Hawaii, Australia and the Canary Islands and in the Southern hemisphere.

In climate application of Grids computing there are some good examples where the Grid projects fostered international climate research. Science Grids have emerged to

[13] Infineon CEO Ploss Calls for Active Industrial Policy – "Only Pan-European Cooperation Can Ensure Implementation of Global Industrial Standards". Infineon Press Release, February 13, 2014

respond to the requirements of the most demanding scientific disciplines (e.g. high-energy physics, bioinformatics) to share and combine the power of computers and sophisticated, often unique scientific instruments. With support from the EU's Framework Programmes, Europe now hosts the largest multi-science grids.

In order for RI partnerships between European and other world regions to be successful and achieve sustainability, they should focus on providing **clear mutual added value and benefit** for all the parties involved.

- For the European research community, RIs in other world regions have the potential to deliver top-level research opportunities and services attracting a widely diversified international community of scientific users. In addition, these RI can also contribute to addressing global challenges that have a large potential impact in participating regions.
- For other world regions, these RI partnerships are especially interesting as a way to procure some of the essential tools for the growth of their research and innovation systems and as a way to leapfrog to the developments carried out around the world in various research areas.

Hosting European RIs in other world areas can be essential when the hosting country has a comparative advantage in terms of location or geographical characteristics, knowledge or biodiversity.

- Geographical comparative advantages happen when there is research that can only be carried out in a specific geographical location. This concerns mainly the topics of: space science (e.g. astronomy, space geodesy, satellite observation, magnetism and radiation); oceans, islands and coastlines; earth sciences (e.g. geographic data, and marine geology), palaeosciences; human genetic diversity, health, longitudinal studies and anthropological studies.
- Knowledge comparative advantages deal with knowledge that is specific to the environment and differs from the established Western views. It relates mainly to disciplines dealing with the natural resource base, health, social sciences and humanities etc., also including indigenous knowledge in a variety of contexts.
- Finally, biodiversity comparative advantages include marine and terrestrial biodiversity as well as existing observation and research sites and networks, biobanks, natural history collections, datasets, etc. Some research dealing with unique specimens, ecological balances and biodiversity spheres are also a function of the geographic position. RIs specialised for such studies are best hosted on location so as to offer a platform for European and local researchers to interact.

The scientific needs will therefore not only influence the development of a global RI network as such, but also the geographical focus of such collaboration.

One should make a distinction between collaboration with RI and policy makers in developed and emerging economies. Different mechanisms, needs and priorities apply.

Cooperation and collaboration between the EU and other developed economies

Participants point out that the coordination and support actions funded in the FP7 RI programme have had the effect of reinforcing cooperation with countries such as the United States, Japan, Australia and Canada. These projects have also helped maintaining the competitive position of Europe in the wake of increasing investment for RIs in other world regions.

European collaboration is generally seen abroad as a prerequisite for establishing relations on equal footing with other areas, based on the combined scale of RI at European level. In addition, Framework Programme support is seen as a 'seal of approval', both indicating quality of research as well as political support, making international cooperation easier (e.g. DRIHM2US). Although this is a positive outcome of the programme, it also bears potential risks. Should a particular RI not

manage or not need to renew FP funding, this could be interpreted abroad as withdraw of support from the EC, which wouldn't necessarily be the case.

Some interviewees indicated a need for more exchange with high technology regions like Japan, the USA, Canada, Australia and New Zealand. Such increase in cooperation should be set within the context of the efforts supported by the European Commission for the internationalisation of research in general. Synergy between RI network development activities and scientific needs is key for the programme efficiency and effectiveness, and the sustainability of its effects.

Cooperation and collaboration with emerging economies and other world regions

It is worth discussing the pertinence and impact of activities that focus specifically on international collaboration and cooperation with other world regions such as Africa, Latin America, India and East Asia. International collaboration is needed to promote both European policy goals as well as European technologies worldwide. In addition to digital inclusion, globalisation of research requires establishing links to all continents. It also contributes effectively to stability, security, and prosperity in the world, and is closely aligned to achieving development goals and to addressing global economic and societal challenges.

International cooperation in some of these areas, however, is hampered by capacity shortages, caused by the absence of infrastructure and lack of organisation or leadership regarding a strategic vision for S&T collaboration. This suggests that building capacity in these areas through RIs is a priority for Europe. The activities in the programme have contributed to making these areas new research partners by developing communication services and analysing the feasibility of direct links.

In the area of communication networks a chain of projects established the connection to research facilities between Europe and **Latin America**. The EU-Aid project enabled the creation of a basic connection so that a Latin American research network could be established. During FP7 two projects invested in communication services and the feasibility of a direct link. Through the funding Latin America has become a partner on eyesight. The commodity Internet could have connected the rest of the world but high bandwidth and advanced services could not be implemented in a cost effective manner.

Communication networks connect researchers in **both directions**: Latin American researchers can participate in EU projects without the need to be continuously physically present all the time. They can, for example, participate in the CERN particle physics experiments that make use of both European and Latin American GRID facilities. A huge community of young researchers have profited from these investments. The exchanges and common work strengthens the ties between European countries and Latin America. An example of this is European researchers making use of the optical astronomy facilities in Chile. Sharing facilities, ideas and human capital is widening the resource base and adding diversity. Both are critical factors in the race for talents and scientific success.

Cooperation with Africa in the field of science, technology and innovation has strengthened in recent years. Yet this research is still often funded out of development cooperation budgets, in which case the final word rests with external donors. Hence the growing interest in Africa for research activities that are financed in line with Africa's own strategies and priorities. The European Union's ERAfrica (European Research Area Network for Africa - Developing African-European joint collaboration for Science and Technology) project is a response to this concern. It facilitates the networking of European and African research donors and encourages joint calls for proposals to promote long-term cooperation between EU Member States and /or associated countries and African countries.

We can take a closer look at the activities regarding EU-Africa and EU-Latin America cooperation as examples of an area where the support of the programme has enabled a rapid evolution of research infrastructures.

Case 9 EU-Africa co-operation in RI (Int'l collaboration)

When the programme started, pricing was the main barrier for implementing sufficient bandwidth in African countries in order to make the sharing of research information a reality. During the last five years, thanks to the work of DANTE and the different African NREN associations such as the Ubuntunet Alliance, there has been a drastic reduction in costs from around 4,000$/Mb per month in 2007 to 150 $/Mb in 2013 in most South and East African countries. Through projects such as AfricaConnect, the EU has also contributed to develop the regional interconnections between countries. AfricaConnect builds on the roadmap prepared by the FEAST study and at present time most of the internal connections between different countries have been established. In terms of sustainability, the cost of intercontinental links is shared on a 80-20% basis between the EU and Africa. However, participants point out that while the specific NREN are sustainable, a lack of support would slow down development considerably.

As a result of the rapid improvement of the African network, the projects in the FP7 RI programme have focused on the next stage of RI development, mainly in engaging the research community to start using RI and e-Infrastructures for their work. The foresight project ERINA4AFRICA (a follow up of the ERINA and FEAST projects) focused on the identification of potential for e-Infrastructures in Africa in the e-Health, e-Government and e-Learning domains. In addition, the EIAFRICA project focused on supporting the emergence of the e-Infrastructures community in Africa and promoting its access to European e-Infrastructures. Now that the basic network infrastructure is in place, the focus has shifted in identifying potential e-Infrastructure pilots, with some examples under way in biology, drug discovery, climate monitoring, etc.). Other essential things going forward are to engage the research communities around these application areas and help NREN associations such as UbuntuNet and WACREN to develop the capacities locally so that these initiatives can grow and become sustainable by themselves.

Outside of the domain of e-Infrastructures, the PAERIP project promoted RI partnerships between the EU and Africa more generally, investigating their success factors and potential impacts. The expectation is that future projects will focus on the development of e-Infrastructures, cloud and grid services in particular scientific domains, which will start to become commonplace in African science, especially amongst the younger generation of researchers.

Participants point out that there are also specific initiatives in the field in Africa funded by the US (building ICT capacity and training) and UNESCO (generating awareness of the benefits of grids and cloud computing). However, the support from the EC through the Framework Programme is regarded as the most important, as well as the most structured and systematic.

At present time, European and US companies have carried out the entire infrastructure developments in Africa. However, at the current stage of development participants also expect to start engaging African industry during the next five years.

Case 10 EU-LATAM co-operation in RI (Int'l collaboration)

In the area of communication networks a chain of projects established the connection to research facilities between Europe and Latin America. The EU-Aid project enabled the creation of a basic connection so that a Latin American research network could be established. During FP7 two projects invested in communication services and the feasibility of a direct link.

The EELA e-Infrastructure is a high capacity, production-quality, scalable Grid Facility providing round-the-clock, worldwide access to distributed computing, storage and network resources for a wide spectrum of applications from European and Latin American scientific communities. The follow up EELA-2 project (E-Science Grid Facility for Europe and Latin America) started in 2008 and concluded in 2010. It was funded with €2.1m and aimed to provide an empowered Grid Facility with versatile services fulfilling application requirements and ensure the long-term sustainability of the e-Infrastructure beyond the term of the project.

Finally, the EU-Latin America cooperation GISELA project (Grid initiatives for e-science virtual communities in Europe and Latin America) aimed to ensure the long-term sustainability of the European – Latin American e-Infrastructure and thus the continuity and enhancement of the Virtual Research Communities (VRC) using it. It started in 2010 and concluded in 2012. It was funded with €850k.

Through the funding Latin America has become a regular research partner of Europe. High bandwidth and advanced services could not be implemented at a cost effective manner using

commodity Internet solutions. Now dedicated research communication networks connect researchers in both directions. Latin American researchers can participate in EU projects without the need of being present all the time. They can, for example, participate in the CERN particle physics experiments that make use of both European and Latin American GRID facilities. The exchange and common work strengthens the ties between European countries and Latin America. There is an inherent link between a low latency connection and video conferencing requiring these and the acceptance of services by researchers. European researchers can thus make use of the radio astronomy facilities in Chile. A direct link between the EU and Latin America is likely to lower the costs for both research and economy due to more competition.

4.4 Impacts on industrial innovation

Research infrastructures may have important benefits to offer that go beyond their primary fundamental science mission. One of the most immediate benefits of research is the generation of **new knowledge**. The practical application of that knowledge in different environments is what is known as innovation, which then is likely to manifest in further social and economic benefits.

The FP7 RI programme was expected to contribute to the creation of industrial innovation from this perspective.

Effects of the programme in this sphere are limited, or however lower than expected. However, there are a lot of potentially 'hidden' effects. In fact, there are a variety of channels and mechanisms through which academic knowledge can be transformed into productive knowledge—ranging from direct use of knowledge inputs, to instruments, tools, techniques and background knowledge, to highly qualified human resources. Several of these channels take time to emerge and become measurable. They were therefore **beyond the reach** of this study. In fact, this evaluation was conducted at a time when more than half of the FP7 RI projects (54%) had not yet concluded their activities and for only one third (29%) there was a time lapse between end of project and evaluation of more than a year.

The literature reveals that there are six broad classes of innovation effects that are known to arise from the substantial public investments being directed to RI, which include: (1) User-led innovation, (2) Research-based innovation, (3) Knowledge spillovers, (4) Technology transfer, (5) Clustering and agglomeration effects, and (6) Systemic innovation. In addition, the use of the RI by the private sector itself allows for risk reduction and the acceleration of new product development. These innovation outcomes are to a large extent dependant on each other (Exhibit 33).

Exhibit 33 Tabulation of main innovation outcomes and types of innovation

Category of activity	Main activity	Innovation benefits
Design, building & upgrading of RI	• Procurement	• User-led innovation (New/improved scientific instruments) • Clustering/ agglomeration
Use of RI by research	• Scientific research	• Research-led innovation /Scientific breakthroughs • Knowledge Spillovers
	• Engagement with industry	• Technology transfer (joint ventures, collaborative R&D, spin-offs, etc) • Systemic innovation
Use of RI by industry	• Industrial R&D	• Risk reduction for new product development

Source: Based on Simmonds, P. (2013)[14]

[14] Simmonds, P. et al., Big Science and Innovation, Technopolis, 2013

In this section we structured our findings along the three categories of activities:

- Industry as supplier. These include economic effects that result from the suppliers' provision of technological advances / solutions required by RI, which can underpin subsequent success in other markets (Section 4.4.2)
- Commercialisation of research results. Innovations that result from the insights and learning arising from the public-sector research carried out at the RI, including licensed access to IP (royalties) or spinoffs (Section 4.4.3)
- Industry as user. Innovations that result from the direct use of a facility by industry, through collaborations with academic research groups or proprietary research (Section 4.4.4)

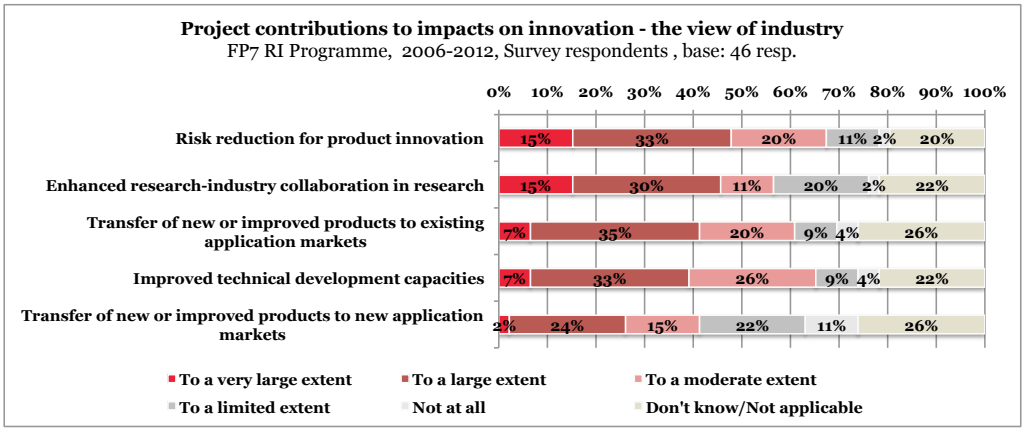
We start this section with a consideration on the potential of innovation impacts of the FP7 RI programme (Section 4.4.1). A final section provides an overview of the major barriers. (Section 4.4.5)

4.4.1 The FP7 RI programme potential for impacts on industrial innovation

Taking into consideration the time frame of this study, we set the focus for our analysis on collecting **early indications of impacts on industrial innovation,** i.e. factors that are known to facilitate the creation of economic benefits for industry participants, such as research-industry collaborations.

Industry actors that were involved in the FP7 RI programme were quite positive on the programme (future) effects (Exhibit 34). Close to half of these survey respondents indicated contributions of their projects to risk reductions for product innovation and an increase in their collaborations with the research actors; ~40% indicated (expected) contributions to 'the transfer of new or improved products to existing application markets' and an improvement of their technical development capabilities.

Exhibit 34 Project contributions to impacts on innovation (survey responses)



Notes: Even though representative for the programme sample, the small number of industry actors taking part in the survey implies that these results should be considered as pattern indications only. They also do not allow for an analysis at scheme or thematic area level.

4.4.2 Industry as supplier

The most direct economic effect from RI activities is the creation of turnover for the industry and service sector due to the supply of equipment and tools (software methods, etc.). In general this turnover is limited for the FP7 projects (since these are not focused on building RIs and therefore physical procurement has happened only to a limited extent), but in some projects future **procurement** may be significant.

In general, there were no significant activities in terms of procuring commercial market products and services as a result of EC funding. And when it was the case like in the context of GEANT for connectivity products, or around RI support for CERN

and its partners, no major spillover impacts were mentioned beyond servicing as a marketing example towards potential new customers, support for anyhow on-going RTD, and contributing to revenues. This is largely due to the fact that European funding is more focused on providing funds for the (additional) costs arising from European level coordination, cooperation, and research projects, rather than on subsidising investment in new equipment, additional hard- and software.

Longer-term effects of the FP7 RI activities can be expected thanks to the involvement of industry in I3 and especially the design projects, with the task to develop 'instrumentalities' such as experimental equipment, instruments, and techniques. These tasks often imply significant challenges and opportunities to innovate. The technological advances required for the next generation telescopes and particle accelerators, for example, create possibilities for commercial innovations just as these fields have in the past. These instrumentalities can have a significant commercial value for customers outside the project. This was the case, for example, for the cross-referencing and data interconnectivity tools that were developed in the I4Life and 4D4life projects (see case below)

For industry to draw full benefits of these efforts made in the course of the RI projects close **research-industry collaborations** need to be created. The utility from an industry perspective is that (service-providing) companies depend on close dialogue with the scientific community to understand their needs. This dialogue is important and is best realised through participation in joint projects.

Case 11 I4Life (Impact on industrial innovation - EEES)

The Catalogue of Life (CoL) is the worlds most advanced attempt to compile a list of all species existing on earth. Such a catalogue is desired for a number of reasons: claims to the ownership of plants or derived products, for example on the topic of plants with medicinal properties; monitoring of the amount and diversity of species; monitoring of the geographic dispersion and invasion of species; and as a reference for lists of endangered species.

I4Life was an e-infrastructure / VRC project. The project started in 2010 and focused mainly on interconnecting several datasets already in existence, to automate their relational links with the CoL Although the I4Life and 4D4life projects have been mostly academic and commercial parties did not participate, the cross-referencing and data interconnectivity tools that were developed have high commercial value. A spin-off company has been established and collaboration with a publisher has started. Additionally, the CoL is useful for pharmaceutical companies and biotech companies. Interviewees also say that the skills developed by participants during the project are in high demand by the IT industry. Bio-informatics seems to function as a training ground with many challenges to learn from.

Methods developed in CoL are useful in literature reference and archival software. Interviewees mention dissemination of methods to PenSoft, a scientific book and journal publisher. The 4D4Life and I4Life projects also work as a good training environment with hard challenges for programmers. They have little trouble finding a job after the projects, as over 70% of the programmers had found a job not long after the project ended.

Commercial parties such as pharmaceuticals but also food- and beverage industries use the CoL for reference.

4.4.3 Commercialisation of research results

We find several indications of the (potential) exploitation of the **research results** themselves (knowledge).

- In the Life sciences, research infrastructures are important for innovation in basic science as well as for translation of results and technologies into the health system and industry. Infrastructures that are at the translational level (e.g. ECRIN, EATRIS, TRANSVAC, BIOMEDBRIDGES) are of particular importance for existing (vaccinology, biologicals production, new antibiotics etc.) and emerging treatment areas like gene and cell therapy. The need for fast and deep access to biological information is at the core of knowledge-based industries in the life

sciences in Europe. This need is addressed in a large number of projects, although the conditions to provide access are not always favourable for industry. The preparatory phase projects have developed frameworks for collaborating with the industry only recently so they still need to demonstrate their success.

- In the area of laser facilities (materials sciences & analytical facilities thematic area), the academic research in the user projects and in JRAs can bring results that lead to innovations and ultimately have an impact on economy. In LLE, this can be expected for innovations in laser facilities and their components and for the laser based research in application fields such as life sciences and health (bio-imaging technologies), chemistry (kinetics of chemical reactions) and energy research (solar cells).
- In the energy, earth & environmental sciences thematic area, the Catalogue of Life (the database with all known species, created a.o. with support from I4Life and 4D4Life) is useful for pharmaceutical companies and biotech companies. The ability to predict and monitor severe weather further away in time and space (as promoted by DRIHM2US) has attracted the interest of (re-)insurance companies. Atmospheric monitoring in particular is regarded with interest by agriculture industries, the (offshore) wind energy industry, transport sector, etc.

Economic activities such as **spin-off** companies can also result from the science itself. Considering the overall size of the EC RI programme funding, the number of start-ups for which information became available is rather marginal, though. One genuine start-up could be identified in the context of the OCAM project, where *First Light Imaging*™ is commercialising and selling worldwide its "flagship product - the OCAM² camera" allowing for unparalleled picture taking with astronomical instruments as well as for satellite earth observation.

Finally, a new business model emerging is **'science as a service'**. Industry is cutting down costs for in-house R&D programmes and looking to out-source R&D to high quality research institutions or biotech spin-offs with the hope that these partnerships and investment will help to populate their pipeline of new products. To increase efficiency, cut costs, and streamline their businesses, companies are willing to collaborate and hand over their not-so-core competencies in exchange for the infrastructure, expertise, and support of third-party providers. As RTD becomes much more specialized and multi-disciplinary, no single SME or even large firm can master all of the necessary techniques, or purchase all of the necessary equipment to make significant advances.

Approaches for exploiting this opportunity are being explored in science-related domains, albeit not yet on the same scale, and in national RIs. Examples relate to the FP7 RI project PRACE and EarthServer.

4.4.4 Industry as user

During this study, we identified a few cases where industry access to RI and knowledge exchange with the scientific communities enabled product innovation. Below we describe a couple in the field of materials and analytical facilities, illustrating the efforts made for knowledge transfer and their results.

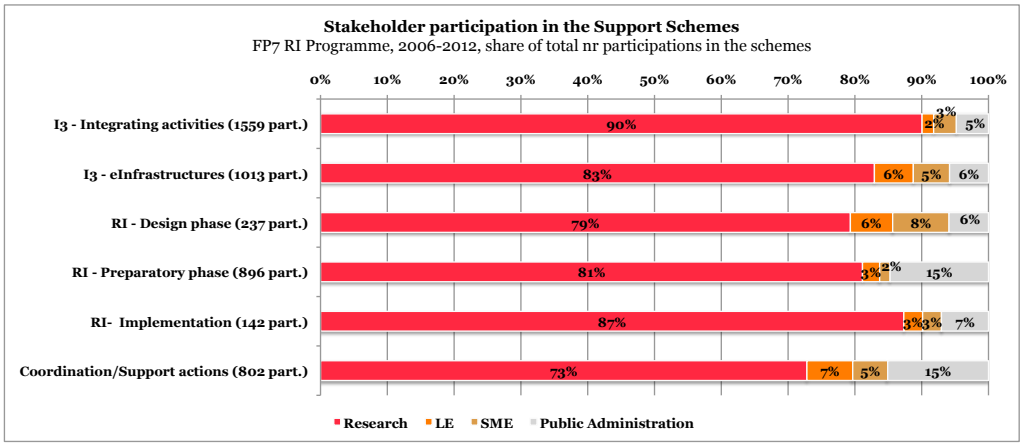
In the field of earth sciences, large companies and SMEs used research infrastructures to carry out material or instrumentation testing as part of their development work. In these kinds of collaborations, not only the content of these activities was important but also the tacit knowledge that was exchanged during the collaborations between the research and the industrial communities. The SERIES project, for example, realised better access for companies to testing sites which led to better testing of buildings etc., which in the long term will lead to better seismic resistance of buildings (which means better economic value).

Many interviewees underlined that the relevance of RIs for innovation can increase considerably in close to all scientific fields covered by this study. The infrastructure

services that could be provided by high performance computing facilities to both SMEs and large companies in need of advanced computer simulations are expected to produce significant spillovers - similar to those of bio banks for life sciences, pharmaceutical and medical device companies, or by large scale social science data gathering like supported in SHARE for social security, public health and labour market policies. It was generally acknowledged that this could lead to improved global competitive positions of European actors.

It is obvious that the impact on industry as user is limited due to the **low participation** numbers in the programme – both as a participant and 'external' user of the RI. Exhibit 35 shows that low participation rates were especially the case for the Integrating Activities projects and the ESFRI projects (Preparatory Phase and Implementation). The case studies showed that in those projects, development of technological tools such as software and middleware was entrusted to computing scientists rather than (private sector) engineers. It would be worth investigating whether this was justifiable because of the exploratory nature of the developments needed, whether it was due to a perceived lack of business case for the private sector, or whether the cause should be found in the social/cultural sphere (lack of contacts, mistrust, etc).

Exhibit 35 Stakeholder participation in the support schemes (composition analysis)



Case 12 EUMINAfab (Impacts on industrial innovation - MS&AF)

The 'Integrating European research infrastructures for micro-nano fabrication of functional structures and devices out of a knowledge-based multi-materials repertoire' - EUMINAfab project is one of the seven projects funded under the sub-theme 'Micro & nanoscience'. It was supported under the support scheme I3 - Integrating activities. EUMINAfab structures the ERA of micro-nano manufacturing (European platform MINAM) by implementing and further developing a distributed infrastructure for creating knowledge and enabling scientific breakthroughs, even to next generation products.

EUMINAfab is the only project in the thematic area 'Material Sciences & Analytical facilities' that (next to the research phase) also covers the production phase. The project represents a balanced infrastructure of research, academy and industry, its geography.

Innovative ideas based on solutions using micro and nano fabrication technologies require access not only to high-end equipment but also the essential highly skilled personnel. It is not possible for SMEs or even most research departments to justify investment in a comprehensive range of technologies and trained personnel, especially when the need is to try out the feasibility of a new idea or develop a one off tool. EUMINAfab seeks to overcome these barriers and provides access to 36 installations and a portfolio of state-of-the-art technologies for structuring and characterisation of a multitude of new, novel and emerging functional materials at the micro and nano scale – to the benefit of users ranging from fundamental science to industry-oriented research.

Companies that use the facilities, use this for their research. They can try new ideas on a very early development stage; they do preliminary testing and use the facilities for specific research purposes. Also they come in contact with advanced research in the field of micro and nano manufacturing and get involved in the network of the research communities in this field.

There are some examples of user companies that have developed products also based on using the EUMINAfab facilities which have been published in CMM International (Commercial Micro Manufacturing). This includes publications on a Belgian firm that has developed a new part for a sensor device and a German firm that has developed a new process for layers on biosensors.

Case 13 ETSF (Impacts on industrial innovation - MS&AF)

Although the focus in the ETSF project is clearly on fundamental research, and the effects on innovation are long-term and indirect, there are anyhow some indications on its impact. The main example (or mechanism) is the introduction by ETSF of calls for research projects by users that are not members of the ETSF consortium. In these so-called **'user projects**', organisations that propose research projects ask for using ETSF data, tools and experts, at little or no costs. As such, the number and variety of ETSF users increases. The calls are relatively open; they allow for research with a clear societal need 'instead', or in addition to, purely academic research. Around 150 projects were funded during the period in which ETSF was supported by I3-e-infrastructure scheme. EC support allowed ETSF to keep financial and other barriers for users low. Of the 150 projects, 60% were proposed and performed by theoretical groups, 30% by experimental groups (e.g. universities highly involved in research at Europe's synchrotron facilities) and the remaining 10% by industry.

ETSF has made several efforts to increase the level of industry financial support, as for example by signing a number of Memoranda of Understanding with industry (e.g. EDF, Mitsubishi, Siemens and Saint-Gobain), succeeding to increase the number of industry-driven user projects and involving industrial representatives in the steering committee of projects. ETSF partners have developed the Materials Evolution Project (in which firms get exclusive access, for one year, to research results and technological trend studies). Working with industry increases income and economic impact, it also stimulates fundamental research as companies raise new types of questions and ask for innovative solutions.

4.4.5 Barriers for industry engagement

Interviewees and experts consulted in this study, as well as stakeholder consultations outside of this study, point at a certain number of barriers for a better exploitation of RI for innovation. These are:

- The rules for access to the RI as 'external' user, centred around the 'science case' and using academic criteria for the assessment of the project, based on peer review by scientists
- The limits set to the use of RI by industry (in the case of PRACE, for example, a maximum of 5% of the total computing resources of a single PRACE system)
- Rigid applications of the rules for publishing of the research results deriving from the use of the RI, not taking sufficiently into account the IPR needs and priorities of industrial players
- Risk avoidance behaviour among industry players (especially SMEs), in particular if access needs to be paid for.
- Insufficient communication and information transfer to industry players and an overall lack of understanding of the potential user community in the industry sphere among RI management
- More in general, lack of a clear framework that facilitates, regulates and thereby improves industry access to research infrastructures

4.5 Societal impacts

Impacts on society are typically **long-term** and most importantly, depend on the uptake of the project outputs by industry or public services actors. In the context of this study, taking into consideration the time frame of the evaluation exercise, we can therefore consider only the potential for impacts in the social sphere.

The considerable share in funding for the integration of RIs that cover the fields of environment, earth and energy and the success of the projects in that field indicate that impacts on **environmental policies** may be large. By means of non-governmental platforms as IPCC, research results (that to a large extent are obtained by means of the use of Research Infrastructures) are fed directly into the political arena. More indirectly (expectations about) improvements of technologies may also affect energy policies of member states.

A similar consideration in terms of potential impacts in the **healthcare sector** can be made in relation to the budget share for the field of life sciences.

In the preceding Chapter 3.2 we considered that the limited funding for RIs in the field of social sciences & humanities indicated a lack of consideration for the role of the **social sciences** in providing strategic information for policy making in other areas of societal importance. The quality outputs of projects like SHARE confirm this perception of a missed opportunity.

When exploring and discussing potential wider implications and benefits from a societal point of view, e.g. for government and industry/stakeholder policy and strategy formulation, the employment market, for exports, commercial opportunities in other industrial markets, etc. there is wide agreement amongst interview partners that research infrastructures could and should play an enhanced and much more critical role than presently, and that a re-adjustment of funding policies would be welcome to better include and allow access for and usage by industrial companies, governments, civil society stakeholders etc.

4.6 Impacts on RI policy making & funding

A major objective of the programme was to improve and consolidate the coherence of RI policy making and optimise RI funding in Europe. The programme would hereby contribute to the creation of the European Research Area and facilitate a stronger positioning of Europe in the global policy sphere. The programme was expected also to create more synergy with other European Commission initiatives such as the Structural Funds in order to maximise resources for RI development and integration at the European and global level.

Our analysis showed that the programme reached some effects in fostering and consolidating coherence in policy making. We cover this topic in Section 4.6.2, considering also the role of the ESFRI roadmap and the support schemes from this perspective.

In Section 4.6.3 we report on our main findings related to the optimisation of RI funding. From our analysis emerged that the interests of the national policy makers were focused on the traditional scientific fields and research infrastructures (e.g. single-site physical sciences and astronomy RI). In Section 4.6.4 we reflect on the barriers for impact achievement in these fields.

We start this section with an overview of the input from the survey participants.

4.6.1 The view of the survey respondents

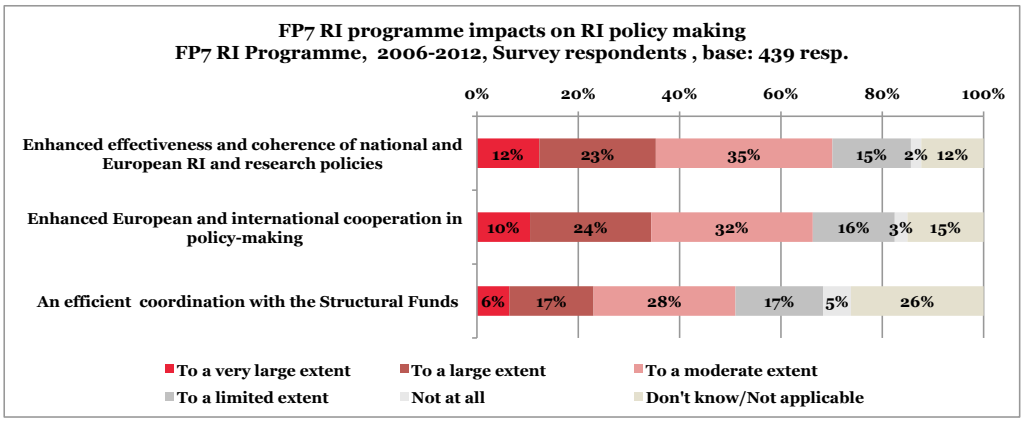
In the opinion of the survey respondents, the FP7 RI programme made a moderate contribution to the effectiveness and coherence of national and EU policies and cooperation in policy making at European and international level. Only ~35% of the survey respondents considered such a programme outcome, compared to the ~70% agreeing with the statement that the programme contributed to an enhanced co-

operation in research and an optimised functioning and development of RI in Europe (Exhibit 36).

However, participants in the coordination & support actions scheme had a significantly more positive view: ~50% of respondents agreed to a (very) large extent that the programme had reached effects in those fields.

The limited effect on an improved coordination with the Structural Funds was an opinion shared by all.

Exhibit 36 FP7 RI programme impacts on RI policy making (survey responses)



4.6.2 Foster and consolidate coherence in RI policymaking

A major task of the FP7 RI programme was to act as a driver and coordinating force for an improved coherence of RI policies in Europe. It did so by taking a "**coordination through the support of self-organisation**" approach, similar to the approach taken in other parts of the Framework Programme.[15] In this approach, the major mechanism to reach integration and strengthen co-operation is by providing *platforms and instruments for an improved communication* among the actors involved. Below are some examples of these mechanisms and their role and value.

New or updated **roadmaps** have been developed in many scientific fields and sub-disciplines during the course of this programme, bringing together all relevant research communities with the aim to develop consensus around a comprehensive strategy at the European level. These roadmaps have an important impact on an improved coordination at the policy-maker and funding agency level and can be expected to guide future policy and investments.

FP7 RI projects, and in particular the preparatory phase activities, provided the forums that would allow R&D policy makers and funders to discuss harmonisation of **concepts and key legal and ethical issues**. This is a crucial topic for European RIs that has to be addressed in advance as they have an important effect in the buy-in of the different countries and in defining the technical aspects and functionalities of the RI with a view to achieving sufficient critical mass.

The **ERANet projects** have been beneficial and a useful vehicle for the stimulation and development of joint strategies (e.g. Astronet) and joint work on policy areas, e.g. Eridwatch and Meril, have created opportunities for "considered debates". These activities have a strategic value also for the Commission in that they provide

[15] Arnold, E. et al, *Understanding the long term impact of the framework programme*, Technopolis Group, European Commission, 2011

Commission officials with background information and the possibility to play an active role, especially if the Commission holds management of these studies.

Information was provided also in order to foster learning within the policy-making community. Examples are the studies developing conceptual frameworks for the assessment of RI - to the benefit of the European Commission and national policy makers, as well as the RI. Finally, cluster projects have supported the re-use of best practices and lessons learned.

Apart of setting the base for an ongoing strengthening of the European RI eco-system, the different sub-systems in this scheme have also had other specific values and roles.

The RI Design and Preparatory projects are considered a valuable addition to the national funding landscape and help to progress concepts for new RIs from the ideas-stage to a stage where national funding agencies may commit to fund them. Interviewees stated that the FP7 RI Programme clearly covered a gap in RI funding through these projects; there is nothing else available at this stage in the development of new RIs. Interviewees considered the **design studies** as highly useful, to the benefit of both researchers and policy makers. For the national policy makers, the results of these projects constituted valuable input for their strategy development in specific fields.

Interviewees active in the materials sciences & analytical facilities thematic area considered as follows the relevance and utility of **preparatory phase activities**:

- These projects provided the required forums that allow R&D policy makers and funders to discuss harmonisation of concepts and key legal and ethical issues. These issues have to be addressed in advance as they have an important effect in the buy-in of the different countries and in defining the technical aspects and functionalities of the RI with a view to achieving sufficient critical mass
- Preparatory phase projects have fostered the development of frameworks and agreements between consortium partners and their respective national funding organisations. In addition, these preparatory activities have provided a way to collectively screen the feasibility of moving forward with some new infrastructures. The relevance of these activities lies in that they provide the groundwork necessary to improve harmonisation of concepts and definitions in some scientific areas, obtain sufficient buy-in of the different countries and define technical aspects and functionalities of the RI with a view to achieving sufficient critical mass.

Criticism from the interviewees in relation to the Construction/Upgrade RI projects related especially to the **lack of strategy** in the implementation of these projects covering the different life stages of an RI. Interviewees were perplexed especially on the approach to fund numerous Preparatory stage projects, in most cases without any view on a possibility for continuation. This initial EC support has set expectations in the research communities, while the lack of funding availability inevitably will lead to frustrations and disappointments.

The role of the European Strategic Forum on Research Infrastructures - ESFRI

The European Strategic Forum on Research Infrastructures (ESFRI) constitutes the most important coordination platform to enable the 'self-organisation' of the national policy making communities. ESFRI therefore acts as a strategic instrument to develop the scientific integration of Europe and to strengthen its international outreach. One of the means ESFRI used is the ESFRI Roadmap. The ESFRI roadmap has raised the importance of RIs in the EU as a policy issue and has had great influence on national policies for Research Infrastructures.

ESFRI was established in 2002, bringing together representatives of the EU Member States, appointed by Ministers in charge of Research, and a representative of the European Commission. The countries associated with Framework Programmes for Research were invited to join in 2004, in which year the Competitiveness Council

asked ESFRI to draw up an initial European agenda in the form of a roadmap for large-scale research facilities.

The ESFRI roadmap – published in 2006 – set out a list of RIs of pan-European importance, representing the outcome of systematic consultations with scientists and users. It provided a list of 35 new or significantly upgraded RIs to be developed by 2015-2020. The list was extended in 2008 through the identification of ten additional RIs mainly in the fields of environment, biology and energy; and further in 2010, with six more in the fields of energy and biological sciences. The roadmap now contains 48 projects.[16] A conservative estimate of the total development cost of the RI projects included in the ESFRI (European Strategy Forum for Research Infrastructures) roadmap amounts to nearly 20 B€, and, on average, 2M€ will be required annually for their efficient operation (ESFRI 2009). Under the present difficult economic situation, ESFRI projects are facing different challenges in raising the necessary funding for their realization.[17]

In the context of the EU2020 strategy, the Innovation Union flagship contains a commitment to complete or launch construction by 2015 of 60% of the ESFRI roadmap priority RIs. All the ESFRI projects are funded by various groups of EU Member States and Associated Countries. To date, the EC has supported the preparatory phase of close to all RIs on the ESFRI roadmap.

In 2012, the EU Council of Research Ministers communicated that it "emphjasises the need for renewing and adapting the mandate of ESFRI to adequately address the existing challenges and also to ensure the follow-up of implementation of already on-going ESFRI projects after a comprehensive assessment, as well as the prioritisation of the infrastructure projects listed in the ESFRI roadmap".

The activities of the ESFRI led to the following major effects in terms of impacts on coherence and co-ordination of RI policies:

- The processes for the development of the roadmap have led to an *increased networking between researchers and policymakers*. This created a more defined stakeholder group and the policy impetus was accompanied by increased financial support. More in general, there is significant European added value in enabling researchers and policy-makers from across Europe to come together to articulate and prioritise their needs and develop a common vision for future investments
- Several countries used or are using the ESFRI Roadmap as a blueprint for the development of *national roadmaps and the setting of national priorities*, including existing and new research infrastructures. The roadmaps help to define national budgets, facilitates ensure political support and allow long-term financial commitment. At the moment 20 countries have a national roadmap for research infrastructures, 8 countries are preparing a national roadmap and 5 countries have none. The national roadmaps and ESFRI are in many countries aligned: a research infrastructure in ESFRI requires serious commitment in terms of investments at a national level, thus influencing national research and science policies.
- The roadmap has set the basis for the subsequent development of *new integrated research infrastructures at the European level*, based upon consensus and a buy-in from the national policy makers

[16] Research Infrastructures in the European Research Area, A report by the ESF Member Organisation Forum on Research Infrastructures, ESF, 2013

[17] Mitsos, A., High Level Panel on the Socio-Economic Benefits of the ERA, Final report, European Commission, DG Research, 2012

However, our analysis showed also some shortcomings:

ESFRI was set up in a time when the role of ICT as an enabler for the development of research infrastructures was not as prominent as today. As a consequence, ESFRI focuses predominantly on research infrastructures and has the role of advisory body for the research infrastructures part of the programme, since 2009 essentially guiding the programme activities in that field. The advisory body for the e-Infrastructures part of the programme, instead, is the e-Infrastructure Reflection Group – eIRG, founded to "define and recommend best practices for the pan-European electronic infrastructure efforts". This ongoing **silo approach** research infrastructures/ eInfrastructures, both at the European and national levels, is increasingly inadequate in a time where eInfrastructures are a basic component of any research infrastructure.

The ESFRI has recognised this issue and has increased its collaboration with the e-IRG. However, we seem to be still far from seeing reflected in the ESFRI roadmap the "co-evolution of Research Infrastructures, e-Infrastructures and user requirements" the 2010 eIRG Blue Paper expressed a need for.

There are **inherent risks** to the '"coordination through the self-organisation' approach, i.e. the stakeholder community – in this case the national policy-makers and scientists – may take over the role of coordinator and create a 'lock-in' situation, essentially acting directly or indirectly as decision-maker. This seems to be the current situation for the ESFRI.

The ESFRI is an intergovernmental body where national interests combined with the interests of science play a dominant role, with little steering possibility for the European Commission. In addition, experts consulted in this study consider that it is a bottom-up body where real strategic decisions are not taken, partly because of the complexity of the field, and partly because of the lacking power for decision making of the country representatives involved.

They see the need for a more holistic approach to Research Infrastructure than is currently the case, and especially, a strategic vision for Europe.

The role and value of the Construction/Upgrade of RI scheme

In all thematic areas, the policy mix included Construction/Upgrade of RI projects; in the Physical sciences and Engineering area (P&E), these projects accounted for 44% of the EC funding. The construction/upgrading projects are of high value to this community.

Apart of setting the base for an ongoing strengthening of the European RI eco-system, the different sub-systems in this scheme have also had other specific values and roles.

The RI Design and Preparatory projects are considered a valuable addition to the national funding landscape and help to progress concepts for new RIs from the ideas-stage to a stage where national funding agencies may commit to fund them. Interviewees stated that the FP7 RI Programme clearly covered a gap in RI funding through these projects; there is nothing else available at this stage in the development of new RIs.

Interviewees considered the **design studies** as highly useful, to the benefit of both researchers and policy makers. For the research communities the R&D to support the development of the new RI constituted an opportunity for the creation and sharing of knowledge, contributing to Europe's leading-edge science and technology outputs. For the national policy makers, the results of these projects constituted valuable input for their strategy development in specific fields.

Interviewees active in the materials sciences & analytical facilities thematic area considered as follows the relevance and utility of **preparatory phase activities**:

These projects provided the required forums that allow R&D policy makers and funders to discuss harmonisation of concepts and key legal and ethical issues. These issues have to be addressed in advance as they have an important effect in the buy-in

of the different countries and in defining the technical aspects and functionalities of the RI with a view to achieving sufficient critical mass

Preparatory phase projects have fostered the development of frameworks and agreements between consortium partners and their respective national funding organisations. In addition, these preparatory activities have provided a way to collectively screen the feasibility of moving forward with some new infrastructures. The relevance of these activities lies in that they provide the groundwork necessary to improve harmonisation of concepts and definitions in some scientific areas, obtain sufficient buy-in of the different countries and define technical aspects and functionalities of the RI with a view to achieving sufficient critical mass.

There is especially a need for the analytical techniques and devices that can be used by the smaller and medium size research groups. This applies for facilities that are too expensive to be bought by these groups. They have no funding for analytical and physical facilities. These facilities have to become cheaper or the access to these facilities elsewhere should be improved.

Criticism from the interviewees in relation to the Construction/Upgrade RI projects related especially to the **lack of strategy** in the implementation of these projects covering the different life stages of an RI. Interviewees were perplexed especially on the approach to fund numerous Preparatory stage projects, in most cases without any view on a possibility for continuation. This initial EC support has set expectations in the research communities, while the lack of funding availability inevitably will lead to frustrations and disappointments.

4.6.3 Optimisation of RI funding in Europe

Complementary funding of the FP7 RI projects

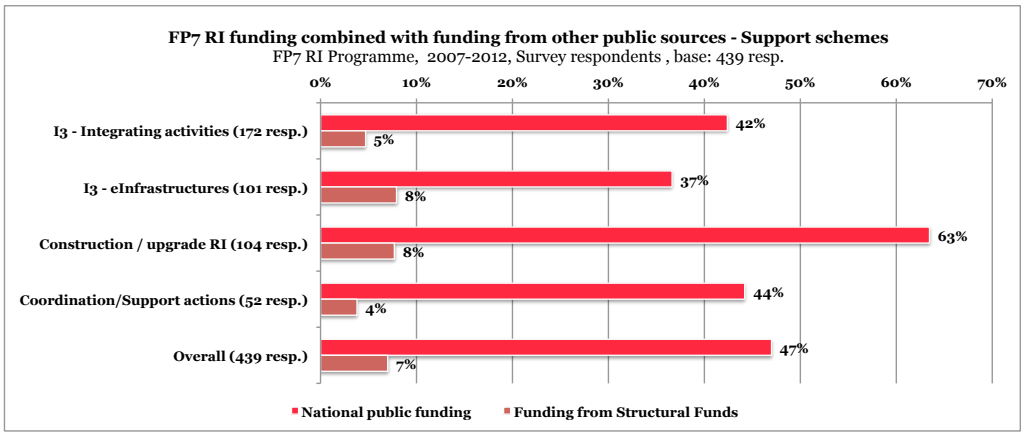
In the context of the research infrastructure, the FP7 programme has a funding function additional to the resources of the Member States and has been able to pool and leverage resources by taking up a coordinating role.

The improved functioning of RIs and reduced fragmentation suggests that an **optimisation of funding** for RIs has been achieved. Most of the funding for large research infrastructures (approximately 95%) comes from the member states. However, these effects seem to be **limited** to certain scientific fields and traditional research infrastructure typologies, as well as to the research infrastructures that are included in the ESFRI roadmap.

Overall, ~50% of the survey respondents indicated additional funding from national sources for their FP7 RI project (Exhibit 37). This regarded in particular respondents active in construction/upgrade of RI projects (63%), as can be expected seeing their focus on the implementation of the ESFRI roadmap. I3 –eInfrastructure projects were the ones benefitting less often of such complementary funding (37%).

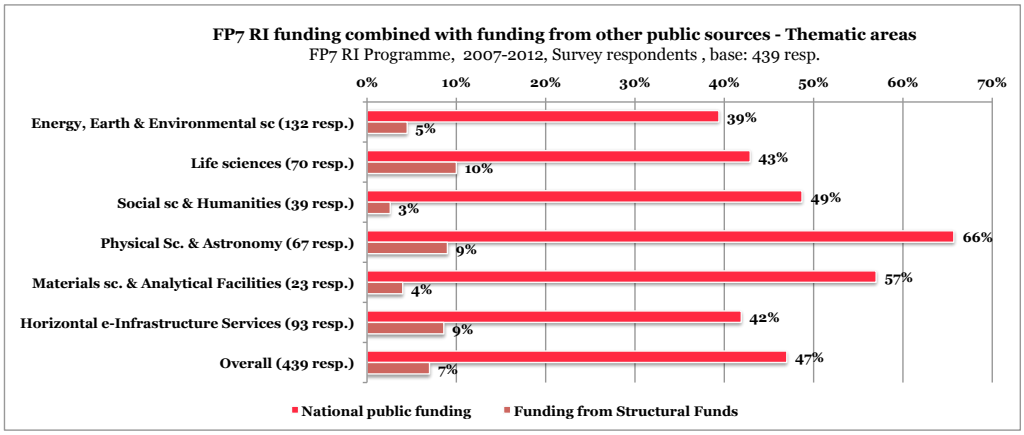
National support seems to be more consistent in the newer EU member states, suggesting a policy commitment in those countries for the integration of RI and research more in general and inclusion in the European RI landscape. Respondents located in these countries indicated more often additional national funding than their peers in the EU15 (57% versus 45%). However, they drew more benefit of the Structural Funds only to a limited extent (9% versus 5% of respondents).

Exhibit 37 Complementary funding from other public sources in the support schemes (survey responses)



At a **thematic area** level, especially respondents involved in the Physical sciences and engineering TA indicated complementary national funding (66%). Respondents active in the Energy, earth & environmental sciences, Life sciences, and the Horizontal e-Infrastructure services TA indicated least often support from national sources.

Exhibit 38 Complementary funding from other public sources in the thematic areas (survey responses)



Note: Data on the Materials & analytical facilities TA are included for the sake of completeness. The low number of respondents active in this field of research limits the statistical validity of these data; they are therefore to be considered merely an indication of patterns

The analysis of the survey responses at the aggregated project level confirms the picture emerging from these data at TA: national funding was granted especially for **single-site research infrastructures** and less frequently for distributed RI and in particular, virtual RI (Exhibit 39).

Exhibit 39 Complementary funding from other public sources – type of RI (survey responses, at the project level)

	National funding	No national funding	Grand Total
Single-site (10 RI)	80%	20%	100%
Distributed (36 RI)	61%	39%	100%
Virtual (31 RI projects)	55%	45%	100%

Synergy with the Structural Funds

In order to increase the pooling of resources for research infrastructures, the intent in FP7 was also to enhance the synergy between the RI programme and other EC programmes or initiatives such as the Structural Funds.

Synergies with the support from the Structural Funds were limited in FP7: overall, additional funding by means of the Structural Funds was 7%. The majority of the respondents see impacts to a limited extent or not at all (see Exhibit 37, above). This is certainly the case for the Coordination and Support actions and to a lesser extent for the integrating activities and eInfrastructures.

In the interviews it was stated that SF funds are complementary to FP7 funding, while SF can be used for the actual construction of RI and FP7 mainly support coordination and integration. The degree of **synergy and coordination** between funds for research infrastructures from the framework programme and Structural Funds is considered not very high and the main reason is the lack of alignment of objectives. The RIs funded by the Structural Funds are focussed on the regional situation and regional benefits and there is a weak connection with European rationales for RIs. More in general the SF and the FP7 RI programme has different objectives. The SF aims at cohesion and convergence of regional inequalities, while FP7 aim at research excellence. Furthermore, SF and PF7 have procedures that are not aligned. Structural Funds do not use calls. The allocation of Structural Funds is made operational through the so-called Operational Programmes. This implies that advocates of research infrastructures have only limited windows of opportunities to get their ideas in operational programmes. Also the time frames are unequal. Setting up large Research Infrastructures usually takes substantial lead times. Structural Funds procedures are aimed at spending the resources relatively swiftly.

In recent years there were attempts to increase the synergy between the SF and FP7. In 2010, DG Research and Innovation and DG Regio developed a joint document presenting the opportunities for funding the development of research infrastructures from Structural Funds[18]. This document contains a mapping of the RI in the ESFRI roadmap that are eligible to apply for structural funds and contains additional next steps in terms of communication channels with the Managing Authorities and the different stakeholder groups of the Research Infrastructures and their Regional Partner Facilities (RPFs). The final report of the expert group on synergies came out in 2011 with the recommendation to use the remaining time of the current programming cycle to explore and test the possibilities for enhancing the interoperability of the programmes and instruments[19].

Also for the next programming period, the European Commission is pushing for more coordination of funding instruments in order to provide the necessary leverage of funds to make new RI possible. Both funding instruments, Horizon 2020 and the future Cohesion Policy funds, share the same strategic goals of serving the Europe 2020 strategy for smart, sustainable and inclusive growth. The Multiannual Financial Framework 2014-2020 provides the necessary regulatory elements facilitating linkages and promoting synergies between the funds[20]. This might improve synergy and coordination in the future.

---

[18] Synergies between FP7 and structural funds for research infrastructures. Available from: http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=structural_funds

[19] Vught van, F., Synergies between FP7, the CIP and the Cohesion Policy Funds. Final report of the Expert group. DG Research and Innovation, 2011

[20] Working document of the commission services on synergies between Horizon 2020 and Cohesion Policy funds. Multiannual Financial Framework 2014-2020, Fiche no. 28. 22 March 2012.

Although the CP funding has distinct specific objectives to those in Horizon 2020, the smart specialisation strategies are the tool the regions can use to support key research projects in line with Innovation Union objectives, notably ESFRI Research Infrastructures projects, while respecting the objectives of cohesion policy.

4.6.4 Barriers for impact achievement

For the individual pan-European RIs, a major barrier for the attainment of complementary funding – influencing also the level of sustainability of the RI - is the tension between the European and the national/regional interests for RI funding. The European perspective stresses excellence, while national/regional policy makers push for he involvement of national actors. In addition to this policy factor, the lack of **synchronisation** and common approaches to RI funding in the different member states constitutes a major difficulty.

In this context, more information and understanding of the national policy makers' position and responsibilities in the national RI governance system may be useful. Interviewees indicate, for example, that these policy makers need to take account of the bottom-up needs of the researchers in combination with the top-down strategy of ESFRI. A working group in Science Europe looks at the procedures at national levels and intends to publish a report that will explain/make understand how decision-making operates at the national levels and will set out the role of the agencies in this process.

Another issue mentioned by experts consulted is the lack of a **comprehensive and holistic view** on research infrastructures.

An example at the national level is the difficulty to convince policy makers for investment in RIs taking the full cycle perspective. Interviewees states that it is easier to convince national policy makers to fund new RI than to convince them for funding of major upgrades, maintenance, attracting good technical staff.

An example at European level is the lack of collaboration and synergies with other EC programmes and initiatives – beyond the Structural Funds. Interviewees considered that this indicated an apparently lacking consideration of the core function of RI, i.e. enabling research. They brought forward examples of initiatives where clear synergies exist and where the RI programme should seek more visibility; one of these was the Marie Curie scheme, where RI are not addressed, despite the fact that RI constitute a major point for researcher mobility.

4.7 European added value of the FP7 RI programme

The mandate for this study was to focus on those aspects and effects where the programme made a difference in its effects on research infrastructures in Europe, in comparison to national funding programmes and the impacts of research infrastructures in general. In other words, the European dimension and its added value constituted the core of the analysis. This section therefore takes a function of summarising the information on impacts provided in the preceding chapters.

We structured it as follows: in section 4.7.2 we report on the findings related to the additionality of the EC funding for the RI projects, in Section 4.7.3 we describe the European added value of the FP7 RI programme for specific scientific fields, and in Section 4.7.4 we provide the main findings of the exploratory (and limited) cost/benefit analysis that was conducted in the context of this study.

We start this section with an overview of the inputs provided by the survey respondents.

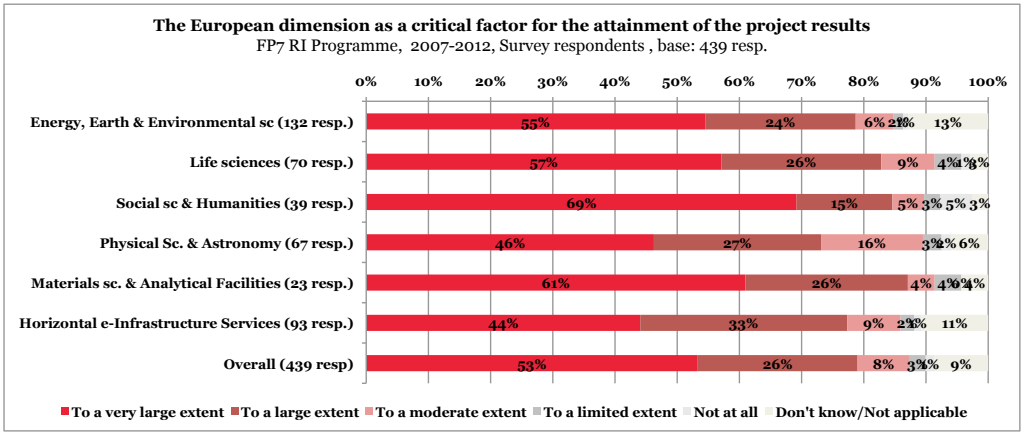
4.7.1 The view of the survey respondents

The European dimension was a critical factor for the attainment of the project results for the majority of respondents (80%).

Especially respondents active in the Construction/upgrade RI schemes (predominantly preparatory phase projects) indicated a very high European added value from this perspective (60% considered the EU dimension a critical factor 'to a very high extent', compared to 53% in average).

The analysis at thematic area level shows a high added value of the funding at EU level especially for the projects in the Social sciences and humanities, Life sciences and Energy, Earth & Environmental sciences TA. Respondents active in the Physical sciences & Astronomy areas are less positive.

Exhibit 40 The European dimension as a critical factor for the attainment of the project results



4.7.2 The additionality of EC funding

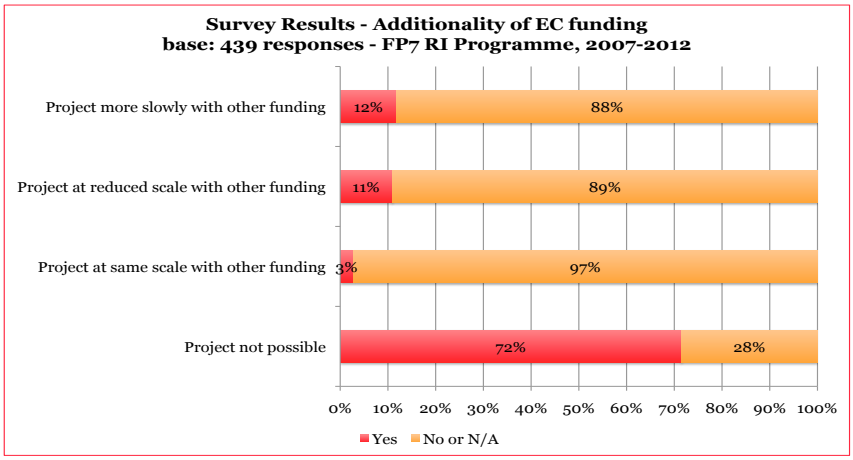
Additionality is at the heart of justification of policy intervention, in this case the Commission investment. It is therefore a critical factor for evaluation. It was posed in terms of what difference the intervention made and whether the difference justifies the intervention.

The survey responses confirm the high level of added value of the programme: 70% of the respondents stated that their project would not have been possible without EC funding; the remaining 30% considered that it would have been possible to find alternative funding, but in close to all cases that would have implied a reduced scale or speed.

These positive responses seem in contrast with the outcomes of the FP6 evaluation[21], where only a minority of projects (8%) considered that without EU funding the project would not have taken place. This study concluded, 'While few projects [8%] clearly stated that their project would not have been possible without EC financing, the large majority were of the view that the European funding enabled certain activities that would otherwise not have been possible."

[21] Juhlin, M. et co., *Research infrastructures in the Sixth Framework Programme – Evaluation of pertinence and impact*, Synthesis Report, Matrix Insight Ltd, Ramboll Management, PREST, 2009

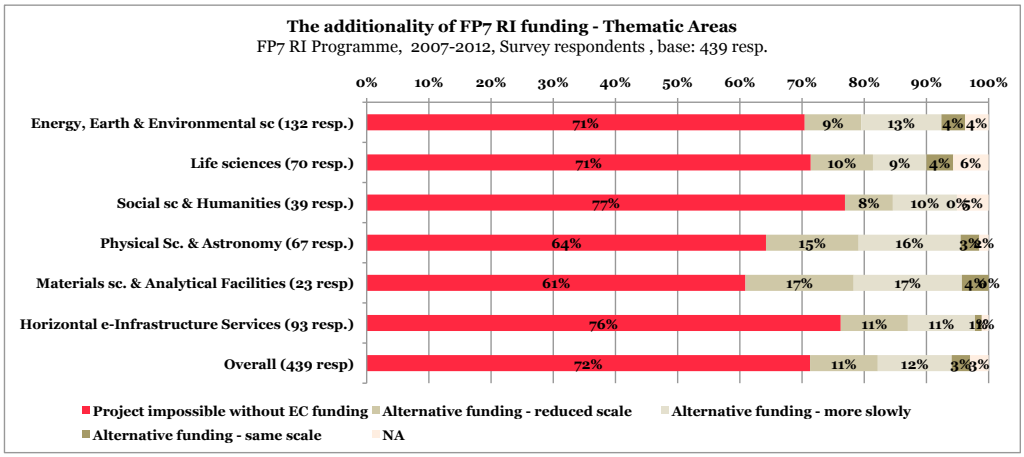
Exhibit 41 Additionality of EC funding (survey respondents)



While there is no significant difference between the different support schemes, the analysis at Thematic Area shows a considerably lower-than-average level of EC-funding additionality among the respondents involved in projects targeting the physical sciences & astronomy TA. In this TA, ~35% of respondents considered that an alternative funding would have been possible, compared to ~25% in most of the other TA.

The section below looking into the European added value as described by the interviewees in the thematic area case studies sheds some more light on this topic.

Exhibit 42 Additionality of EC funding – thematic areas (survey respondents)



4.7.3 European added value for research in the scientific fields/thematic areas

Energy, Earth and Environmental Sciences

In almost all projects the FP7 RI programme leads to better coordination of EU (RDI) policy and improved input of EU in global policy process. In its turn this leads to amongst others reduction of parallel development, better quality of research, increased operability on a global scale and increased visibility of research solutions. Related to this (and valid for most e-Infractructure related projects) there is large EAV in harmonisation of data and bringing together scattered datasets. Also outside the e-domain standardisation of methodologies and technologies at European (or world) scale is an important EAV.

Because of the FP7 activities the scale of research increases (networking as well as pooling of resources), which makes it possible for EC researchers to stay at forefront of research in the world: this cannot, in quite a large part of the EEES domain, be done at a national scale. FP support is also sometimes seen as Seal of approval, both indicating quality of research as well as political support, making international cooperation more easy (e.g. DRIHM2US)

In some cases EC funds address a funding gap that results in direct work performed on the topics that are relevant to the EC and the European community as a whole (METAFOR/ICOS). The same is valid for transnational access. This would often not have been realised without additional funding at EC level (SFERA, SERIES)

European Added Value however is **not always realised** as a matter of course, as the case of the research platforms (comprising two project: ERICON AB and COPAL) shows. In these cases the FP7 Preparatory projects were not enough to realise joint investment in RI, because agenda's of national environmental research institutes were not aligned, budgets needed were high and timing was difficult (not only because of decreasing funds because of the crisis, but also because the continuous development and related time scale of research vessels within the stake holding nations was different: not all countries needed to replace a ship or aircraft at the same moment).

Life sciences

In the Life Sciences area report it is concluded that, although the costs of biological research infrastructures are relatively low, the costs of developing and maintaining a research infrastructure at any site would be too high for a single organisation. However, they are needed to attract industry to Europe and to carry out research at the highest quality level possible. This implies the need for interaction between sites and, in particular for newer EU Member States that cannot afford all needed RIs, RIs overarching national borders are needed. Access beyond national borders is needed to optimally make use of the available expertise, samples, etc., especially if high costs are involved that are not agreed upon between the institutions or nations.'

Many projects contained some element of standardisation and harmonisation. The added value of European efforts in this area is significant, as common standards and definitions and harmonised rules are essential in collaboration and sharing of data and achieving better results.

Of equal great importance is the added value of the European activities for networking and connectivity. By bringing together different European stakeholders for collaboration they are able to pursuit ideas that would not have been achieved without a pan-European effort.

The last type of added value of the European efforts that we observed is the pooling of resources (funding and people). The EC funding resulted in an increase of national investments, leveraging the total amount of funding. Also, the creation of a research community and critical mass of the smartest minds, will lead to a decrease of duplication in investments.

To conclude, for the majority of the projects investigated in the case studies, EC funding has been essential. Aside from the fact that the funding was needed to address the common European goals and to increase connectivity, EU funding also acknowledged the importance of the project, thus bringing more attention to the project.

The added value of EC funding is especially high with regards to preparatory phase projects such as EATRIS, BBMRI and ELIXIR. The need for such pan-European RIs was widely recognised, but no country was willing to pay the costs alone. The EC funding for this preparatory phase was essential to mobilise the member states and to encourage them to pay for these costs. The EU funding provided a framework to reduce fragmentation and allowed the member states to join forces.

Materials Sciences and Analytical Facilities

One of the main European added values of the FP7 RI projects in this TA is that users from all over Europe can apply for experiments on facilities all over Europe. They can make use of the facilities and also of the local technical expertise that is needed for their experiments. LLE and EUMINAfab give user access to high-end facilities that are only available in a restricted number of places. In ETSF, free availability concerns theoretical and technical support from ETSF researchers (including professors and PhD students).

As access is given to users external to the facilities, this leads to a more efficient use of these facilities. The large and expensive installations such as CERN and ISPRA, or those of CNRS, are popular and will stay popular and it is difficult for researchers to get beam time. But this does not apply for smaller facilities such as the laser labs or micro and nanofabrication technologies, which are nevertheless very important and valuable for research. The FP7-RI programme opened access to external users also to small-medium scale facilities thus making the operation of RI more efficient (higher utility rates).

The ETSF project has a similar European added value. First, the ETSF consortium set up a new scheme for reviewing, selecting and supporting user-driven projects that can be submitted by actors outside the ETSF consortium; this new scheme was set up after the EC-funding ended. Second, the ETSF package of free software is used by a range of scientists from universities and public research organisations from all over Europe. Most software packages are developed or adapted for specific studies; there are few organizations for storing, keeping, sharing, commercializing this kind of software, or making academically written codes more robust and available to other. There is no custodianship i.e. no one takes the responsibility to keep and preserve them. ETSF fills this gap in the field of spectroscopy.

In this way the EC is supportive in increasing the performance and integration of research facilities in Europe.

Without the EUMINAfab project, the partners would be active only at the local level and operate in an isolated way. The main added value is that through this project the partners can learn from each other and this leads to an integration of the local activities. This applies also for the LLE project but here this added value was already present in the partnership as a result of the previous experience during LASERNET.

The research equipments used in the FP7 RI-projects in this thematic area are very expensive and for that reason it is necessary that these facilities and the related research activities are harmonized in Europe. This is what is being done in the FP7 RI-projects with the aim at decreasing fragmentation of research facilities in Europe.

Inside LLE, external laser scientists and researchers from different application fields (see below) not only have access to a laser facility. In addition to the access the external users can also perform collaborative experiments with local scientists and write joint publications. As a result of the LLE-projects there has been a significant increase in the international collaboration in laser science, leading to an increase in the level of EU research in this area and to a leading position of Europe in the field of laser science.

For EUMINAfab and ETSF the main indications of their contribution to Europe's position in the relevant fields of science are the long list of publications.

The use of LLE and EUMINAfab infrastructures stimulated among the involved researchers a lot of original ideas and new scientific projects. Through the EUMINAfab TNA activities, users have got access to cutting-edge facilities for micro-nano fabrication and could learn more about the research fields in which these facilities are used by the hosting groups. The research topics in JRA projects are the result of a combination of issues coming from two or more research groups. The cross-disciplinary cooperation in JRA projects has consequently arose novel research topics and the acquired data have been used for elaborating new proposals.

In the LLE project, the TNA activities have not only triggered many new research ideas, but also improved the performances of advanced laser sources and stimulated international competition. New basic knowledge has been generated that can be used in different application areas.

As mentioned above, the impact of the LLE chain of projects on the level and international rank of Europe's laser science has been considerable.

Physics and Astronomy

The increasing scale and complexity of the RIs required to meet the needs of cutting-edge physics and astronomy leads inevitably to higher costs and, in a world of tightening public budgets, the coordination of resources and removal of duplication is essential to ensure the best use of public resources. Furthermore some RIs are of such scale that no one country could undertake them alone. Therefore there is an increasing need for coordination to design and build new RIs and to optimise and widen the use of existing facilities, and here there is a role of the Commission.

The establishment of new RIs is an incredibly long process, sometimes taking decades, not only to design, test and build but to agree participation and funding, governance models and legal structures. Historically, new RIs have been driven 'bottom-up' by the research community who then garner support from funding agencies and their peers. International RIs require parallel activities across all potential participating countries, inevitably slowing the process. At this early and critical stage of development there is the potential for considerable European added value. Coordination support for policy-makers and funding bodies as well as preparatory actions can provide an important impetus to the development of new RIs. Ultimately, RIs are funded by national funding agencies, (increasingly working together), but EC support is used to kick-start or catalyse development activities.

Linked to this, is support for the development of research and infrastructure roadmaps. Here there is significant European added value in enabling researchers and policy-makers from across Europe to come together to articulate and prioritise their needs and develop a common vision for future investments.

The RI funding is highly relevant and appropriate for the research community in that funding has supported all of the proposed RIs in physics and astronomy included in the ESFRI roadmap, the ground-based RIs in the Astronet roadmap and the upgrades required for CERN and other facilities in particle and nuclear physics contained in the European Strategy for Particle Physics (ESPP). It has also enabled explorations into additional potential RIs such as the Large Aperture European Solar Telescope (EST) and Einstein Gravitational-wave Telescope (ET). There is a difficult balance to be struck between supporting identified priorities and allowing new ideas to be explored and developed but the programme has been able to support both types of activity. However the community would be concerned if the ESFRI roadmap, in particular, became the sole driving force for the programme.

Finally European added value is present in EC support for integration activities in encouraging and facilitating disparate facilities to work together for mutual benefit, community building and longer-term coordination.

Social sciences and Humanities

Case study interviews with stakeholders and independent experts indicate a clear and substantial European added value of FP7 RI activities in Arts and Humanities as well as Social Sciences. Many of the RI activities addressed can only be done at European level and only with European support.

European collaboration increases access to data, quality of data and research results, while reducing the costs for individual researchers and organisations.

The fragmentation problem concerning RIs in the Arts & Humanities is phrased by the ESF: "Digital infrastructures are developing rapidly but unevenly, and there is an

urgent need for coordination, standardisation and sharing of experience to prevent unnecessary duplication and the atomisation of good initiatives."[22]

For CHARISMA and DC-NET (cultural heritage), European added value was phrased in terms of European coverage of the consortia; involving additional actors and countries; and FP7 and Horizon 2020 support being crucial for individual RIs and for collaboration between the various national and European RIs.

In the SHARE case study, European added value was perceived an understatement. European surveys can only be done at European level, with European funding. Any other model, such as funding by three to five leading countries, would jeopardise harmonisation and continuity. Moreover, only a European survey can contribute substantially to harmonisation with surveys in the US and other parts of the worlds ('academics debates and negotiations between equals').

Case study interviews with stakeholders and independent experts indicate a clear and substantial European added value of FP7 RI activities in Arts and Humanities as well as Social Sciences. In short: many of the RI activities addressed can only be done at European level and only with European support. Clear steps are taken towards becoming a European research community (cf. the European Research Area).

Horizontal eInfrastructure services

The FP7 funded eInfrastructures GÉANT, EGI and PRACE give access to innovative infrastructures that offer high capacity services not matched by any commercial or national offer.

In the case of horizontal e-Infrastructures and services, European collaboration has led to the development of new methodologies and tools, which make the management and provisioning of advanced services easier and more systematic. In addition, it has fostered a stronger and more integrated NREN community.

For sub-areas such as High performance computing, collaboration across the EU has helped bring on board smaller and less resourced countries that otherwise could not afford Tier-0 systems, minimising internal disparities. Researchers in small, not so well resourced Member States profited from FP7 HPC and communication network funding the most, stressing the relevance of the programme for European cohesion. Coordinated procurement throughout Europe and transnational access has supported specialisation in architectures. As the HPC community is small, major hardware developments are based on activities at the European level. In addition, European collaboration in this area has helped establish a user and provider community, lowering the barriers of entry to access HPC resources and developing unified services that allow researchers to seamlessly switch between centres or relocate computing tasks (e.g. DEISA2 and PRACE).

For grid and cloud activities, collaboration at the European level has allowed to train and build a user community of grid computing, to establish a production-quality grid infrastructure in Europe and to work towards the "gridificaction" of on-going research initiatives. In areas such as climate sciences, these grid projects have fostered new global research (e.g. E-Science Grid Facility for Europe and Latin America).

4.7.4 Cost/benefit ratio

The cost/benefits analysis grouped stakeholders of the infrastructure in four categories: providers of the infrastructure, users or beneficiaries of the services of the infrastructure, industry suppliers (if present), and funders. It was clearly able to show, that European funding for research infrastructures and eInfrastructures leads to a

[22] ESF, *Research Infrastructures in the Digital Humanities* (2011)

strong overall return for Europe. Several effects would not have materialised without the funding by the EC or would have taken far too long to arrive. The funding by the EC clearly has a facilitating effect here. Seven out of eight cases already today show a positive return although many of the benefits of these infrastructure activities will only be reaped in the future.

The findings of the analysis also indicate the usefulness of distinguishing between RI projects with a development focus and those with a learning/coaching focus when considering their long-term perspectives.

Infrastructures with a development focus were found to have a need for kick-off funding only, while long-term funding should be considered for those with a learning and coaching focus. This should be clarified earlier in the project to sustain funding and avoid service interruption. Horizon2020 has set off in that direction already.

4.8 Sustainability of the pan-European RI

In this final section we cover the issue of the pan-European research infrastructures' sustainability, or more precisely, the sustainability of their full European dimension.

In Section 4.8.1 we describe the context and the issue, to then go into more detail and describe the current funding models and the level of risk that they present in Section 4.8.2.

Sustainability of the pan-European research infrastructures is a major issue. The FP7 RI programme succeeded only to a certain extent in alleviating the tension between the priorities and governance responsibilities of the national policy makers and the policies at the European level, reflecting the needs of the research communities. This has inevitable repercussions on the potential for an ongoing funding of the European research infrastructures at the same size and scale.

4.8.1 Sustainability of the research infrastructures' European dimension

Long-term funding for research in general is increasingly an issue at the national levels and there is no financial plan at the national and/or European level to finance RIs in the long term. Such a plan must not only comprise the investments in the construction of large research infrastructures, but also sources to exploit and maintain the facilities. Sufficient structural funding in many countries is lacking and due to the economic/financial crisis there is even an increasing pressure on resources for research and infrastructures in particular.

In Europe, approximately 95% of the funding for large research infrastructures is provided by the member states. Countries are showing considerable interest in participating in the projects from the ESFRI Roadmap and launch national projects, but the general concern is that investment is not sufficient. Sustainability of RI is also related to the upgrading of the instruments and/or facility. Developments occur at a high speed, so major upgrading is needed for several RIs, an issue that often is not taken into account by national policy makers when launching or supporting new RIs.

Several studies and reports that we consulted in this study considered that the Research Infrastructures would no longer be able to grant free **transnational access** to researchers without European funding, especially in the current context of financial crisis.

According to interviewees, this problem may occur especially for the **distributed and virtual research infrastructures**. In the preceding chapters we noted that distributed and virtual research infrastructures in general receive less frequently funding from national sources; they also have more often the European dimension at the core of their existence. These infrastructures are therefore more vulnerable to changes in decision making at the national level and more dependent on European funding.

For the single site research infrastructures, in fact, there is a long-standing international habit that excellent scientists are given access with a minimal charge; access is provided based on quality and few national policy makers object to providing access to researchers based in other countries in these cases.

Interviewees considered that this should be recognised and that for the 'real' distributed research infrastructures, the EC should foresee funding instruments for the central node that drives the RI, giving centralised access and taking centralised decisions on investments and data policy.

The case below reproduces our conclusions on sustainability of RIs in the social sciences & humanities sector.

Case 14 Sustainability of transnational access in the social sciences & humanities thematic area

It is obvious that transnational access to RIs in the whole SSH domain is a crucial point. The aim of many of the RIs in the SSH domain is to offer open access to a comprehensive dataset or collections supported by advanced (ICT) tools. In order to serve the SSH research community and other users, the RIs should offer not only transnational access, but also offer multilingual and multimodal approaches. In this respect a (more) international approach is needed. Only a common exploitation of the RIs can take into account the European diversity and improve open access.

The lack of a sustainable funding stream for RIs in both the Arts & Humanities and the Social Sciences is considered to be the main problem. RIs in the Humanities and Social Science are underfinanced, both on the national and European level. In order to foster the competitive position of European research in the SSH domain, a substantial effort on the funding side should be undertaken in the next years and in a midterm perspective, with clear milestones concerning funding strategies. Since there is a need of overarching RIs, special attention should be given to funding at a European level. A common and targeted European funding stream can prevent redundant financing of similar projects on the national level, in part due to a lack of knowledge about similar projects in other countries.

4.8.2 The need for a longer-term funding model

Several existing pan-European RI count on the **private sector** for their sustainability. However, experts state that a funding model based on private sector involvement is feasible only in specific fields of research and for specific types of RI. A longer-term funding model based on industry investments is therefore not always a feasible road.

Most pan-European RI depend on public funding for their sustainability and turn to the national Member States to continue their activities and services. Their funding model is therefore based on an **aggregation of national funds**.

The current state of financial crisis brings on the foreground the fragility of this model. A typical example is the sudden and unexpected withdrawal of Germany from the European Square Kilometre Array (SKA) project, part of a global effort in the field of astronomy. Another example is the case of he SHARE survey.

Case 15 SHARE (Sustainability of the FP7 research infrastructures – SSH)

SHARE is the Survey of Health, Ageing and Retirement in Europe. It consists in a chain of projects that has received EC support from 2005 onwards. In 2004, the European Commission (via Fp5) funded between 95% and 100% of SHARE and its 1st survey/wave. Between the 1st and 4th survey, the number of countries increased, some of them co-funding their national survey and their involvement in the SHARE RI. Gradually, while the emphasis of SHARE went from preparation, design and testing to continuation, increasing the number of countries and building up the longitudinal dimension, EC funding decreased and national funding increased.

Currently, (2013, wave 5), the balance is as follows: Member States: 63%; European Commission: 19%; US NIA: 6%; German Federal Ministry of Education and Research: 13%. European Commission support comes from FP7 and Structural Funds (for countries that are eligible). The split is roughly 50/50. In addition, SHARE is supported by DG Employment (concerning specific countries) and collaborates with DG SANCO.

The current funding structure is perceived as highly complex, highly dependent on financial resources and political priorities at the national level and implies substantial risks for the continuity of the SHARE survey. Between the 4th and 5th survey/wave, two countries stepped out because of near bankruptcy of one country, and a complete and temporary lack of interest in academic research (by the new political party in charge). When countries drop out of the survey this leads to negative impact on the coverage and quality of the survey, which affects all countries involved. Changes in the number of countries (and gaps in time series) hinder national comparative studies. SHARE follows the *same* panel of persons/respondents over several years (cf. a longitudinal study). With countries dropping out, individual respondents drop out, which reduces the value of their contribution to previous surveys/waves.

In the context of funding from different sources, interviewees reported no tensions between the various objectives of SHARE or between the actors that fund SHARE. The main objective is to gather, and provide access to, data that is relevant for research and policy in the field of health, ageing and retirement. This is in the interest of all countries and the European Commission. To closely involving private actors such as large pharmaceutical firms could lead to conflicting objectives, e.g. in terms of confidentiality of personal data and its commercial use which is likely to reduce the willingness of respondents to participate.

An issue that frequently emerges in the discussions around the sustainability of the European research infrastructures is the limitation of the **project-based funding approach,** at the European but also – and increasingly – at the national levels, hindering any long-term planning in the RI management. The adequacy of funding for research infrastructures on a project basis is questioned, highlighting the short-term effects and the impossibility for long-term planning under these circumstances.

In 2009, the EC communicated the following:

> "Project-based, short technology development cycles may undermine the interoperability of grid infrastructures, thus hindering cross-disciplinary cooperation and economies of scale. The EGEE and DEISA projects have already gone a long way to combining disciplines and coordinating strategies. To ensure long-term sustainability, these endeavours must evolve into truly pan-European organisation models that will open grid e-infrastructures to all scientific disciplines and complement national funding strategies in support of e-Science. Several National Grid Initiatives are emerging to respond in a coordinated and cost-effective way to the needs of scientific disciplines for computational resources."[23]

In fact, the **EGI.eu** governance structure is built on the sustainability model used also for the GEANT, i.e. a funding from national sources and **national 'daughter' grid initiatives**. However, in its latest communication the EGI.eu admits the fragility of this sustainability model in the current economic crisis.

Also the HPC community is looking for a longer-term funding model. In 2010 the PRACE community made the first steps in that direction and established itself as an **international non-profit** named 'Partnership for Advanced Computing in Europe AISBL' with 25 member countries.I t can be said that Europe has caught up in the last seven years to become an agile follower in HPC. Software and applications are strong. To stay at the top, however, and achieve the ambitious goals set out by the Commissioner and the Council it is lacking a clear financial roadmap with a stronger EU contribution that better levels the contributions. Today funding is very unevenly distributed caused to a substantial amount by the Member states owning the tier-0 systems. Some share of the funding could be changed from project funding to a more permanent funding.

The community is currently working on a 2015-2020 strategy. A European initiative is definitely required because needed investments can only be borne by the richest

[23] COM(2009) 108 final, ICT INFRASTRUCTURES FOR e-SCIENCE, European Commission, 2009

economies in Europe and access for small countries is at risk if sustainable funding cannot be found.

Allowing activity-based costing for EU research projects requiring the HPC resources would be an alternative way of financing. However, this would be in contrast to the open access and open data rulings.

The **ERIC legal framework** is increasingly seen as a potential sustainability model, setting the basis for a more stable longer-term funding stream – even though it does not guarantee commitment.

However, interviewees pointed out that there still is weak interaction and a weak decision making process. ERIC can accommodate many different implementation modes and allows for flexibility, but in practice it is also used to allow a non-intervention strategy and gives large autonomy to national decisions on contributions. It also doesn't consider sufficiently a risk mitigation strategy (what if one of the partner countries can no longer pay?). In other words, a better functioning from the perspective of fostering longer-term commitments requires a tightening of the rules.

5. Conclusions and recommendations

The FP7 RI programme has made a significant step forward in the efficiency and effectiveness of its support to the European research infrastructure compared to the programme in FP6.

An important facilitator for this highly positive evolution was the more coordinated approach to the funding of existing and new distributed research infrastructures or networks of research infrastructures in Europe, based on the ESFRI roadmap. The shift in focus towards the delivery of user-tailored e-Infrastructure services and the development of a multi-layer e-Infrastructure ecosystem resulted crucial for the creation of the globally connected European Research Area in Research Infrastructure.

The Programme has brought e-Science into the European research system, helping researchers and engineers to stay at the forefront.

There is nonetheless room for improvement. The most important needs are

- Greater focus on exploiting the innovation potential of the Research Infrastructures
- Even though progress has been made compared to FP6, the coherence of European RI policy making – and especially RI funding – needs to be improved and refocused on developing an holistic European vision
- Stronger cooperation between the scientific and e-Infrastructure communities is crucial to strengthen Europe's capacities in e-Science and Europe's competitive positioning in research at the global level
- Reducing the tendency to funding fragmentation at the EC level
- There is a need for a strategic vision for Europe
- The sustainability of the European Added Value is a major issue.

Our recommendations are:

- Tackle the sustainability issue through new funding and/or governance models
- Promote a more holistic and comprehensive view on research infrastructure among national policy makers. This involves both developing a European vision and connecting it with the role of national and regional planners in using the Structural Funds, so it will involve not only funding programmes but also wider coordination activities
- Consider whether it is satisfactory that the ESFRI roadmap should be the sole driver of EC RI funding priorities
- Further strengthen the cooperation between ESFRI and eIRG and the scientific/e-Infrastructures communities as a whole
- Improve the coordination of RI strategy among DGs
- Improve synergies with other EC services/initiatives – beyond the Structural Funds
- Support the development of distributed RI in Social Sciences
- Strengthen the innovation element in the RI, e.g. through financial incentives for SME use of RI, stronger emphasis on economic impact and user-orientation as selection criterion, revision of regulations and access rules in line with industry needs, …

Appendix A – Bibliography

A vision for strengthening world-class research infrastructures in the ERA, Report of the Expert Group on Research Infrastructures, 2010

A. Calvia-Goetz (Chair) A. Franciosi S. Larsen J. Marks K. Tichmann R. Wade M. Zic Fuchs, Assessing the projects on the ESFRI roadmap - A high level expert group report, 2013

Adam B. Jaffe, Manuel Trajtenberg and Rebecca Henderson. Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. Quarterly Journal of Economics, Volume 108,, Issue 3, p. 577-598.

Antoni, T. et al., *Ende des DGI-2-Projektes. Zukunft der zentralen Grid-Dienste*, 2012

Aspire, *The Adoption of Cloud Services*, 2012

Attig, N., *HPC in Europe* (Power Point Presentation), Forschungszentrum Jülich, Jülich Supercomputing Centre, 2008

Baxter, R. et al., *EUDAT Sustainability Plan (D2.1.2)*, EUDAT – 283304, 2013

Ben Martin and Puay Tang, The Benefits from Publicly Funded Research, SPRU Electronic Working Paper Series No 161, Brighton: Sussex University, 2007

Biobanks for Europe. A challenge for governance. European Commission, DG Research and Innovation, 2012.

Biobanks need pharma. Editorial. Nature 461, 448 (24 September 2009)

Borsch-Supan, A. (2013). The Survey of Health, Ageing and Retirement in Europe, SHARE. In: Kleiner, B, Renschler, I., Wernli, B., Farago, P. and D. Joye (Eds.), Understanding Research Infrastructures in the Social Sciences, Zurich: SEISMO, pp.123.134.

Bundes-Höchstleistungsrechenzentrum Universität Stuttgart (HLRS), *Richtlinien für die Organisation, die Nutzung und den Betrieb*, 1996

Bundesministerium für Bildung und Forschung, *Roadmap für Forschungsinfrastrukturen. Pilotprojekt des BMBF*, 2013

Communication from the Commission, Europe 2020: A Strategy for Smart, Sustainable and Inclusive Growth, COM (2010) 2020, Brussels 3.3.2010

Costas Fotakis, *FP7 Interim Evaluation: Analyses of FP7 supported Research Infrastructures initiatives in the context of the European Research Area,* European Commission, 2010

Decision No 1982/2006/EC of the European Parliament and of the Council of 18 December 2006 concerning the Seventh Framework Programme of the European Community for research, technological development and demonstration activities (2007-2013)

Deloitte, Global life sciences outlook: Optimism tempered by reality in a "new normal", 2013

Development of impact measures for e-Infrastructures, Final study report, Fraunhofer ISI, ZEW, European Commission, DG Information Society & Media, 2012

Dominic, C., Periodic Report, European Commission, 2012

e-IRG roadmap 2009 - Draft for consultation, 18th December 2009

e-IRG Roadmap 2012

EARNEST, *EARNEST Study Questions for NRENS on Organisation and Governance*

EGI-InSPIRE - EGI Platforms roadmap, EGI.eu, 2013

ELLA – Europe Link with Latin America*, Feasibility Study for a direct Europe Link with Latin America – Communication and Marketing material (D7.1.1)*, 2012

Energy Thematic Working Group Report 2010. European Strategy Forum on Research Infrastructures (ESFRI), 2010.

Enrico, M. and Tyley, S., *Annual Report (DS1.1.3,3),* DANTE, GÉANT, 2012

eResearch2020 - The Role of e-Infrastructures in the Creation of Global Virtual Research Communities

ESF European Science Foundation (2011). *Research Infrastructures in the Digital Humanities*.

ESF European Science Foundation (2012). *Research Infrastructures in the European Research Area*. A report by the ESF Member Organisation Forum on Research Infrastructures.

ESFRI European Strategy Forum on Research Infrastructures, *Strategy Report on Research Infrastructures; Roadmap 2010, 2011*

ESFRI European Strategy Forum on Research Infrastructures, *Environmental Sciences Thematic Working Group Report 2010*, Brussels, 2011

ESFRI European Strategy Forum on Research Infrastructures*, European Roadmap for Research Infrastructures – Report 2006*, 2006

ESFRI European Strategy Forum on Research Infrastructures, *Physical Sciences and Engineering Working Group, Roadmap Working Group Report 2008*, 2008

ESFRI European Strategy Forum on Research Infrastructures, *State of Play of the Implementation of the Projects on the ESFRI Roadmap 2010*, European Union, 2012

ETP4HPC – European Technology Platform for High Performance Computing, *ETP4HPC Strategic Research Agenda Achieving HPC leadership in Europe*, 2013

European Commission, Consultation on possible topics for future activities for integrating and opening existing national research infrastructures, Assessment report, DG Research & Innovation, 2013

European Commission, *Enabling Science: EU Support to Research Infrastructures in the Life Sciences*, DG Research and Innovation, 2013

European Commission, *High-Performance Computing: Europe's place in a Global Race Brussels*, COM(2012) 45 final

European Commission, *ICT Infrastructures for e-Science*, COM(2009) 108 final

European Commission, *Industry and Innovation in e-Infrastructures for Horizon 2020*, Report on the Consultation Workshop, DG Information Society and Media, 2012

European Commission, *Life Sciences and Biotechnology – A Strategy For Europe*, COM(202) 27

European Commission, *Research Infrastructures for Industrial Innovation, Workshop*, DG Research, 2011

European Commission, *Revision of the state aid rules for research and*

development and innovation, DG Competition, 2012

European Commission, *Riding the wave – How Europe can gain from the rising tide of scientific data – Final report of the High level Expert Group on Scientific Data*, 2010

European Commission, Self-Assessment of the Effectiveness of IST-RTD in the 6th FP - Ex-post Evaluation of the IST Research in FP6, European Commission, DG Information Society, 2007

European Commission, *Work Programme 2012 – Capacities – Part 1: Research Infrastructures*, C(2011)5023, 2011

European Telescope Strategic Review Committee, Report on Europe's 2-4m telescopes over the decade to 2020, 2010

GRDI 2020 – Towards a 10-year Vision for Global Research Data Infrastructures, *GRDI2020 Final Roadmap – Global Research Data Infrastructures: The Big Data Challenges*, DG Research, 2012

Grid4Life, *Richtlinien zur Förderung von Forschungsvorhaben auf dem Gebiet „Grid-Dienste für Wirtschaft und Wissenschaft"* (Förmlicher Förderantrag), 2008

Horlings, E., Gurney T., Somers, A., van den Besselaar P., The societal footprint of big science, Rathenau Instituut Working paper 1206

House of Lords Select Committee on Science and Technology, *Scientific infrastructure. Call for Evidence*, 2013

Information Society Research and Innovation: Delivering results with sustained impact - Evaluation of the effectiveness of Information Society Research in the 6th Framework Programme 2003-2006, European Commission, DG Information Society & Media, 2008

International Data Corporation (IDC), *A Strategic Agenda for European Leadership in Supercomputing: HPC 2020*, 2010

International Data Corporation (IDC), *Financing a Software Infrastructure for Highly Parallelised Codes*, 2011

Inventory of existing PA-RIs cooperation, OSIRIS - Towards an Open and Sustainable ICT Research Infrastructure Strategy , European Commission, DG Information Society & Media, 2011

Kleiner, B., Renschler, I., Wernli, B., Farago, P. and D. Joye (Eds.). Understanding Research Infrastructures in the Social Sciences, Zurich: SEISMO.

Knowledge without Borders – GÉANT2020 as the European Communications Commons, Report of the GÉANT Expert Group, European Commission, DG Information Society & Media, 2011

Koski, K., *Material from Finnish datacenters* (PowerPoint Presentation)

Laure, E., The European e-Infrastructure ecosystem, The Connexions Project, 2009

Leon, G. et al., *A vision for strengthening world-class research infrastructures in the ERA*, Report of the Expert Group on Research Infrastructures, European Commission, 2010

Maatwerk in onderzoeksinfrastructuur – Strategisch investeren in grootschalige onderzoeksfaciliteiten, Adviesraad voor het Wetenschaps- en Technologiebeleid – AWT, 2013

Malawski, M. And Nowakowski, P., *Specification and Costs of Bought-in Requirements for Cloud Compute (WP2) and Data (WP3) Services (D2.5),* VPH

Share, 2013

Marechal, B., *White Paper on Lessons Learned*, CETA-CIEMAT, GISELA – Grid initiatives for e-Science virtual communities in Europe and Latin America, DG Research, 2012

Martin, B., Irvine, J., Spin-off from basic science: the case of radio-astronomy, Physics in Technology, Institute of Physics, Vol 12, No. 5, 1981

Matsuura, A.Y., Thrupp, N., Gonze, X., Pouillon, Y., Bruant, G. and G. Onida (2012). The ETSF: An e-Infrastructure that Bridges Simulations and Experiments. In: Computing in Science & Engineering, January/February 2012.

Ministry of Science, Research and the Arts of the state of Baden-Württemberg, *Response of Baden Württemberg to Consultation on the Review of the EU state aid rules for research, development and innovation (R&D&I)*, 2012

Moulin, C., Ciula, A., Nyhan, J. et al. (2011). Research Infrastructures in the Digital Humanities, ESF 42 Science Policy Briefing, September 2011, Strasbourg: ESF.

OECD (2013). New Data for Understanding the Human Condition. Paris. OECD.

OECD GLOBAL SCIENCE FORUM Report of the Workshop on Large Facilities for Studying the Structure and Dynamics of Matter Copenhagen, 20 - 21 September, 2001

OECD Global Science Forum, Report of Roadmapping of Large Research Infrastructures (2008) and Report of Establishing Large International Research Infrastructures: Issues and Options (2010)

OECD Global Science Forum, Report on Roadmapping of Large Research Infrastructures, December 2008

Ostasz, M. And Rerquena, S., *PRACE Integrated HPC Access Programme for SMEs (D5.2)*, DG Research 2013

President's Council of Advisors on Science and Technology, *Sustaining Environmental Capital: Protecting Society and the Economy,* 2011

Renschler, I., Kleiner, B. and B. Wernli (2013). Concepts and key features for understanding social science research infrastructures. In: Kleiner, B, Renschler, I., Wernli, B., Farago, P. and D. Joye (Eds.), Understanding Research Infrastructures in the Social Sciences, Zurich: SEISMO, pp.11.18.

Requena, S., et al., *10th e-Infrastructure Concertation Meeting - PRACE: How e-research infrastructures can catalyse European industrial competitiveness*, 2013

Sanderson (2007). Smart networking. In: Nature (News article in the Business section), Vol.450, 6 December 2007.

Science.Business, *Supercomputer for all. The next frontier for high performance computing*. *Special Report*, 2013

Stahlecker, T., Kroll, H., Policies to build RI in Europe – Following traditions or building new momentum?, Fraunhofer ISI Working Paper, R4/2013

The business models for ICT Research Infrastructures, Analysis and Conclusions regarding Public Authority — Research Infrastructure Interaction, Report of the project 'Towards an Open and Sustainable ICT Research Infrastructure Strategy – OSIRIS', DG CNECT, 26/07/2012

The effectiveness of the Design Studies and Construction of New Infrastructures support schemes under the Sixth Framework Programme for Research, European Court of Auditors, Special Report No 2 /2010

The Research Infrastructure Information Base in Europe – Summary of the

Roundtable Debate of 6 November 2013, MERIL

Thiel, R. et al., Deliverable on Evaluation and Exploitation (D7.1), VPH Share, 2012

Timo Leimbach (Fraunhofer ISI) Simone Kimpeler (Fraunhofer ISI) Mickael Pero (Fraunhofer ISI) Irene Bertschek (ZEW) Daniel Cerquera (ZEW) Benjamin Engelstaetter (ZEW), Development of impact measures for e-Infrastructures, European Commission Information Society and Media Directorate General, 2012

Transnational Coordination of European Research Infrastructures, Committee for Research Structure of the Class for Physics, Royal Swedish Academy, 2012

United Nations: Convention on biological diversity. Rio de Janeiro, 5 June 1992

Van de Sanden, M. et al., EUDAT Early Candidate Services (follow up) (D5.2.2), EUDAT – 283304, 2013

Van der Graaf, M. And Waaijers, L, *A Surfboard for Riding the Wave. Towards a four country action programme on research data. A Knowledge Exchange Report*, Knowledge Exchange, 2011

Van der Hoeven, J., *Insight Report*, PARSE.Insight – INSIGHT into issues of Permanent Access to the records of Science in Europe, Thaesis, 2010

Veronica Willmott, *ERICON Science Perspective 2015-2030*, Alfred Wegener Institute for Polar and Marine Research

Vught, Frans Van (2011). *Synergies between FP7, the CIP and the Cohesion Policy Funds Final report of the Expert group*. Directorate-General for Research and Innovation Directorate C – Research and Innovation Unit C.5 — Regional Dimension of Innovation

Wittenburg,P. And Willem, E., *Data Management Landscape Characteristics and Community Requirements (D.4.1.2)*, EUDAT – 283304, 2013

Working document of the commission services on synergies between Horizon 2020 and Cohesion Policy funds. Multiannual Financial Framework 2014-2020, Fiche no. 28. 22 March 2012.

Zuijdam, F. et al. (2011.) *The role and added value of large scale research facilities.* Report to the Netherlands Ministry of Education, Science and Culture, Amsterdam: Technopolis, 2011

Appendix B - List of experts and interviewees

The study team thanks the experts and participants in the programme that supported us in the study. These included:

Experts	Name & surname	Organisation
Methodology experts	Costas Fotakis	Foundation for Research and Technology-Hellas (FORTH)
	Kate Barker	University of Manchester, MIoIR
	Michael Stampfer	Vienna Science Research & Technology Fund (WWTF – A)
	Terttu Luukonen	The Research Institute of the Finnish Economy (ETLA – FI)
Field experts supporting the analysis at thematic area level	André Faaij	Utrecht University (NL)
	Claudine Moulin	Universität Trier (DE)
	Costas Fotakis	IESL, FORTH (GR)
	Elisabetta Borsella	ENEA (IT)
	Ferenc Hudzek	Eötvös L. University (HU)
	Hansjörg Hauser	HZI Braunschweig (DE)
	Jean-Claude Guédon	University of Montreal (CA)
	María José Carroquino	Instituto de Salud Carlos III (ES)
	Martin Claude	Directeur de recherche CNRS (FR)
	Michael Schultz	formerly NERC (UK)
	Konstantin Arutyunov	University of Jyväskylä (FI)
	Rob Fender	University of Southampton (UK)
	Robin Arak	Archway Engineering Limited (UK)
	Stefan Wesner	High Performance Computing Centre Stuttgart (DE)
	Zarifah Reed	Sentinext (FR)
Participants in the workshop	Abad Chabbi	INRA, France
	Alison McDonald	Digital Archiving Consultancy Limited
	Eeva Ikonen	Academy of Finland
	Ekkehard Mochmann	
	Giorgio Rossi	Laboratorio Nazionale TASC, INFM-CNR
	Heikki Sundquist	Finnish National Bank
	Juliane Jarke	Lancaster University Management School, UK
	Leif Laaksonen	CSC - Scientific Computing Ltd., Finland
	Luc Paques	INRA, France
	Luis Magalhães	Technical University of Lisbon, Portugal
	Mariell Juhlin	Ramböll Management Consulting
	Norbert Meyer	Poznan Supercomputing and Networking Center
	Peter Elias	University of Warwick, UK
	Richard Wade	Science & Technology Facilities Council, UK
	Robin Arak	Archway Engineering (UK) Limited
	Vassilis Maglaris	NTUA, Greece

Interviewees	Name & surname	Organisation
Environmental sc., earth sc. & energy	Alistair Culham	University of Reading
	Antonio Parodi	CIMA research foundation
	Bryan Lawrence	University of Reading
	Chris Edwards	STFC
	Christoph Waldmann	Marum
	Dario Papale	university of tuscany
	David Giaretta	Science and Technology Facilities Council. Alliance for Permanent Access (UK)
	David Gochis	University of Carolina
	Francois Amiranoff	CNRS
	Hank Loescher	NEON inc.
	Isabel Oller	CIEMAT – Plataforma Solar de Almeria (ES)
	Jean Louis Brenguier	Metéo France
	Jörn Thiede	Alfred Wegener Istitut,
	Jose Manuel Perlado	Universidad Politecnica de Madrid
	Leonard Rivier	Institut Pierre-Simon Laplace
	Markus Döring	Global Biodiversity Information Facility
	Michael N. Fardis	Univ. of Patras, (GR)
	Nicole Biebow	Alfred Wegener Institut
	Peter Baumann	Jacobs University Bremen
	Vincent Robert	KNAW
	Zoran Rakicevic	Institute of Earthquake Engineering and Engineering Seismology, IZIIS (MK)
Life sciences	Alexandre Bonvin	Utrecht University
	Claudio Luchinati	University of Florence
	Federica Tanlongo	GARR - The Italian Research and Education Network
	Frank de Man	EATRIS Office
	Frederik Lantier	Institut national de la recherche agronomique
	Georges Dagher	INSERM
	Gerjan van de Walle	Philips Innovation Services
	Giovanni B. Frisoni	Vice Scientific Director
	Guus van Dongen	VU university medical center
	Hans van Zonneveld,	Philips Research
	Jan Van Den Biesen	Philips Research
	Jan-Eric Litton	Karolinska Institutet
	Janet Thornton	European Molecular Biology Laboratory
	Johannes Janssen	DFG German Research Foundation
	Klaus Lindpainter	Thermo Fisher Scientific
	Kurt Zatloukal	Medical University of Graz
	Mahavir Singh	LIONEX Diagnostics & Therapeutics GmbH
	Marián Hajdúch	Institute of Molecular and Translational Medicine (IMTM)
	Mark Palmer	Medical Research Council
	Niels Kramer	Philips Innovation Services
	Odile Leroy	European Vaccine Initiative
	Paul Kersey	European Bioinformatics Institute, EMBL
	Stephanie Suhr	European Molecular Biology Laboratory
	Veronika Paleckova	The Academy of Sciences of the Czech Republic
Material sc. &	A. A. Fotiadi	Université de Mons - Faculté Polytechnique, Belgium

Interviewees	Name & surname	Organisation
analytical facilities	Anthony R. Flambard	Organisation Julich - Division `New Materials and Chemistry`
	Claes-Göran Wahlström	Lunds Universitet, Sweden
	Dieter Schinzer	Otto von Guericke University of Magdeburg, Germany
	Dominic Tildesley	CECAM (Centre Européen de Calcul Atomique et Moléculaire), France.
	Frank Vork	Philips Innovation Services, The Netherlands
	Giovanni Onida	University of Milan, Italy
	Oldrich Renner	Institute of Physics of the Academy of Science, Czech Republic
	Pablo Garcia-Gonzalez	The National Distance Education University (UNED), Department of Fundamental Physics, Madrid, Spain
	Susan Anson	Karlsruhe Institute of Technology (KIT)
	Thanos Stubos	National Research Centre Demokritos in Athens (GR)
Physics & astronomy	Bruno Leibundgut	ESO
	Gerry Gilmore	University of Cambridge
	Ian Lishman	CERN
	Janet Seed	STFC, UK
	Johannes Andersen	Copenhagen University
	Johannes Andersen	Nordic Telescope Scientific Association (NOTSA)
	Micahel Krisch	ESRF
	Petros Rapidis	Demokritos national center for scientific research
	Robert Jones	CERN
	Sergio Bertolucci	CERN
	Svetlomir Stavrev	CERN
	Wilfried Boland	NOVA
Social sc. & humanities	Alice Dijkstra	The Netherlands Organisation for Scientific Research
	Antonella Fresa	Instituto Centrale per il Catalogo Unico delle biblioteche Italiane e per le informazione bibliografiche
	Axel Borsch-Supan	Max Planck Institute for Social Law and Social Policy
	Brunetto Brunetti	University of Perugia
	Claude Martin	University of Rennes / EHESP
	Claudine Moulin	Universitaet Trier FB II
	Dieter van Uytvanck	Max Planck Institute for Psycholinguistics Nijmegen
	Gregor Petric	University of Ljubljana, Faculty of Social Sciences, Slovenia
	Max Kaase	Jacobs University Bremen
	May Cassar	University College London
	Melissa Terras	University College London
	Nikolaus Himmelmann	University Cologne
	Peter Farago	University of Lausanne
	Pierre Mounier	Ecole des Hautes Etudes en Sciences Sociales, Paris
	Renee van Kessel	The Netherlands Organisation for Scientific Research
	Silke Schneider	Leibniz Institute for the Social Science (GESIS)
	Steven Krauwer	Utrecht University
Horizontal e-Infrastructure services	Jack Dongarra	EECS Department; University of Tennessee
	Alberto Masoni	INFN (Italian National Institute of Nuclear Physics), Calgiari
	Andrew Treloar	ANDS
	Annaïg Le Guen	Genci
	Bernard Marechal	CIEMAT
	Cathrin Stover	Dante
	Damien Lecarpentier	CSC

Interviewees	Name & surname	Organisation
	Depei Qian	Sino-German Joint Software Institute, Beihang University, Beijing
	Erwin Laure	Computing centre Stockholm
	Florencio Utreras	RedClara
	Gary Grider	Los Alamos National Laboratories
	John Chevers	Dante
	Kimmo Koski	CSC
	Ludek Matyska	CESNET and Masaryk University, CZ
	Mark Parsons	EPCC, The University of Edinburgh
	Michael Resch	University of Stuttgart, High Performance Computing Center
	Peter Wittenburg	Max Planck Institute for Psycholinguistics
	Sanzio Bassini	Dipartimento SuperCalcolo, Applicazioni ed Innovazione, CINECA
	Sebastian Semmler	TMX
	Sergi Girona	Barcelona Supercomputing Center
	Tiziana Ferrari	EGI.eu
Policy coordination & support	Gonzalo Leon	Polytechnic University of Madrid, Spain
	Janet Thornton	EMBL-EBI UK
	Johannes Janssen	Deutsche Forschungsgemeinschaft
	John Marks	European Science Foundation, ESF
	Patrick J.C. Aerts	Nationaal eScience Centre
	Peter Fletcher	STFC
	Simon JE Taylor	Brunel University
	Tiwonge Msulira Banda	UBUNTUNet Alliance