European Strategy Forum on Research Infrastructures
Long-Term Sustainability Working Group

Long-Term Sustainability of Research Infrastructures

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ESFRI Scripta Volume II

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Foreword

The second volume of the ESFRI Scripta series is dedicated to the outcomes of the *ad hoc* Working (WG) Group on Long-Term Sustainability (LTS) of Research Infrastructures.

The LTS WG was created by ESFRI in 2016 to comprehensively respond to the Conclusions of the Competitiveness Council of the European Union of 27th May 2016 that "*underlines the importance of ensuring Long-Term Sustainability of Research Infrastructures and invites the Commission to prepare together with ESFRI and relevant stakeholders a targeted action plan*".

ESFRI has previously developed its concept of lifecycle of the Research Infrastructures in the framework of the Roadmap evaluation exercise, and at all stages of the lifecycle different aspects of sustainability were identified. The LTS WG has analysed the Long-Term Sustainability of Research Infrastructures from a broad perspective taking the ESFRI viewpoint well beyond the mere economical analysis. Scientific excellence is the condition *sine qua non* for sustainability throughout the entire RI lifecycle, and its persistence is crucial in the long-term operational phase. Excellence in science and outstanding quality services to the users are imperative for the successful performance of each

Research Infrastructure, and they are addressed in the monitoring and reviewing processes by ESFRI.

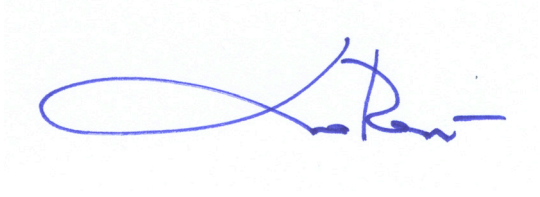
The report proposes 7 main recommendations covering the key aspects of Long-Term Sustainability of Research Infrastructures. These recommendations are expanded into 35 specific points ranging over securing highly qualified and motivated human resources, realizing a robust transfer of information to society from the Research Infrastructure via a quality-controlled e-Infrastructure, building an effective interface between RIs and innovation activities, understanding the actual value of the diverse benefits to society, addressing the optimal governance and management structure and promoting coordination among RIs.

This volume of ESFRI Scripta contains the full LTS WG report as approved by the ESFRI Forum in June 2017 and then shared with the European Commission to jointly address, with a multifaceted but overall consistent analysis, the mandate of the Competitiveness Council on Long-Term Sustainability of RIs.

It represents an advanced expert analysis of substantial value on the sustainability issues connected with the large investments associated with Research Infrastructures, but does not represent in any way commitments of the ESFRI Member States and Associated Countries at political or economical level.

I wish to thank the LTS Working Group and its Chair for the high quality report, the ESFRI Forum for supporting its publication, and the technical editors Maddalena Donzelli, Marina Carpineti and Petra dell'Arme for their work.

Milan, October 2017



Giorgio Rossi
Chair of ESFRI

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Executive Summary

Research Infrastructures (RIs), from large facilities such as CERN to distributed data networks, play a vital role in Research and Innovation and recent years have seen a strong growth in the number of RIs that are operational or planned across Europe. Whilst these RIs offer great opportunities, they also present the challenge of ensuring that they can be operated sustainably at a high level.

History shows that a robust long-term vision is the most important prerequisite in order to successfully and sustainably build and operate a RI. As with any other vision, this vision also requires an adequate framework and must be embedded in a supportive policy driven environment to be successful. RIs are typically operational for several decades so they require continuous and stable support. Sufficient time and support must be given to the RI to fully unfold and develop its full potential. This support cannot be reduced to financial considerations alone, though very important, but rather be founded on a broader consensus – nationally and EU-wide – as it is typically well beyond any electoral or standard budgetary planning period. Research Infrastructures must be recognized as long-term strategic investments at all levels, deeply rooted in society, and indispensable both for enabling and developing excellence in their respective scientific domains, and also as key players contributing to competitiveness with a very large

perimeter. The long-term benefits of Research Infrastructures to society at large are unquestionable irrespective of the size or scientific focus of the RI concerned. Unintended discoveries resulting from long-term RI operations may have a similar impact as the scientific achievements that are foreseeable. Large scale scientific installations intrinsically shape the region where they are located and as such they are important not only as contributors to competitiveness, but also to agendas for cohesion and integration. RIs also have a tremendous impact on skills and education agendas irrespective of their size, increasing the competences of their staff, researchers and students, and through their outreach to pupil and students and the general public they steadily improve the perception and understanding of science and technology in society at large.

In response to the Council request[1], namely, to draw up an action plan on the Long-Term Sustainability (LTS) of RIs, the European Commission (EC) proposed to ESFRI to set up a Working Group on this matter. Input to that plan is presented in this report, which results from work of the LTS *ad hoc* Working Group and targets large single-sited pan-European Research Infrastructures as well as distributed or data Research Infrastructures, though the application might be limited in certain cases for the latter. The recommendations are also of relevance for international organizations or large national RIs with meta-regional outreach. It is not the intention of this report to question the subsidiarity principle and the recommendations should be viewed as options for consideration only. Similarly, some of the recommendations go a little beyond traditional research agendas, as strong overlaps exist with several other policy domains – for example education, cohesion, competitiveness and social policy. However, here the report only hints at the need to maximise the strategic view of RIs from those other

1. Conclusion of the Council of the European Union of 27th May 2016 on FP7 and the Future Outlook: Research and innovation investments for growth, jobs and solutions to societal challenges. Doc. 9527/16
http://data.consilium.europa.eu/doc/document/ST-9527-2016-INIT/en/pdf

domains, emphasising the need for timely and effective exchange, while the responsibilities of the individual actors remain untouched. The example of structural funds used for RI investments, clearly demonstrates the need to adjust research and cohesion/competiveness policies, it challenges regulatory framework, requires consultations between the different national ministries, between the corresponding DGs of the European Commission, and challenges timely cross-border communication at a meta-regional level, ideally prior to the start of drafting operational programmes. Similarly, the integration of RIs into broader competitiveness concept at national or European levels is critical to Long-Term Sustainability.

Main recommendations

MAIN RECOMMENDATIONS

1. **Establish and maintain excellence** through the entire lifecycle of RIs by all appropriate means, by securing adequate framework conditions, and by opening the RIs up to the world.

2. **Ensure that RIs have the right people in the right place at the right time** by strengthening and harmonising national research and educational systems to make sure that all essential skills are available.

3. Harmonise and **integrate a vision for convergent operation of RIs and e-Infrastructures** in Europe to ensure cost-effective service provision to the user communities.

4. **Fully exploit the potential of RIs as innovation hubs** by incorporating strategies for their development into national and European innovation policies.

5. Set up effective means of **determining the economic and wider social value of RIs**, and incorporate these benefits into science-policy-society dialogues.

6. Establish adequate framework conditions **for effective governance and sustainable long-term funding for RIs at every stage in their lifecycle**, together with effective management.

7. Foster broader **coordination at National and European levels** when designing processes for planning and supporting national and pan European RIs and so enhance their strategic value.

In keeping with the Terms of Reference (ToR) of the ESFRI LTS *ad hoc* Working Group the recommendations are directed at European, National – including regional – levels and at the Research Infrastructures. We retain this terminology for the sub-recommendations, though some of them also concern other stakeholder groups. In order to keep the recommendations simple and understandable, a simplified logic is used in addressing the individual actors. Recommendations referring to the "European level" are directed not only at the services of the European Commission – i.e. the individual DGs RTD, CONNECT, REGIO, and others – but also address, wherever it is appropriate, the member state bodies at "supra-national level" – Council of Ministers, ERAC, ESFRI, e-IRG, and others. Similarly, when referring to "National levels", the recommendations are directed not only towards national ministries, but also address, where appropriate, the administrative sub-units – for example Länder, Cantons and Regional representations – and eventually also funding agencies if they have competences in the national decision/funding/evaluation process of RIs. Although several of the recommendations directed towards RIs also address universities and research organizations the RIs are deliberately picked out of the pool of other relevant stakeholders and society at large, as they have a particularly prominent role to play. Thus, it shall be understood that, the report is intended to directly reply to the request of the Council and ESFRI in line with the ToR. The recommendations do not address all the components of the Quadruple Helix – i.e. Government, Research Performing Organisations (RPO, universities and public research laboratories), Business & Industry, Public Services and society at large – equally.

Introduction

This report is ESFRI's response to the conclusions of the Competitiveness Council of 27th May 2016[1], which "*underlines the importance of ensuring Long-Term Sustainability of Research Infrastructures and invites the Commission to prepare together with ESFRI and relevant stakeholders a targeted action plan*". It complements the findings of a targeted consultation, which was launched in December 2015 by the EC to identify trends and possible corresponding actions that could be developed with Member States and stakeholders at regional, national and European levels, to strengthen the LTS of RIs. The results[2] of this consultation served as a starting point for consideration by an *ad hoc* Working Group established by ESFRI in summer 2016. The ToR and the members of the Working Group, who represent policy makers, RI managers and members of the user community, are provided in the **Appendices** of this report. This Working Group drew on its diverse expertise and on extensive discussions from November 2016 – March 2017, to draw up a set of recommendations which are presented in this document at several hierarchical levels. Firstly, a set of seven main recommendations is presented. These recommendations convey clear political messages, highlighting the main conclusions of the working group and provide the framework around which the rest of the report is structured. Each recommendation is developed further as a subset of more concrete sub-recommendations, which are then rationalized further with a supplementary text, which also contains supporting evidence and examples of good practice.

Research, Development and Innovation (RDI) are recognized as key-drivers of economic growth in Europe. It has been demonstrated that ⅔ of the economic growth in Europe derives from RDI, and

2. Report on the Consultation on Long Term Sustainability of Research Infrastructures, 2016, ISBN 978-92-79-58988-1
https://ec.europa.eu/research/infrastructures/pdf/lts_report_062016_final.pdf

that RDI accounts for 15% of the productivity gains[3]. The impact of public Research and Technical Development (RTD) funding is large and significant and as RIs are important research enablers they should stay very much at the centre of such activity. RI sustainability requires stability, continuity and predictability, i.e. robust and yet flexible governance. History shows that a robust long-term vision is the uttermost prerequisite in order to successfully and sustainably operate a Research Infrastructure. As with any other vision, this also requires an adequate framework and must be embedded in a supportive policy driven environment to be successful. RIs are typically operational for several decades so they require continuous and stable support. Sufficient time and support must be given to the RI to fully unfold and develop its full potential. This support cannot be reduced to financial considerations alone, though very important, but rather be founded on a broader consensus – nationally and EU-wide – as it is typically well beyond any electoral or standard budgetary planning period. Research Infrastructures must be recognized as long-term strategic investments at all levels, deeply rooted in society, and indispensable both for enabling and developing excellence in their respective scientific domains, and also as key players contributing to competitiveness with a very large perimeter. The long-term benefits of Research Infrastructures to society at large are unquestionable, irrespective of the size or scientific focus of the RI concerned. Unintended discoveries resulting from long-term RI operations may have a similar impact to the scientific achievements that are foreseeable. Large scale scientific installations intrinsically shape the region where they are located and as such they are important not only as contributors to competitiveness, but also to agendas for cohesion and integration. RIs also have a tremendous impact on skills and education agendas irrespective of their size, increasing the competences of their

3. The economic rationale for public R&D funding and its impact, European Commission (policy brief), March 2017, ISBN 978-92-79-65270
https://ri-links2ua.eu/object/document/326/attach/KI0117050ENN_002.pdf

staff, researchers and students, and through their outreach to pupil and students and the general public they steadily improve the perception and understanding of science and technology in society at large. Thus, sustainability of Research Infrastructures is an important prerequisite for maintaining continuous economic growth at national and European levels.

The following seven sections elaborate on the main recommendations above. Explanations and rationalisations are supported where possible by concrete examples of good practice.

Detailed recommendations

1. Establish and maintain excellence

RIs play a key role in the advancement of knowledge and technology and provide an important link in the innovation chain. This is exemplified in Europe by the 29 ESFRI Landmarks which have been presented as "*pan-European hubs of scientific excellence, generating new ideas and pushing the boundaries of science and technology*" and "*important pillars of European research and innovation for the next decade*"[4]. The evaluation of the RI programme in FP7[5] acknowledged that R&D conducted in RIs contributed strongly to its strengths in areas such as adaptive optics, novel photonics and robotics. RIs also play an important role in training the next generation of researchers, and facilitating collaborations and closer co-ordination and integration of research across states.

The quality that underpins all of these benefits and is the *sine qua non* for Long-Term Sustainability is *research excellence*. **Here the factors and actions that provide the best environment for such excellence to thrive are considered.**

4. ESFRI Chair Prof. John Womersley in "*Strategy Report on Research Infrastructures*", 2016, ISBN 978-0-9574402-4-1
https://ec.europa.eu/research/infrastructures/pdf/esfri/esfri_roadmap/esfri_roadmap_2016_adopted.pdf

5. Evaluation of Pertinence and Impact of Research Infrastructure Activity in FP7 – EPIRIA, Final Report, Technopolis group, 2014, ISBN 978-92-79-38965-8
http://publications.europa.eu/resource/cellar/37c857a0-76c5-4b89-ade4-3b98be3d2443.0001.01/DOC_1

Specific recommendations

Establish and maintain excellence

1.1 **The European Commission, National Authorities and Industrial Partners** should all support by adequate means the endeavour for excellence at RIs throughout their entire lifecycle, which may include the pursuit of excellent in-house scientific research and the development of new technology for users.

1.2 **The European Commission** should, together with **National Authorities**, develop guidelines for standardized, effective and robust evaluation procedures of RIs through independent international peer-review.

1.3 **The European Commission** should, together with **National Authorities** and **RIs**, develop a methodology to improve the tracking of the use of European RIs in publications and other outputs and encourage the implementation of this system at a Pan-European level.

1.4 **The European Commission, National Authorities** and **RIs** should develop or continue to support mechanisms for funding transnational access (i.e. users from outside countries that fund the RIs), recognizing that openness of RIs is a driver to achieve and sustain scientific excellence.

1.5 **Research Infrastructures** should keep pace with the development of science in their respective scientific fields, periodically assess their performance and relevance, and keep track of cutting edge technology, all in consultation with their user communities, to be able to provide state-of-the-art instrumentation and services.

1.6 **Research Infrastructures** should ensure that their procedures to evaluate and select users' proposals and projects are based on transparent, excellence-driven processes.

1.7 **Research Infrastructures** should ensure that they attract the very best research groups, including those that do not yet use them, through effective communication of the opportunities for excellent research that they provide.

Explanatory notes for the specific recommendations

Research excellence requires state-of-the art instrumentation and cutting-edge methodology, high-quality staff, services and support, and leading users who bring the most challenging or significant problems. To achieve and maintain all of these factors requires a number of conditions to be met: a culture that encourages and supports strong in-house research and/or technical development; effective engagement with the user community and access mechanisms that encourage and facilitate the very best researchers to the RI. All of these activities need to be underpinned with a funding framework that provides adequate support and long-term planning perspectives (**recommendation 1.1**). This is essential to ensure that high-quality services can be provided reliably and continuously to establish the RI as the supplier of choice to their research sector, as well as an employer of choice for the very best staff. It is also needed to ensure that effort and investment can be sustained over long periods to develop the next-generation technology that provides a competitive edge and can help drive innovation.

The factors that enable research excellence must be supported not only financially but also through a series of policy interventions, across a widely distributed national and European environment of RIs by all actors. Some of the recommendations for interventions that promote scientific excellence are also presented in the later sections of this report, particularly with regard to "skills" (**section 2**), "data" (**section 3**) and "innovation" (**section 4**). In general, all of these considerations need to be incorporated in national and European roadmaps, as well as the strategies of host organisations, where appropriate, in keeping with the principle that investment into excellent RIs is an instrument of increasing regional competitiveness, and a key component of European cohesion policy.

RIs are linked with needs of massive and long-term funding in the different phases – i.e. project based funding in the design and preparatory phase, large investments in the implementation phase, steady and continuous funding in the operational phase, and costs associated with the last phase, which are usually not accounted for initially. Therefore, it is important that a standardized and effective evaluation methodology (**recommendation 1.2**) is established to justify the accountability of spending, to support evidence-based policy considerations and to make transparent funding decisions. Robust evaluation is also very useful to the RIs themselves, helping to maintain high standards, improve operational efficiency and inform strategy and planning. The user community also benefits because it informs them where the best services are offered, and where they need to be improved and inform their input into consultation with public authorities over their research strategy and planning. All of these organisations or bodies should play a role in setting up and conducting the evaluation.

The evaluation should lead with the quality and the socio-economic impact of the science enabled by the RI (**section 5**) as well as its technical excellence, but also include some or all of the following, depending on the point in the lifecycle of the RI: the strength of the services provided, including access policy, data management and exploitation, development of skills and outreach activity, the governance, management and operational efficiency.

Evaluation should be conducted in an open, transparent manner by independent experts and as far as possible should use a common assessment framework across RIs or classes of RIs to enable evaluations performed in different countries to be as coherent as possible and to provide comparisons across different scientific domains. This, together with international members on review panels, will provide an international perspective to facilitate comparison with other national or international RIs, including exemplars, which is particularly important

for those RIs distributed across different states. Evaluation must be also tailored to the characteristics of the Research Infrastructures, but still ensure that it covers specified objectives defined more generally for RIs, again facilitating strategic prioritisation for funding bodies.

Despite the role scientometric data play in quality assessments in research, and though a variety of instruments exist to attribute scientific outputs to particular researchers or scientific institutions, procedures to trace back research results or outputs to individual RIs on an aggregated level has not been developed yet. This deficit, which is crucial for evidence based policy decisions and for RI performance monitoring is addressed by **recommendation 1.3**.

When assessing the scientific excellence of RIs, a key indicator is some measure of the quality and perhaps also the quantity of publications or other scientific results such as the number of theses published and outputs such as new technology, including software, produced by their users. At present there are significant challenges in tracing such outputs, either because of users who do not declare all of them or outputs that are less directly linked to the RI. Such assessments may also be invaluable in gaining insights into the demographics of users and more generally the relation between the service provided by a RI and the range of research it enables. It is therefore important that a programme is established to ensure that all such outputs are captured more effectively and efficiently in future, with clear rules and expectations for users so that they adopt best practices in reporting. An example of a system that could help is the use of Persistent IDentifiers (PIDs) for data resources: most certification schemes for data Research Infrastructures now require the use of PIDs.

The statutes of the Social Sciences ESFRI RI **CESSDA** require that the service providers adhere to the Data Seal of Approval and the principle of trusted digital depositories, which implies the use of PIDs in their data and metadata. **CSC Finland** is designing a persistent identifier number for RIs in their national roadmap. This can be combined with the ORCID-identification of the researcher so together one can track all the RIs that a specific researcher has used and *vice versa*.

Though Open Access (OA) is a broadly accepted concept, and moreover forms the pillar of the European innovation policy – Open Science[6]– particularly with regard to publications and data (see also **recommendation 3.1**), it still represents a challenge to both the RIs and the funders, in particular, when it comes to Transnational Acces (TNA) to RI services. Funding models based on national contributions have problems to rationalize third country access, though these represent clear European added value (**recommendation 1.4**). It is self-evident that the more open the access to RIs, the wider the net is cast to attract excellent users with excellent science. This can be seen in the user profile of analytic facilities such as synchrotrons and neutron sources where access proposals selected on the basis of the best science are significantly international in character, even at national facilities. Furthermore, the more diverse the user base, whether it is the area of science or technology, or the nationality or culture, the richer the exchange of ideas and perspectives provided in meeting scientific and technical challenges. Such exchanges are also important in aiding European integration and accelerating development in areas where research communities are less well developed.

6. Open Science
http://ec.europa.eu/research/openscience/index.cfm?pg=home

It is therefore important that there are effective mechanisms to encourage and support TNA to RIs for excellent science that passes peer review (see also **recommendation 6.2**), recognising that there may be significant political challenges in opening national and international facilities up to users from countries that do not contribute financially. This is particularly challenging for the larger, physical facilities where operational and investment costs may be very high, and creative models should be developed[7]. Even for virtual services, where costs are usually lower, there are still challenges for effective TNA, including internal restrictions, licenses and legislation.

A Research Infrastructure that from its origin has facilitated open and easy access to its resources is the **European Social Survey (ESS) European Research Infrastructure Consortium (ERIC)**. The **ESS ERIC** is conducting biennial surveys in most European countries. So far 36 European countries have participated in the survey in 7 rounds. Data and metadata are made available to users simultaneously around the world free of charge. This together with the high quality data and services offered has made ESS ERIC one of the most widely used RIs exceeding 100,000 unique users and annually close to 15,000 downloads of data and metadata. The value of this is reflected in part in the strong publication record of the ESS ERIC – with 3,140 English language publications to date.

Recommendation 1.5, which calls on RIs to stay at the forefront of science, periodically assess their performance and relevance, and keep track of cutting edge technology, in close consultation with their user communities is essential for RIs to be able to provide and continue to provide state-of-the-art instrumentation and services.

By definition RIs provide facilities that are beyond the means of individual researchers and generally beyond the means of individual

7. One principle to bear in mind is that although some countries may not be able to pay much into large RIs in terms of cash, the human capital they provide is very valuable

institutions. They present research communities with the opportunity to access cutting edge technology, state-of-the-art data and metadata handling, dedicated expertise and user support, often in an open access environment that stimulates creativity and scientific excellence. However, such facilities only retain their competitive edge if they keep pace with the latest developments in their respective scientific fields and advances in techniques and technology. Failure to do so inevitably leads to decline, first in the quality of users and the science that is delivered, difficulties to attract and retain the best staff and ultimately the likely loss of funding.

The **benefits of long-term investment in RIs** may be illustrated by both the **Institut Laue-Langevin (ILL)** and the **European Synchrotron Radiation Facility (ESRF)**, both located in Grenoble and respectively still world-leading facilities for neutron scattering and X-ray science. Periodic upgrade programmes at ILL have ensured that its facilities remain at the forefront of technology and scientific achievement, with the latest 'Millennium Programme' delivered over a decade of development increasing the average brightness of its instruments by orders of magnitude in its fourth decade of operations at a fraction of the cost of building a new facility. The ESRF has also been transformed by many orders of magnitude in effective brilliance over the decades and is set to jump to yet higher standards with its new Extremely Brilliant Source upgrade towards the end of this decade.

It is therefore crucial that RIs engage with the research community and industry to keep abreast of developments in both science and technology, aided by expert panels that have both internal and external representation, and through collaborations with other RIs and research organisations. They should also routinely assess their capability and performance in relation to the needs of their user communities, identifying gaps between their demands and the services and tools offered. This requires elements of the rigorous evaluation processes outlined above (**recommendation 1.2**). It also requires an effective

communication mechanism and dedicated personnel who actively establish collaborative links with local, national and international partners and discover and exploit potential synergies among different stakeholders of the RI.

All of this will enable the RI to develop a vision for future scientific and technical challenges, a medium to long-term strategy to meet those challenges and a delivery plan that is regularly updated. Enacting such a plan requires adequate and stable funding to ensure that RIs can provide services that are both reliable and excellent and most likely to attract and grow a strong and vibrant user community that delivers excellent science and innovation. Such funding should also be provided within a long-term framework (see also **recommendation 6.4**) because some of the technical developments and upgrades essential to achieve the most ambitious and rewarding visions have long timescales for planning and delivery[8]. Such commitment fuels not only the leaps in capability of RIs that enable ground-breaking advances in science, but also ensures that the very best staff and users are engaged, strengthening further those RIs.

Such developments should not be undertaken independently by each RI, but rather collaboratively wherever there is common ground and synergy in technology, methodology and expertise. Here programmes such as INFRADEV under Horizon 2020 – INFRADEV-4-2014/2015 – are tremendously helpful, aiming to "*ensure coordination and synergies between the largest possible number of ESFRI projects and other research infrastructure initiatives in a thematic area, where proposals should address a coherent set of common activities and be comprehensive*". Projects that develop synergies and complementarity, between the RI initiatives in specific thematic areas should also be available for the ESFRI Infrastructures in the future.

8. As exemplified by the EIROforum organisations, see http://www.eiroforum.org

A key ingredient for excellence at RIs is the quality of the users and the research they bring. It is essential that selection processes are open, transparent and informed by independent expert opinion with an emphasis on scientific excellence and the overall strategic priorities of the RI (**recommendation 1.6**). This is generally provided by a selection panel with international representation which understands the operations and strategy of the RI. Attention should also be given to ensuring that the application and assessment process is readily accessible to users who are not familiar with the RI or even expert in the techniques offered because they too may bring excellent research. This requires clear, readily understandable information and perhaps also some degree of institutional support or advice to be provided to attract and support such applicants.

RIs should ensure that they attract the very best research groups (**recommendation 1.7**) through effective communication of the opportunities for excellent research that they offer (see also **recommendation 7.5**). the user community, current and potential, and thus exploit their full potential.

Particular thought and effort should be put into identifying and targeting groups or even sectors of research which do not yet use specific RIs, perhaps because they are unaware of the opportunities or believe that there are barriers to access, be they lack of suitable training or cultural background. Attracting such new users or responding to existing users should be part of the vision and strategy mentioned in **recommendation 1.5**, often requiring foresight and consultation to understand their specific methodological and technological needs. The first engagement with new users may also need dedicated resources for training and support. Retaining these and more established users will also require some degree of continued support and constant vigilance to ensure that confidence and trust is maintained, and availability and access to services remain easy and predictable.

2. Ensuring the right people are at the right place at the right time

The most important resource for a RI is, arguably, its human capital. This includes its own staff, who play many roles – designing, building, operating, using, supporting and managing – as well as the user community who exploits it for research and innovation. Most of these roles require very specialised skills or experience to be effective and many of them are rare for a variety of reasons. The set of skills required by a RI may change markedly during its lifecycle so demand and supply can change rapidly. RIs also operate across traditional domains and disciplines, requiring, for instance scientists with experience in handling large and complex data sets, or in working with engineers to design bespoke and often highly innovative equipment. RIs generally also combine the character of a scientific or technical institute with a service provider, requiring operators who have experience and insights into scientific or technical issues whilst also being a professional manager. Users too, in academia or industry, generally need some degree of training to appreciate and exploit the potential of RIs in their research.

The critical dependence of the performance of RIs on people with the right skills and experience throughout their lifecycle should not be left to chance so a set of measures are recommended to mitigate this risk.

Specific recommendations

Ensuring the right people are at the right place at the right time

2.1	**All levels** should recognise that sufficient staff equipped with specific skills are required at different stages of the lifecycle of RIs and they should establish guidelines for qualifications and evaluation for the recruitment and training of RI managers and operators.
2.2	**At all levels** staff mobility and exchange programmes for project management and capacity building should be developed for RI personnel aided by greater harmonisation across countries of career paths, pension schemes and salaries as well as exchange and re-integration schemes between RIs, and universities and also with business and industry.
2.3	**At the European level** it must be ensured that a sufficient number of suitably trained people of all types (users and staff) are made available to RIs through training programmes via EU-networked national schemes, e.g. organised and funded through I3-like programmes.
2.4	**National Authorities** should support and harmonise research and education programmes linking RIs with universities and, where appropriate, also business and industry at PhD, post-doc and more advanced levels in order to provide specialised skills and training, some of which should go beyond traditional curricula (for example data scientists and RI managers).

Explanatory notes for the specific recommendations

People with different and highly specialized knowledge, competence and expertise are required throughout the lifecycle of a RI, from design to construction, operation and decommissioning (**recommendation 2.1**). National Authorities should recognise this need and take measures to provide or increase capacity drawing on regional or European support

where appropriate and European evaluation and monitoring processes should systematically consider the status of provision of human resources and the measures taken to ensure that they are adequate. Such measures could include specialized education and training programmes set up through collaborations between universities and RIs, with the latter providing not only specialised expertise but also hosting practical training, including medium to long-term residential courses. It would be highly desirable for such initiatives to be co-ordinated across Europe to ensure that those who are educated and trained can transfer and apply their skills and knowledge as effectively as possible across RIs in different countries. Where appropriate this could involve harmonising curricula, standards and accreditation criteria as well as exchange of students with RIs in other countries.

Such initiatives should be developed and supported by national, regional and European funding schemes and should include not only graduate level students in preparation to be users or staff members of RIs, but also mid-career scientists and engineers, including those who wish to become RI managers. For a more efficient implementation of such "skill-building" programmes across Europe, it would be useful to establish guidelines for qualifications and for evaluation during recruitment processes, elaborated by RIs according to their needs at different phases in their lifecycle.

The changing demand for different people with different skills at the different stages in the lifecycle of a RI presents a challenge and an opportunity, particularly during the transition between phases. For example, there is a fall in demand for engineers with very specific skills at the end of the construction phase of many RIs and an even more abrupt drop in demand when a RI is closed or decommissioned. This risks the dispersal and probable loss of these valuable skills and experience – assets that could be put to good use at another RI that lacked such skills. In principle such people are free to move between RIs

and countries as demand for their skills changes, but there are significant barriers in place, including differences in salaries and pension schemes, and limited knowledge and information about opportunities elsewhere.

One way to address this challenge (**recommendation 2.2**), reducing such barriers and freeing up movement, would be to establish a formal framework to encourage mobility of operators and managers within the European RI system. This should include training schemes, where transfer would be on a temporary and probably short-term basis, as well as longer-term or indefinite periods of work, helping to smooth out the gaps in potential supply and demand of skills across Europe. Schemes should include skilled people towards the end of their career, for example exchange programmes between different institutions with mutual benefits, aimed at highly experienced professionals.

Barriers arising from national regulations in career paths, salaries, and pension schemes should be lowered to facilitate mobility. Although the structure of salaries will be nation-dependent, it would be desirable to establish some common threads in remuneration of RIs' employees to facilitate mobility between the European RIs. Re-integration schemes should be developed as well for professionals moving from universities or research organizations towards the RIs and *vice versa*. To improve the impact of RIs on innovation it would also be advantageous to establish or strengthen the flow of trained people in both directions between RIs and industry to exchange skills, knowledge and cultural appreciation.

Training programmes tailored for the different RI-related subjects could be established at a national level under an organizational umbrella at a European level to ensure the international dimension – for example training schools for neutron, synchrotron and laser facilities could be organized under one of the I3 pillars (**recommendation 2.3**). This could ensure that attention is paid to regional and national needs whilst organised at an international level with regards to the programme,

exchange of practice, speakers and students. The model is a European network of national "schools" hosted by the RI with contributions from universities and perhaps also industry. Different programmes, harmonised at a central level, can be tailored to fit the needs of the various types of "students" – managers, users, etc. It would be useful to establish a tradition for at least one of these schools, for example a "*High school for top RI managers*". The European Commission should be encouraged to fund schemes similar to Marie-Curie RISE actions, oriented, however, to provide training and favour mobility between universities and industry towards and from RIs. There is a wealth of experience in business planning in existing RIs which could be easily used as a basis for the training of managers for new facilities.

There are several examples of good practices within the European RIs system, aimed at nurturing skills through specialised training and mobility support actions. A well-established and successful example is offered by the **HERCULES European School**, a 1-month school, started in 1991, which "provides training for students, postdoctoral and senior scientists from European and non-European universities and laboratories, in the field of neutron and synchrotron radiation for condensed matter studies (biology, chemistry, physics, materials science, geosciences, and industrial applications). It includes lectures, practicals, tutorials, and visits to several Large Facilities"[9]. Among the keys to the success of the HERCULES School are the high profile and quality of the course coupled to on-site practical laboratory experience, the European dimension and strong links between the RIs involved and universities.

There is an increasing need to develop and encourage some of the rather unusual career tracks on which RIs rely – for example at the boundary between science and engineering for skills required in designing and building next generation equipment or those at the interface between data analysis and empirical science – "data scientists"

9. HERCULES European School
http://hercules-school.eu

in general (**recommendations 2.4** and **3.1**). There is also an increasing need to ensure that RIs are better equipped to understand and engage with industry and business – and *vice versa* – to accelerate innovation and better appreciate the opportunities provided by rapidly evolving technological developments. To train new professionals to fill these roles, and populate new career tracks, universities and other higher educational establishments should provide master courses and short focused training programmes with RIs and, where appropriate with business and industry. RIs should quickly adapt and possibly reserve for themselves a role of incubator and facilitator of new ideas and technologies or serve as a test bed for new developments.

An example of good practice is the "summer" and "thematic" schools organised by **CERN** and addressing a broad spectrum of students and trainees, from undergraduates to teachers, to expert researchers. As with the **HERCULES School**, key to success is the excellent level of communication and the close links between the RI and the network of European and global universities. This is complemented by the highly qualified and respected CERN Fellowship Programme which supports early stage researchers and career development.

3. Harmonise and integrate the operation of RIs and e-Is

The Long-Term Sustainability of RIs involves the generation and the exploitation of digital data, products –including software – and services. RIs such as those on the ESFRI Roadmap produce and are dependent on rapidly increasing amounts of data. To take full advantage of the major investments in RIs the data they produce need to be made openly and easily available to researchers, across a broad span of fields, in sustainable environments. To enable this, the data need to be managed, stored and preserved in a cost-efficient way, with appropriate quality and safety assurances, fostering access across borders. To reach this goal, e-science solutions for enabling access, storage, preservation and curation of large amounts of data need to be made available. Data infrastructure therefore is a central part of the research ecosystem, which enables researchers and other stakeholders from research, education, society and business to use, re-use and exploit data for the benefit of science and society.

To be successful further initiatives should be undertaken to sustain programmes for promoting coordination between RIs and e-Infrastructures (e-Is) at different levels – policy, governance, practitioners – to create new innovation drivers in data exploitation for science and society, including industry. ESFRI and e-IRG have already worked together for some years at a European level[10] including the engagement of the e-IRG in drawing up the ESFRI Roadmap, but this should also be followed up at a national level. The different RI and e-I research communities think quite differently at present so it is important that they talk to each other and find common ground and

10. Group of European Data Experts – GEDE is supported by RDA Europe and aims to promote, foster and drive discussions on data-related guidelines and core components and a concrete data fabric configuration. Currently the Group comprises over 40 invited experts from European Research Infrastructures, with the ESFRI and e-IRG Chairs acting as observers.

common solutions. This is always a challenge. A start has been made but all stakeholders should further promote existing initiatives such as the Research Data Alliance (RDA)[11]. Digitalization of the valuable outputs of RIs will lead to enormous innovation by fostering novel use and re-use of data and scientific products beyond thematic boundaries.

This has to be supported from the beginning for all phases of the lifecycle of RIs, from design through implementation to decommissioning. This will help to close the gap between RIs and e-Is regarding the Long-Term Sustainability of service provision and data management. European and National Authorities and the EC should take effective measures to create synergies between RIs and e-Is to facilitate service provision, data and metadata integration. The recommendations presented here have been envisioned with the goal of fostering the adoption of incentives and effective measures to establish synergies between RIs and e-Is aligning national and regional initiatives with the pan-European perspective.

11. Research Data Alliance
https://www.rd-alliance.org

Specific recommendations

Harmonise and integrate the operation of RIs and e-Is

3.1	**European and National Authorities** should develop and implement a new culture, which acknowledges the need of new skills to optimise future use, reuse and multiple use of data, increasingly across disciplines.
3.2	**European and National Authorities** should harmonise different existing funding models between RIs and e-Infrastructures at all levels.
3.3	**European and National Authorities** shall develop stable and robust certified repositories and registries for data preservation following the FAIR – Findable, Accessible, Interoperable, and Re-usable – approach.
3.4	**European and National Authorities – including RIs** – should foster international cooperation to support the global dimension of data management and interoperability among RIs generating data, products, software and services for science and society.
3.5	**National Authorities** must assure that **RIs** have prepared data management plans as a basic eligibility criterion for funding right from the beginning; requirements for such plans have been developed by e-IRG/ ESFRI and others.

Explanatory notes for specific recommendations

In the data-intensive scientific world, new skills are needed for creating, managing, analysing and making available large quantities of data for re-use in different scientific contexts across narrow disciplinary boundaries. **Recommendation 3.1** addresses this point – but see also **recommendation 2.4.** Long-Term Sustainability of RIs requires a change of culture for data management. Several indicators emphasize that the

development of data Infrastructures for re-usage and re-combination will be a driver of innovation and excellence. To exploit this, it is mandatory to educate the next generation of scientists in data science or more generally to become data professionals, stimulating cross-disciplinarity and data preservation. It is necessary to develop data skills in all research domains, advancing progress in science, data management and long-term preservation. Different stakeholders are involved in this process of education and training to data science, including National Authorities (for policies and incentives), funding agencies (for sustainability of open science following ethical principles), scientists (to support educational initiatives for open science and data science), and society (to use data and services coherently with ethical principles).

Pan-European RIs are able to attract world-class scientists, who can tackle the grand challenges faced by society by addressing ground-breaking research questions, requiring the production of high-quality data and attracting the best talents to address them. This implies that RIs are essential parts of the education, research and innovation systems, because they can foster an innovative use of the data providing a proper environment for training and educating the next generations in data science.

Actions are needed to hormonise the different existing funding models and cycles between RIs and e-Is at regional, national and European levels (**recommendation 3.2**). Dedicated programmes should be encouraged and undertaken to overcome the present lack of procurement models for RIs for designing coordinated data access and IT service provisioning. These represent effective contributions to implement the business models of both RIs and e-Is. This implies that costs for different services and their provision are made transparent and that different options for implementing and evaluating them are investigated.

Exploiting the innovation potential of data generation and provision requires the adoption of feasible business models relying on a win-win approach between public and private endeavours. Sustainability also concerns supporting the costs for Open Access. Funding agencies and National Authorities should also foster initiatives to support computational tool developers to tackle big scientific challenges through open source approaches. Europe needs its own cost-effective solutions for data preservation developed through sustainable models for Open Science[6].

There is a specific need to develop stable and robust repositories and registries based on widely agreed core components for data management and preservation following the **FAIR – Findable, Accessible, Interoperable, and Re-usable – principles**[12] (**recommendation 3.3**). This involves governance (of data and service provision including sharing efforts and responsibilities between RIs and e-Is), financial (funding for data storage and preservation), legal (licensing and open science commons), and technical issues (interoperability, traceability). This is essential in order to achieve the cost-efficient implementation of services and maintenance of data repositories for long-term data preservation. It is worthy of note that several ESFRI Landmarks have been designed to curate, preserve and make data available for re-use – CESSDA, DARIAH among several others.

There is a specific need to implement policies at European and National level to help data repositories preserve their data holdings, ensuring the interoperability of implemented services, and building the trust of service providers. These policies should facilitate the adoption of cost-efficient solutions for maintaining preservation activities for data and services supporting interoperability, usability, authenticity, accessibility, discoverability, visualisation and replication. Initiatives like the

12. For reference on the FAIR data principles see for example http://www.nature.com/articles/sdata201618

European Open Science Cloud and the European Data Infrastructure, recently launched by the European Commission, should be built upon sharing policies and sustainability models with National Authorities.

Though several global initiatives exist and have produced a number of policy documents[13], the global dimension of data management has not yet been recognized and reflected sufficiently in the various RI policies. Adequate measures shall introduce mechanisms and measures allowing better management of data produced by the RIs (**recommendation 3.4**) and new models allowing interoperability of data, products, and services shall be explored, at all levels. Supporting data science includes the development of appropriate policies and the adoption of effective incentives. Policy makers and funding agencies are recommended to take action to ensure that conditions for funding research grants at regional, national and European level are adopted. Data management plans for data creation, access/sharing and re-use are a must and therefore a precondition for funding. But funding has to include the financial support for open access and long-term preservation.

Actions should be undertaken to implement codes of conduct and ethical guidelines in order to foster open science commons. This includes education and promotion of legal and ethical principles on data sharing. Actions should also be undertaken to foster data availability policies in scientific journals coherently with open science commons and ethical principles.

Initiatives should be undertaken to enable global usage of research data within the given discipline, across disciplines, and in new research settings that could possibly not be envisaged at the time of creation of the data. This requires international cooperation to adopt shared and standardized data and metadata formats, as well as to foster federative

13. The Data Harvest Report – sharing data for knowledge, jobs and growth https://www.rd-alliance.org/data-harvest-report-sharing-data-knowledge-jobs-and-growth.html

approaches for user identification, authorisation, authentication and accountability of data providers. Initiatives such as the RDA or the World Wide Web Consortium (W3C) can represent good practices to move in this direction.

In order to support the data policies mentioned above, concrete measures shall be introduced into the national RI evaluation and monitoring processes – i.e. a data management plan shall be required already at the very early stages of the RI planning and its implementation shall be regularly assessed and monitored, as one of the preconditions for funding throughout the entire RI lifecycle (**recommendation 3.5**). The attractiveness of RIs for users (including industry) strongly depends on the provision of quality-controlled and standardized data relevant to the development of products and services for different stakeholders. This implies the elaboration of Data Management Plans, which involve technical (discoverability, interoperability, usability, traceability, authenticity, visualization and replication), legal (data policies and access rules, IPR), governance (for the whole data lifecycle from generation to preservation) and financial (secure funding for data generation and preservation) issues. This is presently a challenge for all the RIs. This also involves the harmonisation of investments at national and European level and also regional, for both single-sited and distributed RIs. This is crucial to make data and service provision a real driver for innovation and excellence.

Initiatives should be undertaken to foster the identification of clear roles for data management – e.g. users, data-providers, service providers, infrastructure hosting organizations, and IT scientists – distinguishing responsibilities and formalised relations to ensure effective and cost-efficient solutions for maintaining high-quality standardized services. Funding paths should be defined and sustainability for all parts of the Research Infrastructure – including IT service provision through e-Infrastructures – should be secured. Guidance to the grant holders

and RI managers on data management solutions and sustainability is recommended.

4. Fully exploit the potential of RIs as innovation hubs

Research Infrastructures, as enablers of high quality research, providers of advanced services and data as well as prescribers of leading-edge technologies, have an innovation potential that deserves to be exploited more fully to ensure Long-Term – financial and societal – Sustainability and acceptance. This innovation potential is associated with the construction and upgrade phases, when the drive to push back technical boundaries stimulates or enables development with high technology companies, with the operational phase when service provision to users can lead to scientific discoveries and novel ways of exploitation, as well as with the re-use of data.

There are, however, many significant challenges to fulfilling this potential: imperfect communication, and lack of awareness of the needs and opportunities of RIs and all the economic players – industrial and service companies as well as NGOs; entry barriers for accessing RIs; insufficient human resources, particularly at the interface between RIs and the commercial sector. Some of these challenges can be met by creating a more efficient integrated and coordinated ecosystem for RIs and industry in which every player in the socio-economic value chain is involved, including public authorities at local, regional, national and European level, depending on the scale and scope of the RI.

It is also crucial that the culture in and around RIs provides fertile ground for innovation, bringing together scientists from many, diverse backgrounds – both disciplinary and nationally – encouraging serendipity, a lively exchange of ideas and stimulating cross-disciplinary activities, including far more extensive and effective use and re-use of data. The importance and the challenges of developing a strategy to strengthen and improve the relations between RIs and industry

and to promote the potential for all aspects of innovation at Research Infrastructures has been the subject of a special Working Group on Innovation established by ESFRI in 2013 and reporting in 2016[14].

14. Working Group on Innovation, Report to ESFRI – March 2016
http://ec.europa.eu/research/infrastructures/pdf/esfri/publications/wginno_final_report_032016.pdf

Specific recommendations

Fully exploit the potential of RIs as innovation hubs

4.1 **European and National Authorities** should encourage the development of innovation ecosystems around RIs and stimulate innovation-oriented activities within RIs, including the innovation potential of data generation and service provision. National Authorities should strongly support the implementation of Innovation Parks in the vicinity of the RIs, regardless of whether they are of national or of Pan-European interest.

4.2 **National Authorities, RIs, Research Performing Organisations and Business & Industry** should facilitate procedures for RIs to become partners in the development and commercialization of innovations and of putting innovations at the service of the broader public born there and encourage RIs to facilitate early involvement of Business & Industry and Public Services in the supply of high tech components and increase the awareness of RI staff of these matters.

4.3 **National Authorities** should work with **RIs**, Business & Industry, Public Services and Research Performing Organisations to develop and co-fund exchange programmes for staff and PhD students to raise mutual awareness by the RIs, Research Performing Organisations, Public Services and Business & Industry of their needs, opportunities, operations and culture.

4.4 **RIs** should encourage and support Public Services and Business & Industry to engage with and exploit them more fully by identifying their needs and by tailoring user policies and practices to meet these needs.

4.5 **Research Infrastructures** and **Research Performing Organisations** should establish structures and culture in which (open) innovation is most likely to thrive, including: recruitment of an officer to implement innovation policies with dedicated resources, supported by an advisory body composed of representatives of appropriate industries or commercial activity; raising the awareness and incentivising of staff to engage in innovation activities.

Explanatory notes for the specific recommendations

RIs are essentially immovable entities, with the exception of distributed networks such as databanks, so their wider and more effective involvement in the innovation chain implies that they should provide the kernels of innovation campuses, possibly with other RIs, attractors for clusters of innovation partners (**recommendation 4.1**). This will require proactive support from National Authorities through policy and funding initiatives to encourage universities and institutes to create such campuses around RIs, attracting businesses, including Small and Medium-sized Enterprise (SMEs), to locate there and provide fertile ground for start-ups, drawn by the prospect not only of exceptional research facilities, but also a highly skilled, vibrant research community. Further encouragement for private companies and business associations to engage should be provided through legal arrangements such as tax-exemption to recruit PhD and post-docs who have been trained at RIs, and locate them at the innovation hubs. Yet wider integration of partners can be encouraged through a hub and spoke model, with spokes radiating from the hubs of the innovation campuses to partner organisations, facilitated by both virtual tools – remote access being an increasingly common way to engage many RIs – and facilities at the hub such as research hotels to host both academic and industrial partners.

The **GIANT Partnership** (Grenoble Innovation for Advanced New Technologies), which includes two large-scale RIs – ESRF and ILL – gave birth to the NanoElec public-private partnership, led by the CEA. It incorporates a comprehensive "Characterisation Program" exploiting synchrotron X-ray and neutron capabilities, together with CEA's Nano-Characterisation Platform, for industrial research and innovation in electronics. All the key global players installed around ESRF and ILL – STMicroelectronics, SOITEC and Schneider – are involved in the project. The combination of the RIs with a leading technology research institute and strong industry anchors is a heady mixture, able to unlock the innovation potential of the synchrotron X-ray and neutron facilities in this regional ecosystem and beyond.

In order to stimulate innovation all along the RIs' supply-chains, National Authorities should help to remove the barriers for companies, particularly SMEs, to develop new technology including that based on discoveries and development at RIs. Such activity often has a high commercial risk because development times and costs can be very high and unpredictable and the markets are very specialised.

Mechanisms should be put in place (**recommendation 4.2**) to encourage and support RIs to continue to work with partners who were involved in the earliest stages of an innovation born in a RI, all along the value chain through to the development of a commercialized product. For example, the acquisition by a RI of a forefront component or a new set of data may be a source of innovation for the future owner and the supply chain. So this operation must be carefully prepared by mutually improving the knowledge of the capacities of each other, RIs alert potential suppliers well ahead of such tender opportunities and as far as possible international or European standards should be used to prepare specifications.

The Harwell Campus in the UK hosts several RIs, including the Diamond synchrotron facility, the UK national neutron facility ISIS, and the UK Central Laser Facility. This concentration of facilities is complemented by the Research Complex at Harwell which is a research hotel that enables visiting academics and industrial researchers to better exploit the RIs. The critical mass of facilities and researchers has attracted further investment in meso-scale infrastructures such as a state-of-the-art Cryo-EM centre that is a national resource for academia and industry which together with the others RIs is attracting an increasing level of industrial activity, including technical development.

Procurement processes should be also developed to encourage a wider range of companies to engage more effectively with RIs. The innovation potential of the supplier should be stimulated through unconventional procurement procedures – competitive dialogue, PCP, PPI, conditional contract – including when necessary specific safeguard provisions or IP rights for protecting tangible or intangible assets. The rigid application of "juste retour" principles, particularly for construction of large international facilities with significant levels of in-kind contribution does not always lead to a very efficient and effective use of resources. Public purchase procedures should be applied discerningly when Structural Funds are used for building advanced research and development platforms. In general contracts should be awarded on the "best-value-for-money" principle.

It is also important that RIs develop a culture in which opportunities to recognise and develop disruptive technology are likely to thrive. This could involve financial incentives for the teams or individuals at RIs who contribute to such developments, and closer engagement of such staff in discussion with designers and developers in industry. It is also important that RIs identify, and where appropriate exploit, their intellectual property and other intangible assets, including the immense wealth of "electronic know-how" tied up in software produced at RIs to

be developed further for wider use and exploitation in the outside world. In parallel and when appropriate, European and National Authorities should develop the use of market studies to understand better the potential to exploit the ideas, services or products of RIs at every stage of the value chain.

The **NAOS project** aims to increase the amount of deep submersible buoys implanted by France within the European Euro-Argo ERIC project from 10 to 15 units per year over 10 years. Thanks to the recruitment of post-docs, NKE, a SME from Lorient (Brittany), has been preferred for ensuring the industrialisation and the commercialisation of this new generation of submersible buoys able to embark new biogeochemistry sensors. NKE is the exclusive licensee of IFREMER for the exploitation of this buoy technology and aims to become a European leader in oceanographic instrumentation.

It is urgent and essential to bridge the cultural gap between the research world – including academia – and the business sector and this requires training and other actions such as exchange schemes for staff and students to raise awareness on both sides of the divide (**recommendation 4.3**). Such exchanges can only start once suitable partners have identified each other so an essential step is to raise mutual awareness, possibly by supporting at national and European levels the participation of RIs in industrial fairs and showrooms, and of industry in meetings or workshops run alongside major scientific conferences. Facilities at innovation hubs and campuses could further support awareness raising and closer engagement, for example by making it easier to host short, medium and long-term visits by academics and industrial researchers alongside the RIs and/or in research hotels. In the particular case of RIs, there is a distinct lack of staff in companies who have a research-oriented training or are even aware of the potential of RIs in their sector; equally, RIs commonly have few or no staff with any experience in business or industry, even at the very senior levels of management or on Boards

of RIs. The last of these could be addressed by including members of the commercial world on Boards or advisory bodies for RIs (see also **recommendation 4.5**).

Over 900 scientists and engineers from RIs and industrial companies supplying synchrotrons were brought together over 3 days in 2012 at the **11th International Synchrotron Radiation Instrumentation Conference**, jointly organized by ESRF and SOLEIL in Lyon (France)[15]. Talks were given on instrumentation techniques and on innovative procurement tools while industrial exhibitors presented their wares at more than 90 stands and academics presented over 200 posters on future development of equipment and services at RIs.

RIs should encourage and support public bodies and business and industry to engage with and exploit their services more fully by identifying their needs and by tailoring user policies and practices to meet these needs (**recommendation 4.4**). This starts with a clear commitment to providing such services in their vision, and a clear delivery strategy, impressing on staff throughout their organisation that this is essential for their Long-Term Sustainability so that it permeates their culture. It also requires an informed understanding of what industry needs and how best to meet those needs. This should flow from the actions described in the **recommendations 4.3** and **4.5**, particularly the establishment of advisory boards with industrial members, and an industrial liaison office to direct and deliver fruitful engagement with industry. All of this should also be followed up with an evaluation of how successful the RI is at such engagement, with KPIs that capture the extent and nature of contact with industrial users and suppliers, and the degree to which it is translated into the sale and delivery of services, and outcomes, including socio-economic impact (for example profits and jobs created) as well as social benefits (**section 5**).

15. The 11th International Conference on Synchrotron Radiation Instrumentation http://www.lepublicsystemepco.com/files/modules/freezones/ProgrammeSRI2012-Web2.pdf

Particular activities that RIs could perform in this regard include: facilitating better access to data and services which foster cross-disciplinary applications, and create innovation drivers for data exploitation; encouraging and supporting the creation of an intermediaries' club comprising research laboratories involved in high-level TRL research and of private consultant companies (e-technology platforms, software service-oriented start-ups) as facilitators for SMEs to help them make the best use of the RIs. The role of these intermediaries could be subject to clear access contracts based on fair access fees able to equally remunerate both the intermediaries and the facility.

BrightnESS is a European Union-funded project of H2020 for the European Spallation Source (ESS). The project will ensure that key challenges are met in order to build an ESS that can deliver high impact scientific and technological knowledge. The project aims to support the construction of ESS in key technical areas and in-kind coordination, providing resources for the development, testing and optimization of ESS's state-of-the-art technologies. The BrightnESS project will ensure that:

- The extensive knowledge and skills of European companies and institutes are best deployed for the construction and the operation of ESS.
- The technology transfer between ESS and the European institutions and companies is optimised.
- The maximum technical performance is obtained from the ESS target, moderators and detectors in order to deliver world class science and insights for materials technology and innovation.

RIs should establish a dedicated unit - commonly called the Industrial Liaison Office (ILO) - whose role is to establish a vision and strategy to ensure innovation will thrive (**recommendation 4.5**). With the support of senior management the ILO will help to establish a culture in which staff at all levels are also committed to this ideal and seek opportunities for innovation with enthusiasm and ingenuity.

This unit should be led by an innovation Liaison Officer (LO) recruited at a level that reflects the importance and responsibility of the position, empowering the person not only to develop the RI's strategy in this domain but also to interact with industrial users at a reasonably senior level. The LO should set up an Advisory Committee for all industrial relations – users, suppliers, developers – primarily comprising influential representatives of the different industrial sectors and perhaps also representatives of National Authorities responsible for innovation policy and delivery. This Advisory Committee should help the ILO to conduct a strategic classification of potential users of the RI in order to identify their needs as well as possible and to meet the particularities of each sector.

CERN has twenty-five years of experience in the management of **Industrial Liaison Officers** who individually act as representatives of a CERN Member state in charge of ensuring the proper contacts and flow of information between CERN and the firms in the Member state concerned. They have their own forum where they liaise and organize common actions such as setting up consortia between firms of different countries.

The ILO should also engage more widely in collaborative activity across Europe with ILOs of other RIs, either as existing RIs, projects, landmarks or emerging projects. Such activity may include benchmarking exercises, joint workshops, enhanced cross-border brokerage events, specific training linked to this part as well as to gender dimension of Research and Innovation, and twinning schemes. Special attention should be given to enhance the visibility and competence of LOs, including helping less experienced industrial partners in acquiring the know-how needed in the procurement relations with Research Infrastructures. While RIs are very diverse, there are often synergies in technologies, methods and actual or potential industrial partners so that the greater the extent of

such networking and collaborations, the greater the likely benefits to the partners.

5. Demonstrating the economic and wider benefit to society of RIs

There is increasing political and social pressure at all levels for RIs to demonstrate the positive contribution they make to society in general, including the impact on regional and national economies, and the benefits they offer to our citizens through the science they deliver, such as better healthcare, a cleaner environment or developments to communications and transport. This Socio-Economic Impact (SEI) is also an increasingly important factor in deciding whether to construct an RI, in setting the level of funding for operations, and in informing decisions about the lifetime and ultimately closure of an RI. It is therefore important that adequate measures are put in place to estimate the SEI of current and planned RIs within a pan-European framework to enable the most effective comparisons and strategic decisions to be taken at both European and national levels.

Both the definition and measurement of SEI present considerable challenges. SEI may be manifested in many, diverse ways that depend on the nature of the RI such as the domain or discipline of the activity, whether it is engaged directly in empirical studies or developing and exploiting databases, and whether it is central or distributed, national or international. It can reveal itself from very local to global scales and it may span the entire lifecycle of the RI, from planning and construction, through operations to closure and dismantling or decommissioning.

The ways in which SEI is measured may also be very broad and varied, from the direct financial benefit of a RI – putting money into local, national, EU economy through payment of wages, purchase of products and services and secondary job creation – through the impact or value of the science itself – noting that it is often trickier to establish causality, particularly over long time-scales, and when the data created is then shared and used more widely. The benefits of such research can also

be very varied, from creation of products to welfare of society – curing disease, environmental improvements such cleaning up air or water – to impact on cultural, public institutions and social policy, e.g. legislation for the environment or healthcare and practice development, and the value to industrial partners who may use the RI or go on to develop and market technology from the RI. Some of these benefits may be measured through patents filed or prototypes produced, income generated, competitive grants raised or jobs created. Operation of RIs also has an impact in terms of skills and training, from students, including masters and doctoral students, through apprentices to the staff and users of the RI.

The determination of SEI is complicated further by the difficulty of establishing causality between the activities or research enabled by a RI and its value or potential value to society, quite possibly with a very long time delay or induction period, though there are cases where this has been attempted[16]. The benefits of the activity at RIs may also be much broader or very different from the original motivation or intention – for example the invention of the world wide web at CERN.

16. Research Excellence Framework Impact
http://www.hefce.ac.uk/rsrch/REFimpact/

Specific recommendations

Demonstrating the economic and wider benefit to society of RIs

5.1 **The European Commission** should together with **National Authorities support** the development of a model with key performance indicators to evaluate the socio-economic value of RIs, support its adoption across Europe, and use the findings to promote and encourage the use of RIs for the greater good. This model should aim to provide comparisons between different types of RIs while recognising the great diversity in scientific domain and character, the wide range of benefits they bestow on society, and different national environments.

5.2 **National Authorities and funding bodies** should be explicit about the role that socio-economic benefits play in their strategy and funding decisions so that RI operators are aware of its significance and take appropriate action when developing strategy and operating models to enhance it in the future. Periodic monitoring of societal impact should be a part of the regular assessment of the RIs.

5.3 **National Authorities** should adapt the model developed at a European level to their particular national needs, implement it in their national evaluation processes of the socio-economic value of RIs, and feed this back to provide comparisons across Europe. This value should be promoted to the broader society by all means.

5.4 **Research Infrastructures** should dedicate sufficient resources both to evaluate their value to the economy and society at large and to communicate this to targeted audiences, from the general public to policy makers as part of local, national and European science-policy-society dialogues to gain acceptance and support at all levels.

Explanatory notes for the specific recommendations

Given all of the challenges to determine SEI, it is perhaps not surprising that there have been only a few in-depth studies of individual RIs to

date[17, 18, 19]. If this is to be extended across RIs in different domains and disciplines to help establish priorities and inform strategic decisions at both European and national levels, a standard methodology should be established and adopted, hence **recommendation 5.1**. The heterogeneity of the things being compared defies a "one size fits all" solution, yet it will be important to establish a set of standardised measures that have specific meanings for different domains and facilitate comparisons across domains. Several attempts to approach the issue of socio-economic impact are ongoing. Models for evaluating socio-economic impact of RIs have been developed by projects[20] supported by the European Framework Programme (FP7, H2020). An extensive reference frame was collected within the OECD (Organization for Economic Cooperation and Development) Global Science Forum (GSF) activities[21] and an ongoing GSF initiative is aiming at developing, based on personalized interviews of individual stakeholders, a set of recommendations including key performance indicators for measuring socio-economic impact of RIs[22]. This OECD GSF activity is expected to deliver results in early 2018.

It is pointless to establish a robust methodology to determine the socio-economic benefit of RIs if it is not adopted widely and effectively (**recommendation 5.2**). It is also important that RIs understand how such

17. The Impacts of Large Research Infrastructures on Economic Innovation and on Society: Case Studies at CERN
https://www.oecd.org/sti/sci-tech/CERN-case-studies.pdf

18. New Light on Science – The Social & Economic Impact of the Daresbury Synchrotron Radiation Source, (1981 - 2008)
https://www.stfc.ac.uk/stfc/cache/file/4304D848-4E42-468A-89984CE70C5CB565.pdf

19 ISIS Lifetime Impact Study (2016)
http://www.stfc.ac.uk/files/impact-publications/isis-neutron-and-muon-source-lifetime-impact-report/

20. EVARIO, http://cordis.europa.eu/project/rcn/97196_en.html; ERINA+ http://cordis.europa.eu/project/rcn/95676_en.html; RIFI http://cordis.europa.eu/project/rcn/91271_en.html

21. OECD GSF initiatives
http://innovationpolicyplatform.org/system/files/RI%20socio-eco%20impact%20recent%20bio_20151120_webref.docx

22. What is Impact Assessment?
https://www.oecd.org/sti/inno/What-is-impact-assessment-OECDImpact.pdf

measures may be used by National Authorities and funding bodies in establishing strategy, prioritising resources and taking decisions to fund construction or operation of RIs. National Authorities should therefore communicate very clearly to RIs precisely what their policy regarding socio-economic benefit analysis is and establish with the RIs a periodic assessment process as part of their performance assessment (see also **recommendation 1.2**). Such procedures are already in place or being established in some countries and some international organizations – for example at CERN[17]– and it is anticipated that they will play a key role in sharing their experiences and best practices more widely.

It is also important that the principles and methodology established at European and global (OECD) level are adapted to particular local circumstances when applied at national and regional levels, where economic factors and societal needs may be more specific (**recommendation 5.3**). This applies both to the means of capturing and evaluating SEI, and also to reporting back its value. Effective communication of SEI is vital to inform both the decision makers as well as society at large, and win the hearts and minds of the general public and with that their political support. It is also vital that local – national and regional - value and opinion is shared across Europe and fed back to decision makers in the Commission so that there are better connections between the centre and the grassroots and more cohesive pan-European policies.

A further challenge to developing and applying effective measures of SEI lies with the RIs themselves, many of which have little or no awareness or experience of such concepts or activities. This is perhaps reflected in the relatively low priority given by RIs compared with funding agencies in establishing SEI in the ESFRI consultation on LTS. Indeed, in some cases where the scientific focus of a RI is very "fundamental" in its nature, the staff may even be hostile to the suggestion that SEI should be measured – though as noted above no less an organisation than CERN

has been a pioneer in capturing and reporting its own SEI. It is therefore crucial (**recommendation 5.4**) that RIs ensure that they have the means and processes in place to assess their benefit both to the economy and society in general. This will require the encouragement and support of National Authorities expressed in **recommendation 5.2** and a firm and effective commitment by the RI to outreach activities to disseminate socio-economic value which should extend all the way from the local community, to ensure that they enjoy the greatest possible local support, all the way through to the European Commission.

6. Effective RI governance, long-term funding and effective management

According to the H2020 definition[23], Research Infrastructures means facilities, resources and services that are used by the research communities to conduct research and foster innovation in their fields. Where relevant, they may be used beyond research, for example for education or public services. They include major scientific equipment or sets of instruments; knowledge-based resources such as collections, archives or scientific data; e-Infrastructures such as data and computing systems and communication networks; and any other infrastructure of a unique nature essential to achieving excellence in research and innovation. Such infrastructures may be single-sited, virtual or distributed. In the definition section of its Public Roadmap 2018 Guide, ESFRI emphasises the various organisational models that can apply to RIs and then describes further the characteristics of single-sited and distributed infrastructures.

Although RIs may have different needs according to their configuration and their activities, it is vital that the common elements of their governance, their funding and their management guarantee long-term sustainability. Effectiveness in these "administrative matters" will facilitate the core activities of the RI and thus lead to general effectiveness and efficiency.

Ideally governance models for RIs make sure that the roles and commitments of all the different stakeholders – International, European, Member States or Associated Countries, Regions, Research Performing Organisations, Research hosting institutions etc. – are well defined,

23. Article 2 (6) of the Regulation (EU) No 1291/2013 of 11 December 2013 – Establishing Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020) http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:347:0104:0173:EN:PDF

agreed, coherent and completely consistent with their Long-Term Sustainability.

RIs should only be constructed if there is a strong science case, promising scientific excellence for a significant user community, together with a sound business case presenting substantial impact and benefits commensurate with the budget, and that there are clear and adequate arrangements for funding in place, for construction and an initial phase of operations, with a model for funding further operations subject to review. RIs are part of a wider research landscape, nationally and at a European level, so strategies and funding to build or operate them should be developed in the context of national and European roadmaps. RIs too should have a long-term vision and strategy that sets the frame for multi-year planning, and this, together with periodic performance review (see also **recommendation 1.2**) should also inform funding decisions.

Specific recommendations

Effective RI governance, long-term funding and effective management

6.1	**At the European level** continue to launch initiatives which improve the management of RIs through the exchange of best practices and lessons learnt, and contribute to strategic planning, evaluation, and training.
6.2	**European and National Authorities** should contribute to the development of a feasible business model that exploits innovation potential, support for costs for Open Access and incorporate these into the national governance models.
6.3	**European Commission** together with **National Authorities** should explore improving the ERIC regulation so that its potential may be more fully exploited.
6.4	**National Authorities** should consider governance models which provide the right balance between long-term funding commitments (including operation costs and strategic developments) and regular evaluation of the RI performance.
6.5	**Research Infrastructures** must develop, right from the start of the planning phase and prior to the roadmapping exercise, a comprehensive business plan covering all stages of their lifecycle including upgrading and decommissioning.

Explanatory notes for the specific recommendations

ESFRI together with the European Commission has organised some Exchange of Experience (EoE) workshops that have enabled RIs to discuss the successes and obstacles they have encountered in the different phases of their lifecycle (see also **recommendation 7.4**). An example of this is the first EoE workshop "How to make the most effective use of Horizon 2020 Preparatory Phase Funding". This enabled

established landmarks to share the lessons learnt and best practices with the newly selected ESFRI projects and aimed to facilitate the preparatory phase and achieve faster implementation. This should reinforce the effect expected by the stricter criteria for the inclusion in the ESFRI Roadmap and reduce the time towards implementation.

Similarly, an informal ERIC Network was set up a few years ago, bringing together members of the ERIC Committee and ERIC managers and staff to tackle all sort of topics related to the ERIC regulations and to the daily management of ERICs. Before that, the RAMIRI project[24] significantly contributed to the training and networking of people involved in pan-European RIs.

This kind of initiative needs to be continued (**recommendation 6.1**) and could become even more practically-oriented and less formal, allowing the exchange of real work experiences, coaching and mentoring and guidance on overcoming difficulties encountered throughout the lifecycle of a RI. A particular focus could be given to challenges such as the elaboration of a business model, governance, data management, long-term funding models, access policy and human resources. There is also still a great demand for the development of funding models and business models which are appropriate for the different types of RIs – small, large, single-sited, distributed, virtual or physical. These events should not be restricted to ESFRI RIs or ERICs. Other RIs such as the members of EIROforum, e-Is or H2020 RI projects could also be involved. One very important aspect to take into account is that these workshops should bring together experienced people from RIs that have already been implemented and have operational experience and novices from new RIs or RIs to be (see **recommendations 2.3** and **7.4**).

24. RAMIRI Project: Realising And Managing International Research Infrastructures http://www.ramiri.eu/

Moreover, short training sessions on specific fields such as the management of RIs, consortium development or on one of the topics mentioned above could also be developed. They should be rigorously prepared with professional trainers and based on real situations and experience. They should also be interactive and combine theoretical aspects and hands-on exercises. In order to further develop this sort of mutual-learning initiatives, the Commission should not exclude the possibility to allocate some of its H2020 funding related to LTS to this topic – through a dedicated coordination and support action for example.

The **Extreme Light Infrastructure (ELI)** is an ESFRI RI of Pan-European interest in the field of Natural Sciences (high-power laser science and applications), now in the final stage of the coordinated construction in three sites (Pillars) having Hungary, the Czech Republic and Romania as Host countries. Whereas the total implementation cost – approx. 820 M€ – includes about 15% of national funding and 85% of ESIF[25] funding, the operation costs - the total operational costs of the ELI ERIC are estimated to be about 77M€ per annum - under the "open access" model for international users will have to be covered through contributions by all countries from which users will originate, mainly non-Host countries. The role of both in stimulating the involvement of the EU Member Countries and to provide "gap funding" or "start-up" support possibly combining synergistically different funding schemes (e.g. the ESF[26] and H2020) may define the difference between success and failure in the start-up phase of ELI, as well as of other RIs whose construction would be supported by ESIF funding.

25. European Structural and Investment Funds
https://ec.europa.eu/info/funding-tenders/european-structural-and-investment-funds_en

26. The European Social Fund
http://ec.europa.eu/esf/home.jsp.

Different initiatives could be taken at the European and national level in order to foster concepts such as innovation and open access and to elaborate RI business models which integrate these concepts (**recommendation 6.2**). One of the ways to achieve the promotion of these concepts could be the systematic inclusion of components linked to innovation potential – e.g. the inclusion of industrial users – in the RI user policy. Open access, including international open access, could also be further supported through the development of mechanisms covering partially or totally the costs incurred by the RIs in this regard. The use of the co-funding scheme or the eligibility of these access costs for H2020 projects such as European Research Council (ERC)[27] or Marie Sklodowska-Curie Actions (MSCA)[28] are possible avenues to explore (see also **recommendation 7.1**). Business models developed in different ways at European and national levels should then be introduced into the evaluation process of the RIs by National Authorities in a transparent fashion. The development of a transparent unit cost model for RIs could also be considered.

A few years after its development, the ERIC has become the legal framework chosen by the majority of newly implemented Research Infrastructures on the ESFRI Roadmap, the ESFRI Landmarks. The main advantages of the ERIC, in comparison to other legal statuses, are that it is recognized by all EU Member States, that it is relatively flexible and rapid to adopt and that it provides exemptions from VAT and excise duties. In practice however, and despite the establishment of the ERIC Network or the publication of detailed guidelines, this relatively new legal framework is presenting some teething problems that should be addressed in a coordinated way between the European Commission and the National Authorities (**recommendation 6.3**). VAT exemption is

27. European Research Council
https://ec.europa.eu/programmes/horizon2020/en/h2020-section/european-research-council

28. Marie Sklodowska-Curie Actions
https://ec.europa.eu/programmes/horizon2020/en/h2020-section/marie-sklodowska-curie-actions

certainly the most debated issue. In order to avoid further divergence of interpretation of these VAT rules, a collective and constructive clarification of its application would be welcome. A task force with EC and national experts could be set up for this purpose.

HR-related issues are also very common for ERICs. As an example, although ERICs are autonomous legal entities which can recruit their own staff – according to their employment policy which has to be specified in the ERIC statutes – several ERICs do not hire their staff directly but have them seconded from the institution hosting the ERIC. Moreover, ERICs face challenges typical for all RIs involving European staff. An improvement of the European employment policies, including mobility and pension rights, would facilitate the functioning of the ERICs (this aspect is strongly interconnected with the issues outlined in **recommendation 7.1**). Furthermore, it is important to notice that the flexibility of the ERIC statutes may also weaken their ability to ensure appropriate long-term financial commitments from the members. In order to ensure sustainability, it is essential that all the financial obligations are clarified in the ERIC statutes (see also **recommendation 6.4**).

The last decades have seen the establishment of more and more new pan-European RIs – mainly distributed ones – for which the chosen legal structure is often lighter and more flexible than those used in the past for large single-sited infrastructures such as the EIROforum members. The duration of the financial commitment of the members of these new RIs can vary from one or two-years to a more structured or long-term funding commitment, depending on the decision-makers or on the arrival of new initiatives. New governance models which provide the right balance between long-term funding commitments – including operation costs and strategic developments – are being considered (**recommendation 6.4**).

Examples for the inclusion of regular evaluation by independent external committees in the ERIC statutes are the ESFRI RIs **SHARE ERIC**, the Survey of Health, Ageing and Retirement in Europe, and **INFRAFRONTIER**, the European Research Infrastructure for phenotyping and archiving of model mammalian genomes.

Another but different example is the evaluation of the large single-sited ESFRI RI **FAIR**, the future accelerator facility. According to a Council based decision it has been peer reviewed recently. Very large single-sited RI are often quite expensive, so commitments need time which delays construction. The FAIR Council therefore decided to conduct twice an international peer review exercise during construction which evaluates project status concerning governance, funding and scientific case. Both assessments were very positive, so the implementation is proven successful.

Funding arrangements that offer some degree of medium and long-term stability enable the most efficient planning and operation of RIs, and instil in the user community, including industry confidence that they can access them reliably and regularly, and making it more likely that they will be more fully integrated into their own research strategies. It is also important that funding frameworks offer the long-term perspectives essential for the substantial and often ambitious technical developments that enable RIs to remain at the forefront of technology and thus continue to offer the research community the very best opportunities to achieve scientific excellence and make the greatest impact on innovation. It is equally important that continued funding is provided on the basis of periodic and robust performance evaluation (see also **recommendation 1.2**), including scientific and technological excellence, socio-economic impact, the strength and engagement of the user community, and management.

Building a new RI cannot be improvised. From the design phase onwards, the RI will have to work on a business plan covering all

important elements for its development and all phases of its lifecycle (**recommendation 6.5**). This document should present the scientific and technical aspects of the RI, including data management. The scientific case should be based on a sound user community and take into account the landscape analysis. The possible upgrades as well as the organisation of the decommissioning should also be put forward. The business plan should also include a financial plan, giving as accurate an estimate as possible of the RI costs and incomes – including its various and possibly new sources of funding – presenting the expected in-kind contributions and their management and integrating some risk analysis and contingency plan. There is still a great demand for the development of funding models and business models which are appropriate for the different types of RIs – small, large, single-sited, distributed, virtual or physical. A goal of the InRoad project, which is mentioned in **recommendation 7.2**, is to analyse these different models and find or define some good practices. The strategy for consortium development and confirmation of commitments should also be explained in the business plan. The expected daily functioning of the RI, i.e. its governance structure, HR policy, procurement policy, financial management – focusing on cost control, cost efficiency and transparency– should also be introduced. Last, but by no means least, the business plan should be updated throughout the lifecycle of the RI.

The Federal Ministry of Education and Research in Germany included as a precondition for proposals in the national roadmap procedure a commitment for up-to ten years funding for the operation of the RI. This commitment has to be signed either by a major Research Performing Organisation or the specific institute which will host the respective RI. It should be noted that in Germany RPOs such the Helmholtz Association in Germany are funded institutionally and have the construction and operation of RI in their mission. So they act like National Authorities with regard to RIs, performing their own prioritisation and evaluation exercises autonomously.

The minimal key requirements recently developed by ESFRI for the evaluation of new proposals and the monitoring of its projects cover all the phases of the lifecycle of a RI, from its design to its termination, as well as different aspects of the scientific and implementation dimensions. These minimal key requirements could help the RIs to develop and update their business plan by serving as a reference for all determining features to be taken into account.

7. Coordination at National and European levels

RIs are recognised as key elements in research and innovation policies, for boosting the generation of scientific knowledge, for accelerating technology development, and for enhancing both technological and social innovation. The effective investment in and use of RIs is one of the priorities for realising the European Research Area (ERA).

Cutting edge science and technology are international – policies should reflect this and be coordinated at a national and European level. In other words: don't just mind your own business – look at the bigger picture.

European countries have a richness of creative R&I systems and cultures in a relatively tightly packed area. These should be shared with each other to result in mutual learning exercises to strengthen the European region as a whole but still leave space for smart specialization where divergence is necessary to strengthen the regions.

Specific recommendations

Coordination at National and European levels

7.1	**European** and **National Authorities** should aim for stronger convergence of a broader range of research related policies at EU and national level – innovation, employment, social security, pension schemes and mobility rules etc. – and in particular, reinforce coordination between Member States on all aspects of the RI lifecycle.
7.2	**National Authorities** are invited to harmonise and synchronise the development of investment strategy for their RIs to the greatest possible extent with a pan-European vision by taking advantage of the landscape analysis and roadmapping procedures developed by ESFRI and other players at the global level.
7.3	**European, National Authorities** and **RIs** shall further develop platforms for communication and promotion for RIs of potential meta-regional, European, and global relevance which are mature enough for engagement strategies.
7.4	**Research Infrastructures** should take full advantage of RI self-organisation and coordination at the EU level, which allows efficient sharing of best practices among them and includes also mutual learning exercises.
7.5	**Research Infrastructures** should ensure that they have effective means of communicating and engaging with all their stakeholders throughout their lifecycle and in particular new RIs should do this right from the start of their design phase.

Explanatory notes for the specific recommendations

As already indicated there are different examples of research related policies at EU and national level which call for a stronger convergence (**recommendation 7.1**). Beyond the possible coordination of research and regional policies – i.e. Structural Funds – fields such as employment

or finance-related policies could be further developed to be more supportive of research initiatives such as RIs.

A typical example is mentioned in the skills section (see **recommendation 2.1**): if the competences of skilled people, who are in less demand in one country or RI are not compatible with the mobility rules or pension schemes in different countries, less flexibility is possible to exploit the richness of highly skilled people around Europe. Here it is essential to harmonise policies for facilitating secondment and mobility at European level as well as to reinforce coordination between Member States and Associated Countries to share the approach for providing in-kind contributions to the construction and operation of RIs. The governance must be adapted to the multinational structure, with even more stringent requirements for compatible employment, taxation, social security, pension schemes and mobility rules.

A further example is the relation between the funder and the user. In a European-wide research eco-system without a one to one connection between those two, it is essential to have a common understanding across all disciplines where everybody contributes at a fair level. These monetary imbalances may lead to restricted access to RIs. Funding for the operation – to gaining access – should be at the National and European level. And if European-wide free access beyond a few percent of users from countries *not* contributing to the funding of the facility is planned, then the EU has an important role to play - increasing the instrument of TNA. Concerning access, there is a demand for better business models on RIs side and much easier accounting models on the funders' side. Splitting the funding for access down to the individual research project lead to a huge administrative overhead, makes it cumbersome and slower for new users to get access, and users with excellent projects may not be able to even apply for beam time because they had not foreseen the need when the research project was initially approved or alternatively they have funding but no need for the specific

facility. Last but not least the technological basis of RIs as well as a large fraction of users of all types of RIs can lead to even more innovations if well-defined European wide IP rules are in place.

It is also essential that the various departments or ministries involved in RIs at EU or national level aim at a coherent and well-coordinated approach. The thematic attribution of policies can indeed sometimes create difficulties in managing RIs as a whole portfolio – for example the physical science or the nuclear RIs will often be the responsibility of a different ministry than the cultural RIs. At the European level, this could also lead to reinforced internal coordination within the framework programme, where elements linked to the Long-Term Sustainability of RIs – such as the eligibility of access costs – are integrated into other sections or into the rules of participation of the programme.

Convergence of all these policies will help to provide a more harmonised and balanced distribution of excellence in R&I all over Europe and therefore lead to better cohesion.

In 2002 ESFRI has been set up by the EU Council of Science Ministers – Competitiveness Council – to support a coherent and strategy-led approach to policy making on RIs in Europe. It was this ESFRI process which stimulated more and more Member States and Associated Countries in Europe to set up their own strategic national roadmaps taking into account the ESFRI RIs. Those national roadmaps act as reference documents on a national scale, aiming to guide and prioritise national and regional investments, safeguarding future RIs of strategic relevance, fostering their ability for international insertion, and thereby increasing the capacity for research and innovation, both nationally and regionally.

However, due to the very varying nature of different national R&I systems, the scope, components and processes leading to the establishment of these strategies are hardly comparable. But they are a

valuable source for mutual learning exercises within Europe and also beyond. At least RIs funded across countries call for coordination and synergies of these processes where possible and appropriate.

So, it is for example widely recognized and further underlined by ESFRI that RIs need to be based on an extensive demand analysis as part of the business case. It is also widely recognized that a data management plan is a major requirement for sustainability of the research results of RIs as well as interdisciplinary transfer which leads to innovation (see **recommendation 3.5**). Furthermore, the establishment of efficient funding and governance structures and principles that serve the purpose and assure high quality output/impact of the RIs, with a minimal administrative overhead are of key importance.

Since 2002 the ESFRI process has been evolving continuously, evaluation of new proposals is based on an extensive landscape analysis of the current and future RI ecosystem, new ideas have to be incorporated in. Ideally a RI roadmap offers a basis to design an action plan for the implementation of the RI, and propose short- and long-term milestones accompanied by evaluations and financial commitments. Since ESFRI was given the mandate to closely monitor the implementation of RIs a set of minimal key requirements for implementation have been agreed on.

Again, these advanced ESFRI methodologies and also others such as the GSO Framework criteria could stimulate the further development and harmonisation of national processes due to simple acknowledgement of these – just agreeing on these as common principles and applying them for example in centralised or shared evaluation or peer review exercises (**recommendation 7.2**).

A good practice example in this respect is a quite new initiative: The EU funded project InRoad[29], which aims to a better synchronisation of priority settings and evaluation mechanisms for RIs brings together for the first time high-level stakeholders from the Member Countries and Associated Countries which are responsible for decision making and funding of RIs. This is a very important initiative, currently with a seed status and needing to be treated with great care and patience. It needs some time to generate trust - at least in current political times where nationalism may be more prominent than coherence in European countries. But if this important initiative works, leading to greater compatibility and synchronisation of decision making and funding strategies in European Member States and Associated Countries, an important step will have been taken in the direction of a stronger Europe.

RI or RI concepts which may be of global relevance often evolve from the initial ideas of scientific communities followed by a long process of strategic priority setting, planning and design – typically at national level, but increasingly also at regional and even global level (**recommendation 7.3**).

Considering the already existing international cooperation of some scientific communities, the potential for more cooperation on issues related to Global Research Infrastructures (GRIs) has been recognized by the Carnegie Group since 2007. At the first G8 Ministerial meeting, held in Okinawa on 15th June 2008, it was decided to establish a Group of Senior Officials for RIs (GSO) to take stock and explore cooperation on Global Research Infrastructures (GRIs). The GSO is a valuable dialogue forum, restricted to G7 countries plus further seven (AU, BR, CN, IN, MX, RU, ZA). The GSO is in close cooperation with further fora, such as OECD/GSF and ESFRI, dealing with international cooperation.

29. InRoadmap Project
http://inroad.eu/

All these fora are very useful for an exchange of ideas and experience giving strategic advice and recommendations on policies on a meta level on very concrete themes like access, user strategies, evaluation methodologies, data management etc. for the RIs. ESFRI with its Roadmap and GSO with its Framework – on which the first open list of RI of potential global relevance is based – already raise visibility for those RIs which are listed[30].

But these policy fora need continuous support on national levels for developing measures to implement those recommendations together with RI operating institutions/ organizations:

- RIs may need support and exchange of experience to analyse whether they are mature enough for enlargement and if not to improve their maturity – e.g. is the RI or even its concept mature enough to include international partners in its legal entity or potential legal entity.
- RIs may need support to raise awareness of the potential benefits of membership in potential new member countries, particularly among their research communities. This requires a very good communication and promotion strategy, including a keen understanding of the needs of potential new users, and it may also take considerable time to build up significant interest and support.

Exchange of Experience workshops of ESFRI RIs supported by the EC (see also **recommendation 6.1**) have been recognized as a valuable instrument for sharing best practice among different RIs and mutual learning exercises. EC Framework programmes should further support these valuable instruments (**recommendation 7.4**) leaving more space for real exchange by giving the opportunity for self-organized workshops

30. Report from the commission to the european parliament, the cuncil, the european economic and social committee and the committee of the rings
http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0567&from=EN

which may be thematically specified as for example on business model development, access policy, enlargement and communication policies.

As it is still a major financial issue for distributed RIs to get sustainable funding for common activities on national levels – especially long-term sustainability of data, quality assurance of the data, their storage and access to the data – this turns out to be the same for EoE workshops addressing common problems. These workshops always need a well experienced lead (e.g. consultants) but still leave freedom for creativity (e.g. new ideas and best practice) and self-organisation. In this respect the EC should spare no expense nor efforts to jump into the free space to fill the gap.

Communication and engagement with all potential stakeholders right from the start of the planning of a potential RI is always good practice. Many RIs struggle to communicate effectively with the right people to explain demand and impact and still need support in communication strategies (**recommendation 7.5**) as mentioned before (see **recommendation 1.7**). This can be a particular challenge for RIs such as biobanks or some e-Is which may be seen merely as service providers and do not have as prominent a profile as some of the larger facilities, yet may play a central role in R&I, particularly if demand is high. As a consequence their value can be overlooked and they may suffer regarding integration in research programmes. In these cases it is particularly important that that they have an effective strategy for promotion.

Although the establishment of ESFRI by the EU Council of science ministers was an important step in the direction of greater sustainability and convergence in the ERA, there are still many people at the national levels who may not really understand its value for excellence in R&I. RIs are not merely research projects but guarantee the sustainability of research results and transfer them to future generations. The horizontal

aspect of RI-strategies and the varied configurations of RIs can also complicate the perception of their value.

A major but perhaps not so prominent example for excellence are the epidemiological registers of Scandinavian States which combine the health research data of generations with methods of modern biotechnology and data curation and lead to an enormous boost in health research and innovation. To go even a step beyond is the combination of health research data with socio-economic data of several countries which is done by the **SHARE ERIC**. This may lead to societal and cultural innovation not only for the European but also the quality of life of the worldwide population. This needs to be communicated as effectively as possible to the stakeholders and needs to underpin its sustainability.

Appendices

Terms of Reference

In the meeting of May 27th 2016, the Competitiveness Council discussed the ESFRI 2016 Roadmap and the Long-Term Sustainability (LTS) issue. In this context, the Competitiveness Council "*underlines the importance of ensuring Long-Term Sustainability of Research Infrastructures and invites the Commission to prepare together with ESFRI and relevant stakeholders a targeted action plan*".

The Sustainability debate will focus on the pre-conditions identified by the consultation launched by the Commission in December 2015. These pre-conditions include funding and governance aspects of RIs, socio-economic impact as well as the management and exploitation of data and the innovation potential of RIs. All relevant stakeholders will have the opportunity to state their position, as these pre-conditions clearly call for a multi-stakeholder approach.

ESFRI was considered by the Council as a key stakeholder in the context of LTS, as it represents national governments and funding agencies involved in strategic decision-making on Research Infrastructures. In order to comprehensively respond to the Council conclusions, covering the full spectrum of the LTS debate, ESFRI sets up a dedicated Working Group.

The objective of this WG is to provide a consolidated input to the European Commission (EC) for the preparation of the Action plan mentioned in the Council conclusions, addressing the Long-Term Sustainability of Research Infrastructures.

The Working Group Mandate

The Working Group will provide inputs and recommendations to the EC on the best ways to address the LTS pre-conditions for Pan-European RIs (as identified by the 2015 consultation):

- Ensuring Scientific excellence;
- Managing tomorrow's RI - Skills of managers, operators and users;
- Unlocking Innovation potential of RI;
- Measuring socio-economic impact of RI;
- Exploiting better the data generated by the RI;
- RI Lifecycle – Upgrading of RI;
- RI Lifecycle – Decommissioning of RI;
- Ensuring sustainable governance of RI;
- Funding the construction and operation of RI;
- Structuring the international dimension of RI.

Working Arrangements

The Working Group on Long-Term Sustainability will meet regularly and consequently report to the ESFRI Forum on its findings. The WG will analyse the current LTS challenges and will formulate recommendations on potential policy measures which could be implemented at different levels – national, regional, European and International – to respond to these challenges.

The WG will be chaired by Mr. Jan Hrusak. The WG membership will consist of high-level representatives of funding decision bodies, Research Infrastructures managers/experts and European Commission representatives from DG RTD and DG CNECT.

The members and experts will be appointed by ESFRI delegations. The EC will appoint its representatives. The ESFRI Secretariat will be assisting in the work of the WG.

The specific expertise of the members is considered crucial, as an in-depth knowledge and decision-making power on the current funding models, governance strategies and best practices at Member States level is a necessary element for formulating effective recommendations. The WG should also cover technical expertise on RI management and operational issues, as these aspects will also play a role in the concrete actions to foster the Long-Term Sustainability of Research Infrastructures.

The WG can decide to create operational drafting sub-groups to organize the outcomes along the specific pre-conditions.

The WG members will participate in the dedicated Stakeholders Workshops, which will be organized by the European Commission with other relevant stakeholders.

The WG may invite external experts on an *ad hoc* basis.

Deliverables and Timeline

The WG is expected to debate on the specific LTS pre-conditions and to provide regular inputs to the European Commission for the preparation of the Action plan.

The recommendations will be discussed in the ESFRI Forum meetings. The Final Report will be prepared by March 2017 and will be adopted by the Forum.

Membership

Name	Affiliation	Country
Chair		
HRUŠAK Jan	Academy of Sciences of the Czech Republic	CZ
Vice - Chair		
LENOIR Laurence	Belgian Federal Science Policy Office, BELSPO	BE
CAMINADE Jean-Pierre	Ministère de l'Education nationale, de l'Enseignement supérieur et de la Recherche	FR
CLAUSEN Kurt	PSI - Swiss Academies	CH
COCCO Massimo	EPOS (Coordinator)	
HARRISON Andrew	DIAMOND Light Source	UK
HENRICHSEN Bjørn	Director of NSD – Norwegian Centre for Research Data	NO
MIRON Catalin	ELI-DC (Deputy DG)	
PETRILLO Caterina	ESS-neutron Council	IT
RITTER Claudia	DLR Project Management Agency	DE
SARKJOIA Merja	Academy of Finland	FI
EC Representative		
BURGUENO ARJONA Augusto	DG Research & Innovation	EC
EC Representative		
FROISSARD Philippe	DG Research & Innovation	EC

Glossary

CERN	Conseil Européen pour la Recherche Nucléaire – European Organisation for Nuclear Research
EC	European Commission
e-I	e-Infrastructure
e-IRG	e-Infrastructure Reflection Group
EoE	Exchange of Experience (workshops)
ERA	European Research Area
ERC	European Research Council
ERIC	European Research Infrastructure Consortium
ESFRI	European Strategy Forum on Research Infrastructures
ESRF	European Synchrotron Radiation Facility
ESS	European Social Survey and European Spallation Source
EU	European Union
FAIR	Findable, Accessible, Interoperable, and Re-usable (principles for data storage)
GRI	Global Research Infrastructures
GSF	Global Science Forum
GSO	Group of Senior Officials (of RIs)
H2020	Horizon 2020 (EC Framework Programme 8)
ILL	Institut Laue-Langevin
ILO	Industrial Liaison Office
KPI	Key Performance Indicator
LO	Liaison Officer
LTS	Long-Term Sustainability
MCSA	Marie Skłodowska-Curie Actions
NGO	Non-Governmental Organisation
OA	Open Access
OECD	Organization for Economic Cooperation and Development
PCP	Pre-Commercial Procurement
PID	Persistent Identifiers

PPI	Public Procurement of Innovation solutions
R&I	Research and Innovation
RDI	Research, Development and Innovation
RISE	Research and Innovation Staff Exchange
RI	Research Infrastructure
RTD	Research and Technical Development
SEI	Socio-Economic Impact
SME	Small and Medium-sized Enterprise
TNA	Transnational Access
TRL	Technology Readiness Level

Chair of the Long-Term Sustainability Working Group and scientific editor

Jan Hrusak
Academy of Sciences
of the Czech Republic

Photo credits: Jan Hrusak

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