EUROPEAN COMMISSION / European Research Area / Research Infrastructures

A vision for strengthening world-class research infrastructures in the ERA

Report of the Expert Group on Research Infrastructures

Research Policy

Interested in European research?

Research*eu is our monthly magazine keeping you in touch with main developments. It is available in English, French, German and Spanish. A free sample copy or free subscription can be obtained from:

European Commission
Directorate-General for Research
Communication Unit
B-1049 Brussels
E-mail: research-eu@ec.europa.eu
http: //ec.europa.eu/research/research-eu

European Commission

Directorate-General for Research
Directorate B – European Research Area: Research Programmes and Capacity
Unit B.3 Research Infrastructures

Contact: janine.delahaut@ec.europa.eu

http://ec.europa.eu/research/infrastructures

EUROPEAN COMMISSION

A VISION FOR STRENGTHENING WORLD-CLASS RESEARCH INFRASTRUCTURES IN THE ERA

Report of the Expert Group on Research Infrastructures

European Research Area

2010

EUR 24186

EUROPE DIRECT is a service to help you find answers to your questions about the European Union

Freephone number (*):
00 800 6 7 8 9 10 11

(*) Certain mobile telephone operators do not allow access to 00 800 numbers or these calls may be billed

Luxembourg: Publications Office of the European Union, 2010

ISBN: 978-92-79-14214-7
DOI: 10.2777/79690

Printed in Belgium
Printed on white chlorine-free paper
European Commission

PREFACE

Research infrastructures (RIs) lie at the heart of the knowledge triangle – the beneficial combination of research activity, specialised education/training and innovation that advances our knowledge and understanding across all scientific domains. European research infrastructures are the large-scale or singular facilities, scientific instruments, distributed facilities and interconnected networks, funded by Member States and supported by Community budget of the European Union and shared widely within and between scientific research communities.

The processes of identifying, funding, designing, developing, constructing, managing and sharing such infrastructures are complex and costly. Yet the efficient and timely realisation of all these processes is vital to the healthy development and more rapid implementation of the European Research Area (ERA). It is for this reason that the European Commission established an Expert Group to review the current situation and to make recommendations that will assist, improve and hopefully accelerate these processes. This work is also based on the analysis of the evolution of conclusions and recommendations of the first Expert Group published in 2008 by the EC and the conclusions and debate on RIs during the ERA Conference last 21-23 October, 2009.

In my role as the Chair and on behalf of this Expert Group, we put forward in this report a wide range of recommendations for consideration by the variety of agencies that have an interest in promoting European research infrastructures within the ERA. These include, amongst others, the Council of Ministers, the European Commission, the European Strategy Forum for Research Infrastructures (ESFRI), the ministries in Member States in charge of RIs, higher education institutions with research interests, existing research infrastructures and, of course, the scientific research communities themselves.

We title our report *A vision for strengthening world-class research infrastructures in the ERA*. This reflects the fact that, in the course of our work, the members of the Expert Group developed views of the evolution of the ERA and used these to guide our recommendations. To illustrate these we place some imagined headlines at the front of a number of chapters of this report. These may currently appear to be distanced from reality, but we include them to indicate what might be achieved if our recommendations for strengthening the ERA are realised.

On behalf of all members of the Expert Group I would like to thank Hervé Pero, Christos Profilis, Konstantinos Glinos and Kyriakos Baxevanidis from the European Commission, and Carlo Rizzuto as chair of ESFRI for their support and help during these months.

Gonzalo Leon
Chair, Expert Group on Research Infrastructures

CONTENTS

EXECUTIVE SUMMARY

Introduction

Building on the work of a first Expert Group and their report which was published in March 2008[1], the European Commission established a second Expert Group to review and re-examine the role of research infrastructures (RIs) within the European Research Area (ERA). While some of the recommendations proposed by the first Expert Group have now been implemented, several require additional attention. This report provides further recommendations for developments and improvements, organised into the following areas:

- research infrastructures, global challenges and internationalisation;
- the role played by RIs in strengthening research capacity within the ERA;
- prioritisation procedures;
- decision-making, funding and governance processes;
- e-infrastructure and access;
- the legal framework; and
- evaluation and impact assessment.

There is a wide range of research infrastructures across Europe. As well as those listed within the ESFRI[2] roadmap there are many others, often identified in national roadmaps or previously recognised by national agencies, that are key to the framework of the ERA. Research infrastructures play a crucial role in developing and maintaining the ERA. Support for a deeply connected and extensive implementation and use of e-infrastructure and data access is central to this role.

The Expert Group developed a vision for 2020 on the status, role and scientific impact of RIs in relation to the evolution of the ERA. This can be characterised via two scenarios which span a spectrum of possible futures. We term these '**Europe lacking a consistent approach**' on the one hand and '**Europe's new renaissance**' on the other. The boxed descriptions overleaf outline these scenarios in broad terms. The former equates in many respects with the ***status quo*** or, at least, the situation likely to prevail in 2020 if no further actions are taken to promote a more energetic approach to the issues we address in this report. Some might argue that the latter scenario is naïve. Nonetheless, we adopt this as the research landscape we target, being convinced of the value of that scenario to improve European competitiveness.

The role that research infrastructures play in supporting the development of the ERA will depend on the future scenario. The analysis and recommendations included in this report were written taken into account the need to move towards scenario 2, with a pragmatic approach to the practical difficulties and political problems that must be addressed along the way. Recognising the obstacles that block the path between these two scenarios helps identify the actions to be undertaken by those agencies that have a stake in the promotion and development of research infrastructures. Some of the recommendations we make for actions are quite specific whereas others are intended to promote debate and will require further exploration, elaboration and negotiation before they can be implemented. All are important in maintaining the momentum needed to create the necessary conditions for world-class research and innovation throughout the European Union (EU) and beyond its borders.

1 See *http://ec.europa.eu/research/infrastructures/pdf/ri_era-expert-group-0308_en.pdf*.

2 The European Strategy Forum for Research Infrastructures (see *www.cordis.europa.eu/esfri/*).

Scenario 1: Europe lacking a consistent approach…

Although many universities and research centres across Europe are recognised at world level and some regional clusters of these are at the highest level of scientific and technological competitiveness, the European Research Area remains fragmented. The efficiency of research investments benefits some Member States, which are able to develop international alliances, but political motives of Member States weigh heavily in investment decisions. Consequently there is overlap between different entities, and the overall effectiveness of the ERA is weak. The development of ERA is largely unbalanced across Europe and some sign of 'brain drain' is appearing or increasing in some countries.

Scenario 2: Europe's new renaissance…

The need to promote an integrated approach to research as a key European policy has been embraced by political leaders and policy makers. As a result, increasing research funds, pooling of resources between all Member States, new financial engineering approaches to combine various funding sources and effective ERA governance, have worked to generate effective, efficient, focused and highly complementary research investments. The subsequent boost to research capacity, reinforced by productive circulation of knowledge, talented researchers and skilled technologists and engineers is generating wide and long-lasting benefits for the economy and society and has increased cohesion among Member States.

AREA 1 | Research infrastructures, global challenges and internationalisation

For the EU global challenges are important drivers for the identification, construction and operation of large research infrastructures, both single-sited and distributed ones linked by high-speed networks for optimal sharing of data and resources. These challenges include climate change and carbon emissions, energy resources and their secure supply, viral pandemics and trends in non-communicable diseases, food security, the consequences of the ageing population, biodiversity, global security and economic interdependences. Additionally, the quests for knowledge at both the sub-atomic and astrophysical levels and on the nature of life play a major role in determining and shaping the demand new research infrastructures.

The scale of these challenges is such that they require research infrastructures which are often beyond the resources available at national or regional levels. They require collaborations which involve the very best scientific expertise in the world. They provide the platforms which bring together human and other resources, from wherever they are located, to address research issues that cannot be tackled by one or two Member States or regions alone.

Recommendations

- In order to promote global research infrastructures the linkage between the ESFRI roadmap and non-European or international roadmaps needs to be developed further. Non-European partners should be considered in the ESFRI activities as potential partners of RIs with provisions to participate in some of the ESFRI discussions.
- Member States and the European Commission, supported by relevant expert groups should give special consideration to the development and/or extension of reciprocal agreements facilitating use of non-EU research infrastructures by the EU research community and vice versa.
- International collaboration in developing, deploying, operating and strengthening interoperability on e-infrastructures should be further promoted. Such infrastructures enable the establishment of virtual research environments and promote world-wide access leading to productive research collaborations and a higher quality of results.

» An appropriate forum, set-up at international level, should be able to assess global research infrastructures and their strategic relevance in a world-wide context. There is a need for clear and unambiguous representation of pan-EU interests in RIs in this forum. This would be more than a 'voice for European RIs'; it would provide a vital link between non-EU partners and their European counterparts.

AREA 2 | Research infrastructures and their role in strengthening research capacity within the ERA

'Research capacity' must be interpreted within the context of research requirements. It describes the potential that arises via the combination of scientific knowledge, technological expertise, managerial skills and other human and physical resources to address specific research questions. Within the ERA it refers to the need to combine these elements in ways which facilitate collaborative efforts by all Member States to promote effective, efficient and ground-breaking research.

Today there are relatively fewer researchers in Europe than in Japan or the USA. Most countries are experiencing a shortage of scientists and engineers that may have harmful consequences in the long run for the advancement of the knowledge society. In this context, research infrastructures have the ability to create rich research environments and attract and retain researchers and experienced engineers/technologists from different countries, regions and disciplines. The construction and operation of effective and timely research infrastructures is one important part of the process of building research capacity. They also provide the 'nuclei' for skills and knowledge formation, either via the centralisation of such skills or through networked collaboration between researchers by emphasising multidisciplinary teams. Training of researchers and engineers through experience with RIs is an integral part of this research capacity building process.

Recommendations

» New approaches to European wide collaboration in constructing and using research infrastructures with active inclusion of the smaller EC countries and new Member States should be established. These could include targeted schemes for researcher mobility and the promotion of access regimes which favour new and/or small Member States. Developing distributed pan-European RIs, e-infrastructures and related services or adding these capabilities to pre-existing facilities can be used as a tool for building an efficient and effective ERA with contributions from all Member countries.
» More support should be given by Member States to the development of 'Regional Partner Facilities '(RPFs) as a useful way of building capacity and encouraging balanced development throughout Europe. Additionally, Member States and the European Commission should consider developing new models (financial, including new EC Financial Perspectives and Financial Regulations; legal; etc.) for funding RIs, taking into account the non-economic character of research (in particular investments in their construction/upgrade); this would stimulate regional development and facilitate better access to available funds (e.g. the Community Framework Programmes, Structural Funds or European Investment Bank).
» Fostering human resources is key to the efficient operation and the long term vitality of RIs. Steps should be taken to ensure continuity of accrued employment benefits for mobile researchers and experienced engineers and to promote management skills.

- The close relationship between universities and RIs contributes to an effective educational and scientific ecosystem, which can be attractive and supportive for industry. A significant increase in research funding across the EU would require a concomitant increase in the output of trained researchers from the higher education sector, and RIs can contribute to this effort, helping provide multidisciplinary training needed by the industry and to tackle the grand challenges. Better interaction between European and national programmes, also covering the training of researchers through RIs, should be encouraged.
- Research infrastructures create 'knowledge factories' and have been shown to stimulate technological innovation deriving from the basic research they foster. The concept of a research infrastructure should evolve to encompass not only scientific but also technological developments, often within a multidisciplinary context. Their potential to stimulate innovation through IPR exploitation and 'spin-off' creation and the scope they offer for commercial exploitation of knowledge so generated should be encouraged, along with complementary reforms strengthening demand-led innovation and entrepreneurship.

AREA 3 | **Prioritisation procedures**

There is, at present, little or no coordination between Member States of the prioritisation procedures they employ to determine how limited national funds should be allocated to research infrastructures on their national roadmaps, either for new infrastructures or for the continuing support for existing RIs. Given that the major part of research infrastructure funding will be provided via Member States, harmonisation of prioritisation criteria and procedures is an obvious first step which should underpin national funding decisions.

We identified three different approaches to tackle this problem. The first approach would be to develop the prioritisation process within the aegis of ESFRI. There is some merit in such an approach, given that ESFRI is already tasked to draw up the European roadmap for research infrastructures. The use of ESFRI working groups to identify priorities within specific science domains should be consolidated although it does not solve the prioritisation problems across domains and the subsequent decision making. A second approach would be to designate the European Commission as an 'honest broker' charged with aiding and assisting Member States with the process of prioritising research infrastructures or, at least, facilitating the harmonisation of prioritisation procedures used by Member States. Prioritisation is a politically sensitive process, with Member States seeking to link the funding of research infrastructures with decisions on their location and industrial capabilities. For this reason, we can also envisage a third approach – the creation of a separate entity, reporting to the European Council, charged with responsibility for the coordination and harmonisation of the prioritisation procedures to be adopted by one or several Member States in a later stage. This would complement the work of ESFRI in this area.

Recommendation

- We recommend that ESFRI analyse more in depth the need to prioritise research infrastructures across scientific domains and consider these and other possible ways of mitigating the problems by proposing an adaptation of its mandate or the creation of a separate entity to the Council of Ministers.

AREA 4 | Decision making, funding and governance processes

For large-scale research infrastructures, whether single-sited or of distributed nature, many different funding schemes may be used to facilitate the construction and operational phases. It is important to combine different sources of funding and to develop governance processes and management structures in ways which provide both single-sited and distributed RIs with the flexibility to respond to evolving research, innovation and educational challenges.

Recommendations

- Partial 'Europeanisation' of national or regional facilities should be supported. This process should be implemented as an open process promoted by the EU (e.g. via the ERIC regulation) with explicit proposals from affected Member States, in connection with the implementation of the Regional Partner Facilities. The networking of national facilities should be explicitly promoted.
- The use of varied national and international sources of funding for the construction and/or operation of RIs is termed 'variable geometry funding'. In applying the variable geometry approach, better coordination in the implementation of European, national and international roadmaps is needed. Non-European partners could be involved in these variable geometry configurations if applicable. This would ensure better coherence and complementarity in research infrastructure implementation and major upgrading.
- Funding in general and in particular funding of 'open access' operations (see Area 5 overleaf) could become increasingly difficult, as countries cut national budgets following the boost in public spending to aid recovery between 2009 and 2011. This makes it imperative that the strongest possible case should be made to stress the pivotal role played by RIs in maintaining/improving the overall quality of the EU research system, to ensure future economic and social development and wellbeing.
- Specific European instruments are needed in addition to intergovernmental approaches and Framework Programmes. Possibilities include Joint Programming, the development of Public-Private Partnerships, Joint Technology Initiatives and the use of ERA-NET+. Structural funds also constitute a relevant funding source for the construction of research infrastructures. Future regulation for structural funds could support enhanced programmes for research infrastructures (i.e. on enhanced inter-territorial cooperation focused on RI) both for ERDF and ESF funds.
- The EC and ESFRI should promote the development of more industrial-oriented research facilities, via greater involvement of the private sector and by giving a role/voice to industrial associations. The potential for European charities and foundations to become involved in the construction or operation of pan-European RIs could be explored and promoted through fiscal measures and other schemes.
- On issues related to governance, during the preparatory phase in the development of new or upgraded research infrastructures, careful consideration should be given to preliminary analysis of the governance structure and management scheme (both during the construction and operation phases). Likewise, economic sustainability, risk assessment, transparency and accountability, are all important and should be considered in addition to legal and financial issues.
- On issues related to management, it is recommended that further optimisation of the use of research infrastructures could be achieved by enhancing cooperative and remote operation tools based on e-infrastructures.
- As plans for the next Framework Programme evolve, the creation of a specific 'European Fund for Research Infrastructures' should be considered within the framework of these discussions.

AREA 5 | e-Infrastructure and access

The development and management of access arrangements to RIs, either for their operation or for sharing of their research functions, is critical to their value as research resources. The full spectrum of e-infrastructure, including computing, data, networks, software and related competences, has to be supported in a balanced way to achieve efficiency in building the ICT ecosystem supporting access to RIs and sharing their research functions. Closer collaboration between research communities and providers of e-infrastructure and related services needs to be promoted. The mode of operation has to move from project based activities towards a sustainable model with guaranteed resource and service development to make the long-term commitment attractive for research groups.

Recommendations

- Open peer-reviewed access to RIs promotes competition and enhances the international reputation of the ERA as a research friendly environment. However, such access brings with it additional costs which must be recognised as fundamental to the operation of RIs.
- Methods to promote resource exchanges and pooling among Member States should be piloted. Concepts to utilise existing resources more efficiently by sharing critical or unique resources at pan-European level will be important in this respect.
- To achieve these objectives (open access and resource exchange/pooling), emphasis should be placed on the development of integrated e-infrastructure based services (e-Science services) for researchers, addressing common needs of different scientific communities and enabling the sharing of resources among them.
- e-infrastructure expertise provided by e-IRG should be available for ESFRI. Given that e-infrastructure pervades all aspects of the construction, operation and management of RIs, there is a clear need to forge a much closer working relationship between these two bodies.
- A specific focus should be placed on managing and developing data infrastructures and expertise. Efficient trans-European access to online content should be taken into account when developing the processes. Collaborations addressing multidisciplinary data management challenges that would benefit from synergy should be promoted.
- Software development and deployment will play a central role in the efficient development and use of e-infrastructures. In this context new and multidisciplinary collaborative actions should be promoted, both for stimulating scalable application development for various scientific domains and for developing efficient middleware addressing outstanding issues with regard to authentication, accountability and security.
- Concerning the critical area of High Performance Computing resources, the pooling of Member State and EC research investments will strengthen the position of European industry and academia in the use, development and manufacturing of sustainable and greener computing technologies and services.

AREA 6 | The legal framework

To further the development of the ERA, a beneficial legal environment is a key requirement. Such an environment facilitates the progress of research actions, aids in attracting scientists and researchers, smoothes the innovation process and offers appropriate protection to intel-

lectual property rights. Until 2009, the legal framework at European level was fragmented. The development of the ERIC regulation now allows for the emergence of favourable conditions for the incorporation of collaborative projects for research infrastructures of pan-European interest, although existing legal frameworks will continue to be used. Future progress, particularly in the field of public-private partnership should complement this legal development, allowing better support for technological innovation-related projects.

Recommendations

- In developing and using world-class research infrastructures, one of the major aspects to take into account is the protection of Intellectual Property Rights. The Commission should therefore take great care of reinforcing this aspect in the implementation of ERIC through specific guidelines.
- ERICs should be fully accessible across the ERA and utilised efficiently to promote mobility and the training of researchers, thereby increasing their attractiveness and strengthening the ERA. Further consideration must be given to the need to facilitate and promote the mobility of technological and managerial expertise between RIs across the ERA, particularly with respect to the relative attractiveness of careers and the consequences of a lack of cross national mobility for career development.
- Non-European partners may have difficulties in using the ERIC framework as the basis of a legal agreement. Further monitoring of this aspect of the new regulation is recommended.
- The development of research test facilities at European level and sharing RIs for scientific and industrial use might require the setting-up of a specific new legal framework or extension of the scope of the ERIC directive to facilitate the participation of the private sector.

AREA 7 | **Evaluation and impact assessment**

Decision makers need relevant information about the range of impacts (scientific, technological, economic, social and environmental) of existing and proposed RIs to underpin their funding decisions. Likewise, research infrastructure managers need to be fully aware of performance factors based on the evaluation of relevant indicators. While considerable efforts are currently being made by a number of bodies to establish more robust measures of impact, there is as yet no clear set of methodologies across the domains of interest to stakeholders. Nor is there any agreed set of measures at the EU level which constitute performance indicators for the evaluation of RIs.

Recommendations

- The different impact studies carried out at national and international level should be reviewed to strengthen the methods used to measure the scientific, social, economic, environmental impacts (both direct and indirect) of research infrastructures.
- Current efforts (e.g. ERAWATCH) should be extended in such a way that they assist with monitoring the evolution of RIs, principally by collecting relevant information for impact assessment in a harmonised manner.
- The concept of a 'common methodology' for impact assessment of RIs should draw on expertise developed in social, economic and environmental disciplines and will be multidisciplinary by definition and covering the whole ecosystem related to specific RIs.

- All RIs of European relevance should be committed to carry out periodical impact assessment exercises, monitored by external committees, to provide information about the way they fulfil their goals and serve societal demands. The European Commission and/or ESFRI should gather and publish the results.
- The different dimensions of the management of the RIs should be assessed, such as overall governance of the facilities, financial practices, management of human resources, innovation policy, intellectual property rights, etc. This should be designed to generate an agreed set of performance indicators.

1. RESEARCH INFRASTRUCTURES, GLOBAL CHALLENGES AND INTERNATIONALISATION

VISION 2025

Autumn 2025… High level representatives from Australia, Brazil, China, the European Union, India, Russia, South Africa and USA met recently in Brussels to discuss the implementation of the major research infrastructures, which were decided at the G8 + 5 meeting held in Washington in spring 2023. They expressed their satisfaction with the development of the new facilities, which will in the near future increase the support to needed new research to face the common health, environmental, and societal challenges at world level. The total investment for these new research facilities amount to €10 billion, with a running cost of €1 billion per year, shared by the different regions on the basis of their GDP (revised formula in 2020).

1.1 Introduction

The term 'research infrastructures' refers to facilities, resources or services of a unique nature that are needed by the scientific and technological communities to conduct basic or applied research in the whole range of scientific and technological fields. This definition includes the associated human resources and covers:

- major equipment or group(s) of related instruments used for research purposes;
- knowledge based-resources such as collections, archives, structured information or systems related to data management, used in scientific research;
- information and communication technology-based infrastructures such as grid computing, networks and communications.

Research infrastructures may be 'single-sited' physical facilities (a single resource at a specific location), 'distributed' (a network of distributed resources), or both (e.g. where 'virtual' access to a core facility is provided electronically). These include inter alia: large-scale research instruments; 'test-bed' facilities; collections; depositories, public repositories, libraries; databases; biological archives; clean rooms; high-speed communication networks; networks of computing facilities; research vessels; satellites and aircraft observation facilities; coastal or natural observatories; telescopes; fusion energy demonstrators; synchrotrons; neutron sources and particle accelerators.

Large-scale research infrastructures are defined as those facilities with many or all of the following features: large research capacity, trans-national relevance, requiring sizeable investment and, generally, having high operating costs. They may be unique or rare, and have a consequential impact on science and research at both the global and European level.

By offering unique research services and attracting young people to science and through networked facilities, research infrastructures help structure the scientific community and therefore play a key role in the construction of an efficient research and innovation environment. Because of their ability to assemble a 'critical mass' of people and investment, they carry out cutting-edge research, thus contributing to national, regional and European economic development. They are also influential in attracting the best researchers from around the world and in building bridges between national and research communities and scientific disciplines.

1.2 Global challenges and research infrastructures

The realisation of the European Roadmap for the Research Infrastructures is of outmost importance within the process of the implementation of the 2020 Vision for the European Research Area (ERA). In view of the globalisation of research and the emergence of new scientific and technological powers China and India, we urgently need to speed up, and, to that end, incentivise, the construction of a new European research area. It is very important that we ensure as soon as possible that the European Union is an area in which researchers, technologies and knowledge can move freely, where there is effective coordination of research activities and where the best possible use is made of resources. This requires, amongst other things, that we have large research infrastructures at the European level.

Across all scientific disciplines, research activity increasingly involves international collaboration, either because of the need to pool knowledge and share large-scale research infrastructure or through the very nature of the research challenges being addressed. Global research challenges emanate from problems and issues that have a world-wide impact and are recognised across nations as major scientific issues. They are of a scale or complexity that goes beyond the reach of most national resources and have to be addressed on the global level. Europe is well positioned to either take or to share leadership with other nations in addressing such challenges, or to provide the focus for relevant expertise and research infrastructure within a global network.

The following examples highlight some of these challenges and illustrate the variety of research infrastructures required to address them.

Climate change is one of the major global challenges at the forefront of scientific and political debates. The predicted temperature rise will lead to changes in precipitation patterns, reduction of glaciers and polar sea ice and sea level increase. Global observations, combination of data from various sources, and modelling of the complex climate system are needed to address climate change questions. The required research infrastructures include sophisticated observation systems (e.g. satellites, ships, terrestrial and marine long-term observatories), world data bank systems and super computers.

Sufficient, secure and sustainable energy supply is the key to a secure future. The pending crisis of energy supply is rooted in the world-wide rising demand for energy and in the use of fossil fuels as primary energy sources. Anthropogenic CO_2 emission from burning of fossil fuels is a driving factor for future global temperature rise. Hence, efforts are being made world-wide to develop carbon-free or carbon-neutral energy

sources and to cover future energy demands in a sustainable way. These range from renewable energy supply via wind, solar, wave or tidal power to biomass or fusion technologies. While many technological developments in the area of renewable energy supply are of a smaller scale, the highly complex technology of fusion research needs international collaboration on a grand scale to build the major research infrastructures that are required.

Biodiversity is threatened all over the world by direct human impact and climate change. Loss or geographic shift of species can alter the structure and functioning of biological ecosystems and may have severe economic impacts in the long run. For such research a global net of regional observation sites, remote sensing and modelling is required. Large-scale experimental facilities to simulate future conditions assist the study of changes or adaptation to these conditions. Both large-scale experimental facilities and observation sites need to be installed in different climatic regions and linked by global research networks.

The *study of infectious diseases*, particularly of new strains of pathogens, is a response to a global threat that is enhanced by growing world-wide travel and trade. Examples like the pandemic flu outbreak highlight the danger to society and the need for global remedies. This type of global challenge requires distributed health observation sites, very efficient data and information exchange systems, as well as high security laboratory centres for molecular analysis, strain collections and common databases for molecular genetic data.

Population change, driven by changes in fertility, mortality and migration – which are linked to poverty, drought, disease or to wealth, abundant natural resources and health care – pose huge challenges to policy makers in terms of the provision of housing, transport, food, health and education services and security. The social and economic consequences of demographic changes, brought about by increases in longevity on the one hand and the rise in non-communicable diseases on the other, present policy makers with profound problems – requiring the very best evidence base that a global research agenda with shared access to large-scale data resources can provide.

A better understanding of the nature of *economic interdependencies* between nations and regions is crucial for the formation of global economic policies which can help prevent recession and promote sustainable economic development. The uneven nature of development in many countries also forms an impediment for the creation of political stability and global security. Much relevant information exists which can address these issues, yet the infrastructure required to gather and analyse this information is rudimentary.

Such issues are not the only drivers of the demand for international research collaboration and associated new or renewed large-scale research infrastructures. Some of the earliest research infrastructures which have facilitated international collaboration were astronomical observatories and particle accelerators. The quests for knowledge at both the sub-atomic and astrophysical levels and on the nature of life represent potent factors in determining the demand for research infrastructures that are hugely expensive to build, operate and maintain. Equally important is the need to provide and maintain the electronic communications and data transmission infrastructures that make possible global collaborations and the more efficient use of the research potential they offer.

1.3 Internationalisation and the demand for knowledge sharing

It is not simply the *global* nature of research challenges that has promoted a growing international research agenda. With the rise of international trade, increased economic interdependencies between countries and the continuing development of Information and Communications Technology (ICT), organisations and individuals around the world experience and create ways to attract and capitalise on internationally mobile technology and knowledge resources. Research infrastructures are instrumental in building long-term capacity and establishing unique regional advantages that can help attract mobile resources. The attractiveness of research infrastructure in a particular location may be boosted by linkages between researchers, innovators, entrepreneurs, financiers, and other actors and institutions that matter for knowledge accumulation and use. In this new environment, the traditional focus on *technology transfer* has increasingly given way to a focus on *knowledge sharing*. The concepts of 'brain drain' and 'brain gain' have traditionally been used to signify that there may be winners and losers. With knowledge sharing however, internationalisation brings the potential for win-win through dynamic processes of 'brain circulation'. European research infrastructures, operating in the global context, are therefore set to have a crucial influence on the pan-European system by attracting a global research community and linking industry, higher education institutions and governments in fundamental processes of knowledge creation and use for the long term.

Internationalised European research infrastructures are thus providing, in various ways, focal points for global collaboration. The driving force is the recognition that global challenges can only be tackled via such collaboration and world-wide networking between research groups which use them. These challenges are therefore central in the identification of world-class research infrastructures.

1.4 Promoting international collaboration for large-scale research infrastructures

During the first meeting of the G8+05 that was held in Okinawa in 2008, science ministers acknowledged the necessity of promoting international cooperation in large-scale research facilities through the exchange of relevant information, by allowing other countries access to such facilities, including wider access by industry, and by sharing information on plans to construct new large-scale research facilities in order to promote mutual international use by international groups or individuals, to avoid investment duplication and to facilitate cost-sharing where appropriate[3].

A number of different organisations and fora exist which provide mechanisms through which issues relating to collaboration, partnership and sharing of research infrastructures can be established. These range from international organisations such as the CERN, the world's largest particle physics laboratory and the Organisation for Economic Cooperation and Development (OECD)[4], to official settings such as

3 See the G8 Science and Technology Ministers' Meeting: Chair's Summary (June 2008) (**http://www8.cao.go.jp/cstp/english/others/g8summary-e.pdf**).

4 The *OECD Global Science Forum* is a venue for meetings of senior science policy officials of OECD countries. It contributes to the identification and exploitation of opportunities for strengthening the global research infrastructure, including better international co-ordination, sharing and rationalisation of new or existing resources.

the ERF[5] or the EIRO forum[6], from coordination bodies linked to the European Council such as the SFIC[7], to specific projects such as GEANT[8]. Furthermore, several countries have established bilateral or multilateral coordination groups with similar goals[9]. While these serve various constituencies of interests (e.g. physical research laboratories) or groups of countries, there is no overarching body which is truly international and interdisciplinary to address issues relating to the gaps between the global research challenges and global research infrastructure needs.

To assist EU Member States and the European Commission with the process of identifying pan-European research infrastructures, the European Strategy Forum on Research Infrastructures (ESFRI) was established in April 2002. It brings together representatives of EU Member States and associated states, appointed by ministers in charge of research, and one representative of the European Commission. ESFRI works to support a coherent approach to policy-making on research infrastructures in Europe and provides a focus for international negotiations relating to other research infrastructures outside the EU and for which global participation is required. It is an advisory body rather than a decision-making instrument, seeking primarily to identify research infrastructures of pan-European relevance. It does not prioritise the research infrastructures it identifies, but establishes the link between research challenges and highlights the need for collaboration between EU Member States in their construction, upgrade or sharing. Although ESFRI provides a vital forum at the European level, European research infrastructures need to be considered and promoted in a world-wide context during the decision making process and in their subsequent development. The EU, or simply some Member States, could take the initiative in addressing this issue.

In parallel with ESFRI, the e-Infrastructure Reflection Group[10] (e-IRG) was founded to define and recommend best practices for the pan-European electronic infrastructure efforts. It consists of official government delegates from all EU countries. The main objective of the e-Infrastructure initiative is to support the creation of a political, technological and administrative framework for an easy and cost-effective shared use of distributed electronic resources across Europe. The e-IRG produces white papers, roadmaps and recommendations, and analyses the future foundations of the European Knowledge Society.

5 *European association of national Research Facilities laboratories* (ERF) provides for the coordination of a range of research facilities across European large-scale research laboratories in the areas of particle physics, lasers and high energy sources.

6 *Forum for European Intergovernmental scientific Research Organisations* (EIROforum) is a collaboration between seven European intergovernmental scientific research organisations that are responsible for infrastructures and laboratories. It is currently comprised of seven member organisations including CERN, EFDA, EMBL, ESA, ESO, ESRF and ILL.

7 *The Strategic Forum for International Scientific and Technological Cooperation* (SFIC), set-up in 2009 is a dedicated configuration of CREST (Comité de la recherche scientifique et technique*)* - itself an advisory body whose function is to assist the European Commission and the Council of the European Union in performing the tasks incumbent on these Institutions in the sphere of research and technological development). The objective of the SFIC is to facilitate the further development, implementation and monitoring of the international dimension of the European Research Area.

8 GÉANT is a pan-European e-infrastructure, which link together national research and education networks. It is composed today of more than 50,000 km of optical fibres.

9 An example of a regional infrastructure coordination group is provided by NordForsk. Via the Nordic Research Initiative 'Joint Nordic Use of Research Infrastructure', it aims to promote efficient cooperation between the Nordic countries, including the Baltic countries and NW Russia, in terms of research and researcher education of the highest international quality. This also includes cooperation between academia and industry.

10 See *http://www.e-irg.eu/*

1.5 Recommendations

Vision

Global challenges will remain as important drivers for the identification, construction, development and operation of large research infrastructures and distributed systems linked by optimal resource sharing and exchange. Such research infrastructures serve as crucial nodes or distributed platforms for research and technological developments which have global benefits in terms of the knowledge they generate and the technologies they help create. They help strengthen technological and knowledge specialisation and help build local capabilities whilst enhancing global networks, value chains and markets.

Reinforcement of ERA in the world

In order to promote global research infrastructures the linkage between the ESFRI roadmap and other roadmaps from non-European partners needs to be developed further. Non-European partners should be considered in the ESFRI activities, and research infrastructures outside Europe but with European participation should be included in the scope of the ESFRI roadmap. The strategic importance of global research infrastructures within the ESFRI roadmap needs to be assessed.

Concerning the e-Infrastructures and taking into account their particular role in interconnecting communities in a world-wide scale and in enabling the sharing of resources (data, computers, software etc.), it is important that the European Commission pursues a continuous dialogue and establishes coordination mechanisms between funding agencies and other relevant actors from other world regions in an effort to achieve maximum possible alignment of peer efforts (e.g. between GEANT and Internet2 in the USA). The aim of initiatives in this area should be to provide European researchers with unimpeded connectivity and effective access to the international research communities and resources.

Actions

It is recommended that:

- In order to promote global research infrastructures the linkage between the ESFRI roadmap and non-European or international roadmaps needs to be developed further. Non-European partners should be considered in ESFRI activities.
- Member States and the European Commission, supported by relevant expert groups should give special consideration to the development and/or extension of reciprocal agreements facilitating use of non-EU research infrastructures by the EU research community and vice versa.
- International collaboration in developing, deploying, operating and strengthening interoperability on e-infrastructures should be further promoted. Such infrastructures enable the establishment of virtual research environments and promote world-wide access leading to productive research collaborations and a higher quality of results.
- An appropriate forum, set-up at international level, should be able to assess global research infrastructures and their strategic relevance in a world-wide context. There is a need for clear and unambiguous representation of pan-EU interests in RIs in this forum. This would be more than a 'voice for European RIs'. It would provide a vital link between non-EU partners and their European counterparts.

2. RESEARCH INFRASTRUCTURES AND THEIR ROLE IN STRENGTHENING RESEARCH CAPACITY WITHIN THE ERA

VISION 2020

Spring Council 2020… The joint meeting of research and regional development ministers ended yesterday, 25 March, with an agreement to continue the financial efforts at national and European level to strengthen the network of Regional Partner Facilities, which now covers the 30 countries of the European Union. European Research Infrastructures, together with their national and regional facilities, now support the research of 1.5 million European researchers and are contributing significantly both to the training of the new generation of European PhDs and the formation of innovative technology-based spin-offs. The total funds available at European level to support research infrastructures (new and existing) amount to about €1 billion per year for the research funds and have averaged €1 billion per year from the Structural Funds for the period 2013-2020. These will be increased by 50% for the next financial perspective period 2020-2027.

2.1 Introduction

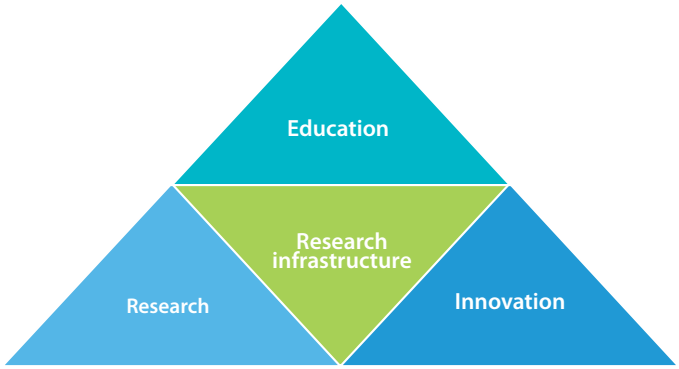
Research capacity building was identified as a key issue in the 2006 ESFRI roadmap report and related activities have been recommended by the Council of Ministers or research ministers of Member States since then. Not only is the implementation of the 'ESFRI identified' projects seen as a way of reinforcing capacity building in Europe, specific needs from sectoral policies are also emerging. For example, the Energy Council recommended in February 2008 that there should be an increase in current efforts in the field of energy to improve and enlarge the Community's world-class knowledge base.

The Competitiveness Council of May 2008 recognised that efforts must be continued to increase the capacity of regions across Europe to access, use, construct and operate research infrastructures. This chapter identifies key challenges for Europe and concludes by considering the regional dimension of infrastructure development, examining in particular the role of Regional Partner Facilities.

2.2 Research infrastructures, research capacity and the 'knowledge triangle'

In October 2005, at the Hampton Court informal meeting, the Heads of State called for urgent action to achieve world-class excellence in both research and education. Towards this target, Europe should therefore not only develop the three corners of the knowledge triangle (innovation, education, research), but also complete this picture by reinforcing the links between the main actors (people, academia, industry), obtaining a strong knowledge 'diamond', where research infrastructures are at the centre and act as the natural bridge between the different corners.

Figure 1: Research infrastructures positioned within the 'Knowledge Triangle'



'Research capacity' relates to the interaction between education, research and innovation. Research capacity building is defined at one level as those activities which improve an organisation's ability to achieve its research goals or a person's ability to accomplish specific research tasks. At a higher level it relates to the basis for the implementation of public policies within regions or countries, beyond the interest of individual organisations. Three basic categories relate to research capacity building: the development of research skills and knowledge in ways that contribute to human development; the institutional and legal framework within which research is conducted; and organisational performance.

Research infrastructures can be seen as strategic centres of excellence for research and training; many also have the potential to facilitate public-private partnerships. Since activities in these facilities and related networks lie at the frontiers of science, they stimulate the interest of young people who wish to embrace scientific careers. Access to and use of these technologically well-equipped facilities or databases enables young researchers and students to tackle complex problems as part of high-level interdisciplinary teams, qualifying them, in an outstanding manner, for tasks in science or industry, and fostering their career mobility.

However, as noted by ESFRI in its first roadmap report, Europe suffers from three weaknesses: insufficient funding, lack of an environment to stimulate research and to exploit results and a fragmented nature of activities and of resources. Recognition of these weaknesses has fuelled the idea of a European Research Area.

2.3 Research infrastructures and the development of a knowledge society

Research infrastructures contribute to the development of a knowledge society, not only by carrying out research, but also through the combination of various expertises from different backgrounds, from development of communication capacities and strengthening the interaction between research and industry. These arise not just via the use of such facilities by researchers in collaboration with industry, but also from the construction and maintenance of facilities, creating important supply and demand effects. Innovation capacity building can be seen through the new technologies applied in constructing world level research installations or from spin-off products and/or start up companies. Research infrastructures also profit from industrial design and construction expertise, project management expertise or development of new technologies (e.g. new detectors, innovative design features, and new robotics) and new engineering processes.

Therefore a main component of the innovation process and sustainable development is the cooperation of competent partners in science and industry. The landscape of Europe shows that, where research infrastructures have their site, science and technology clusters are often co-located. They are at the centre of the 'knowledge triangle'.

2.4 Regional dimension

An important element in building European research capacity is to ensure that the full research potential is unlocked within all regions of Europe. This implies giving special attention to convergence regions and acceding countries, as well as to the efficient coordination of actions between European regions. This could be achieved by increasing the complementarity of actions in the field of research and regional development and by adopting a wider view of the 'research infrastructure ecosystem' where many complementary activities and smaller infrastructures located in different parts contribute to the same goal.

Within the European Research Area, the development of Regional Partner Facilities is a new and important approach which will assist in improving the European potential of research infrastructures. The Regional Partner Facilities (RPFs) would be associated with large-scale research infrastructures and through such links could share some of the benefits. The specific partnership role of RPFs would include participation in preparation of experiments (at lower costs), better exploitation of results through specialised smaller infrastructures, training young researchers and a broad promotion of research performed at the large facilities. Such facilities could concentrate regional human capital and help turn science and innovation into an instrument of regional development. By such means, regional partner facilities could contributes to a more balanced development of the European Research Area, to 'brain circulation' throughout Europe, as well as reducing the risk of 'brain drain'.

2.5 Recommendations

Vision

The construction and operation of effective and timely research infrastructure is one important part of the process of building research capacity. Large-scale research infrastructures (including distributed ones) require efficient organisation and management to achieve high standards of performance. They also provide the 'nuclei' for skills and knowledge formation, either via the centralisation of such skills or through networked collaboration between researchers.

Reinforcement of ERA

Today there are relative fewer researchers in Europe than in Japan or the USA. Most countries are feeling a shortage of scientists and engineers that may have harmful consequences in the long run for the advancement of the knowledge society. In this context, research infrastructures have the ability to create rich research environments and attract and retain researchers from different countries, regions and disciplines.

Actions

It is recommended that:

- New approaches to European wide collaboration in constructing and using research infrastructures with active inclusion of the smaller EU countries and new Member States should be established. These could include targeted schemes for researcher mobility and the promotion of access regimes which favour new and/or small Member States. Developing distributed pan-European RIs, e-infrastructures and related services or adding these capabilities to pre-existing facilities can be used as a tool for building an efficient and effective ERA with contributions from all Member States.
- More support should be given by Member States to the development of Regional Partner Facilities as a useful way of building capacity and encouraging balanced development throughout Europe. Additionally, Member States and the European Commission should consider developing new models (financial, including new EC Financial Perspectives and Financial Regulations; legal; etc.) for funding RIs, taking into account the non-economic character of research (in particular investments in their construction/upgrade); this would stimulate regional development and facilitate better access to available funds (e.g. the Community Framework Programmes, Structural Funds or European Investment Bank).
- Fostering human resources is key to the efficient operation and the long term vitality of RIs. Steps should be taken to ensure continuity of accrued employment benefits for mobile researchers and experienced engineers and to promote management skills.
- The close relationship between universities and RIs contributes to an effective educational and scientific ecosystem, which can be attractive and supportive for industry. A significant increase in research funding across the EU, would require a concomitant increase in the output of trained researchers from the higher education sector, and RIs can contribute to this effort, helping provide multidisciplinary training needed by the industry and to tackle the grand challenges. Better interaction between European and national programmes, covering also the training of researchers through research infrastructures, should be encouraged.
- Research infrastructures create 'knowledge factories' and have been shown to stimulate technological innovation deriving from the basic research they foster. The concept of a research infrastructure should evolve to encompass not only scientific but also technological developments, often within a multidisciplinary context. Their potential to stimulate innovation through IPR exploitation and 'spin-off' creation and the scope they offer for commercial exploitation of knowledge so generated should be encouraged, along with complementary reforms strengthening demand-led innovation and entrepreneurship.

3. PRIORITISATION PROCEDURES

3.1 Introduction

The 2008 Roadmap prepared by the ESFRI specifies a wide range of research infrastructures across all scientific disciplines. These have been identified by the relevant scientific communities not just in terms of their potential to support world-class research but also through their prospective ability to strengthen and deepen the European Research Area. As noted in the preceding chapter, while ESFRI aims 'to support a coherent and strategy-led approach to policy-making on research infrastructures in Europe', it does not attempt to prioritise the research infrastructures admitted to the roadmap, nor is ESFRI instrumental in the funding process.

The total investment represented by the research infrastructures on the 2008 roadmap totals approximately €16-17 billion over a five year period, an amount that today exceeds the resources available either via national budgets or through European financial mechanisms (e.g**.** Framework Programme funds, Structural Funds, European Investment Bank). There is, therefore, a need to prioritise infrastructures on the roadmap, establishing a time-ordered approach to their construction or renewal which is commensurate with the available resources.

Despite this clear need, prioritisation procedures present numerous issues which must be resolved. The first and most obvious question relates to the criteria that should be used for prioritisation. Other issues concern the relationship between national prioritisation plans and the prioritisation of the European roadmap. Who has ownership of the prioritisation process? Over what time period should this be revisited? This chapter addresses these issues and suggests how they might be resolved.

3.2 What happens at present?

Currently about 11 EU Members States have prepared national roadmaps identifying the research infrastructures they plan to support and most other Member States are in the process of preparing a national roadmap outlining their plans for development and support for research infrastructures. These plans vary significantly in terms of their relationship to the ESFRI roadmap. Some countries have adopted what might be termed an 'ESFRI'-led approach, prioritising research infrastructures from the ESFRI list, possibly with some national additions to that list. Other Member States adopt a 'national interest'-led approach, establishing their roadmap in terms of national priorities, possibly including some of the ESFRI research infrastructures within the national list where there is an overlapping interest or by complementing some ESFRI-listed RIs with national specialised facilities.

There are many common features of the national roadmaps. For example, where national roadmaps are drawn up and prioritised, national budgets to support the prioritised research infrastructures are usually presented. Some countries make budgetary allocations for research infrastructures; these may or may not include ESFRI-listed research infrastructures. Not all countries that produce roadmaps have clearly specified prioritisation procedures. The result is a kind of *de facto* prioritisation depending upon the manner in which the national roadmap relates to and takes account of the ESFRI roadmap and the budgetary allocations that may be made by Member States to research infrastructures on the ESFRI list.

3.3 Criteria for priority setting

Across the world a few countries now have well-established procedures through which research infrastructures listed on their national roadmaps are ordered and set within a timeframe. Reviewing these procedures reveals a number of common elements:

- scientific merit is the single most important criterion for entry of a prospective research infrastructures to a national roadmap;
- roadmaps are used to identify opportunities for large-scale research infrastructures, in some instances a minimum investment is stated;
- collaboration across scientific disciplines is seen as important, especially for research infrastructures that address new interdisciplinary fields;
- unfettered access to research infrastructures (inputs and outputs) is generally regarded as key to the realisation of their full research potential;
- prioritisation procedures are applied because of financial resource constraints.

Prioritisation across scientific disciplines raises issues that are not so visible within a single discipline (where scientists within the field can establish priorities according to a set of goals for which they share some common knowledge). By the very nature of the ESFRI roadmap, covering the infrastructure requirements for all scientific disciplines, prioritisation must be an interdisciplinary activity. Given that the scientific case for any specific research infrastructures on the ESFRI roadmap has already been made, the criteria for prioritisation must reflect other aspects of the RIs. Typically these will reflect dimensions such as:

- an assessment of societal and economic impacts, including opportunities to improve competences of national industry and regional impacts;
- the ability of specific research infrastructures to foster 'knowledge communities', promoting exchange and sharing of scientific 'know-how';
- their contribution to the strengthening of the ERA;
- the extent to which they could help promote interdisciplinary collaboration;
- the 'readiness' of the research infrastructure to proceed through the construction phase and the fit between the costs schedule and available funding;
- sourcing and availability of funds;
- addressing global challenges and closing gaps in world-wide infrastructure availability.

3.4 Who should set priorities for research infrastructures on the ESFRI roadmap?

A number of different approaches to this issue were considered. The first would be for ESFRI to take on this additional role. This could be difficult for a number of reasons, the main one being that it might politicise a body which was designed to provide an independent 'scientific voice' for the EU Member States. ESFRI is structured and positioned so that it can act authoritatively and in the best interests of the ERA. Adding to its responsibilities in this way could have a negative impact on the balance it seeks to maintain.

Another approach would be for the European Commission to act as an 'honest broker', persuading countries to prioritise the ESFRI roadmap at the national level according to agreed criteria, then aligning the results of national prioritisation with the availability of funds (in a 'variable geometry' type solution). While this may be workable, it also presents numerous problems, particularly in terms of the perception by Member States of the role of the European Commission as the final arbiter in a process in which they have considerable national interest, and the possible influence of large countries.

A third approach would involve the formation of a new and independent entity, founded within a Community legal framework and funded at European level by national research infrastructure funding bodies. This entity would assist ESFRI with its continuing and developing role in the process of identifying research infrastructures with pan-European character for admission to the roadmap, but without influence over the ESFRI process. Crucially, it would work with Member States to ensure that national prioritisation procedures were harmonised and that ESFRI research infrastructures were duly prioritised by Member States. It would help identify the variety of funding options available at both the regional, national and EU levels (the so-called 'variable geometry' funding solutions), and it would work to promote the evaluation of the impact of research infrastructures (economic, social and scientific). The final decision on funding would, of course, remain in the hands of Member States which commit their own resources.

3.5 Recommendations

Vision

As far as resources for research infrastructures are concerned, a mismatch between the perceived needs from the research community and the possibilities of funding bodies will remain as the most likely future scenario. This is why prioritisation processes are needed, covering at least two stages. First, the scientific community needs to identify their own priorities within specific scientific domains. Second, the funding bodies will apply socio-economic and strategic criteria for their choices.

Reinforcement of the ERA

There is, at present, little or no coordination between the prioritisation processes which Member States employ to determine how limited national resources should be allocated to research infrastructures on their national roadmaps. Given that the major part of research infrastructure funding will be provided via Member States, harmonisation of prioritisation criteria and procedures is an obvious first step which should underpin the funding process.

Action

It is recommended that:

» ESFRI analyse more in depth the need to prioritise research infrastructures across scientific domains and consider these and other possible ways of mitigating problems by proposing an adaptation of its mandate or the creation of a separate entity to the Council of Ministers.

4. DECISION MAKING, FUNDING AND GOVERNANCE PROCESSES

VISION 2019

18 December 2019: The Research Council meeting yesterday in Brussels agreed with the creation of the European Research Infrastructure Coordination Agency. The newly formed agency, named ERICA, will be tasked to coordinate the voluntary efforts of Member States to operate some European Research Facilities which were created since 2009 (as ERICs), to organise their continuous upgrade and to make proposals to the Council on the implementation of new projects. With the pooling of national and European resources, the agency will have an operational budget of €10 billion per year, with the possibility to use the EIB funds for new projects and organise reimbursement over a period of 30 years.

4.1 Background

The identification and prioritisation of research infrastructures are necessary first steps in addressing global research challenges and building research capacity to strengthen the European Research Area. However, to ensure **the efficient realisation of these ambitions**, complex decisions need to be taken to resolve funding issues and to set in place appropriate governance arrangements for research infrastructures – the high level management processes that facilitate efficient knowledge creation and sharing and sustainable funding.

Decision making, funding and governance structures of research infrastructures are complex and involve many potential stakeholders: the scientific community, national or regional funding agencies, private sector interests and European bodies**.** For some research infrastructures, other international agencies or bodies could be involved. The complex intertwining of these stakeholders is a challenging issue and forms the subject of this chapter.

4.2 Key issues on decision making

Decision making in this context refers to the way that stakeholders and European bodies agree on the funding, construction and operation of research infrastructures in or for Europe. It includes:

- Prioritisation of future research infrastructures from some pre-identified list (see Chapter 3).
- Approval of the implementation of new research infrastructures under complex funding schemes involving a variety of funding sources.
- Site bidding and construction (or major upgrades) of research infrastructures.
- Selecting and establishing the appropriate governance structures.
- Management procedures during the whole life cycle (including the operation phase).
- Establishing sustainable resources for the operation of research infrastructure.

Three key issues on decision making are addressed in this chapter: variable geometry, site decision and international research infrastructures.

4.3 Multilevel decision making on variable geometry schemes

As described in Chapter 3, some Member States prefer to concentrate their resources on particular research infrastructures depending on national priorities or as a part of their national strategy. If a convergence of national interests is feasible, variable geometry configurations constitute the most promising approach for implementing research infrastructures.

Variable geometry constitutes the natural mechanism when the effort is promoted and shared between a small number of partners who jointly assume commitments, funding and use; it implies that decision making is carried out without the involvement of non-contributing partners. Experience has shown that variable geometry configurations are useful because interest in the process is a pre-requisite for involved countries. Unfortunately, they cannot cope with very complex and expensive research infrastructures when European resources are insufficient, when there is a large number of partners, or when other non-European partners are needed.

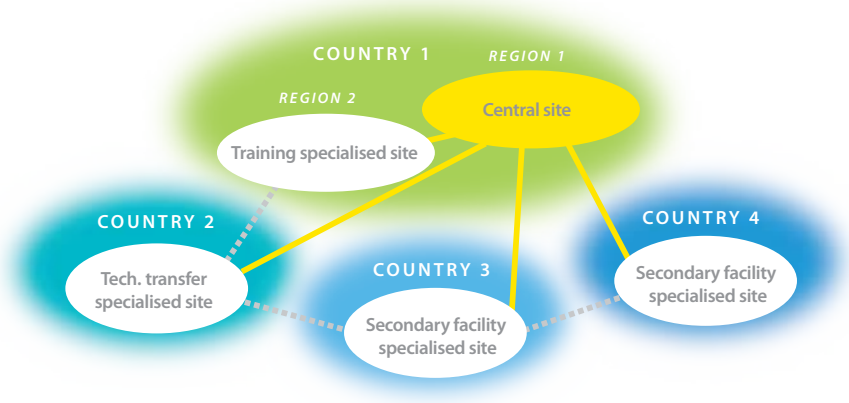
4.4 Site decision

Certain types of research infrastructures might require the satisfaction of particular technical conditions, leading to their location in one particular site. However, many potential sites usually satisfy the technical requirements; consequently a site decision is needed. Remote access to research infrastructures or distributed configurations of research infrastructures may facilitate decision making because the physical site could be partially transparent for users, but this is clearly not always the case, especially when centralised equipment is needed.

For many research infrastructures it is necessary to concentrate the investments in a single site due to physical constraints. This brings benefits for the region or country hosting the research infrastructures in its territory. A possible solution is to adopt a broader approach by increasing the impact of the research infrastructure in Europe. In some cases it may be possible to combine a main site with secondary or specialised infrastructures located in other places (see figure 2).

As described in Chapter 2, the concept of *Regional Partner Facilities* (RPFs) as new forms of alliance is becoming important. They can be seen as distributed structures with strong links to the core infrastructure. The regional partner facilities operate with autonomy, possess some sub networks of research infrastructures or specialised centres (for support or complementary activities), and their engagement and tasks performed are seen as secondary compared to a given core infrastructure. The partner facilities build up regional capacities through a concentration of resources, attracting talented researchers, engaging in competitive research and innovation performance.

Figure 2: An innovative approach for addressing the site problem



4.5 International or global research infrastructures

In some cases, the EU is contributing to research infrastructures located in other non-European countries. In these cases, research infrastructure decision making cannot be addressed by using the same approach adopted for European research infrastructures. International negotiation is required because of the need to obtain legal access to special sites located outside the EU (i.e. for environmental research infrastructures in Antarctica or other areas, or for specialised research infrastructures like telescopes or space platforms) and the need to share costs or knowledge in very expensive cases (i.e. ITER or ISS).

Member States, if they do not need other EU partners, could form direct agreements with the non European host country. In some cases, multilateral negotiations are needed and several Member States could agree on participation in research infrastructures with other non-European partners by coordinating their positions (i.e. a 'European' negotiation team is agreed amongst themselves). In other cases, the EU becomes a partner by representing all Member States implying the acceptance of the 'European voice' (e.g. the European Commission acting on behalf of Member States) during the negotiation phase.

4.6 Key issues on funding

Funding availability conditions the launch of a new research infrastructure because its cost could represent a significant percentage of the available resources for that domain in one specific country or in the whole EU, thereby reducing the possibilities of funding other research infrastructures. The use of multiple source of funding (European Commission, Member States, private sector, and other institutions), different allocation procedure (call, negotiation), accountability (openness, transparency or efficiency) and complementarity amongst EU policies (cohesion, research, competition) will require a formal legal framework.

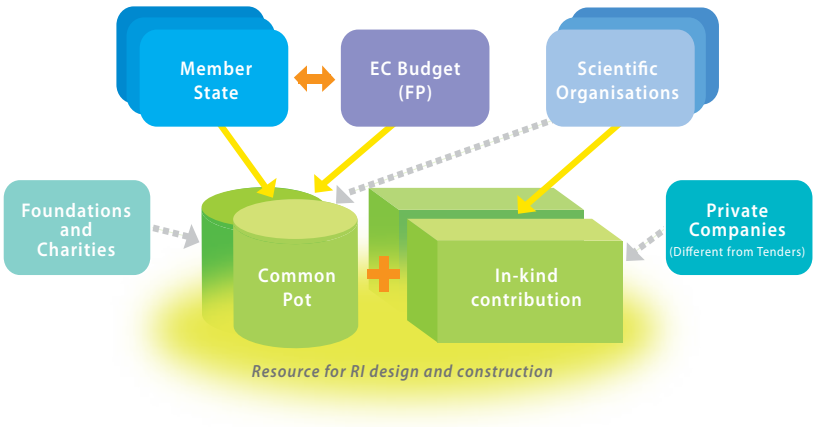
For large-scale research infrastructures, many different funding sources may be used to facilitate the construction phase. It is very important to combine different sources of funding by keeping their individual

purpose and legal framework in a flexible way. Figure 3 depicts main elements for multi-source funding. Legal combinations of monetary and 'in kind' contributions could facilitate the launching of new research infrastructures. Nevertheless, in kind contributions should be accepted through strict quality and cost criteria and not as a priori conditions.

The use of structural funds for European research infrastructures deserves specific attention. The substantial increase of inter-territorial cooperation funds for the provision of in kind components could be an innovative formula for accelerating the launch of research infrastructures and increasing intra-European cooperation. Furthermore, public procurement in research infrastructure is a potential instrument for innovative funding and industry involvement. Within this approach, contracts could also embed RTD for specific high technology components and training activities.

If the EU devotes much more funding to research infrastructures, less funding could be available for other types of RTD projects or activities within a stable budgetary regime. This issue is extremely important in the discussion on the future reform of EU budget. Moving towards the next Framework Programme, the creation of a specific 'European Fund for Research Infrastructures' should be considered within the framework of these discussions.

Figure 3: Multi-source funding of European Research Infrastructures



4.7 Key issues on governance structures

The management of research infrastructure addresses several problems and challenges concerning globalisation and internationalisation, legal status, financial issues, governance, risk sharing, etc. A sound management structure depends on the implementation of the right governance structure for research infrastructure and covering its effective use, maximum lifetime exploitation, maintenance and steady financial support.

Comprehensive management methods aim to achieve a number of objectives, including: high level user services; better interaction among all interested partners and future consumers; productive links with industry and educational organisations; open access to and use of scientific data and their protection. Such an environment motivates the research process whilst simultaneously promoting innovation and supporting a rational use of natural resources.

Key principles underpinning the governance of research infrastructure should be:

» the involvement of all research infrastructure members in the development, planning and overall monitoring of the facility;
» ensuring transparent and accountable governance and operational arrangements;
» guaranteeing contemporary e-tools for communication and decision-making;
» ensuring that the research infrastructure research programme is led by scientific members; an external scientific advisory board should be created to support this task.

Vertical research infrastructure management applies mostly to single sited research infrastructures. This is hierarchically organised with concomitant consultative bodies for policy making and managing processes. Spatial and horizontal oriented structure is applicable to distributed, e-infrastructure and virtual research infrastructures. This second managing model is structured around a core-hub model, supported by various specific councils with different responsibilities and competences. The basic feature of this kind of management organisation is the multi layer level of governance.

Key issues that should be considered when applying spatial management structure are:

» site decisions for the hub of the distributed-types of research infrastructures;
» ensuring balance between the hub and spokes;
» staffing issues of the core team and distributed partner institutions.

It should be noted that Regional Partner Facilities (RPFs) will have a more complex management structure, i.e. a mixture of vertical management, following the single-sited type and elements of spatial management for the regional facilities.

4.8 Recommendations

Vision

For large-scale research infrastructures, being single sited or of distributed nature, many different funding sources may be used to facilitate the construction and operational phases. It is very important to combine different sources of funding and to develop governance and management structures, which allow each individual facility to fulfil its mission as well as providing the flexibility to respond to evolving research, innovation and educational challenges.

Reinforcement of ERA

Considering current and future challenges, in particular the competition to provide efficient research infrastructures with other regions in the world, the ERA will be strengthened by reinforcing the decision making and funding processes through governance structures well organised at European level.

Actions

It is recommended that:

- Partial 'Europeanisation' of national or regional facilities should be supported. This process should be implemented as an open process promoted by the EU (e.g. via the ERIC regulation) with explicit proposals from Member States, in connection with the implementation of the Regional Partner Facilities. The networking of national facilities should be explicitly promoted.
- In applying the variable geometry approach, better coordination in the implementation of European, national and international roadmaps is needed. Non-European partners could be involved in these variable geometry configurations if applicable. This would ensure better coherence and complementarity in research infrastructure implementation and major upgrading.
- Funding in general and in particular funding of 'open access' operations (see Area 5 below) could become increasingly difficult, as countries cut national budgets following the boost in public spending to aid recovery between 2009 and 2011. This makes it imperative that the strongest possible case should be made to stress the pivotal role played by RIs in maintaining/improving the overall quality of the EU research system, to ensure future economic and social development and wellbeing.
- Specific European instruments are needed in addition to intergovernmental approaches and the framework Programme. Possibilities include Joint Programming, the development of Public/Private Partnerships, Joint Technology Initiatives and the use of ERA-NET+. Structural funds also constitute a relevant funding source for the construction of research infrastructures. Future regulation for structural funds could support enhanced programmes for research infrastructures (i.e. on enhanced inter-territorial cooperation focused on RI) both for ERDF and ESF funds.
- The EC and ESFRI should promote the development of more industrial-oriented research facilities, via greater involvement of the private sector and by giving a role/voice to industrial associations. The potential for European charities and foundations to become involved in the construction or operation of pan-European RIs could be explored and promoted through fiscal measures and other schemes.
- On issues related to governance, during the preparatory phase in the development of new or upgraded research infrastructures, careful consideration should be given to preliminary analysis of the governance structure and management scheme - both during the construction and operation phases. Likewise, economic sustainability, risk assessment, transparency and accountability are all important and should be considered in addition to legal and financial issues.
- On issues related to management, it is recommended that further optimisation of the use of research infrastructures could be achieved by enhancing cooperative and remote operation tools based on e-infrastructures.
- As plans for the next Framework Programme evolve, the creation of a specific 'European Fund for Research Infrastructures' should be considered within the framework of these discussions.

5. E-INFRASTRUCTURE AND ACCESS

5.1 Introduction

The term 'e-infrastructure'[11] describes the comprehensive infrastructure that is needed to address the complex, multi-disciplinary and cross-border needs of modern science. It capitalises on advances in ICT and integrates hardware for computing, data and networks, observatories and experimental facilities, and an interoperable suite of software and middleware services and tools. Such infrastructure is necessary in order to address issues such as the need to store, analyse and process unprecedented amounts of heterogeneous data and information, to enable world-scale scientific collaborations and the access to and sharing of scientific resources and information regardless of their type and location in the world. e-Infrastructure forms an integral part of all research infrastructures, which essentially require computing, data management, network and application development services. Identifying and meeting e-infrastructure needs allows for synergy in service provision and is essential for the global competiveness through increased quality of services in the European Research Area.

Europe is planning for a set of new research infrastructures listed in ESFRI roadmap. Most of these are disciplinary experiments – only one out of 44 projects (PRACE[12]) is specifically dedicated to the development of e-infrastructure. All of the ESFRI-list projects, as also the existing research infrastructures, require e-infrastructure and related services in multiple ways. The target is to develop the European e-infrastructure in a balanced manner. In addition to enhanced computational power and networks, the impact of data management, applications and competence development play key roles in forming the required e-infrastructure. Success in building efficient structures and services depends crucially on collaboration between different stakeholders including research and e-infrastructure providers.

As well as developing such structures and services, it is necessary to promote efficient access to them. Open access supports transnational flow of funds, knowledge, people and the provision of scientific and innovative services.

5.2 Key issues

ICT systems typically have a short lifespan compared to the lifespan of physical research infrastructure. Funding decisions are needed at regular intervals, for example every 3-4 years. However, commitment towards a longer development path for e-infrastructure is crucial since research has a need for sustainable resources. Most of the e-infrastructure is funded through national governments and other national funding organisations, and more collaboration between the countries would strengthen the resource sharing in Europe.

e-Infrastructure can be physically distributed and also utilised from anywhere, providing there is a sufficient connection available. This opens up possibilities to widely promote both European and global collaboration.

11 The term 'e-Infrastructure' has been coined and mainly used in Europe while in other parts of the world other terms are used to describe similar types of infrastructures (notably the term 'Cyber-infrastructure' that is used in the USA).

12 Partnership for Advanced Computing in Europe – designed to create a persistent pan-European high performance computing service and infrastructure.

Integration of the new EU countries and smaller economies within the pan-European e-infrastructure framework promotes their involvement in European development and enables them to profit from the wide range of competencies across the Europe. This will also democratise the research and enable innovation independent of physical location. Best practices and tools for pan-European resource exchange should be developed and piloted to stimulate sustainable collaboration and business models for research infrastructure utilisation.

Most of the ICT hardware industry, such as supercomputers, storage and network equipment, is not Europe based. The field of software packages like operating systems or database management systems is also dominated by non-European firms. Nevertheless, European ICT companies have developed specialised hardware and software products for many sectors and they play a leading role in ICT services globally.

We need to find new ways to increase the dialogue between research and European ICT industry. This is possible by focusing on the whole ICT ecosystem instead of only physical hardware, addressing for example software development, system integration, middleware, services and expertise to support complex research activities. European industry – as a provider of different e-infrastructure components and as a user of the capabilities – has a key role in this development. The best practices to increase industry involvement should be searched for.

It is necessary to support activities, which bring e-infrastructure providers closer to the researchers to understand their challenges and to provide better services. The driving force to service development should be born from researchers' needs, which requires active interaction between scientists and ICT experts. Implementation of the services will be most efficient when the collaboration of the different groups works optimally.

Another area with key impact is software development. Increased scalability is needed to reach sufficient performance in the high-end supercomputing, new and more efficient algorithms are required to cope with the rapid computer technology development and porting effort of the previous generation applications require extensive work and competence. In addition, middleware development focusing in key areas, such as authentication, authorisation and security, is currently strong in Europe and should be strengthened further. Finally, the development and provision of advanced collaborative working services or remote simulation will require substantial attention.

5.3 Facilitating access

Given the exponential growth of information, managing and providing efficient access to data represent a major challenge. Tools and processes to manage data, promote interoperability, integrate databases and ensure access rights require significant development effort in order to promote sustainable services. Pan-European collaboration in this area – especially where it crosses disciplinary borders – is still not sufficient.

A crucial element is a clear policy of access. For fundamental research, free open access is strongly recommended, while for applied research and innovation access conditions should be clearly defined. Management of appropriate usage needs to include the development of clear access control policies, which are seen as fair, efficient and which, wherever possible, promote wider collaboration between different groups of users.

Efficiency of the usage should be reported back to the peer review process to ensure optimal usage of the expensive e-infrastructure resources.

Access to specific databases and depositories for R&D purposes and innovative aims should be considered attentively. The access mechanism governance should assure not only a new knowledge production but also possible spin-off arising, further benefits for users and consumers and steady socio-economic effects. The access rules require consideration for related actions such as conditions for the remote/virtual access, allocation time, ways of access selection, etc.

The policies for the research infrastructure access could be regulated by dedicated public documents where the routes through prioritised fast access, access at any moment, access to e-infrastructure, and issues concerning data protection, software developing and other similar topics are indicated. Generic regulations should define various type of access for regular partners, associated ones, third countries as well as private or public users. The specific provisions for all types of partners, external users, as well as differentiations of services would be a subject of additional agreement.

5.4 Recommendations

Vision

The full spectrum of e-infrastructure has to be supported in a balanced way to achieve efficiency in building the ICT ecosystem for research. The mode of operation needs to move from project based activities towards a sustainable model with guaranteed resource development to make the long-term commitment attractive for research groups.

Reinforcement of ERA

The strengthening of interactions between ESFRI and e-IRG should be continued. The maximum e-infrastructure expertise provided by e-IRG should be available for ESFRI.

Actions

It is recommended that:

- Open peer reviewed access to RIs promotes competition and enhances the international reputation of the ERA as a research friendly environment. However, such access brings with it additional costs which must be recognised as fundamental to the operation of RIs.
- Methods to promote resource exchange and pooling among Member States should be piloted. Concepts to utilise existing resources more efficiently by sharing critical or unique resources at pan-European level will be important in this respect.
- To achieve these objectives (open access and resource exchange/pooling), emphasis should be placed on the development of integrated e-infrastructure based services (e-Science services) for researchers, addressing common needs of different scientific communities and enabling the sharing of resources among them.

- e-Infrastructure expertise provided by e-IRG should be available for ESFRI. Given that e-Infrastructure pervades all aspects of the construction, operation and management of RIs, there is a clear need to forge much closer working between these two bodies.
- A specific focus should be placed on managing and developing data infrastructures and expertise. Efficient trans-European access to online content should be taken into account when developing the processes. Collaborations addressing multidisciplinary data management challenges that would benefit from synergy should be promoted.
- Software development and deployment will play a central role in the efficient development and use of e-infrastructures. In this context, new and multidisciplinary collaborative actions should be promoted, both for stimulating scalable application development for various scientific domains and for developing efficient middleware addressing outstanding issues with regard to authentication, accountability, security and related topics.
- Concerning the critical area of High Performance Computing resources, the pooling of Member State and EC research investments will strengthen the position of European industry and academia in the use, development and manufacturing of sustainable and greener computing technologies and services.

6. THE LEGAL FRAMEWORK

VISION 2014

12 November 2014: the Commission delivered today its report on the implementation of the ERIC regulation to the Council and the Parliament. This regulation was approved on June 2009 and since then 26 new entities have been created under this umbrella, allowing the emergence of truly European research infrastructures. The audit performed by independent experts shows that the management at European level is generating large savings in the operational cost of previously nationally-run facilities, as well as providing the maximum investment in intellectual capital for the European Union.

6.1 Introduction

Significant progress has been made in establishing the legal status of European research infrastructures. The Council of the European Union reached a political agreement on a regulation on a Community legal framework for European research infrastructures on 29th May 2009. As was mentioned in the introductory chapter, the adoption by the Council of the European Union of the regulation providing for European Research Infrastructure Consortia (ERICs) is a major step forward in resolving legal issues relating to the status of RIs, their tax liabilities and their operation. This chapter argues in favour of further extending this framework to ease many of the legal issues that still exist and to facilitate the application of the regulation.

6.2 The current situation

The development of new research infrastructures through the newly approved ERIC regulation[13] will soon meet the basic needs for:

- a recognition of their European identity on a non economic basis;
- a flexible internal structure to accommodate the variety of infrastructure types;
- a legal personality recognised in all Member States;
- providing some privileges and exemptions (e.g. from national value added taxes);
- the creation of appropriate partnerships with partners from third countries.

The ERIC legal framework is based on Article 171[14] of the European Treaty '*The Community may set up joint undertakings or any other structure necessary for the efficient execution of Community research, technological development and demonstration programmes*', which can be used for pan-European research infrastructures necessary for the efficient implementation of Community RTD programmes. Such a framework will indirectly support the reinforcement of a coordination mechanism leading to better decision-making at a European level.

13 Approved by the Council on June 25 2009 / See *http://ec.europa.eu/research/infrastructures/eric_en.html*.

14 With the adoption of the Lisbon Treaty the numbering of articles has now changed. The Article is now 187.

6.3 Key issues and discussions

This Council Regulation will play an important role not only in speeding up the realisation of the proposals which are included in the European Roadmap for the Research Infrastructures, published in 2008, but also by boosting their attractiveness and providing them with a competitive advantage over similar projects elsewhere in the world.

We should also examine the setting up of a RI in priority areas, within the context of the *Joint Programming*, which is initiated by the Member States. In this case, the development of some single or distributed research infrastructures should be included in the proposal of such a common initiative, in order to facilitate the targets of the Strategic Research Agenda. The appropriate legal framework for this purpose should meet the above basic criteria. This approach could be also used for the pre-existing Joint Technology Initiatives (JTIs) implemented through Article 171[15]. In the context of this framework we have in addition to consider not only the public actors, but also the public-private partnerships where these are appropriate.

Indeed the informal Council of July 2008 noted the importance of developing test facilities at European level able to develop the necessary technologies for a competitive Europe. This relates not only to innovations in transport or telecommunication, but also the grand challenges of developing clean energy technologies, decreasing energy consumption and better management of the industrial and societal systems. The current ERIC regulation does not deliver the proper legal environment since it is related to Public-Public Partnership. A new legal framework at Community level allowing the creation of Public-Private Partnership to serve industrial research in the long term is therefore needed.

The purpose of setting up such a consistent legal framework should therefore aim at boosting the international competitiveness of the EU in basic and applied research as well as facilitating the creation of European consortia of research actors. It can help to make it easier to attract world-class researchers and limit the European 'brain drain', and to offer friendly conditions for cutting-edge research. The framework should be consistent with the political objectives, and should increase its positive image at international level. It is also important that the research infrastructure to be set up as a legal entity shall submit an impact assessment with its application (see Chapter 7) and its members shall commit the necessary human and financial resources for its establishment and operation.

Research infrastructures rely heavily on technological and managerial expertise for their development and efficient operation. These high level skills involving, inter alia, engineering, computing network and software development and human resource management are themselves in short supply. Further consideration should be given to legal instruments that would help promote the mobility of these skills by ensuring that accrued employment-related benefits and rights can be transferred between Member States across the ERA.

15 Now Article 187.

6.4 Recommendations

Vision

A favourable environment, in particular a beneficial legal framework, is needed to help developing research actions, attracting scientists and researchers, facilitate the participation of industry, charities and foundations, incorporate non European partners, generating spin-offs and innovation, protecting intellectual property rights, as well as using available funds in the best manner.

Reinforcement of ERA

Until 2009, the legal framework at European level was very fragmented, based mainly on national law. The development of the ERIC regulation allows the emergence of favourable conditions for the setting-up of collaborative, sustainable projects for research infrastructures of pan-European interest. Future developments in the field of public-private partnership would complement the current panorama, allowing better support for technological innovation-related projects.

Actions

It is recommended that:

- In developing and using world-class research infrastructures, one of the major aspects to take into account is the protection of intellectual property rights. The Commission should therefore take great care of reinforcing this aspect in the implementation of ERIC through specific guidelines.
- ERICs should be fully accessible across the ERA and utilised efficiently to promote mobility and the training of researchers, thereby increasing their attractiveness and strengthening the ERA. Further consideration must be given to the need to facilitate and promote the mobility of technological and managerial expertise between RIs across the ERA, particularly with respect to the relative attractiveness of careers and the consequences of a lack of cross national mobility for career development.
- Non-European partners may have difficulties in using the ERIC framework as the basis of a legal agreement. Further monitoring of this aspect of the new regulation is recommended.
- The development of research test facilities at European level and sharing RIs for scientific and industrial use might require the setting-up of a specific new legal framework or extension of the scope of the ERIC directive to facilitate the participation of the private sector.

7. EVALUATION AND IMPACT ASSESSMENT

7.1 Introduction

Decision makers, whether at funding or management levels, need clear indicators to justify their choices. This chapter considers two related issues. First, how should the pan-European relevance of research infrastructures be assessed and evaluated in order to provide information to make informed decisions on their sustainable support, upgrade or decommissioning? The second issue relates to the definition and measurement of their impact: how should impacts be defined? The chapter concludes with recommendations relating to the mechanisms through which evaluation and impact assessments could be conducted.

7.2 Towards common evaluation criteria at the European level

The pan-European character of research infrastructures is normally analysed according to ex-ante factors ('inputs'), which can be gathered under three categories, as defined by the Community Research Programmes:

- *Scientific excellence:* A research infrastructure of pan-European relevance should have the potential to bring significant improvements in the relevant scientific and technological fields as compared with nationally available facilities. The facility should ensure open access to all interested researchers, based on the quality of the user proposals. Its proposed research staff should have demonstrated a high level of appropriate research competences.
- *Capacity of management:* a research infrastructure of pan-European relevance should demonstrate appropriate management structure and procedures; quality and relevant experience of its staff; appropriate allocation of resources to be committed for its open access (budget, staff, equipment).
- *Capabilities to generate impacts:* a research infrastructure of pan-European relevance should possess appropriate capabilities (budget, staff) for the dissemination and/or exploitation of project results and knowledge, as well as for the management of intellectual property and for spreading scientific excellence in its particular domain. Such research infrastructures should prove their potential to make scientific knowledge and advances accessible to potential users, in particular for industry, in terms of direct access and/or use of the data generated by the facilities. They should also provide focal points for relevant training of researchers and engineers.

However, to complement the input analysis and before any decision-making, it is crucial to analyse ex-ante the potential 'outputs' provided by such facilities:

- The first approach to evaluate potential outputs should be based on the *contribution to science and technology.* Evaluation of the European character should be based on several criteria, including potential for discoveries, knowledge creation and development of new technologies, leadership role of the research infrastructure in the international research community, attractiveness of the facility and the quality of research services they offer as well as on their potential research training and educational role.

- To be recognised as of pan-European character, research infrastructures should also demonstrate how they help *strengthen the development of an efficient European Research Area* by better integrating national efforts, avoiding sub-critical facilities, and placing Europe as a world leader for high-level research services. In this context the evaluation of this character could also be based on how research facilities, including e-infrastructures, help Europe to pool its resources for better performance and capacity of research services. These are indispensable for staying at the forefront of research over the next decades, providing the research communities with the tools they need, therefore increasing European potential at international level. The evaluation could also help develop a governance of existing facilities at European level, therefore paving the way towards real distributed facilities of international relevance.
- The pan-European character is also linked with the broad impacts that such infrastructures bring to the *sustainable development of the European society* as well as to their contribution to the competitiveness of Europe in the knowledge society. This should be linked with the assessment of the efficiency of their research services, helping to better tackle global challenges and societal needs (in particular environmental or health challenges), or to support innovation and economic activities (in particular through the supply of needed new technologies). Outreach activities could include meeting demands for scientific and technical skills by industry and governments, building up strategic knowledge of relevance for Europe and dissemination activities promoting the use of new scientific results. Research infrastructures can be attractive working places, stimulating interest of young people who may wish to enter scientific and technical fields. At the same time, they can be a reservoir of labour force available to industry in need for specific technical skills by contributing to the training of researchers. Relevance for the labour market can also be assessed with respect to long term industrial needs and/or coherence with long term economic development and sustainable strategies.

The table 1 proposes how these inputs and outputs might be combined for assessment and evaluation of research infrastructures in a matrix of analysis.

Such analysis should be applicable to the whole ecosystem of research infrastructures at European level, ranging from single-sited facilities to distributed ones, from national to regional partner facilities. The main responsibilities for assessment and evaluation would nevertheless lie with research infrastructure public authorities, and also to other funding bodies (i.e. private sector) supported by independent experts, based on studies and data periodically gathered by the research infrastructure managing bodies.

Table 1: Evaluation procedures: inputs required and outputs generated

		Outputs generated		
		Contribution to Science and Technology	Strengthening the European Research Area	Sustainable development
Inputs required	Scientific excellence	Frontier research	EU Science and Technology challenges	Contribution to understanding and solving the Grand challenges
	Management capacity	Efficient research services	Transparent and effective governance	Long term balanced budget
	Capabilities to generate impacts	Knowledge to inform policy makers	European leadership in science and technology	Understanding the long term socio-economic and environmental impacts

7.3 Impact assessment: who needs this information and why?

Impact assessment shares many common elements with evaluation procedures, but usually forms part of the process of bidding for funds to construct an infrastructure or to extend its operational life or decommissioning. Impact assessment is often used to inform procedures for the allocation of public funds prior to the construction or upgrade of research infrastructures or it assists with decisions over the site location and timing of construction.

Support for the construction of new or upgraded research infrastructures comes from a variety of sources; the scientific community is the primary voice making the case for research infrastructures. National and supra-national funding agencies must also be convinced that the funds they are charged to allocate are spent wisely. Policy makers have overall responsibility for public spending. The business community may have interests in specific research infrastructures if opportunities for technical and/or scientific collaboration are promising. Finally, the general public must give tacit support for the significant allocations of public funds that are made.

7.4 What are the impacts of research infrastructures?

The impacts of research infrastructures relate, therefore, to the impacts of the research and innovation that they facilitate. These can be classified as direct *scientific impacts,* the new knowledge created and the theoretical advancement of science achieved via the research they facilitate, and indirect or *technological impacts,* the innovations in the production of goods and services that arise as spin-offs from the development of research infrastructures or the benefits accruing from the advances in scientific knowledge that stem from their operation.

Apart from scientific and technological impacts, other types of impacts may be defined. These are:

Economic impacts The short term contribution to economic growth and employment arising from the construction and day-to-day operation of a research infrastructure. Medium to long-term effects on the economy relating to technological advances induced by the operations of an RI.

Social impacts The contribution to general wellbeing arising from progress made in science, which stems from the research process and its contribution to improving the quality of life of citizens.

Political impacts The contribution to political stability and cohesion, resulting from the construction and operation of a research infrastructure and from the advances in science it facilitates.

Environmental impacts The *Direct effects* relating to the construction and operation of a research infrastructure (e.g. energy consumption, CO_2 footprint, water needs, other impacts on physical environment). *Indirect effects* such as the improvement in environmental conditions stemming from advances in science facilitated by a research infrastructure.

From a scientific perspective, economic and environmental impacts may seem irrelevant – the value of a research infrastructure to the process of scientific discovery may be regarded as the single most important aspect of its potential impact. But consideration of the economic impact of research infrastructures becomes particularly relevant in times of economic recession, a point which has helped shape the US *American Recovery and Reinvestment Act 2009* and its allocation of a budget of $126 billion for science and research infrastructures. Equally, consideration of the environmental impacts of research infrastructures can prove particularly helpful in gaining public support for their construction.

Table 2 shows the relationship between the nature of the interests in impact studies and the type of impact. The strength of the interest is indicated by the number of asterisks shown in each cell of the table. It shows that, whereas the scientific community and funding agencies will have a major interest in the scientific and technological impact of research infrastructures, other interested parties will have interests in the wider range of impacts identified in this table.

7.5 Measuring impact

Despite the general interest in the measurement of impact, particularly the measurement of innovation, there is no common terminology or standard approach to aid the definition and measurement of impacts. What is clear is that the variety of impacts and their range requires that an array of different sources of information and analytical methods are used to measure and monitor impacts. An indication of these sources, in terms of research methodologies and information requirements, is shown in Table 3.

7.6 Recommendations

Vision

The scientific and science policy communities will increasingly need relevant information about scientific, technological, environmental and socio-economic challenges to justify their actions. Likewise, policy managers obviously will base their decisions on clear and consistent information regarding these challenges. Finally, research infrastructure and research infrastructure policy managers must be fully aware of effectiveness factors followed by their assessment and evaluation.

Reinforcement of ERA

While considerable efforts are currently being made by a number of bodies to establish more robust measures of impact, there is as yet no clear set of methodologies or programme of work which addresses the impacts of research infrastructures across the domains of interest to the range of parties identified in this chapter. There is no single 'one size fits all' method for the measurement of impacts, but a common analytical framework would prove more transparent and would be of more value to the wide range of interests identified for an efficient an attractive ERA.

Actions

It is recommended that:

» The different impact studies carried out at national and international level should be reviewed to strengthen the methods used to measure the scientific, social, economic, environmental impacts (both direct and indirect) of research infrastructures.
» Current efforts (e.g. ERAWATCH[16]) should be extended in such a way that they assist with monitoring the evolution of RIs, principally by collecting relevant information for impact assessments in a harmonised manner.
» The concept of a 'common methodology' for impact assessments of RIs should draw on expertise developed in social, economic and environmental disciplines and will be multidisciplinary by definition and covering the whole ecosystem related to specific RIs.
» All RIs of European relevance should be committed to carrying out periodical impact assessment exercises, monitored by external committees to provide information about the way they fulfil their goals and serve societal demands. The European Commission and/or ESFRI should gather and publish the results.
» The different dimensions of the management of the RIs should be assessed, such as overall governance of the facilities, financial practices, management of human resources, innovation policy, intellectual property rights, etc. This should be designed to generate an agreed set of performance indicators.

Table 2: Interested parties and their link to impact studies

Interest from	Scientific impact	Technological impact	Economic impact	Social impact	Political impact	Environmental impact
Scientific community	***	**	*	*	*	*
Funding bodies	***	***	*	*	*	*
Policy makers	**	**	***	***	***	***
Business community		***	***			*
General public	**	***	***	***	***	***

16 See *http://cordis.europa.eu/erawatch/*

Table 3: The measurement of the impact of RIs and methods of analysis

Type of impact:	Measurement of:	Methods of analysis:
Scientific impact	Scientific outputs; rate of utilisation of the resource; training and capacity building	Peer review; bibliometrics; statistical reports; administrative records held by research infrastructures; surveys of users
Technological impact	Actual and potential spin-off products and services; links to private sector; national statistical information on inputs and outputs	Survey of spin off companies and activities; in-depth interviews with scientific staff of research infrastructures; innovation surveys; factor productivity analysis.
Economic impact	Contribution to GDP at regional and national levels; employment and incomes created at local, regional, national and supranational levels	National and regional accounting input output models; autoregressive variance analysis models; analysis of administrative data held by RIs
Social impact	Contribution to family and community wellbeing; amenity value of the facility	Synthetic reviews of evidence from science based on use of RIs; local population surveys
Political impact	Contribution to political stability, cohesion	Interviews with key informants; analysis of media publications
Environmental impact	Impact on air, water quality; energy balances; CO2 footprint	Synthetic reviews of evidence from science based on research infrastructures; analysis of energy use; analysis of environmental measures

8. CONCLUDING REMARKS

On 2 December 2009 the Lisbon Treaty entered into force. This provides new impetus to progress and strengthen the concept of the European Research Area. Once realised, this will create a unified area all across Europe which will:

- enable researchers to move and interact seamlessly, benefit from world-class infrastructures and work with excellent networks of research institutions;
- share, teach, value and use knowledge effectively for social, business and policy purposes;
- optimise and open European, national and regional research programmes in order to support the best scientific research throughout Europe and coordinate these programmes to address major challenges together;
- develop strong links with partners around the world so that Europe benefits from the worldwide progress of knowledge, contributes to global development and takes a leading role in international initiatives to solve global issues.

World-class research infrastructures are key elements for the construction of ERA and the efforts at the national and Community levels to design, build and operate them form basic ingredients of science and technology policy.

Realising the vision of the ERA is important not just for future of the European Union. It matters at the global level because research in many fields now transcends national boundaries. As we illustrated in the first chapter of this report, the European Union now faces what we term 'the new renaissance' – the opportunity presented by the Lisbon Treaty to move its research agenda from one which is currently fragmented and inefficient in many respects, to one which has a strong research base and is coordinated and shared in ways which promote the best scientific research environment in the world.

For the development of world-class research infrastructures within the ERA, many aspects still require additional attention. This set of recommendations which the Expert Group has identified is offered as valuable input for debate and decision making both at the European level and amongst all relevant stakeholders across the EU.

ANNEX: MEMBERS OF THE EXPERT GROUP ON RESEARCH INFRASTRUCTURES

Thomas Andersson
President, Jönköping University
Sweden
thomas.andersson@iked.org

Peter Elias (Rapporteur)
Professor, IER, University of Warwick
United Kingdom
p.elias@warwick.ac.uk

Kimmo Koski
Dr. Tech. Managing Director,
CSC - Scientific Computing Ltd
Finland
kimmo.koski@csc.fi

Gonzalo Leon (Chairman)
Vice President for Research, Polytechnic University of Madrid
Spain
gonzalo.leon@upm.es

Karin Lochte
Professor, Alfred-Wegener-Institut für Polar- und Meeresforschung
Germany
Karin.Lochte@awi.de

Christos Vassilakos
Counsellor for Research & Technology,
Permanent Representation of Greece to the EU
c.vasilakos@rp-grece.be

Albena Vutsova
Ministry of Education and Science
Bulgaria
a.vutsova@mon.bg

Support from the European Commission services

Hervé Péro, Head of Unit, and Christos Profilis, Project officer, Research Infrastructures, Directorate-General for Research; Konstantinos Glinos, Head of Unit, and Kyriakos Baxevanidis, Project officer, GEANT and e-Infrastructures, Directorate-General for Information Society and Media

A vision for strengthening world-class research infrastructures in the ERA

Luxembourg: Publications Office of the European Union, 2010
2010 –51 pp. – 17,6 x 25 cm

ISBN: 978-92-79-14214-7
DOI: 10.2777/79690

Building on the work of a first Expert Group, the report of which was published in March 2008, a second Expert Group reviewed and re-examined the role of research infrastructures within the European Research Area.

The report provides further developments and recommendations outlining a more integrated approach for the setting up of world-class research infrastructures.

The Expert Group drew a vision for 2020 on the status, role and scientific impact of research infrastructures in relation to the evolution of the European Research Area.

The report can be downloaded at:
www.ec.europa.eu/research/infrastructures/publications_en.html

KI-NA-24-186-EN-C

Publications Office

ISBN 978-92-79-14214-7