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COMMISSION STAFF WORKING DOCUMENT

Long-term sustainability of Research Infrastructures

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ACRONYMS GLOSSARY

Institutional:

AC – Associated Countries
CERN – European Organization for Nuclear Research
CESAER – Conference of European Schools for Advanced Engineering Education and Research
EARTO – European Association of Research and Technology Organisations
EC - European Commission
ERF – The European Association of Research Infrastructures
ERRIN – The European Regions Research and Innovation Network
ESA – European Space Agency
ESFRI – European Strategy Forum on Research Infrastructures
ESRF – The European Synchrotron Radiation Facility
EU – European Union
EUA – European University Association
EU-LIFE – Center for Genomics Regulation, CRG
ILL – Institut Laue-Langevin
LERU – League of European Research Universities
MS – Member States
OECD – Organisation for Economic Co-operation and Development

Non-institutional:

DMP– Data Management Plan
EFSI – European Funds for Strategic Investments
EOSC – European Open Science Cloud
ERA – European Research Area
ERIC – European Research Infrastructure Consortium
ESI Funds–European Structural and Investment Funds
FAIR - Findable, Accessible, Interoperable and Reusable
FP – Framework Programme
GSO – Group of Senior Officials
ILO – Industry Liaison Office
IPR – Intellectual Property Rights
KIC - Knowledge and Innovation Communities
KPI – Key Performance Indicator
LHC – Large Hadron Collider

LTS – Long-term sustainability

R&D – Research & Innovation

RI – Research Infrastructure

ROI – Return on Investment

RPO –Research Performing Organisation

RSFF – Risk Sharing Finance Facility

RTO – Research and Technology Organisation

SME – Small and Medium Enterprise

SQF – Sectorial Qualifications Framework

TNA – Trans- National Access

VAT – Value-added Tax

WG – Working Group

EXECUTIVE SUMMARY

1. INTRODUCTION

Research Infrastructures[1] (RI) play an essential role in the advancement of knowledge and technology. They contribute to the full spectrum of science by offering services that enable discovery, technology development and invention. They drive technological progress, which depends on both transformative research and innovation.

Europe has a long tradition of scientific excellence and has built a worldwide reputation in RI. This has been made possible by pursuing national investments and more recently by developing a coherent and strategy-led approach to policy making on pan-European RI development, with the support of the European Strategy Forum on Research Infrastructures (ESFRI). This strategic approach of RI development has generated clear advantages, such as avoiding duplication of efforts, pooling resources, rationalising RI use, standardising processes and procedures as well as consolidating the global leadership of European RI. Advantages of such a European approach is also illustrated in the EU Reflection Paper on the future of EU finances, where this approach is "*a clear value added when action at European level goes further than national efforts (…) Cross-border programmes have transformed border areas helping to remove sources of conflict and create new economic opportunities*[2]".

ESFRI has been successful in developing a medium to long-term vision on the needs of the European scientific communities, which led to the consolidation of a roadmapping process[3] at European level. In addition, the European Research Infrastructure Consortium (ERIC) Regulation has also significantly contributed to the structuring of the European RI ecosystem.

However, putting into place and maintaining such a landscape of excellent RI serving the needs of the scientific communities and other stakeholders has a price. Many RI (especially the large physics and analytical facilities) are extremely expensive with

[1] The term 'Research Infrastructures' refers to facilities, resources or services of a unique nature that have been identified by European research communities to conduct top-level activities in all fields of science. This definition includes the associated human resources, covers major equipment or sets of instruments, in addition to knowledge-containing resources such as collections, archives and data banks. RI may be located in a single site (for example, large telescopes, Synchrotrons, High Performance Computing) or can be distributed across even large number of sites working jointly (for example, biobanks, archives, marine stations).

[2] EU Reflection Paper on the future of EU finances, June 2017, p. 12. http://ec.europa.eu/budget/mff/hlgor/library/reports-communication/hlgor-report_20170104.pdf

[3] While the term "roadmap" is widely used for planning of RI in Europe, it is not universally applied to the results of strategic long-term planning exercises. For additional information, please consult the OECD Global Science Forum, Report on Roadmapping of Large Research Infrastructures (2008).

construction price tags that can go well beyond a billion Euro[4] and related operational cost that, on average, on a yearly basis, amount to around 10% of their construction value. The increasing number of implemented pan-European RI, such as the ESFRI projects and the ERICs, weighs therefore more and more on the national science budgets, hence raising the question of their long-term sustainability[5].

Furthermore, the EU funding programmes only cover a fraction of the RI overall activities for the integration and opening of national RI and the initial development of pan-European RI - through grants and loan guarantees. In addition, European Structural and Investment (ESI) Funds are being used by some Member States to cover construction costs[6], but their expected impact is not always in line with the RI objectives nor the regional development objectives (in particular the performance indicator of number of researchers employed after the finalisation of the construction, i.e. self-financed not ERDF subsidised)[7].

The consultations that were carried out to stakeholders have highlighted the fact that the question of the sustainability of RI goes well beyond funding only, touching upon several dimensions such as scientific excellence, socio-economic impact or innovation, which, for the purpose of this Staff Working Document, will be presented separately but contribute as a whole to the overall sustainability objective. All these pre-conditions need to be addressed at European level over the entire RI life cycle - from initial planning up to termination.

The present Staff Working Document is a compendium of the outcomes of these consultations and is to set the basis for a discussion with Member States and stakeholders on the measures to be taken at all levels in Europe to address RI sustainability in medium and long-term. The resulting Action Plan will trigger and structure the debate with RI funders, users and operators, in order to arrive at a sound basis to work for a sustainable European RI and will consequently contribute to the discussions of the next Framework Programmes and future ESI Funds. Its implementation will require a strong level of engagement between the EU and its Member States, the RI managers and operators, their user communities in behavioural and structural reforms. The aim is not to identify a single solution that would fit all realities due to the diverse nature and legal setting of the different RI – national, regional and European. Finally, it is important to highlight that

[4] The investment required for completing the construction and reaching the full operational capacity of the 29 pan-European RI - so-called Landmarks identified in the 2016 ESFRI Roadmap is estimated at EUR 12.4 billion with an operational budget of EUR 1.4 billion/ year. The capital value of 6 out of the 29 ESFRI landmarks published in 2016 exceeds EUR 1 billion.

[5] The definition of RI sustainability used for this report is the one adopted by the OECD which defines it as the capacity for a research infrastructure to remain operative, effective and competitive over its expected lifetime.

[6] Both for initial implementation and for upgrading.

[7] In order to be eligible for ERDF support, RI projects have to contribute to economic, social or territorial cohesion, to sustainable development and structural adjustment of regional economies (Article 2 ERDF Regulation (EU) No 1301/2013). Moreover, they have to contribute to the implementation of the research and innovation strategies for smart specialisation (RIS3) priorities that were identified in an entrepreneurial discovery process (involving enterprises, research and public sector) and to the implementation of the multiannual plan for plan for budgeting and prioritisation of investments in RIs of the country or region (see Annex 1 to the Common Provisions Regulation for ESI funds (Regulation (EU) No 1303/2013).

while the focus of the Staff Working Document is on publicly funded Pan-European Research Infrastructures, the findings are clearly relevant also at national and regional level.

2. SETTING THE BASIS FOR LONG-TERM SUSTAINABILITY

RI Long-term sustainability (LTS) has been flagged as a policy priority[8], since the Informal Competitiveness Council of July 2014[9]. As a result of the May 2016 Competitiveness Council Conclusions, the Commission was invited to develop an RI long-term sustainability Action Plan, in close cooperation with ESFRI and other relevant stakeholders.

The Commission launched a stakeholder consultation process, which encompassed:

- an online consultation (*Annex II – Stakeholders Consultation Report*) targeting key RI stakeholders,
- dedicated regular meetings with ESFRI[10], EIROforum and its members, ERA stakeholders and observers as well as ERICs,
- a Stakeholders' workshop (*Annex III – Outcomes of Stakeholders Workshop*) to validate the possible elements of an LTS action plan.

This consultation process was based on LTS interrelated conditions and had the aim to trigger the debate on potential actions to tackle the identified challenges:

- Ensuring scientific excellence,
- Attracting and training the managers, operators and users of tomorrow,
- Unlocking the innovation potential of RI,
- Measuring socio-economic impact of RI,
- Exploiting better the data generated by the RI,
- Establishing adequate framework conditions for effective governance and sustainable long-term funding for RI at every stage in their life-cycle,
- Structuring the international outreach of RI.

Each sub-section builds on a long-term sustainability pre-condition, depicting the Stakeholders consultation results, illustrated by best-practice cases, and focusing the debate on possible actions to be taken up.

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[8] The European policy context is strongly influenced by a number of EU initiatives and programmes, which are detailed in Annex I - Overview on EU policies and programmes on RI.

[9] In July 2014,the Informal Competitiveness Council highlighted the importance of long-term sustainability of RI, stressing that open access to RI and data, better links with industry as well as policy prioritisation based on a multi-level approach, at national, European and international level, were key to ensure sustainability.

[10] In July 2016, a dedicated ESFRI Working Group (WG) on the long-term sustainability of RI was established and this WG developed a report, which serves as a strong input to this policy debate.

2.1. Ensuring scientific excellence

Scientific excellence is unanimously recognised as the main driver for Research Infrastructure development.

In order to maintain its positioning, Europe needs to continue investing in RI so to guarantee, as highlighted by EIROforum, *efficient operations, continuous maintenance and timely upgrades of instrumentation and/or operational modes in order to ensure that the facilities correspond to the present and future requirements of their communities*.

As highlighted by ESFRI the maintenance of this excellent level of capacity requires a collective effort of all involved actors at European and national level to *support by adequate means the endeavour for excellence at RI throughout their entire lifecycle, which may include the pursuit of excellent in-house scientific research and the development of new technology for users.*

Such quality must also be regularly assessed. The stakeholder consultation demonstrated the need for independent international scientific and technical evaluation committees to guarantee that the (optimal) services offered actually reflect the requirements of the different user communities.

The main elements that were proposed for consideration in the frame of the consultation were:

- Encourage the adoption of transparent Access policies across Europe;

Most stakeholders highlighted that the Charter for Access to Research Infrastructures[11] plays a key role in supporting researchers' mobility in the EU.

There is a wide consensus on the fact that European RI **should have in place transparent access policies** developed according to the definitions, principles and guidelines contained in the Charter.

- Promote excellence as the main driver for access to Research Infrastructures;

The consultation process highlighted that some of the stakeholders would clearly support **the "excellence driven access mode", as defined by the Charter, as requirement for funding at regional, national, European and international level**.

The discussions also indicated that still about 53% of the European RI do not apply international peer review for the selection of the user projects and for attributing access. And that **this situation needs to be rapidly addressed. A number of stakeholders[12] suggested for peer review procedures to be included within the access policies**

[11] The excellence-driven Access mode is exclusively dependent on the scientific excellence, originality, quality and technical and ethical feasibility of an application evaluated through peer review conducted by internal or external experts. It enables users to get access to the best facilities, resources and services wherever located. This Access mode enables collaborative research and technological development efforts across geographical and disciplinary boundaries.

[12] Among these CESAER and ERF.

articles of each RI as requirement for funding at regional, national or European level.

More in general, in line with the current discussions in the frame of International fora such as the Group of Senior Officials on global Research Infrastructures the possibility of **an RI guaranteeing that a share of excellence driven access is provided free of any other conditionality (e.g. to be national of a funding member)** was considered as an additional option to foster excellence of RI.

- Stimulate the establishment of technical evaluation review and management committees;

The Stakeholder consultation indicated that 21% of the RI do not have in place an international Advisory Scientific Committee, which led to highlight that t**he establishment of Technical Evaluation and Management Assessment Committees is a necessity** to ensure the RI offer state of the art services.

Such committees (which, as emphasised by CESAER, should also cover the ethical dimension), configured as distinct bodies in the governance of RI, should also advise on the development of the science agenda and portfolio and periodically review them in order to guarantee effective response to the user community requirements.

Most of the stakeholders, among which ESFRI, indicated in this respect a need to ***develop guidelines for standardized, effective and robust evaluation procedures of RI through independent international peer-review***[13] as an active measure to increase the widespread adoption of such instruments.

- Develop Key Performance Indicators in support of scientific excellence;

While excellence is undoubtedly acknowledged as the fundamental driver for any RI, the measurement of the level of excellence of a single facility is not immediate and is mostly achieved through indirect indicators such as, most commonly, the number of scientific papers which make reference to the RI.

In general, many of the stakeholders indicated the need to **develop a comprehensive assessment mechanism based on a set of Key Performance Indicators** (KPI) to measure the excellence level of the output of RI.

- Establish a set of principles for excellence;

Going in the same direction, some of the Stakeholders (among which notably LERU) suggested the **development of a set of principles for excellence** that *would allow (potential) academic and industrial users to assess the quality of a RI and to enable the RI to show their dedication to excellent research*.

- Track the usage of research Infrastructures;

As suggested among other by ERF, **users of RI could be required to refer to the access contributed by the RI in their published scientific and technological results or in the**

[13] ESFRI long-term sustainability WG report

context of other types of data records, as a condition to be accepted. This would allow to have explicit references enabling a more comprehensive monitoring of the services provided by the RI and of their impact.

2.2. Attracting and training the managers, operators and users of tomorrow

RI have a broad impact on scientists' skills development in Europe and the availability of competent managers and technical staff running the RI is also a concrete critical requirement for any RI to guarantee the quality of its output. During an RI lifecycle, staff skills requirements change as the RI evolves from a design/construction stage to a service provision phase. However, a basic set of skills, mainly related to governance and business plans development, remain stable throughout the RI lifecycle and could be better acknowledged by the relevant communities at a European level.

The development of the right set of accredited RI staff skills and a career track requires a close link with Academia. On this particular matter, EIROforum, among others, highlighted the need to preserve strong connections with national educational systems: *doctoral and post-doctoral programmes can be designed together with universities, enabling young researchers to acquire hands-on experience at the RI while maintaining links to the home universities*. It is also widely acknowledged that a critical mass of scientific talent needs to be built up through *mechanisms such as attractive employment conditions, transparent recruitment practices, openness to diversity and adaptable PhD and post-doctoral curricula*[14].

Concerning **skills development for managers**, although it is widely recognised that the successful management and leadership of an RI requires a complex set of competencies, there is still a need for a stronger effort to develop harmonized curricula, standardized careers paths and staff exchange programmes targeting managers and operators. Despite the European initiatives -RAMIRI[15] and RItrain[16] - in this field, these still remain stand-

[14]EIROforum discussion paper: Long term sustainability of Research Infrastructures

[15]RAMIRI (Realising and Managing International Research Infrastructures) project, funded by the Commission under FP7, delivered an educational and networking programme for people involved in planning and managing international research infrastructures. It led to the training of around one hundred managers and the publication of a web-based handbook (available at: http://www.ramiri-blog.eu/). This handbook has a specific focus on the life cycle of a RI, legal and governance issues, finance, human resources and management aspects.

[16]RITRAIN, supported under Horizon 2020, building on RAMIRI's achievements, is defining a comprehensive set of required competences from managers throughout the life cycle of a research infrastructure and mapping them to existing training courses and programmes. It will then develop new content to fill in the identified gaps and develop an accredited, comprehensive modular curriculum for a master's programme that will be implemented as a pilot at the University of Milano-Bicocca. Additionally, in order to address specific needs of already active research infrastructure managers and foster their continuous professional development, the project will develop a series of dedicated webinars, based on real case studies, and will organise a broad staff exchange programme. See additional information at http://cordis.europa.eu/project/rcn/194941_en.html

alone and one-off initiatives, which require a further degree of European structuring and integration.

Besides a focus on training, transnational mobility[17] also boosts the quality of the research and innovation systems and currently in the EU the **mobility of skilled managers and operators of RI** is limited. There is a need to work on the framework conditions, such as competitive, compatible working conditions and a European RI system to guarantee stable and secure career paths for staff moving around the different facilities.

Regarding the **development of RI user skills**, the stakeholders' consultation highlights that the establishment of dedicated specific training to RI users, including industry users is becoming a more general practice. This is a very positive trend as the 2013[18] assessment of the ESFRI roadmap projects noted that very few of the ESFRI projects had a user training programme in place. The focus on users is becoming stronger, which is a very good practice, as addressing users' needs and providing users' training is crucial for the evolution of the RI scientific case, and, therefore, sustainability.

Still concerning RI users, **mobility of the user community** in Europe has been so far successfully achieved by the current TNA scheme, but such a scheme should be used as a model for the development of national programmes to further open up the RI's ecosystem and improve cross-fertilization between the different RI.

As regards **broadening the range of potential users,** stakeholders put a clear focus on the need to further raise awareness on the RI services and tools, to improve cooperation with industry and academia and to simplify access procedures for new users.

Taking into account this setting and the consultation process, the main elements for further consideration in the future are:

- Support the uptake of a European curricula and dedicated training courses for RI managers;

The link with Academia was raised as critical in this context by stakeholders like LERU, CESAER and ERF. CESAER[19] specifically recommends the development of a **Sectorial Qualifications Framework (SQF)** for RI staff and a tutoring programme using retired (senior) RI staff. On a similar note, ESFRI put forward that *National authorities should support and harmonise research and education programmes linking RI 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*[20]. In addition, ESFRI also emphasised that it would be highly

[17]Science, Research and Innovation performance of the EU, a contribution to the Open Innovation, open science, open to the world agenda 2016, Directorate-General for Research and Innovation, 2016

[18]Assessing the projects on the ESFRI roadmap, A High-Level expert group report, 2014, http://ec.europa.eu/research/infrastructures/pdf/KI0213337ENC_WEB.pdf

[19] Input on LTS of RIs, CESAER, 2016

[20] ESFRI long-term sustainability WG report, 2017

"desirable for such initiatives to be co-ordinated across Europe to facilitate coherent approach and knowledge transfer across RI in different countries[21]. Helmholtz Association puts the focus on blended learning programmes to progress in this domain[22].

The need to have a centralized coordinated training system was considered difficult to implement, but the **dissemination and uptake of a European curricula, building on the RAMIRI and RITRAIN initiatives,** would be seen as an added-value. These certified training courses should include cost-assessment and risk management modules.

- Improve mobility of managers and staff, through exchange programmes;

A significant number of stakeholders, such as EIROforum, ERF, EU-LIFE[23], Helmholtz Association[24], have been highlighting the need to establish staff exchange programmes at European level. In this context, , Science Europe proposed to establish a dedicated action of the Marie Sklodowska-Curie Actions programme for Research Infrastructures[25] to enable short-term mobility of Pan-European RI managers and operators.

Besides this formal framework to encourage mobility of operators and managers within the European RI system[26], there was also a reflection on the need to stimulate these **short-term mobility schemes in national RI policies**, such as in Germany with the initiative of ERA fellowships[27].

- Support transnational access to RI at European and national level;

Cross border mobility of scientists significantly contributes to the excellence dimension both by stimulating RI to provide state of the art services and by increasing the potential level of scientific output. As highlighted by the Helmholtz Association, *the best scientific users should be able to select the best facilities, regardless of whether they are located in their own country*. This is currently one of the main features supported through the "Trans-National Access" (TNA) schemes of the EU Framework Programmes which has been very successful in ensuring mobility and cross-fertilization between the different RI.

There is a very broad consensus that **the Commission should continue supporting the Trans-National Access scheme and possibly further reinforce it**. Many stakeholders concurred that besides the current Trans-National Access scheme of the EU Framework

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[21] ESFRI long-term sustainability WG report,2017

[22] Helmholtz Association long-term sustainability Position paper,

[23] EU-LIFE contribution to long-term sustainability debate, 2016. The staff exchange programmes should allow *interactions between the large and smaller scale RI* and different types of RI.

[24] Joint EIROforum/ERF Proposal for a new mobility scheme for European RIs aimed at setting-up a RISE scheme to the transfer of personnel between RI both at the national level and between EU Member States. EIROforum response to the ERA Framework Consultation, 29 November 2011, additional information available at http://www.eiroforum.org/downloads/201111_mobility_proposal.pdf; Helmholtz Association Position paper on Long term sustainability of Research Infrastructures – 10 November 2016

[25] Science Europe Policy Brief on Research Infrastructures in EU Framework Programming,2017

[26] ESFRI long-term sustainability WG report, 2017

[27] In Germany, for instance, ERA fellowships programme was developed capacity building in the field of science management http://www.era-fellowships.de/en/era-fellowships-ueberblick.php.

Programme, *national RI policies should also integrate a support mechanism to fund transnational access of users outside the RI country*[28], namely to support transnational access of users within the members of the distributed Pan-European RI.

Transnational Access in the EU Framework Programme

Since its establishment, EU funding programme for Research Infrastructures identified as one of its priorities the opening at EU level of existing national facilities. More than twenty years ago, under the 2nd EU Framework Programme for Research, EU started to fund, through the so called transnational access (TNA) activity, access of European researchers to large scale facilities, wherever these facilities were based.

In 2008, the ERA expert group report already showed that "the existence of and access to leading research infrastructures is and will remain a key determinant of Europe's competitiveness in both basic and applied research"[29].

FP7 and H2020 support transnational access to research facilities - with a focus on a **merit based system**, ensuring that the best researchers can get access to the best facilities. Open online virtual access to digital resources, including software and data services, has also been supported under these two Framework Programmes.

Under FP7 240.3 M€ were used for supporting transnational and virtual access. In average 34.3 M€ per year, were invested to support access – as a key tool to accelerate the RI's openness.

In FP7, the TNA scheme set the scene for closer interactions between 25.782 researchers (2032 users were from third countries) in 1094 infrastructures. It facilitated cross-disciplinary fertilisations and a wider sharing of information, knowledge and technologies across fields and between academia and industry. The FP7 Users satisfaction questionnaire in 2016 reflected that 89% of the TNA wouldn't have been possible without EC support.

The Joint Research Centre of the European Commission has just launched the first calls to open its unique, high-value RI to scientists and researchers from the private and public sectors[30]. The opening of the laboratories follows the launch of an online platform which provides easy access in one place to all JRC facilities.

Access to JRC Research Infrastructures

The JRC offers access to its non-nuclear facilities to researchers and scientists from EU Member States, candidate countries and countries associated to the EU Research Programme Horizon 2020. For nuclear facilities, the JRC will open to EU Member States, candidate countries (on the conditions established in the relevant agreement or decision) and countries associated to the Euratom Research Programme.

[28] ESFRI long-term sustainability WG report,2017

[29] European Commission, Developing World-class Research Infrastructures for the European Research Area (ERA), Report of the ERA expert Group, Luxembourg: Office for Official Publications of the European Commission, 2008

[30] Open Access to JRC Research Infrastructures, https://ec.europa.eu/jrc/en/research-facility/open-access

Scientists will have the opportunity to work in the following fields: nuclear safety and security (Euratom Laboratories); chemistry; biosciences/life sciences; physical sciences; ICT; Foresight. The results will also feed into JRC's mission to support EU policymaking.

In a pilot project, three facilities in Ispra (Italy) with the necessary infrastructure to host visitors will offer access through dedicated calls in the fields of safety and security of buildings and of nanobiotechnologies.

The remaining 38 JRC facilities in Belgium, Germany and the Netherlands are planning to gradually provide access after completion of the pilot phase in 2017-2018.

The JRC provides access in two modes: relevance (excellence) - and market-driven. The **relevance (excellence)-driven** access is exclusively dependent on scientific and socio-economic relevance at European level. It is based on a peer-review selection process following a call for proposals. Projects accessing JRC facilities under the relevance-driven mode are only charged the additional costs associated to such access. **Market-driven** access is granted upon payment of a fee covering the full access costs of the JRC, and it is mainly targeted to industry.

- Stimulate an RI job market at European level;

RI can be seen as *the dead end of a scientific career where only publications count*[31] and this perception needs to be avoided. In order to overcome mobility bottlenecks for RI managers and operators and explore measures to increase the RI attractiveness, stakeholders identified the concrete need to improve the awareness of RI services and tools in the academic circle and beyond.

The development of a service-oriented mission is essential for sustainability and this goal needs to be reflected in the staff and management skills, as stated by an RI *the service provider role goes beyond an academic laboratory – with clients and shareholders; having a good knowledge of operations, contracting, service provision, quality control, etc. without professional provision of services, sustainability is at risk*[32].

In terms of framework conditions, there is a general agreement that there are significant barriers for mobility, comprising different salary conditions, pension schemes and lack of transparency in the job vacancies. ESFRI highlights the need for *a greater harmonisation across countries of career paths, pension schemes and salaries, as well as exchange and re-integration schemes between RI, and universities and also with business and industry*[33].

In this context, the **dissemination of the RESAVER scheme** [34] **-** A pan-European pension fund for researchers to address the pension-related bottleneck to mobility – and

[31] Helmholtz Association long-term sustainability Position paper; ERF Suggested actions for Long term sustainability of Research Infrastructures

[32] EATRIS long-term sustainability position statement 2017

[33] ESFRI long-term sustainability WG report, 2017

[34] In the 2012, ERA Communication the Commission made a commitment to support employers in removing pension as an obstacle for researchers' mobility by "supporting stakeholders in setting up a pan-European supplementary pension fund for researchers". To achieve this goal the Commission initiated

the use of EURAXESS portal [35] **to consolidate a more transparent job market and disseminate the transnational access opportunities** can be seen as two possible measures to support the establishment of a more flexible job and skills market for RI personnel and users.

- Encourage RI to regularly offer dedicated training programmes for users;

Researchers' ability to effectively use and fully exploit RI instrumentation and services highly depends on the appropriate training strategies, which have an impact on the overall excellence of the facility. Developing training programmes for users has a substantial positive impact on the user community size and diversity, in particular, expanding the research infrastructure use to other thematic areas. A more structured effort would therefore be required in this domain to ensure a continuous availability of training to potential users.

RI are encouraged to keep developing **short training modules** (jointly defined by RI and non-academic users) **to capture the interest of potential user groups**. ESA, CERN "summer" and "thematic" schools or 1-month European schools, like the Hercules European School[36] have proved their success in the involvement of different communities to discuss methods, technics and develop cooperation strategies.

- Broaden the range of RI users, by simplifying access rules and the development of a European catalogue of services;

The attractiveness of an RI career is directly linked to the RI reputation as well as its visibility. Measures to increase visibility of services need to be assessed, such as a **system to trace the involvement of RI in publications** or even the potential **implementation of an RI service voucher system**[37].

User skills development implies opening up the RI to different types of users and the general public. User involvement and enlargement strategies are crucial elements for sustainability. For this purpose, RI need to develop continuous mechanisms to feed user feedback into the RI assessment and to stimulate new users, namely by providing

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work on the establishment of a single European pension arrangement for researchers called RESAVER. RESAVER will be a defined contribution plan that will enable mobile and non-mobile researchers to remain affiliated to the same supplementary pension fund when moving between different countries and changing jobs. This initiative should remove supplementary pension as a barrier to researchers' mobility and will contribute to a European labour market for researchers.

[35] Euraxess - Researchers in Motion is a pan-European initiative delivering information and support services to professional researchers. Additional information available at: https://euraxess.ec.europa.eu/.

[36] Hercules European school is a 1-month school, established in 1991, 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, Industrial applications). It includes lectures, practicals, tutorials, and visits of Large Facilities: ELETTRA and FERMI in Trieste, ESRF, ILL in Grenoble, Soleil and LLB in Paris-Saclay, and SLS/PSI in Villigen.

[37] EATRIS long-term sustainability position statement – "A voucher system to access RI services would stimulate use and sustainability of RIs in a competitive manner. Researchers receiving grants at a national level may be given RI access vouchers, which would allow competition (…) for the researcher to choose a high-quality research service provider."

simplified access rules to new user groups and by developing **a European catalogue of services.**

External communication improvement and outreach strategies are considered to be essential tools to reach out to new user communities and to attract the attention of the general public. Public engagement strategies need to be taken into account in the RI core mission, as also stated by CESAER *Open science nights and visitor's centres are no longer sufficient*.

2.3. Unlocking the innovation potential of RI

RI main focus is to perform curiosity-driven fundamental research and to achieve excellence in science, nevertheless their potential to foster innovation is also clearly recognised. The concept of innovation[38] can be considered in this context *lato sensu*, not only focusing on technology development, but also comprising RI's contribution to social innovation, to understand societal attitudes and to develop public policy.

The evolution of the transnational research facilities implies that RI become elements of "supra-national innovation systems"[39] and, in this setting, industrial players can play the role of potential supplier (of the required technologies), user and co-developer.

The current framework for interaction with industry is not ideal and both RI and industry do not fully perceive the reciprocal potential benefits of proactively engaging in collaboration[40].

The lack of an appropriate information flow, different language and objectives tend to increase this gap. An RI, Academia and Industry's mind-set shift is needed as well as a stronger communication of the RI added value beyond the academic circles. CESAER considers it is key to *establish a culture of innovation for RI staff concerning openness; risk taking, flexibility and agility of interactions, trust, integrity and confidence between partners, rapid reaction and co-creation*[41].

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[38] According to the Oslo Manual "An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations". Literature puts forward several approaches on the innovation effects that may arise from public investments in RI, Simmonds (2013) highlights 6 broad classes of innovation effects "1) Use-led innovation, 2) Research-based innovation, 3) knowledge spillovers, 4) Technology transfer, 5) clustering and agglomeration effects and 6) systemic innovation." in Simmonds, P. et al (2013) "Big Science and Innovation", Technopolis

[39] Stahlecket, T.; Kroll, H. (2013) "Policies to Build Research Infrastructures in Europe – Following traditions or Building new momentum", Fraunhofer

[40] Stakeholders indicate that *cooperation is hampered in function of different goals and expectations between industrial users and Research Infrastructures' (9.4%) and of administrative, legal and fiscal burdens connected to working with Research infrastructures (6.4%)*. Results also show that only *20.4% of the budget of RI is dedicated to industrial high tech components procurement and 10.7% of the Access to RI is represented by industrial users.*

[41] Informal Input on LTS of RI, CESAER,11th November 2016, Leuven, p. 6

Open science trends, which advocate for a rapid diffusion of the latest knowledge have already launched a shift in the current mind-set. A strong example of such a change is the construction and operation of the Large Hadron Collider (LHC) at CERN, which has been signalled as the place where *new businesses and business models must be identified, explored and undertaken*[42].

A clear example of the need to improve the communication on RI impacts is that several RI have been in the forefront of the test and launch of new services and technological applications[43], but in most cases there is no clear association between the scientific results and the commercial applications. A co-creation approach to continuously generate, scale and deploy breakthrough technologies with market and social value can be one way to solve this issue.

The use of the co-innovation paradigm, by stimulating products and services co-development could lead to mutual benefit outcomes to both communities, accelerating technology development to the market and to increase RI visibility in the innovation chain. This co-creation approach has been stimulated through several Framework Programme RI projects, such as GREST.

GREST co-creation case

EST, a research infrastructure for ground-based solar physics observations, is a highly technological project with an important involvement of the private sector.

In the achievement of EST goals, GREST project, funded under the H2020 Framework, provides an excellent opportunity to develop new applications during the development of breakthrough technologies, increase the capabilities of the industrial sector and strengthen the cooperation between academia and industry. Three of the key technologies cases are described below:

- **Large-format high-speed prototype detector (ANDOR Technology PLC, United Kingdom) -** detectors initially are developed for solar observations, they are expected to have a wider range of applications which require high-resolution astronomical observations, such as Near Earth Object detection and Pulsar studies and to open new markets in Transmission Electron Microscopy (TEM), Protein Crystallography and X-ray Tomography, providing growth and diversity in existing markets and increase the demand for a skilled workforce in the high-technology sector.
- **Large aperture etalon (A.D.S International, Italy).** As part of the large aperture etalon, the company has developed novel high performance capacitive sensor electronics.

[42] Chesbrough, H. (2015)"From Open Science to Open Innovation", ESADE

[43] Big Science report states that "modern innovations had their seed, or got fertilised at a critical moment, at big science centres, such as Capacitive touch screen, Pharmaceuticals—Five of the top 20 drugs in use were developed using synchrotrons (…), Scratch-resistant eyeglasses—Developed by NASA to provide scratch-proof coatings for astronauts' visors, most eyeglasses now feature it, WiFi—based on technology developed by Australian astronomers to study radiation from black holes, (…) Hypertext Markup Language —The key idea that transformed the academic Internet into the commercial World Wide Web came from a CERN computer scientist trying to make it easier for physicists to interlink their documents. There are many more: cochlear implants for hearing loss, the 'shears of life' to rescue car-accident victims, 'memory foam' for pillows and bedding, dental lasers, the foot and mouth disease vaccine (…) in "BIG SCIENCE: What's It Worth?", (2015), Science Business, CERN, Aalto University, ESADE

This co-innovation process develops innovative instrumentation, as digital seismometers and high precision inclinometers. These instruments have been identified as niche applications for which few suppliers are present at European level.

- **Liquid crystal cells (ARCOPTIX, Switzerland).** The development of new types of liquid crystal cells, different from the standard ones, in order to obtain faster response times, is pushing forward of the manufacturing processes of the company. In addition, new procedures to obtain a higher homogeneity in the optical thickness are being developed which will also increase the performances for the standard devices and the potential uses of these systems, which can lead in the future to produce better products. While liquid crystals have become attractive for applications such as diffractive optics, adaptive optics, or optical metrology, the range of possible applications is ampler, including diffractive optics for the generation of digital holograms or high-speed communication systems.

New initiatives, as ATTRACT[44] or IdeaSquare[45], also serve this purpose by laying down the foundations for disruptive innovation in key critical technologies and by delivering breakthrough technologies for different markets.

The design and co-design of instrumentation and equipment is another possible RI-industry interaction which can create new economic opportunities[46], and where it is essential to bridge the gap between RI and industry, to reduce investment risk and to create a win-win situation. Examples of these developments include the new generation of detectors, virtual astronomical observatories, protein scanners, magnets, energy efficient computers.

The ERID-Watch [47] and EIRIISS[48] studies have assessed the efficiency and market impact of research infrastructures in Europe and focussed on ways to maximise the impact to research and industry from the opportunities presented by the instrumentation development activity at European RI. For instance, EIRIISS identified three main areas where further support is recommended: a specific focus on increasing the visibility of opportunities for interactions between industry and RI; target the support on industries that are more likely to engage with RI and vice-versa and share best-practices in

[44] ATTRACT, developed by CERN and supported by the EIROforum Members, focuses on the development of high-performance detector and imaging technologies. Additional information is available at http://www.attract-eu.org/

[45] Within the frame of the IdeaSquare, precursor of ATTRACT, the state of the art of pattern recognition technology developed at CERN for High Energy Physics have been transferred to Computer Vision domain and are being used to develop a new tool to assist autistic children in their learning process. The underlying code is from augmented reality software, which is based on technology used in detectors at CERN. The project is collaboration between CERN and the Italian university UNIMORE and will be used by the researchers to help with autism studies. Additional information is available at http://home.web.cern.ch/about/updates/2014/12/ideasquare-opens-today

[46] "*The market in Europe for 'big science' RI is estimated to be worth upwards of €10 billion per annum, alone*" - EIROforum Position Paper on Scientific Instrumentation for the EU Framework Programme (Horizon 2020), 1 November 2012

[47] European Research Infrastructures Development Watch (ERID Watch), FP6 project No 043004

[48] European industrial and RI interaction and support study (EIRIISS), FP7 project No 284294

procurement and knowledge transfer, involving networking of procurement professionals and encouraging industry to interact more readily with RI.

In a completely different context, innovation potential can also be expressed through the development of new services. RI can also trigger the new business models and services to policy makers, which is evident in cases such as SHARE-ERIC[49] and EATRIS[50].

As a follow-up of the stakeholders' consultation process, the main elements which deserve further consideration are:

- Increase RI engagement with industry, by fostering their direct and **early-involvement in Advisory Boards** and through dedicated training and exchange schemes;

Initiatives and dedicated actions to foster RI-industry interaction are recurrently put forward by stakeholders, such as Science Europe and Helmholtz Association, which clearly state there is a need for the Commission to provide "the right incentives to tackle the barriers to collaboration between publicly-funded RI and the private sector"[51].

A stronger involvement of industry can also be achieved by the establishment of participation of industrial players in Advisory Boards, 64.3% of the respondents declared not having in place an Innovation Advisory Committee - a dedicated organisational element that would allow to better reach out to industry and to the public sector needs.

Staff mobility and exchange programmes with industry are identified as measures that could overcome the cultural barriers preventing cooperation. As ESFRI highlighted this cultural gap requires *dedicated training and (...) exchange schemes for staff on both sides of the divide*[52].

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[49] SHARE-ERIC findings have strong policy implications. SHARE-ERIC and its' broad data on the economic, social and health situation of European citizens enables Member States (and the European Commission) to base difficult economic and social decisions on evidence rather than beliefs. SHARE has been supporting evidence-based policy making in Czech Republic, France, and Slovenia and advising the Dutch parliament. The European Commission - DG ECFIN, DG SANTE and DG EMPLOYMENT - also use SHARE data to provide long-term projections on pension and health care expenditures, to stress the importance of health prevention and work place quality to foster labour force participation at older ages and to set their indicators for demographic and socio-economic situation. SHARE has been instrumental by the research departments of OECD, WHO and the World Bank.

[50] The European Infrastructure for Translational Medicine (EATRIS) illustrates the effectiveness of interaction between RI and industry in enabling innovative solutions. The project has the purpose of transforming laboratory research outcomes into new ways to diagnose and treat patients. In order to promote translational research, EATRIS signed a framework agreement with the ROCHE Partnering Extending Innovation Network (EIN) to facilitate EIN access to research projects within the EATRIS network. EATRIS also developed a plug-in service – EATRIS Inside to funding programmes in order to improve the translational element of applied research funding, through translational feasibility assessment and match-making.

[51] Science Europe Policy Brief on Research Infrastructures in EU Framework Programming,2017

[52] ESFRI long-term sustainability WG report, 2017

- Enhance the **role of intermediaries** and develop specific mechanisms to stimulate the commercial application of RI services and tools;

Several stakeholders, such as ERF, Science Europe and ESFRI advocated for "mediation" to facilitate tailored industry users support and the need to have brokerage functions to facilitate knowledge and technology transfer for the translation into industrial and commercial environment. The **reinforcement of the ILOs** seems essential to stimulate the RI and industry interaction. ERRIN also pointed out that regional intermediaries and facilitators between academia and industry such as clusters can play a role to ensure impact and integration of RI in the local innovation ecosystem.

In addition, the Knowledge and Innovation Communities (KIC) could play a greater role in supporting the translation of results into commercially-viable solutions, thanks to their services and their distributed presence in local innovation ecosystems in order to favour cross-border collaborations.

- Clarify **industry access rules**, mainly concerning IPR regimes and procedures for accessing RI;

Current access rules are seen as one of the major bottlenecks for industrial access and there is a perceived need to define access rules which can favour industrial usage.

In addition, it is crucial to point out that *in most analytical and material science facilities, there is a large hidden industrial use performed through academic users, estimated to be above 20%*[53] and this can be also seen as a positive channel to improve relations with industry and further **incentivise users to explicitly bring forward their relationship with industry**, namely by providing a reward system for having these services for industry acknowledged in their scientific career paths.

An example of good practice in the definition of IPR regimes for users, including industry, is found in the Framework of access to the Joint Research Centre physical research infrastructures[54], which foresees an extension of the embargo period for the dissemination of the generated data via open access schemes when such dissemination jeopardises the protection or commercial exploitation of the data.

- Support **large scale initiatives and pilots involving RI**, academy and industry through a co-innovation process;

The current dialogue on the development of new funding mechanisms touches a public-private co-investment as an interesting solution, including co-funding schemes, large scale co-innovation initiatives and the launch of pilots.

Among the possible measures to encourage industrial involvement in RI, stakeholders also identified possible **tax incentives for (private) investment** as well as a wider

[53] ERF Suggested actions for long-term sustainability of Research Infrastructures, 2017

[54] JRC Framework for access, https://ec.europa.eu/jrc/en/research-facility/open-access/framework

awareness/ promotion of RI services. **Public-private partnership vouchers** to support cluster activities in RI were also possible options to have a close look at.

- Stimulate **joint innovative procurement mechanisms**, pre-commercial procurement and the link with Public Procurement of Innovative Solutions;

Procurement processes should be considered a mechanism to encourage a wider range of companies to engage more effectively with RI. Pre-commercial procurement enables the early involvement of industry in the preparation of calls for tender and support financing joint technology development between RI and industry and stimulates a close interaction with industry. At European level, there were recommendations on the creation of a coordination mechanism to stimulate joint procurement schemes to coordinate RI investments.

- Develop **strategic roadmaps in key technologies** required for the construction and upgrades of RI in close relation with EIT, KICs and KETs;

The development of strategic roadmaps in key technologies to identify potential technical areas of interest for industrial research in RI were seen as a possible way forward to exploit the RI innovation potential. RI use sophisticated technologies, which can only be developed in large-scale platforms combining R&D, integration and validation.

These platforms would form a distributed network across Europe and provide RI with advanced key technologies and integration services. Their coordination in a given technological domain should contribute to harmonise their operation conditions and increase their efficiency[55]. This would aim at helping European industry maintain or take a leading role in the development of the technologies required for the RI of tomorrow.

Concerning industrially led infrastructures such as wind tunnels, engines test-benches, industrial pilot plants, the Commission services are exploring the possibility of preparing a similar European roadmapping exercise targeted at facilities tailored to industrial needs.

- Foster the use of RI for **pre-normative research**

Large scale RI and testbeds can play a key role for the design and validation of innovative products and technologies, thus bridging the gap between research and innovation, and commercialisation. In this sense, pre-normative research carried out at RI leads to the production of data and guidelines that feed into the standards making process, enabling industry for the market uptake of their innovations.

An example of the contribution of RI to pre-normative research is found in the ECOLEADER (FP5), SERIES[56] (FP7) and SERA[57] (H2020) projects financed by the European Commission Research Infrastructures Framework Programmes in the field of seismic safety of buildings and infrastructures. These projects have granted transnational

[55] In line with the recommendations of the report "KETs: Time to act" (2015) of the High-Level Expert Group on Key Enabling Technologies

[56] Seismic Engineering Research Infrastructures for European Synergies, http://www.series.upatras.gr/

[57] Seismology and Earthquake Engineering Research Alliance for Europe, https://sera-ta.eucentre.it/

access of European researchers teamed with industrial partners to unique and first class facilities, leading to the production of guidelines in support to the drafting of the Eurocodes, the European Standards for earthquake design of buildings and infrastructures.

2.4. Measuring socio-economic Impact of RI

RI have a direct impact on society primarily in function of the knowledge generated through the services they offer. This is complemented by another set of direct economic impacts tied to activities such as the employment of work force during their construction phase or the creation of new jobs and services for their operation and maintenance.

A large emphasis is currently been made on the more indirect socio-economic impacts related to RI investment which are not directly related to the scientific objectives of the RI itself. An illustrative case is represented by the tourism increase in the Canary Islands linked with the establishment of Mount Teide Telescope[58], which was awarded in 2013 the title of 'Starlight Tourist Destination' and which has attracted the attention of tour operators cashing in on the appeal of the night sky and offering special star-gazing walks and astrophotography tours. The EIROforum paper on RI sustainability[59] also underlines that *the invention of the World Wide Web at CERN may be the most prominent recent example of a general benefit to the whole of society*. Several studies have been carried out to attempt modelling the RI costs and benefits[60] as well as to analyse the RI socio economic impact [61,62,63,64]. The initiatives launched so far vary from very structured mathematical modelling[65] to more qualitative approaches[66].

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[58] Additional information available at http://www.iac.es/?lang=en

[59] EIROforum discussion paper: Long-term sustainability of Research Infrastructures (2014) available at: http://www.eiroforum.org/downloads/20150325_discussion-paper-research-infrastructures-sustainability.pdf

[60]Guide to Cost-benefit analysis of investment projects - Economic appraisal tool for Cohesion Policy 2014-2020 (2014), European Commission, Directorate-General for Regional and Urban policy

[61] Research Infrastructures Foresight and Impact (RIFI), FP7 project No 228293, 2009

[62] Impacts of Large-Scale Research Facilities – A Socio-Economic Analysis, Research Policy Institute, (2004)Lund University

[63] Evaluation of Research Infrastructures in Open innovation and research systems (EvaRIO), FP7 project No 262281, 2013

[64]Additional information available in OECD, "The Impacts of Large Research Infrastructures on Economic Innovation and on Society: Case Studies at CERN"(2014),OECD

[65] Cost/Benefit Analysis in the Research, Development and Innovation sector (2016), Center of Industrial Studies, University of Milano. Additional information available at: https://www.csilmilano.com/docs/WP2016_01.pdf

[66] Evaluating and Monitoring the Socio Economic Impact of Investment in Research Infrastructures, (2015)Technopolis

Additional difficulty in proper quantifying benefits is linked to the fact that RI tends to have supranational impact and that makes economic analysis more demanding than for investments with mainly local and regional impact (such as transport projects). As a consequence, Socio-economic impact assessments, although considered strategically relevant by the political decision makers, are not carried out in a systematic manner throughout the life cycle of an RI.

As highlighted by ESFRI, *National authorities and funding bodies should be explicit about the role that socio-economic impact plays 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. Periodic monitoring of societal impact should be a part of the regular assessment of the RI*. Furthermore, the discussions with stakeholders have also indicated the need to have a better assessment of the intangible investments, in quantitative terms, since these remain poorly understood.

As highlighted by the Commission[67], investments in intangible assets tend to be underestimated and there is a need of a fuller understanding of intangibles as a source of macro-economic growth, and corresponding means of measuring knowledge creation and intangible capital (including R&D and taking account of the complementarity and synergies with other intangibles, such as computerised information and economic competences).

The Square Kilometre Array (SKA): Impacting beyond the boundaries of science

The Square Kilometre Array (SKA) is an international project, which illustrates both the direct and indirect socio-economic impact of investment in RI. SKA will develop a radio telescope with a receiving surface fifty times larger than the biggest telescope now in existence. Notwithstanding the scientific purpose of the project, a large number of other significant benefits in terms of technological innovation, industrial development, knowledge and education and other indirect societal impacts have been identified during the preparatory phase of the project[68].

As such, once completed, SKA will generate data at a rate more than 10 times today's global Internet traffic. This will stimulate cutting-edge advances in high-performance computing and Big Data science and will foster the development of global sensor networks and real-time monitoring which impact potential commercial and government applications.

The SKA partners have also been investing in developing the required skills through their dedicated Human Capacity Development Programmes. As an example, in South Africa, already in 2010 more than 700 people, ranging from artisans to postgraduate students and postdoctoral fellows, had already received support from the project. This is causing a surge of interest in studying mathematics, engineering and astrophysics at local universities, and attracting top students and academics from around the world to South Africa.

In addition, a number of opportunities will arise around the demand created by the facilities that will lead to a number of small-scale business opportunities to be developed in the Region, which are expected to drive community development.

[67] European Economic Forecast, European Commission (2016)

[68] Additional information available at http://www.cost.eu/events/ska

As a follow-up of the stakeholders' consultation process, the main elements which deserve further consideration are:

- Contribute to the development of a standardised international approach to measuring the socio-economic impact of Research Infrastructures

Many stakeholders such as CESAER stated that they would support the development of a *common, reliable and normalised reference framework for impact assessment, which would imperatively need to take into account the diversity of RI as well as the evolution of the impact along their life cycle*.

The relevance of Socio-economic impact and the *increasing demand for methodologies and tools for assessing the social and economic impact of RI*[69] has also been confirmed by the OECD Global Science Forum which has then launched a specific initiative aimed at developing a *standardised reference framework of robust and reliable methods, based on agreed indicators, for assessing socio-economic impact of Research Infrastructures*[70].

There was a general agreement on the fact that **the Commission should continue collaborating with the OECD and other relevant international players on the development of a common approach to RI socio-economic impact assessment**.

- Stimulate the further integration of Research Infrastructures in the socio-economic local context.

Physical Research Infrastructures (especially the large analytical facilities) are an integral part of the geographical region in which they are located. Since Regions are important arenas for innovation and are key actors in developing effective regional innovation ecosystem, they can play a role to ensure impact and integration of RI into regional innovation ecosystems.

As stated by European Regions Research and Innovation Network (ERRIN), *Regions are also close to what is happening on the ground and used to collaborating with many different stakeholders (...); they can act as bridges between research and growth policy and inspire cross-silo initiatives*.

EIROforum, highlighted how, by attracting hi-tech companies and specialized facilities, educational establishments, and offering new employment possibilities, RI create an 'innovation hub in their regions which, being in many countries responsible for universities, can then play an important role in the upskilling of RI staff and user communities.

The discussions therefore indicated a **requirement for the Research Infrastructures to consolidate their position and to establish appropriate links with all the relevant entities at regional level**.

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[69] Global Science Forum working document, DSTI/STP/MS(2016)3

[70] Idem Ibidem

- Increase the visibility of Research Infrastructures to society at large

One of the main impacts that RI have is the visibility they provide to science. In this respect RI often have features that appeal to the public and therefore have a complementary role to the universities and other RPO when it comes to public outreach that may stimulate, when appropriately communicated, interest in science and technology of young people and students.

The correlation of RI visibility with the societal impact it is extremely strong although in many cases still understated. **RI need to dedicate sufficient resources to communicate better and better explain their added value**. The engagement with the public at large remains vital to ensure a proper societal understanding of the relevance of the activities of RI. The consequent social acceptance can then indirectly lead to a smoother positive decision to cover its underlying costs by the political level.

2.5. Exploiting better the data generated by the RI

Research is increasingly data-driven and RI are nowadays becoming research data factories, while the complexity and volume of data sets grows exponentially. In parallel, the principles of Open Science are becoming widely accepted and the European Commission has implemented a policy for open access to scientific information including data. As an example, the European Commission has developed the Joint Research Data Catalogue[71], making available to the public a large number of databases, JRC publications and software and modelling tools resulting from scientific work carried out in Europe, including the output from JRC and European RI.

It is thus clear that ensuring better availability, access and reuse of research results and scientific data generated by RI, including for non-research purposes, will be essential to improve research replicability and efficiency, strengthen innovation, develop new activities and boost the productivity and competitiveness of the European industry. Accordingly, data produced with the RI should be as open as possible and as closed as necessary under the FAIR data principles (findable, accessible, interoperable and reusable).

Capitalizing on the power of data requires RI to adopt and implement consistent Data Management policies including the use of Data Management Plans (DMPs).The European Charter for Access to the Research Infrastructures lists Data Management policy as one of the important aspects to be included by RI in their policies and bylaws, while it further recommends that research data produced through the use of the RI be as open as possible to promote further re-use for research, innovation and education purposes. The Charter also addresses DMPs as important instruments for making the most out of the research data produced by the RI. Data Management policies clarify roles and responsibilities that concern data production and stewardship, while DMPs outline

[71] Joint Research Centre Data Catalogue https://data.jrc.ec.europa.eu/

the planning for the production, standards, dissemination, curation of data in their entire lifecycle, long-term preservation, among others. In this context RI should be also addressing challenges identified as important such as ethical and legal issues regarding data, data protection, issues of privacy, inter alia as well as technical, semantic and legal interoperability.

ELIXIR/CORBEL – Harnessing the power of data for improving health care

ELIXIR offers an example of initiatives aimed at exploiting the potential of the large quantity of data generated through research programmes. Because of new technologies such as next-generation DNA sequencing, data produced in life science doubles every few months. New types of data also emerge at rapid pace in this field and they need to be integrated meaningfully. The collection, curation, storage, archiving, integration and deployment of bio-medical data present a huge challenge that cannot be handled by a single organisation or by one country alone. It requires international coordination, and very significant investments. ELIXIR[72], one of three priority ESFRI projects, addresses precisely this challenge. Its purpose is to operate a pan-European research infrastructure for biological information, integrating leading data resources, and providing data services to the scientific community in medicine, biotechnology, food, agriculture and biodiversity. It may also support the management of other life sciences related challenges (personalising medicine, rising healthcare costs etc.). The FP7 BioMedBridges cluster project, and its follow-up project CORBEL in Horizon 2020, which are both coordinated by ELIXIR, involve all the other biomedical ESFRI infrastructures. Through ELIXIR and CORBEL, researchers find easier and more integrated access to the resources they require for their biomedical research. This will directly impact basic discoveries, as well as innovative drug design, leading to the development of new medicinal products and improved health care.

To address the era of extreme-scale systems (exascale databases and computing machines), RI will heavily rely on e-infrastructures, i.e. high-speed connectivity, top-of-the-range computing infrastructures, data management services and storage resources. However, e-infrastructure services are currently too often developed as stand-alone systems by individual RI. e-infrastructure resources and services address several scientific domains and can be more or less customized to meet specific community requirements. One of the most recurrent comments collected during the consultation concern the need to bridge the gap between RI and the providers and operators of e-infrastructures and associated core services.

Addressing this challenge requires designing and prototyping new services to be developed in an integrated and standardised manner to meet the specific needs of the different scientific communities. This implies an effort to integrate and open national research infrastructures by means of 'physical' and 'virtual' access to the research resources (instruments, network, computing and data).

[72] Additional information on ELIXIR available at www.elixir-europe.org

The European Plate Observing System (EPOS) – Moving towards open, interconnected, data-driven and computer-intensive science

In the area of environmental sciences, the European Plate Observing System (EPOS) is another example on how only an integrated approach to data management enables achieving the intended scientific goals. In solid earth sciences, large amounts of data are generated by observational systems, monitoring networks and experimental facilities. These data are essential to understand the Earth's physical and chemical processes that control earthquakes, volcanic eruptions, ground instability and tsunamis as well as those driving tectonics and Earth's surface dynamics. The European Plate Observing System (EPOS) aims at creating a pan-European infrastructure for solid Earth Sciences to foster access to multidisciplinary data, products and services relying on distributed national research infrastructures. The easy discovery of data and products as well as the access to visualization, processing and analysis tools will facilitate the use and re-use of data within the geoscience domain and likely beyond it. EPOS will standardize, homogenize, and integrate data and will handle the volume, variety, variability, and veracity of big data to leverage their accessibility via a virtual research environment.

To achieve this, EPOS has developed a new portal architecture, the Integrated Core Services, connecting data users and data providers for an open and friendly access to data, software services, computing and instrumentation resources. The new infrastructure guarantees interoperability with the Thematic Core Services where data, products and specific services are provided by the involved communities through national and European data centres.

By federating existing scientific data infrastructures and cloud-based services, the EOSC will address the fragmentation of e-services and will provide seamless access to and preservation of data, as well as services for connectivity, computing, data storage and management, among others. The EOSC will facilitate access to FAIR data by fostering data management, discoverability and reuse across all research disciplines; it will help develop specifications for interoperability and data sharing across disciplines and infrastructures, thus contributing to the reusability and interoperability of diverse types of data.

As it is commonly agreed that Open Data carries a cost for data producers (mainly) and for data users, the Commission services committed to draft a Roadmap for governance and funding of the EOSC in the autumn of 2017, for discussion with Member States. The Roadmap will specify concrete options for the long-term sustainability of research data and of the supporting data infrastructures, beyond the life-span of individual research grants

As a follow-up of the stakeholders' consultation process, the main elements which deserve further consideration are:

- The need for RI to take **responsibility for the Data Management** dimension with specific reference to the data storage, curation, access and re-use aspects. The requirement for a more integrated and interoperable approach to the data challenge was also clearly highlighted, keeping into account, whenever necessary, the ethical, privacy, security and copyright and IPR constraints.

- A closer involvement of the RI in the **development of the European Open Science Cloud for Research** with a view to improve interoperability and effective access to and reuse of scientific data.

In this context, RI would participate in the EOSC, aligning themselves to the principles of Open Science they are extensively adopting, helping to shape EOSC and make it fit-for-purpose for European researchers across all disciplines. They would expose their services and data to the EOSC; data produced by the RI should then follow the FAIR principles and be available, enabling the widest reuse possible for scientific and other purposes. In this way the impact of the services and outputs of the RI would be broadened, helping address the needs of all European researchers, as well as SMEs and the wider public, such as citizen scientists.

2.6. Establishing adequate framework conditions for effective governance and sustainable long-term funding for RI at every stage in their life-cycle

The ESFRI roadmaps have led to a convergence in the planning for establishing pan-European RI and have, as a result, triggered similar exercises in Member States and associated countries that have developed National RI Roadmaps, which in addition to indicating national priorities, also identify synergies with the ESFRI roadmap.

However, differences in national budget cycles and of the validity and timing of updates of national roadmaps make joint investment decisions for construction, operation and phasing out of pan-European RI complicated as these differences are amplified when trying to agree a coordinated funding for pan-European RI.

In addition the fact that at national level, Roadmaps and associated funding decisions are made on the basis of competitive calls do insufficiently take into account the long-term commitment needed for RI which lifetime goes well beyond the cycles of updating national roadmaps.

Moreover, and this is visible at European and national level, no mechanism comparable to the way international financial obligations are being dealt at national level with for example for CERN, ESA and other treaty based international research organisations, has been established for pan-European RI.

A possible solution that could be explored is to see whether financial contributions to ESFRI projects and ERICs could be provided under national budget lines similarly and systematically regarded as for international treaty-based organisations. This could provide the RI operators a sufficient stable investment environment allowing these to concentrate on providing high quality services for their user communities instead of continuously looking for funding even for their basic operations.

As also highlighted by the respondents to the consultation, in the current institutional framework, the role of the Commission is presently underexploited as it can play a relevant role in the development of a coherent European RI ecosystem, namely anticipating shortfalls, promoting the visibility of these pan-European RI and safeguarding European interests.

Taking into account that RI are integrated in an evolving ecosystem, regular upgrades are a crucial part of the life cycle of the RI to allow it to stay at the forefront of scientific output and decommissioning should be a considered a natural process. In this decision making process, it appears that cost-benefit and scientific landscaping analysis are widely considered, but there are no common principles for evaluation and accounting of RI to support decision makers to upgrade or decommissioning[73] and no common international accounting standards related to management, evaluation of the "fair-values" and recovery of "sunk-costs" when a RI needs a transition.

In order to inform decision making processes, stakeholders have considered crucial to perform a regular and systematic evaluation and monitoring of ESFRI projects and ERICs assessment in order to clearly identify the need for changes in the current scientific cases of the RI and the new funding instruments and governance mechanisms needed on a long term perspective. ESFRI and the Commission High Level Expert Group for assessing the projects on the ESFRI Roadmap in 2012 have played a role in the methodology development, but there is a need to institutionalize the Assessment process.

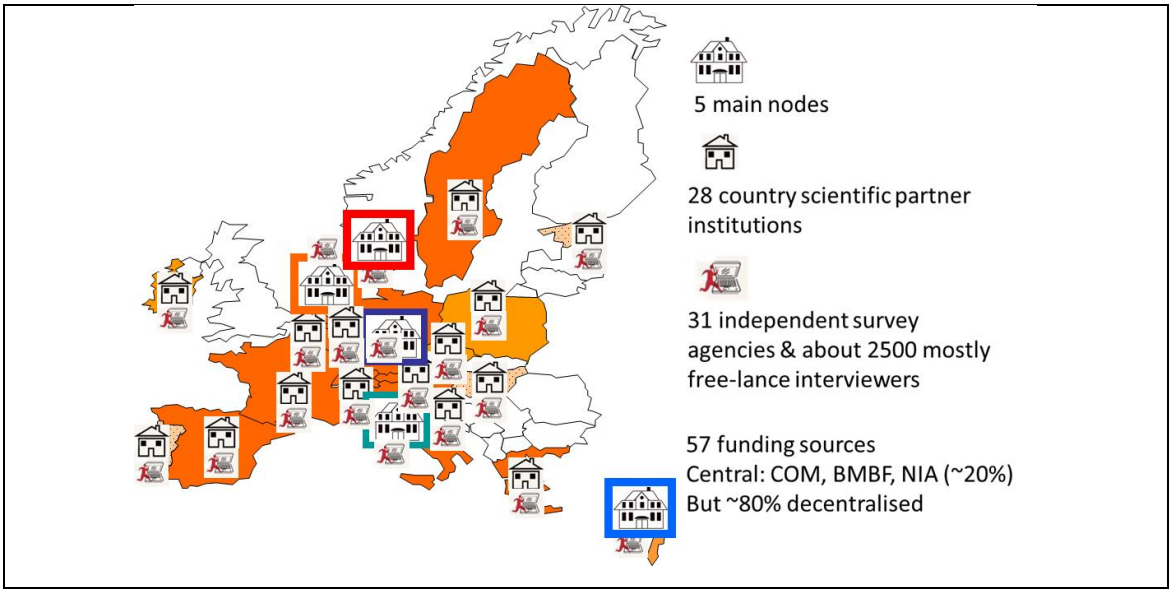
In terms of governance mechanisms, the ERIC Regulation was a response to the European political ambition of creating the European Research Area to enable tackling current challenges, such as internationalisation of research; achievement of critical mass; development of distributed facilities; development of reference models). Currently, there are 14 ERICs and these pan-European RI are a solid attempt to secure funding for operation, by a core group of Member States and associated countries, but their sustainability could be improved (eg.by broadening the participation to a larger group of Member States and international partners).

Even when the ERIC successfully engages the Member States and associated countries in the governance and financing of these RI, the issue of assuring long term commitment remains in many cases.

In the case of SHARE-ERIC Survey of Health, Ageing and Retirement in Europe, performing longitudinal studies relying on regular (small and multi-level) contributions of numerous funding organisations for their operation still represents a sustainability bottleneck.

SHARE-ERIC challenges

[73] However, the possible life evolution, with specific reference to decommissioning is not always addressed appropriately in the early development stages of the projects, as could be shown in the ESFRI report of the 2010 Roadmap which refers to the fact that decommissioning was considered for only 30% of the projects. The stakeholders consultation also highlighted that decommissioning is often not integrated in the RI lifecycle management and in the RI business plan (if produced). Decommissioning phase should also cover the issues of personnel and knowledge so as to allow a smooth and efficient transfer of expertise and know-how to other new or state-of-the-art RI projects like those for instance established under harsh Arctic environment and requiring regular updates.



RI, contributing to EU policy making, currently lack a specific type of EU support, to promote the use of these ERICs collecting and sharing data resources, such as data archives, to researchers benefiting from EU support like Horizon 2020.

The main elements which derived from the consultation process in terms of governance and funding of RI are:

- **Set a minimum target budget reflected in infrastructural investment**;

Achieving the EU goal of 3% of GDP investment in research would improve the sustainability of the RI ecosystem at a national level, but also reflects stability on the commitments for Pan-European RI.

- **Encourage synchronisation of national roadmaps and their alignment with the European RI roadmap;**

Member States and associated countries define their strategies on RI, through a national RI roadmap, which ideally is a process conducted prior to an ESFRI Roadmap update, allowing for effective and efficient collection of political support and financial commitment. The appropriate level of commitment of Member States and associated countries needs to be secured for pan-European RI and several stakeholders suggested the need to look into an **ERA-NET, co-funding mechanism** to ensure this early stage involvement.

The planning and financial engineering of the construction[74], the related national (road mapping and budgetary) procedures, the identification of other funding instruments such as ESI Funds and innovative financing instruments need to be subject of reflection. The consultation process highlighted the possibility of the setting up of a **"ESFRI common pot"** out of which the evaluation of ESFRI projects by experts, the development of

[74] Cost control and management issues of global research infrastructures, Report of the European expert group on cost control and management issues of global research infrastructures, October 2010, ISBN: 978-92-79-17390-5

studies on socio-economic impact as well as exchanges of best practices could be organised.

- Improve **RI' costs coverage**;

Improving the coverage of RI costs implies a higher visibility for their services to the research communities. Turning operational RI costs eligible in research grants, at a national and European level. For instance, in the form of a fixed percentage that would be added to the user costs allowing for the RI to undertake maintenance could be beneficial for the sustainability.

- Improve RI's **bankability** by supporting the development of an RI business model;

The definition of business models was seen by stakeholders a critical tool to facilitate the funding for construction and operation of an RI, as more than half of the RI consulted declared not having developed or regularly updated a business plan in support of their entire life cycle. The development of a credible business plan during the preparatory phase of an RI is recognised as imperative to improve the bankability of RI. Stakeholders indicated the potential requirement for dedicated guidelines for business plan development to be developed at European level.

- **Further exploit the ERIC instrument**;

Stakeholders regard the ERIC instrument as a legal instrument which could facilitate joint efforts and future commitments for the development of a European ecosystem of RI. Stakeholders also responded that the ERIC instrument is relatively new and will still need some time to prove its efficiency. Respondents also considered that the EC should further promote the ERICs as pan-European service providers through the Framework Programme. Stakeholders identified a number of areas for further development of the instrument, such as the VAT exemption, extension of the ERIC applicability to EURATOM, using the ERIC as a legal basis model for international consortia and to research networks.

- Develop a stronger **monitoring, support of the Pan-European RI and the development of an international benchmark** RI landscaping before taking decisions on development/upgrading/termination of an RI.

In order to strengthen the monitoring and assessment of the RI, there is a need to develop a stable assessment mechanism, to be used at European level. There is also a need to develop the appropriate KPIs (qualitative and quantitative performance indicators) for the RI to operate would serve as a good basis to achieve sustainable monitoring and governance of Research and Data Infrastructures.

The need to have an international benchmark was referred as a relevant background to develop a strategic assessment of the European landscape.

- **Better inform the upgrading and decommissioning decision-making process**;

The need to introduce international evaluation and accounting standards as support to decision makers, allowing choices/planning between different options (renewal versus decommissioning) was highlighted by several stakeholders.

The establishment of common guidelines on decommissioning, including provisions for channelling expertise acquired data and research results, know-how from RI users and operators towards other RI was also raised as an important basis to structure a decommissioning process.

- Improve the **synergies with ESI Funds**, to implement national RI roadmaps and to support transnational access schemes between RI;

The European Structural and Investment Funds (ESI Funds) provide substantial investments in research and innovation. Also, for less research intensive regions of the EU, significant amounts of resources are available via ESI Funds. In order to exploit this opportunity, it is important to reconcile the long-term competitive advantages resulting from RI with the short-to-mid-term socio-economic advantages that qualify for the use of ESI Funds, by improving the cost-benefit assessment methods for RIs and enhancing their relevance for the national or regional economy.

The Staff Working Document "Enabling synergies between European Structural and Investment Funds, Horizon 2020 and other research, innovation and competitiveness-related Union programmes"[75] provides guidance for policy-makers and implementing bodies of H2020 and ESI Funds to promote and implement synergies between programmes and funds available. RI are natural candidates for these potential synergies, in particular via the typical use of H2020 and ERDF in sequential projects, from the feasibility studies (H2020/FP), to the construction (ERDF), and use for research activities (H2020 or other projects). Many countries and regions have used this type of synergies, by assessing the contribution of RI to national and/or regional research and innovation strategies for smart specialisation strategies (RIS3)[76]. The EU Reflection Paper on the future of EU finances calls for "*a much more radical approach to simplifying implementation and allowing for more agile and flexible programming*[77]". The post 2020 Framework for Research & Innovation and Cohesion Policy needs to be co-designed from the start. Several stakeholders referred to the need for a coupling between the follow-up of Horizon 2020 and ESI Funds to support infrastructures development and operations.

ELI is one of the emblematic cases of the use of ESI Funds for the construction investment, but there is also a considerable potential to use ESI Funds to support the development of regional nodes of pan-European RI and transnational access schemes, at the national level.

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[75] "Enabling synergies between European Structural and Investment Funds, Horizon 2020 and other research, innovation and competitiveness-related Union programmes - Guidance for policy-makers and implementing bodies" (2014) European Commission, Directorate-General for Regional and Urban policy

[76] More examples at: http://s3platform.jrc.ec.europa.eu/synergies-examples

[77] EU Reflection Paper on the future of EU finances, June 2017, p. 17,

http://ec.europa.eu/budget/mff/hlgor/library/reports-communication/hlgor-report_20170104.pdf

Extreme Light Infrastructure (ELI) – A successful example of synergy between European Research and Regional Development programmes

The Extreme Light Infrastructure (ELI) represents a remarkable example of how the instruments of the EU's regional policy can be used to serve both the objective of economic cohesion and the development of the European Research Area. ELI is pioneering a novel funding model combining the use of EU Framework Programme (FP7 and Horizon 2020) funds for the preparation, European Regional Development Fund for the construction, and member contributions for the operation of the future ELI ERIC. It is also the first ESFRI project to be constructed in Eastern Europe. ELI is a laser facility from the 2010 ESFRI Roadmap that will host some of the most intense lasers world-wide. The facility is a distributed RI currently based on three sites in the Czech Republic, Hungary and Romania, with a construction investment volume exceeding Euro 850 Million, mostly stemming from the European Regional Development Funds (ERDF). ELI has then been awarded two Framework Programme grants, one under FP7 to support its preparatory phase and, more recently, one under H2020 to support its transition, in 2018, under one single legal umbrella of a European Research Infrastructure Consortium ELI-ERIC.

In order to maximise the impact of ESI Funds, the contribution of RIs to industrial development and transformation via a better embeddedness in the innovation eco-systems of the Member States and regions and their research and innovation strategies for smart specialisation should be improved. Similarly, the capacity of RIs in less research intensive regions to connect to international research and innovation networks and attract foreign companies and scientists to use their facilities should be enhanced e.g. via twinning and teaming actions or ERA Chairs.

- **Encourage the use of financial instruments;**

The **InnovFin[78] instruments under Horizon 2020,** the **European Funds for Strategic Investments (EFSI))** and the ESI Funds can provide another potential source of funding for the construction and operation of RI, as already tested at a smaller scale in FP7 with the Risk Sharing Financing Facility (RSFF). However, the capacity of generating revenues by RI is very limited and loans would typically be used for bridging a gap during the construction to cover all construction costs so that the project can move forward or cash flow management.

Providing guarantees for securing loans for the construction or operation of RI

RSFF supported five research infrastructure projects with a total signed loan volume of EUR 628.5 M:

- Alphasat is a joint undertaking of the ESA (European Space Agency) and Inmarsat Plc, a UK-based satellite communications company. Inmarsat obtained a loan of up to EUR 225

[78] InnovFin "EU Finance for Innovators" instrument is a joint initiative of the EIB Group and the European Commission under Horizon 2020. It builds on the Risk-Sharing Finance Facility developed under FP7, which for the period 2007-2013 financed 114 projects of EUR 11.3 billion and provided loan guarantees for another EUR 1.4 billion. More information available at http://www.eib.org/products/blending/innovfin/index.htm

M in 2010 towards the construction and launch of a satellite expected to cost around EUR 598 M.

- Sincrotrone Trieste obtained a loan of up to EUR 20 M in 2010 for the completion and opening of the new FERMI@Elettra light source.
- IBA (Ion Beam Applications) obtained a loan of up to EUR 50 M in 2009 for R&D projects in the fields of cancer diagnosis and therapy.
- ESO-E-ELT, the European Extremely Large Telescope for optical astronomy, is part of the ESFRI Roadmap and obtained a loan of up to EUR 300 M in 2009.
- Oxford Instruments specialises in the design, manufacture and support of hi-tech tools and systems for industry research, and obtained a loan in 2011 of up to EUR 30.83 M.

InnovFin has so far financed five research infrastructures under H2020 with a total loan volume of EUR 527 M:

ESFRI Roadmap:

- CERN – High Luminosity Large Hadron Collider: up to EUR 228.2 M
- European Synchrotron Research Infrastructure: EUR 65 M
- ESS – European Spallation Source: EUR 100 M
- ELI – Extreme Light Infrastructure: EUR 33.8 M

Other Research Infrastructures:

- Cooperation in Science and Technology: EUR 100 M

The **InnovFin Science**[79] is a new instrument which is being defined with the EIB, with the guarantee of the European Commission. This scheme aims to improve access to risk finance for R&I infrastructures (including innovation-enabling infrastructures), universities and research and technology organisations (RTOs).

2.7. Structuring the International outreach of RI

The nature and complexity of the scientific investigations require a global approach for the design and operation of RI addressing them. Global cooperation is also the only option when pooling of resources is necessary to match investment needed for construction and operation of RI.

[79] This instrument finances facilities, resources and services used by the research community to undertake research and foster innovation. Entities with dual teaching and research roles can also benefit. Loans from EUR 25 M to EUR 300 M will delivered directly by EIB.

Global cooperation on RI can also be used as a tool to support or complement the EU external policy and contribute to Science Diplomacy[80] as seen recently with SESAME or in domains such as Arctic research.

The Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME) - Research Infrastructure and Science Diplomacy

A recent example of Science diplomacy is the setting up of the SESAME (the Synchrotron-light for Experimental Science and Applications in the Middle East) international research and technology centre, located in Jordan.

Launched in 2004 under the auspices of UNESCO, its members include Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, Palestine and Turkey. Many other countries such as Brazil, China, Japan, Kuwait, Switzerland the Russian Federation and the US, as well as France, Germany, Greece, Italy, Portugal, Spain, Sweden and the United Kingdom from the EU, are also observers in SESAME.

The project has been designed as a science for peace initiative and has a true scientific value as it is the Middle East's first major international research centre. It fosters scientific and technological excellence in the region, prevents or reverses the brain drain, by enabling world-class scientific research in subjects ranging from biology, archaeology and medical sciences through basic properties of materials science, physics, chemistry, and life sciences. At the same time it builds scientific and cultural bridges between diverse societies, and contributes to international cooperation in science.

SESAME is one of the few projects in the Middle East today where trans-national dialogue is continuing in spite of a very difficult context. SESAME is expected to come into full operation in 2017.

The Commission has supported the construction of the new magnets of SESAME, the training of staff managing and operating the facility and, since 2015, is an observer at the SESAME Council.

The Stakeholders consultation clearly highlighted that the international outreach of RI is currently conducted in a fragmented way. It is in most cases left up to the single RI or projects to develop their international strategy. EU framework conditions on issues such as access, data management, IPR are not systematically taken into account when interacting with third countries.

The strategic relevance of international outreach has recently been fully acknowledged at European level. As a consequence, a step ahead in trying to mitigate the above described shortfall is that international outreach has been recently introduced as one of the assessment criteria of the ESFRI roadmapping process.

In this context, international visibility and optimal communication of the services provided is key in establishing strategic partnerships. As illustrated by CERN, a credible and transparent RI governance and funding model is essential to attract potential new

[80] "New frontiers in science diplomacy"(2010),The Royal Society

members since this allows them to better assess the implications of any possible engagement.

The main elements which derived from the consultation process in terms of governance and funding of RI are:

- Structure the **positioning of EU RI** in the wider international arena;

The discussions that took place in the frame of the consultation process highlighted that global outreach is clearly recognised as a key driver for long-term sustainability. Some of the stakeholders such as the ERF **underlined the importance of a structured international landscaping exercise as the basis for any European approach to RI development**.

Stakeholders also showcased that the establishment of structured dialogues or collaborative mechanisms between European facilities and their potential third country counterparts is not as straightforward as it could appear since many sensitive political factors require to be appropriately tackled as of the early stages of negotiation.

The ERF pointed out that, currently, the EU does not necessarily speak "with one voice". In this respect, some cases presented during the stakeholder workshop in November 2016 highlighted that the **coordination of a European approach in the frame of a wider international setting provides the advantage of increasing the visibility and strengthening the European position** and, at the same time, of better fostering national commitments to the overall initiative.

EURO ARGO – The European contribution to the International ARGO programme

The international ARGO project is the first-ever global, in-situ ocean observing network, providing an essential complement to satellite systems. It is now the major, and only systematic, source of information and data over the ocean's interior. It is an indispensable component of the Global Ocean Observing System required to understand and monitor the role of the ocean in the Earth's climate system.

Started in January 2008, Euro-Argo aims at developing a European "infrastructure" for Argo which would support approximately 25% of the global array.

The Euro-Argo initiative which in 2014 became an ERIC, aims to enhance the collective ability of its European members to contribute to Argo and, by working together, to do so more efficiently. This new infrastructure is beneficial to all partners and enables Europe to build and sustain its "fair" contribution to the global array while providing enhanced coverage in sea areas of particular European interests (e.g. the Nordic Seas, Mediterranean and Black Seas).

The bilateral and bi-regional S&T dialogues managed by the Commission[81] can be a vehicle to disseminate the current investments in RI and to facilitate the development of new partnerships with strategic partners.

[81]The European Union has concluded several Scientific and Technical Cooperation (S&T) agreements with a number of individual countries, from all over the globe. These agreements are based on common interests and priorities, aiming to increase cooperation in research and innovation, additional information available at http://ec.europa.eu/research/iscp/index.cfm

The ESFRI Roadmap process can also serve as a best practice to share with countries and regions interested in establishing a national or regional roadmapping processes.

- Enhance the role of international fora in Research Infrastructure development;

A number of fora have been set up in the international arena to deal with the RI dimension. Amongst these the G7 led Group of Senior Officials (GSO) on global Research Infrastructures and the activities on RI conducted by the Global Science Forum of the OECD. These two groups attempt, in a complementary manner, to derive best practices in policy dimensions such as access, impact assessment, innovation, data management while at the same time setting the conditions for effective collaboration to be initiated amongst the different countries and RI. The consultation process highlighted **the need for Europe and Member States to be strongly engaged in such international fora** while guaranteeing complementarity between the different activities to maximise resource efficiency and to avoid any divergent trends.

3. ELEMENTS FOR THE ACTION PLAN

This section provides a synthesis of the elements, structured by policy dimension, to be considered as a basis for the action plan on long-term sustainability of RI:

1. Ensuring RI at the forefront of scientific excellence

Consolidating ongoing initiatives and practices:

1. Simplify and harmonise access by encouraging European RI to put in place transparent access policies, in line with the definitions, principles and guidelines of the "European Charter for Access to Research Infrastructures";
2. Promote the "excellence driven access mode", as defined by the Charter of the Access, as a requirement for funding the access to RIs;
3. Encourage RI to put in place multidisciplinary support mechanisms, including training modules to broaden the user base;

Tackling new challenges:

4. Whenever possible, guarantee that a share of Excellence driven access is to be granted to the best research projects regardless of their origin and affiliation;
5. Implement effective, robust and systematic evaluation of RI, by developing guidelines for independent international peer-review, such as the establishment of Technical Evaluation and Management Assessment Committees;
6. Assess the quality and impact of the RI and its services, by developing a set of Key Performance Indicators, based on Excellence principles;
7. Require users to systematically acknowledge the contribution of the RI when publishing and disseminating their results, by encouraging the implementation of a tracking system for the RI use.

2. Configuring European RI as skills development and mobility actors

Consolidating ongoing initiatives and practices:

8. Encourage short to medium term mobility between RI through dedicated staff exchange programmes;
9. Facilitate cross-border skills development, by reinforcing the support for trans-national access to RI, at European level;
10. Disseminate the opportunities for access and jobs in an RI through a single and centralised portal, such as EURAXESS;

Tackling new challenges:

11. Develop a standardised European curricula for training of RI managers and operators, building on the RAMIRI and RITRAIN and other initiatives, by structuring a Sectorial Qualifications Framework, namely on leadership, management and data steward qualifications;
12. Encourage national and regional funding programmes to support cross border access to RI;
13. Increase the visibility of RI services and broaden user communities by developing a European catalogue of RI services.
14. Stimulate an internal European RI job market, by promoting initiatives to harmonise career paths, salaries and pension schemes such as RESAVER, as well as exchange and re-integration schemes between RI, academia, business and industry;

3. Unlocking RI Innovation potential and stimulating industry engagement

Consolidating ongoing initiatives and practices:

15. Support the integration of RIs into their regional and thematic innovation ecosystems;
16. Enhance the role of intermediaries by developing specific mechanisms to facilitate knowledge and technology transfer into industrial, public and commercial environments, such as Industrial Liaison platforms shared between several RIs;
17. Increase RI engagement with industry, SMEs and start-ups, by fostering their direct and early-involvement in RI Advisory Boards and through dedicated training and exchange schemes;
18. Include provisions in RI access policies to facilitate the use of RI services by Industry, business and public sector;

Tackling new challenges:

19. Develop instrumentation and technologies in a co-creation process, by stimulating large scale initiatives and pilots involving industry, RI and academia;
20. Develop strategic roadmaps in key technologies required for the construction and upgrades of the pan European RI in synergy other European Research initiatives (such as EIT, KICs and KETs)

4. Boosting RI impact, value and benefits of RI

Consolidating ongoing initiatives and practices:

21. Broaden stakeholders' engagement by developing criteria and narratives to define environmental, social, cultural and political impact and invite RI to communicate

better their added value;

22. Reinforce the integration of RI in the regional scientific, economic and social ecosystem by assessing the contribution of RI to national and/or regional research and innovation strategies for smart specialisation (RIS3);

Tackling new challenges:

23. Support the development and uptake of an internationally accepted model and criteria describing the socio-economic impact of RI for the different types of Infrastructures, based on quantitative and qualitative indicators;

5. Enhancing RI as the pillar for data production and sharing

Consolidating ongoing initiatives and practices:

24. Encourage research data produced by RI to be as open and accessible (including curation and metadata) as possible and compliant with the FAIR data principles;

25. Stimulate RI to establish transparent Data Management Policies in accordance with the "European Charter for Access to Research Infrastructures", clarifying roles and responsibilities of data production and stewardship and increasing standardisation, interoperability of services and research replicability;

Tackling new challenges:

26. Promote the re-use of research data produced by RI for research, innovation and education purposes by supporting the connectivity of RI to the European Open Science Cloud for Research;

27. Encourage RI to promote the use of Data Management Plans addressing the production, dissemination and curation of data (and metadata) in their entire lifecycle, including their long-term preservation;

6. Ensuring effective governance and sustainable life-cycle management

Consolidating ongoing initiatives and practices:

28. Encourage the synchronisation of national RI roadmaps/ budgets and their alignment with the European RI roadmapping process;

29. Stimulate a dedicated budget for European RI investment at national level;

30. Optimise the use of European Structural and Investment Funds throughout the whole RI lifecycle by fostering the development of RI business plans and support RI to meet regional / national RIS3 priority objectives;

31. Optimise the financial planning of RI by facilitating access to EU financial instruments (EFSI, ESIF and InnovFin), namely through the new instrument InnovFin Science targeting RI;

32. Encourage private funding for development of new services and technologies;

Tackling new challenges:

33. Increase transparency in cost calculation and include access to RIs, as an eligible cost in a research grant;
34. Stimulate a stronger early stage involvement of Member States in the development of European RI and develop a stable monitoring system;
35. Provide EU support to newly established ERICs on new services development, interoperability and international outreach; as well as to their operation where there is a clear added-value for EU policy-making;
36. Facilitate the use of the ERIC instrument, by further clarifying the extent to which incentives for investments such as VAT exemption for in-kind contribution can be used by the Member States;
37. Improve bankability of RI by establishing guidelines for the production of RI business plans;
38. Establish guidelines for the termination stage, including provisions for channelling expertise acquired data and research results, know-how from RI users and operators towards other RI;

7. **Promoting European RI in the international arena**

Consolidating ongoing initiatives and practices:

39. Promote visibility of European RI and of their services at international level;
40. Encourage the systematic analysis of the international landscape in the national and EU RI roadmapping process so as to identify potential gaps and complementarities;

Tackling new challenges:

41. Encourage Europe to take leadership in the dialogues on research infrastructures of global relevance with international partners;
42. Promote the use of EU policies, standards and best practices such as access to RI and data management policies for RI as reference in international fora.

4. CONCLUSION

The consultation on the long-term sustainability of Research infrastructures provided a timely opportunity to engage in a transparent and constructive manner with all key stakeholders on the issues that are hampering the optimal management of the European landscape of Research Infrastructures.

The consultation findings, published in June 2016 and the validation workshop of November 2016, where crucial to analyse the main challenges and validate all the conditions hindering RI sustainability. The subsequent cooperation with ESFRI, EIROforum and its members, the ERA stakeholders and the ERICs has led to the identification of key elements to be considered for an action plan addressing the sustainability of Research Infrastructures, as requested by the Competitiveness Council conclusions of May 2016.

The present document proposed a set of policy discussion items that could set the basis for a debate with the Member States and the stakeholders on the measures to be taken at all levels in Europe to address the sustainability of Research Infrastructures in a medium to long-term vision.

The Presidency events, which will be organised in 2018 on Research Infrastructures, will offer the platform for such a debate with the Member States, the funders and managers of Research Infrastructures and their user communities.

The Commission intends to support the implementation of this action plan by facilitating the cooperation and coordination between the Member States and stakeholders and by increasing the complementarity of its' policy instruments, such as the Framework Programme for Research and Innovation and the European Structural and Investment Funds, taking advantage of the opportunities that may arise for Research Infrastructures from the next Multiannual Financial Framework.

ANNEXES

Annex I – Overview on EU policies and programmes on RI

Annex II – Stakeholders Consultation Report

Annex III – Outcomes of Stakeholders Workshop

Annex I – Overview on EU policies and programmes on RI

The European Research Area and the Innovation Union flagship initiative

The Innovation Union Flagship initiative (2010) and ERA Communication (2012) commitments[82] have been fulfilled to a large extent in 2015. The 60% target of implemented ESFRI projects was reached and the cooperation with strategic international partners was strengthened by the adoption in 2013 by the G8 Science Ministers of a Framework for Global Research Infrastructures[83], prepared by the Group of Senior Officials on Global Research Infrastructures (GSO). Similarly, the ERA Communication recommendation led to the publication of the Charter for Access to Research Infrastructures[84] and the definition of Horizon 2020 dedicated actions to support the training of RI managers and the access to pan-European RI.

The 2014 ERA progress report[85] stressed however the need for further synchronisation of national and European roadmaps and the associated pooling of funding. In 2016, the ERA progress report observed significant progress on the linking of national RI decision-making processes to strategic European priorities, but also stressed that there is a need for further coordinated funding for implementation and operation and that a strategy to ensure RI long-term sustainability should be agreed between Member States[86].

The ERIC Regulation

In the context of the accomplishment of the ERA, the ERIC Regulation[87] was adopted by Council in 2009 as a new legal instrument to facilitate the establishment and operation of large European RI among several Member States and associated countries (AC).

The successful uptake of the 2009 ERIC Regulation has been recorded in the first ERIC Report that was submitted to Council Parliament in July 2014 and confirmed by Council Conclusions in December 2014, which welcomed the progress on the implementation of ERICs and invited the Commission to present the next report by 2017. It also invited the Commission and Member States to facilitate the use of the ERIC instrument and to

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[82] Additional information at:http://ec.europa.eu/euraxess/pdf/research_policies/era-communication_en.pdf

[83] Additional information at:
https://ec.europa.eu/research/infrastructures/pdf/gso_framework_for_global_ris.pdf

[84] Additional information at:https://ec.europa.eu/research/infrastructures/index_en.cfm?pg=access_ri

[85] COM(2014) 575 final

[86] ERA Progress report 2016, http://ec.europa.eu/research/era/eraprogress_en.htm

[87] Council Regulation (EC) No 723/2009 on the Community legal framework for a European Research Infrastructure Consortium (ERIC Regulation)

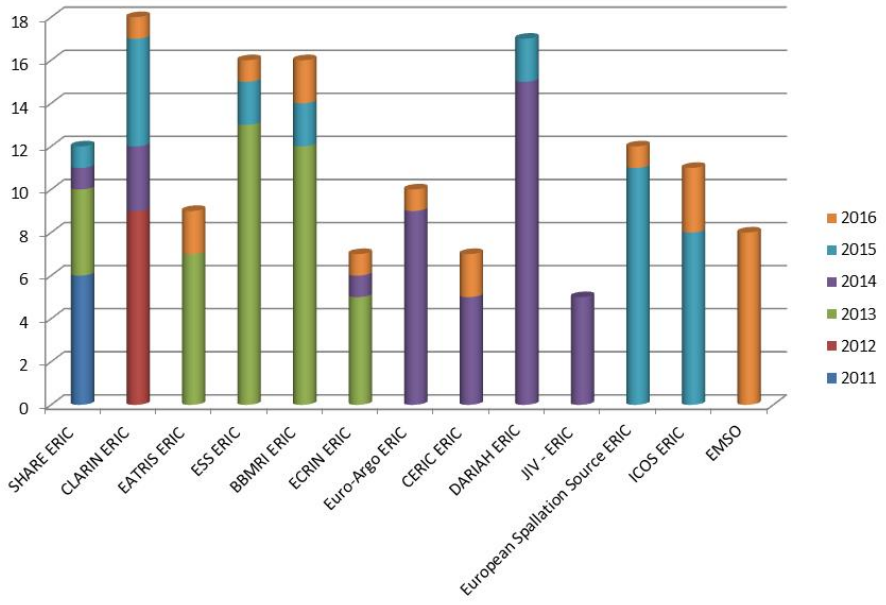
stimulate investments in ERICs and other ESFRI Roadmap Infrastructures, "for example as concerns in-kind contributions".

The second implementation Report addresses Value Added Tax (VAT) exemptions, other incentives for investments in ERICs and the possibility of establishing a European ERIC Registry so that legal certainty can be given both for Member States and third parties. The report reflects on the role of the Commission in the ERICs as possible member or observer, the incorporation of the ERIC in the EU administrative systems as a recognised legal entity and the role of associated countries.

So far 17[88] ERICs have been awarded and it is expected that this number will increase to 20[89] by the end of 2017.

The 17 ERICs combined with ongoing applications will have statutory seats in nine different Member States and one associated country (AT, DE, ES, FI; FR, IT, NL, NO, SE, UK) and will have overall membership of 22 Member States and 3 associated countries. This is illustrative not only of the uptake of the ERIC legal instrument by the Member States and associated countries but also of the usage of instrument by the science communities to further pool resources and activities at pan-European level. Figure 1 provides the status of ERIC implementation of December 2016.

Graph 1- ERICs Membership increase



Source: European Commission, DG RTD, March 2017

[88] The following 15 ESFRI projects are currently established as an ERIC: SHARE, European Social Survey, CLARIN, EATRIS, BBMRI, ECRIN, Euro-Argo, DARIAH, European Spallation Source, ICOS, EMSO, LifeWatch, CESSDA, ECCSEL and INSTRUCT . In addition, two ERICs, CERIC and JIVE are not on the ESFRI Roadmap.

[89] The submissions for EU-OPENSCREEN, EMBRC and INFRAFRONTIER are still expected in 2017.

The ESFRI Roadmaps

ESFRI, a Forum that was set-up following a recommendation of the Competitiveness Council in 2001, supports a coherent and strategy-led approach to policy-making on research infrastructures in Europe, and facilitates multilateral initiatives leading to the better use and development of research infrastructures, at EU and international level.

The first Roadmap was published in 2006 and updated in 2008, 2010 and 2016. The 2016 Roadmap includes 15 RI projects left from the previous editions and added 6 new (Actris, Danubius, Emphasis, EST, KM3Net 2.0, E-RIHS). The focus on these 21 projects results from the successful implementation of the Council recommendation to prioritise **Research Infrastructures** development in the EU[90].One of the main drivers of the new edition of the Roadmap was to prioritize the number of new projects to a manageable size, also in function of the need to guarantee their funding for construction and operation, as to say their long-term sustainability.

The 2016 Roadmap also introduced a new category of RI which are entitled Landmarks. These entail 29 RI, which have reached the implementation phase (comprising construction and operation). These RI will require substantial funding and support in the next years to reach full operational capacity and to ensure their long-term sustainability (estimated investment volume of EUR 12.4 billion with an operational budget of EUR 1.4 billion/ year).

The Framework Programme for Research and Innovation: Horizon 2020

The Commission has continuously supported Member States in their pledge to seek a better alignment of funding commitments for the construction and operation of pan-European RI, mostly through ESFRI.

The Commission has acted, under the successive framework programmes, as a facilitator of user communities' integration, design and clustering of RI, which has set the basis for the development of new European RI, from distributed to single-sited large facilities, with different levels of investment and costs. As a result, pan-European RI are being established in different scientific fields, ranging from bio-banks to cultural heritage, from astronomy, marine biology to physics. There is a combined approach been implemented through the Framework Programme: on one side – top-down - supporting the priorities in function of the shortfalls identified through a landscape analysis and, on the other – bottom-up – allowing for innovative and excellence-based ideas.

[90] These Roadmaps are strategic tools to highlight the main new Pan-European endeavours, which have been put forward by at least 3 Member States or associated countries. The 2016 ESFRI Roadmap introduced a focus on fewer projects, a 10 year rule for the RIs to stay on the Roadmap with a notion of RI lifecycle approach, which will be maintained in the forthcoming updates. Its implementation will rely on the ability of the Member States to secure and align the necessary funding (the estimated budget for the construction of 21 projects in the 2016 Roadmap is EUR 4.100 M and the operation is EUR 275 M/year).

Over the years, the funding for RI support has seen a constant growth, reaching 1.7 billion EUR under FP7 and almost EUR 2.4 billion under Horizon 2020. This support has set the grounds and aligned multilevel efforts to develop a coherent and user-oriented European RI landscape.

Since the launch of Horizon 2020, the Commission also continues to support the early phase development of the new ESFRI projects and help their implementation and operation by developing their international outreach, their innovation potential and their connection to the European Open Science Cloud (EOSC).

The distribution of grants allocated by type of action as well as their expected impact in terms of networking and access is indicated in the following table.

Table 1. H2020 RI Work Programme, Grants managed by DG RTD

Type of action	Number of Grants	EU Contribution	Networked RI	Served users
Design studies for new RIs	8	22.327.476,25		
Preparatory and early phase for new ESFRI RIs	13	34.562.781,25		
Support to individual Implementation of ESFRI RIs	25	137.558.123,81		305
Cluster of ESFRI RIs for interoperability	8	91.911.694,25	24	70
EOSC	1	9.953.067,50		
Integration and opening of national RIs	38	349.178.748,63	753	31.223
Exploiting the Innovation potential of RIs	3	8.927.918,88		
International cooperation for RIs	9	15.454.863,75		
Policy Support Measures	9	12.942.587,25		
	114	**682.817.261,57**	**777**	**31.598**

Source: European Commission, DG RTD, March 2017, Implementation of H2020 RI Work Programmes 2014-2015 and 2016-2017

The activities cover all scientific fields as shown in the following table, nearly half of the allocated budget goes to Life Sciences and Environment.

Table 2. H2020 - Distribution of H2020 RI Grants, per scientific field (management of DG RTD)

Scientific Domain	Number of Grants	EU Contribution
Social sciences and Humanities	13	68.302.468,48
Life sciences	25	163.936.185,81
Environmental Sciences	22	142.463.359,87
Material sciences and Analytical Facilities	12	91.889.049,13
Physical Sciences and Astronomy	21	127.308.787,38
Energy and Engineering	7	46.731.007,65
Information Communication Technologies	4	26.153.874,00
Horizontal policy and inco support measures	10	16.032.529,25
Total RTD grants	**114**	**682.817.261,57**

Source: European Commission, DG RTD, March 2017, Implementation of H2020 RI Work Programmes 2014-2015 and 2016-2017

ESFRI projects participate in the activities of Horizon 2020[91] and the support that they receive through the H2020 grants may cover some of the operational costs that they incur. But these grants are for specific activities and will not allow to fully cover the operational costs of these pan-European RI.

Annex II – Stakeholders Consultation Report

Available at:

https://ec.europa.eu/research/infrastructures/pdf/lts_report_062016_final.pdf#view=fit&pagemode=none

Annex III – Outcomes of Stakeholders Workshop

Available at:

https://ec.europa.eu/research/infrastructures/pdf/lts_research_infrastructures_workshop_report.pdf#view=fit&pagemode=none

[91] As of 20 March 2017, the 14 established ERICs have been involved in nearly 300 proposals and are in the consortium of 91 Horizon 2020 grants with an EU contribution amounting to nearly EUR 50 M.