**OECD Global Science Forum (GSF) Activity**

**“Strengthening the sustainability and effectiveness  
of international research infrastructures”**

**Literature review**

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1. **Introductory notes**

This literature review relies on texts provided mainly by the Secretariat at the OECD Global Science Forum (GSF), complemented with information from staff at the Swiss State Secretariat for Education, Research and Innovation (SERI) and work by the author of this documents, i.e. the assistant to the co-chair of this GSF Activity. All available texts were scanned alongside the terms of reference proposed for this GSF Activity and relevant passages were organised in corresponding chapters below. All referenced literature is compiled in a bibliography, followed by a list of additional questions that emerged as a result of the literature review.

With the exception of two texts (Péro 2011 and 2007), all other references have an online link to documents that are available open access (NB. If clicking on the link produces an error message, copy the link and insert it in the address line of your Internet browser). In addition, the material is also available on the web platform <https://www.innovationpolicyplatform.org/strengthening-sustainability-and-effectiveness-international-research-infrastructures-0/ri-1-0>.

1. **Literature review**
2. **Essential general reading**

European Commission. 2010. [*Cost control and management issues of global research infrastructures: report of the European expert group*](https://ec.europa.eu/research/infrastructures/pdf/cost_control.pdf). Brussels.

Chapters “Political issues” (p. 9-10), “Governance” (p. 11-12), “Project approval” (p. 13-16), “Management” (p. 16-17), “Project controlling and culture” (p. 18-19) and “Costs” (p. 22-23).

[Ramiri handbook](http://www.ramiri-blog.eu). 2013. (online tool, funded under a grant agreement of FP7, the 7th Framework Programme for Research and Technological Development of the European Union).

Chapters 4 “[Finance](http://www.ramiri-blog.eu/index.php?n=Main.Fina)” and 5 “[Human resources](http://www.ramiri-blog.eu/index.php?n=Main.Hure)”

1. **Financial issues**

Chapter 3 “Cost-sharing” (p. 8-15) on the models for operation and construction of the vessel and on regarding contributions foreseen for the consortium members as well as Chapter 5 “Investment vs access” (p. 19-23) on the trade off between member contributions and their access rights to the vessel. (ERICON, 2011)

1. **Best practices and/or novel solutions to help reduce costs for construction and implementation**

“Research funding agencies, institutions, and private and philanthropic organizations have often assumed the initial start up and infrastructure costs and some initial operational costs of individual biobanks. But there has been an underlying belief that biobanks at some point should be capable of becoming ‘‘self-sustaining.’’ This may be achievable in the context of planning a large national infrastructure with a 15- to 20-year life cycle period. But for most existing types of biobanks this has not proved possible (...).” (Watson, 2014, 60-1)

1. **Operating models most appropriate for different types of RIs (single sites, distributed, e-RIs, etc.)**

“While “one-off” project funding can be used to address a specific research question, or to emphasize priority areas for investment in research, it is not an adequate mechanism to support the operation of a large-scale RI and, through this, to build and maintain basic research capability in the long term.” (EIRO, 2015, 4)

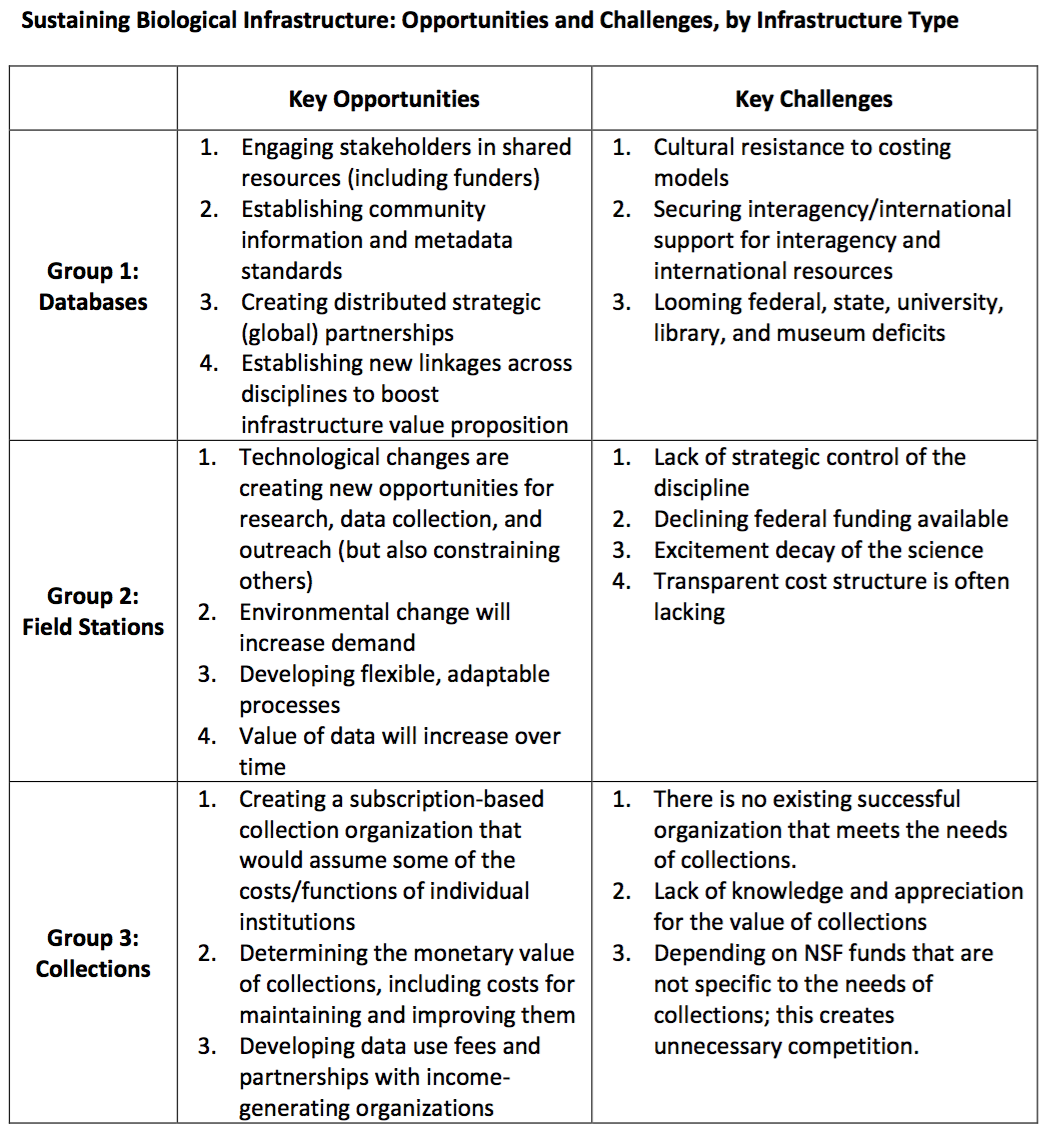
“Considering therefore that all RIs need adequate resources to stay at the front-line – both human and capital resources – these facilities can only be successful if they operate with a favorable long-term perspective, i.e. one that enables long-term financial planning with appropriate guarantees by the funding countries or other shareholders. This implies the existence of regulations ensuring a long-term commitment from the funders. Crucially, the long-term financial planning must cover operations cost, including the necessary maintenance and instrumentation upgrade costs. The long-term nature of basic research calls for long-term security for the supporting RIs. A common characteristic of the EIROs is that they are able to link long-term funding with clearly defined scientific objectives/programmes. In addition to the strong scientific case, transparent evaluation and reporting arrangements facilitate funding decisions.” (EIROforum, 2015, 5)

“In the ensuing discussions, one of the most common challenges that participants identified was the user community’s aversion to fee structures. When exploring funding models that do not rely entirely on   grant funding, many organizations have at least investigated some type of user fee. Depending on the resource and the user community, these discussions can result in serious backlash. In communities where free access to infrastructure is typical, significant cultural change may be necessary for a user- pays model to be successful. Participants identified several broad factors that would be important to this cultural change:

1. Each project needs to analyze its own user community to determine how to implement user fees effectively. Important questions to answer include:
   * 1. What do the users value the most?
     2. What are they willing to pay for, and how much? For example, most users are currently  more receptive to charges for software and services than they are to data access fees.
     3. What level of cost would be prohibitive?
     4. How can we make services personally useful, important, and enjoyable, so that users  are willing to donate to keep the system going?
2. There is a need to involve agencies and the international community. If there are other related  projects out there providing free access, competition will render any user fee model ineffective.
3. It is important to get advice from independent, external experts who are not wrapped up in the  day-to-day use of the resource.

One participant described how they successfully implemented a user fee for their project:

*Because our Governing Board was initially comprised entirely of scientists, they had the same strong resistance to implementing user fees to build a sustainable funding model. There was a conflict of interest, so we brought in members from the non-profit world to help rethink our funding model; some distance between the users and decisions about usage fees was needed. Our rate structure started out very low – the only way we were able to figure out what people were willing to pay was to charge a fee and monitor its impact on use. As it turned out, our rate structure was low. We have been able to increase our fees without seeing a drop in use, while simultaneously increasing the value and demand of our services.*” (ESA, 2010, 3-4)



(ESA 2010, p.5)

“At the top-most level, the concept of sustainability is relatively easy to define: eventually, e-Infrastructure provision and usage will need to become independent of *specific* funding streams such as the UK e-Science Programme. If e-Science produces enough additional value for a large enough number of people then it should be possible to establish business models that guarantee the provision of the necessary funding to sustain an e-Infrastructure.” (Voss, et al. 2007, 1)

“Different biobanking network models have evolved and can be viewed as fostering sustainability primarily in one or more of the three dimensions. For example, in the operational dimension by focusing on components such as consent, biospecimen accrual, and/or shared storage; in the financial dimension by focusing on components such as performance metrics, user access, and customers’ needs; in the social dimension by focusing on components that promote common standards. A well established and successful example of a network in the United States that addresses the operational dimension is the Cooperative Human Tissue Network (CHTN). Adaptations of this model have involved creating a common efficient accrual system for biobanks. An example of fostering sustainability in the social dimension is the Canadian Tumour Repository Net- work (CTRNet) whose funding from the Institute of Cancer Research Canadian Institutes of Health Research (ICR-CIHR) is restricted to network activities (as opposed to biobanking) such as creating certification programs, standard operating procedures and policies. The Public Population Project in Genomics and Society (P3G) and the Biobank Resource Centre (BRC) are examples of re- sources that have harnessed collective knowledge across different networks to further develop and disseminate tools to implement sustainability strategies. The P3G is a not-for-profit consortium that works to encourage collaboration between researchers and biobankers, promotes harmonization of data, optimizes the design, setup and research activities of studies, biobanks, research databases and other similar health and social research infrastructure and facilitates the transfer of knowledge and provides training. The BRC was developed in partnership by the University Of British Columbia Office of Biobank Education and Research (OBER) and CTRNet to provide services and tools that support researchers in establishing and operating biobanks, to educate and promote certification of biobanks in order to enhance quality through adoption of best practice standards, and to publish biobank market research data. This kind of data is essential to successfully execute a biobanking business plan to facilitate shifting to customer focused biobanking. The BRC is an example of a resource that offers strategies and solutions in all sustainability dimensions.” (Watson, 2014, 63-4)

“Many BRCs currently charge fees to those who want to obtain biological materials and gain access to associated databases. Varying fee structures can be applied for access depending on the nature of the biological material, the status and constraints of the institution holding the resources and its relationship with the public and private sectors, national policies and relevant international frameworks.

There are two major models that have been examined and are currently in use by different BRCs:

*Cost recovery*

Cost-recovery is defined as recovering the full or partial cost of a project or service, including both its fixed and marginal costs. Typically, it is discussed in the context of cost recovery from users of the services provided, although direct grant funding can be considered as a particular form of cost recovery and is discussed below. (...)

*Institutional funding*

A common model for the financial sustainability of a resource is through allocated funds obtained from a single public institution towards the respective BRC. This approach is most commonly applied to data resources. An example of this model are the databases operated by the National Center for Biotechnology Information (NCBI; http://www.ncbi.nlm.nih.gov/) which receives funds from both the National Library of Medicine (NLM; http://www.nlm.nih.gov/) and the NIH (http://www.nih.gov/).” (Chandras, 2009, 4-5)

“With regard to the business models examined in this manuscript as potential patterns to be adopted by BRCs for their financial sustainability, the ‘full cost recovery’ model which has already been tested by some resources has proved to not be viable for data resources. The ‘fee- for-service’ or ‘partial cost-recovery’ model is already practiced, at least in part, by some BRCs. For data provided this is contrary to the UPSIDE recommendations, according to which data should be shared, but in practice most BRCs employing this approach are providing material resources, which have substantially higher costs and it is open to debate if these can reasonably be provided completely free of charge. The most promising model examined in this manuscript is ‘Institutional Funding’ which seems to provide a secure environment for the BRCs to develop and implement a secure data management plan and potentially ensure the long-term accessibility of the related project data. Indeed agencies around the world such as the NIH and the EU through ELIXIR (http:// www.elixir-europe.org), are now turning their attention to working out how best to assist the growth of validated and accessible databases.” (Chandras, 2009, 8)

1. **Effective models for securing operational costs**

* “Spreading costs across institutions or a member network. This can reduce overall expenses, particularly if all members are invested and truly value the common infrastructure.
* Positioning data as something new and/or creating software or services. Users are more receptive to fees that are built into a product or service. This increases value as well, so users are willing to pay more.
* Including infrastructure costs explicitly in all grants and contracts to the program. (…)
* Building relationships with partner institutions and state governments to ensure the  infrastructure is relevant. Partners can help take up slack if needed, particularly if the project is important to their own work, and reaching out to state institutions can help justify the project’s importance and need for state funding.
* Beginning initial efforts at creating endowments. This can be challenging in the current economic climate and is a long-term effort, but one with significant potential for long-term, stable funding.
* Charging more for commercial clients, so academic users can pay less.
* Creating economies of scale. Sometimes increasing products and lowering prices can be  financially advantageous. Associating infrastructure with an existing institution or university can  help reduce some overhead costs.
* Charging membership fees.” (ESA, 2010, 2-3)

“**Uncertainty about funding**: uncertainty about funding caused by short-term funding models and lack of diversity of funding sources, leading to an exposure of multiple efforts to the same risks. **Response**: negotiations with funding organisations to provide longer-term funding opportunities, subject to regular review. Transition of software/services to a commercial environment, which develops, maintains, and sells the services/software.” (Voss, et al. 2007, 4)

“ESDS [Economic and Social Data Service] is the UK’s national data service, funded jointly by ESRC [Economic and Social Research Council] and JISC[[1]](#footnote-1), which provides access and support for an extensive range of key economic and social data, both quantitative and qualitative, spanning many disciplines and themes, and available to researchers free at the point of use. It must be questioned whether the e-Infrastructure project would be sustainable under this model. First, as noted above, there are unmistakable signs that, in the future, UK funding bodies will expect institutions hosting research projects to absorb some of the costs of maintaining the research resources these projects create. This may, in turn, encourage host institutions to introduce charges for services provided, such as the micro-payments model adopted by many journal publishers.” (Voss, et al. 2007, 6-7)

“The preservation of high-quality biospecimens and associated data for research purposes is being performed in variety of academic, government, and industrial settings. Often these are multimillion dollar operations, yet despite these sizable investments, the economics of biobanking initiatives is not well understood. Fundamental business principles must be applied to the development and operation of such resources to ensure their long-term sustainability and maximize their impact. The true costs of developing and maintaining operations, which may have a variety of funding sources, must be better understood. Among the issues that must be considered when building a biobank economic model are: understanding the market need for the particular type of biobank under consideration and understanding and efficiently managing the biobank’s “value chain,” which includes costs for case collection, tissue processing, storage management, sample distribution, and infrastructure and administration. By using these value chain factors, a Total Life Cycle Cost of Ownership (TLCO) model may be developed to estimate all costs arising from owning, operating, and maintaining a large centralized biobank. The TLCO approach allows for a better delineation of a biobank’s variable and fixed costs, data that will be needed to implement any cost recovery program. This article represents an overview of the efforts made recently by the National Cancer Institute’s Office of Biorepositories and Biospecimen Research as part of its effort to develop an appropriate cost model and cost recovery program for the cancer HUman Biobank (caHUB) initiative. All of these economic factors are discussed in terms of maximizing caHUB’s potential for long-term sustainability but have broad applicability to the wide range of biobanking initiatives that currently exist.” (Vaught, et al., 2011, 24)

“The current access policies and funding schemes of computing e-infrastructures represent a huge challenge for the sustainable growth of computing e-infrastructures and a serious jeopardy for investments made into these e-infrastructures. In order to be able to address these issues, the economics of computing e-infrastructures has to be understood thoroughly. As a first step in this direction, this paper conducts a set of computing e-infrastructure case studies and discusses the economic issues of different global computing e-infrastructure efforts. The analyses results show that the major shortcomings that need to be resolved are the insufficient involvement of the private sector in the development of computing e- infrastructures, the restricted user access to e-infrastructure resources, and the lack of sustainable funding. As a solution to these shortcomings, we propose a new funding and governing model for computing e-infrastructures. It follows a token-based market mechanism that allows a business-oriented operation of the computing e-infrastructure. We argue that this new model fosters the transition towards a sustainable computing e- infrastructure, being another requirement for successfully implementing the cloud computing vision. Our arguments are supported by an analytical analysis.” (Bany Mohammed & Altmann, 2010, 739)

“Funded by the European Commission under FP7 the OSIRIS project started on January 2010. The OSIRIS consortium is composed of participants involving several institutes, Public Authorities and National Champions across 13 EU Members States and Associated Countries and regions with direct links to existing and future ICT European research infrastructures (RIs), i.e., High Performance Computing, Grids, Networks, Micro/Nanoelectronics and Future Internet. The main aim of the OSIRIS project is to build the platform, mechanism and models required to secure the efficient involvement of Member States, Associated Countries and regions in developing cross border public-public partnerships and to establish a coordinated approach to future large scale investments in international European ICT RIs. For this reason, a thorough analysis of the business models of current international ICT RIs is required. This analysis will be presented in this report. (…) The aim of this report is to provide a source of information on the possible business models of how ICT RIs can be managed and supported once a need for them has been identified and the RI has been founded.

Once the RI has been founded, there are four important aspects that describe the RI business model:

* + Governance;
  + Sustainability;
  + Access Policies;
  + Operational principles.

These aspects are described in detail in this document. Governance describes the control of the RI, in other words who determines the direction the RI will take in the future. Sustainability describes the future of the RI and how it will continue to operate. Whereas the arguments prior to the founding define whether an RI will be created, sustainability defines whether the RI will continue to exist. Access policies describe the interactions of the international ICT with one of its most important stakeholders: namely its users. Operational principles describe how the sustainability, the governance, and the access policies are implemented at an operational level.” (OSIRIS, 2012, 3)

“Some key insights and general recommendations for financing a biobank RI include;

1) The population of biobanks in the UK is extremely diverse, reflecting differences in purpose, location and ownership; size, scale and scope; as well as financing and access arrangements. The cases presented in this report illustrate that it is not possible (or desirable) to apply a standard cost model across such a diverse population.

2) Coordination across this diverse population requires dedicated resources. This could take a variety of forms. A coordination centre may be required and this should be financed centrally by public funds, possibly supplemented by industrial funding. Such a scheme requires careful consideration to allow fair access by all users. Central funding is necessary to support the development and maintenance of a national searchable portal for HBS [human biological samples] and drive quality standards across the biobank population.

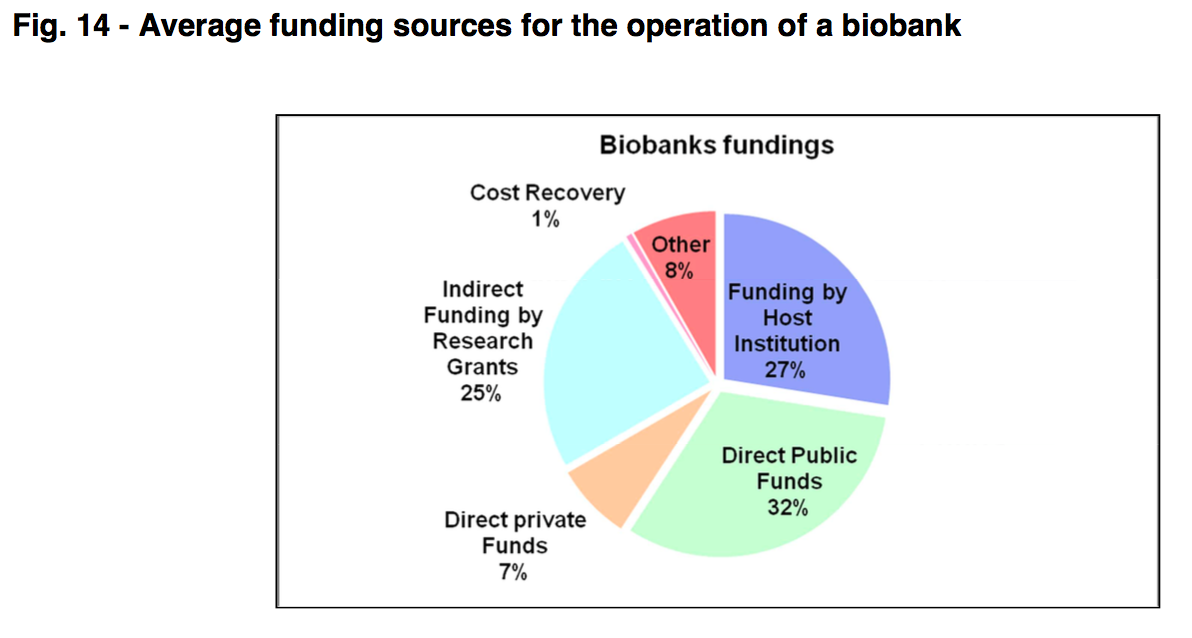
3) The majority of the existing financial arrangements do not support the long-term maintenance and provision of high quality HBS. This report recommends that; a) HBS acquisition should continue to be costed into projects and project proposals to ensure biobanking is driven by research needs; b) core biobanking activities and facilities should be supported by central public funds to overcome discontinuity of funding problems and enable investment in best practice. These core costs could be distributed directly to the host public institutions; and c) the marginal costs associated with accessing samples could be paid for by the user.

These financial arrangements, incorporating the adoption of standards and the enrichment of the annotated data associated with HBS by users, will support the creation of a sustainable distributed biobanking RI necessary for the delivery of stratified medicines, and the realisation of the associated societal and economic benefits. The opportunity costs to the UK of not investing in a comprehensive biobanking RI could be significant.” (Lee, 2013, 6)

“The Research Infrastructure Resource Model (RIR model) presented in this document, provides a method to declare costs for use of research infrastructure based on the full costs generated by the activity. The model has been developed to ensure that state of the art laboratories and scientific equipment can be made available for research and education, and so that the price for use of a RIR can be calculated using a transparent and relatively simple method. Furthermore; the model should contribute to maximisation of the primary operation of the laboratories while keeping the transaction costs as low as possible. The motivation for introducing RIRs is found in changes in the funding schemes and the focus on direct costs. The RIR model presented here has been developed in accordance with the guidelines from The Research Council of Norway. (...) The costs related to a Research Infrastructure Resource consist of four elements:

1. Space – rental and building related costs for research space such as laboratories and workshops
2. Scientific equipment – depreciation costs
3. Common operating consumables and service-/maintenance contracts, i.e. shared costs for all  users
4. Technical support – personnel costs for the technical support staff needed to sustain the operational infrastructure.” (Norwegian Association of Higher Education Institutions, 2014, 2014, 1)

“The soundest and most precise way of considering these costs would in our view be to allow full cost accounting as an option for research organisations operating RI. This would ensure that, where high indirect cost are generated by large RI and are precisely recorded in a sound accounting system, this precision does not get lost in approximations just for EU projects. Should this not be possible, a use of lump sums per unit of access (hours of beam time or days of ship use) might be the best solution, since this would at least assure that the sum would be fixed before the project starts and no ex-post audits would be necessary. This would be in line with the simplification purposes of H2020. In order for such a system to be in line with the usual accounting principles, it would however have to respect the underlying cost calculation of the participants for setting the lump sum, which would certainly challenge the concept of lump sums. In any case, a very precise and participant-specific mechanism for setting the amount of the lump sum would be needed, possibly based on the mechanisms used in FP7 for calculation unit cost for Transnational access. This again would certainly challenge the current concept of lump sums, but it might still be the best of the available options.” (Helmholtz Association of German Research Centres, 2013, 2)



BBMRI, 2012, 48

“The total costs of BBMRI-ERIC will be financed by cash and in kind contributions of Members and other income. Contributions of Members will be calculated according to the following model:

1) The membership contribution of each Member shall be composed of a base contribution and a variable share. Concerning the base contribution Members are stratified in two groups according to their number of inhabitants:

1) 20.000 € base contribution for Members whose number of inhabitants is below 3 Million

2) 25.000 € base contribution for Members whose number of inhabitants equals or exceeds 3 Million The overall amount of the variable share proportion is determined by subtracting the overall amount of base contributions from the overall amount of contributions by Members. The overall amount of the variable share is split among Members based on their percentage of total GDP of all Members.

International organizations shall pay 0.1 per mill of their annual regular budget as variable share proportion if they are Members. The fixed contribution for Observers shall be 30% of the respective category. None of the Members shall pay more than 25% of the overall amount of contributions by Members/Observers. (…) The Members of BBMRI-ERIC will set up their National Nodes under BBMRI-ERIC early in the first quarter of 2013 so that efficient interfaces between national biobanks and the Central Executive Management Office and the BBMRI Common Services can be implemented. The National Nodes are funded directly by each Member Country and are not part of the common BBMRI-ERIC budget. The size of the National Nodes and their budgets will depend on the complexity of the biobanking structures in the individual countries. There are minimal requirements defined for the set-up of a National Node to participate in BBMRI-ERIC. At least one person (National Node Director) reporting to the Director General has to be designated for each National Node. For financial planning National Nodes of an average size are assumed.” (BBMRI, 2012, 52-3)

1. **Costs for agreed upon upgrades**
2. **Funding policies of contributing partners for good medium to long-term planning**

“**Continuity of Funding**

* Research infrastructure funding programs should be ongoing and predictable, to achieve optimal use of funds.
* Infrastructure that continues to be a priority should be able to access funding for ongoing operations.

*Guiding considerations*

* *Ongoing and predictable funding programs support a more strategic, collaborative and planned approach to research infrastructure investment.*
* *Ongoing operational funding for priority national and landmark research infrastructure assists in maximising the benefit from the original investment.*

**Holistic Funding**

* Funding required to support research infrastructure will vary between elements, including capital costs, governance, skilled technical support staff and operations and maintenance. Support should be available to cover these key elements.
* Funding programs should allow some funding for project development costs, either for a facilitation‐based process or for project development and scoping activities.
* In the context where not all national and landmark infrastructure would necessarily be replaced, depreciation for these facilities should not be funded by Australian Government funding programs. (…)

**Co‐investment**

* Co‐investment in research infrastructure is desirable as it demonstrates a commitment by the investing party/ies to the project. Any program requirements for co‐investment should be flexible to leverage maximum support.” (NRIC, 2013, 2-3)

1. **Contributions and tangible/intangible assets, taking amortisation/depreciation into account**

* “Organizations employ diverse methods for cost management and revenue generation, depending on their size and type. Almost all projects rely primarily on grants and contracts for  funding, but almost all are also trying to diversify their revenue streams.
* One core challenge for everyone was that many funders don’t see infrastructure sustainability as a priority; they tend to prefer funding new initiatives, rather than maintaining something that  already exists.
* Everyone agreed that simple maintenance versus being able to adapt, add value, and grow are  two very different trajectories with significant implications for managing costs and developing budgets.” (ESA, 2010, 3)

“Using this definition of sustainability, the following models are commonly used for the assembly and application of resources to *create* and then *sustain* an infrastructure element:

* + Open source: a leader (or a set of leaders) promotes a goal of creating an infrastructure element in a public manner and a community voluntarily forms to work together on this goal.
  + Closed partnership: a set of partners works together to create an infrastructure element, but the partner- ship is not open to external contributions.
  + For profit: a group creates an infrastructure element using its own resources with the goal of later selling, leasing, or licensing the element or its design to recover the expended resource and make a profit.
  + Dual licensing: a group creates an infrastructure element using its own resources with the goal of allowing academic free use (and depending on the license, perhaps gaining further free contributions from that academic community), while also selling, leasing, or licensing the element or its design to industry in order to recover the expended resource and perhaps make a profit, or at least, break even. This model also often has an implicit goal of not allowing other companies to financially profit directly from the element.
  + Open source and paid support: a group supports an open source element in exchange for resources from the users of that support. The support can include helping the users with the existing element, and adding features to the element for the supported users, though these added features become available to all users, not just those who have paid for support.
  + Foundation or government: one or more groups convince an organization that promotes public advancement that creating an infrastructure element will be a public good that should be supported.  (Katz and Proctor, 2014, 3”

“Large sensor-based infrastructures for radio astronomy will be among the most intensive data-driven projects in the world, facing very high power demands. The geographically wide distribution of these infrastructures and their associated processing High Performance Computing (HPC) facilities require Green Information and Communications Technologies (ICT): a combination is needed of low power computing, power and byte efficient data storage, local data services, Smart Grid power management, and inclusion of Renewable Energies. Here we outline the major characteristics and innovation approaches to address power efficiency and long-term power sustainability for radio astronomy projects, focusing on Green ICT for science.” (Barbosa, 2014, 1)

1. **Risk management strategies that can help mitigate unforeseen cost escalation**

“We believe elements of e-Research infrastructure can be placed in a three-dimensional space, as shown in Figure 1, and that doing this will lead to increased understanding of issues related to creating and sustaining these elements. The first axis is the temporal duration of the element. This ranges from 5 years for computer systems, to about 10 years for networks and instruments, 20 years for production software, 40 years for people, and infinity for data, including publications, which can be viewed as a subset of data. Note that these values are approximate and can be debated; they do not completely define the duration of the elements. They are points of reference, and any given infrastructure element might have a shorter or longer duration than the point of reference given above. (In particular, the idea of a temporal duration for an instrument is unclear, but one can certainly consider an instrument as having a lifetime during which it is useful to a research community as shared infrastructure.) However, the key point is that decisions that are made about creating and sustaining infrastructure elements need to include awareness of the expected lifetime of the element. The second axis is the spatial extent of the element. In an academic setting, this might range from a particular laboratory to a department, college or school, university, university system or regional alliance, nation, and beyond. This could also be thought of for general research institutions, which might have alternative administrative units in place of departments, colleges or schools, such as divisions or directorates. The third axis is the purpose of the infrastructure element. This ranges from the element being used for one particular problem—though in this case it’s unlikely to be infrastructure—to it being used for a variety of problems in one discipline (e.g., climate data from Arctic ice cores), to it being used for a variety of problems across a set of disciplines (e.g., molecular dynamics software), to it being used generally across all disciplines (e.g., a network, an HPC system). There are linkages between the temporal duration of an element and its purpose, e.g., although the lifetime of a given software element may be 20 years when just considering its technical context, if the element ceases to be useful to its user community then the life- time will be shortened.” (Katz D and Proctor, 2014, 2)

“In the financial dimension of sustainability we have de- fined three key areas: market strategy, customer focus and brand recognition. While there are many important activities within each of these three areas, the fundamental element should be the development and maintenance of a strategic plan.” (Watson, 2014, 64)

“One of the conditions for the real word’s sustainable development is the occurrence of a social change (also referred to as social development). By the same analogy stated above, this means that an e-Infrastructure can be sustainable only if a change occurs in the way we consider and support Virtual Organisations of users. Any model of long-term sustainable e- Infrastructures should then put the user at the centre and be scalable and dependable.” (Barbera, 2009, 4)

1. **Plan and management costs for termination phase**
2. **Human resources**
3. **Policies/practices to attract and retain scientific, technical and administrative staff**

“Critical mass of scientific talent is based on outstanding scientific opportunity but can be built up through mechanisms such as attractive employment conditions, transparent recruitment practices, openness to diversity, and adaptable PhD and post-doctoral curricula. Additionally, RIs can finance or co- finance studentships and doctoral and postdoctoral fellows. In order to preserve links to national educational systems, doctoral and post-doctoral programmes can be designed together with universities, thus enabling young researchers to acquire hands-on experience at the RI while maintaining links to their home universities. Developing and managing new instrumentation also generates the need to train technologically skilled personnel and ensure their mobility. It should be noted that at the moment RIs in Europe are very successful in attracting the best scientific talents but face difficulties in attracting experts in instrumentation and engineers. RIs can build up their pool of scientific talent by enabling inter-institutional and trans-national mobility at all career levels but with particular focus on young researchers. This can be achieved through short- term visiting exchanges (from lab to lab), organization of scientific events or dedicated workshops, as well as targeted training opportunities. RIs can consider innovative mechanisms, such as engaging in partnerships with industry, in order to facilitate participation of talented researchers and engineers from less developed regions in their training events. For all EIROforum organizations, training the next generation of researchers and engineers is part of their core mission. EIROs have in place training programmes for doctoral and postdoctoral fellows as well as other young researchers and scientific and technical staff, which encourage mobility and exchange of knowledge.” (EIROforum, 2015, 5)

“**Lack of professional support**: there is a lack of professional support offered for many technologies involved and support available is often ill-matched to users’ needs, e.g., in terms of the level of skills assumed. **Response**: provision of support through national centres of excellence for particular research areas and in combination with local provision at research institutions.

**Lack of availability of technical skills**: relevant skills required to develop and operate e-Infrastructures and research applications are not widely available. **Response**: development of specific training programmes such as the Master in e-Science offered by the University of Edinburgh.” (Voss, et al. 2007, 4)

“Furthermore, there is a need to provide a sustained supply of IT professionals with the required technical skills to operate, maintain and further develop advanced e-Infrastructures. Programmes like the MSc course at the University of Edinburgh are an important step in this direction. While it is true that technologies are changing rapidly and that, therefore, ongoing training is required, it is crucial for IT professionals to have a solid understanding of the core principles of distributed computing and those are difficult to learn in relatively short training courses.” (Voss, et al. 2007, 8)

“The workshop discussions highlighted cross-cutting challenges of i) new and changed skills needs which combine technical and scientific skills and require interdisciplinary thinking and communication; ii) recognizing new job profiles and tasks rising from the emergence of computing intensive and data-driven science with integral role of e-infrastructures; iii) need for effective European level collaboration and coordination to avoid duplication of efforts and join the forces for developing high quality human capital for e-infrastructures. Furthermore, there are specific challenges relating to the skills and human resources for i) e-infrastructures development, ii) digital research service provision, iii) scientific usage of e-infrastructures, and iv) the institutional strategies for effectively tackling the human resources challenges. During the consultation, several suggestions for promoting skills and human resources for e-infrastructures were raised. It is necessary to better map the current situation and future needs, and support recognizing and establishing new job profiles and career paths. Specific investment should be addressed to innovating new education and training approaches: creating new specific curricula for e-infrastructures personnel; integrating technical and scientific aspects into cross-disciplinary curricula; encouraging collaborative mindset and computational thinking into education already from early age; on-the-job learning through knowledge transfer from and between experts in terms of short-term courses and staff exchanges. These should be supplemented by encouraging ‘communities of practice’ between e-infrastructures actors, including developers, operators and scientific users.” (European Commission, 2012, 4)

“The purpose of this document is to make concrete suggestions and identify a **pragmatic solution** that would increase employability and facilitate staff mobility within European RIs. Such a solution could be the introduction of **an attractive scheme for the temporary secondment of expert staff** from a **sending RI** to a **receiving RI**.”

“**It is proposed to establish a Europe-wide secondment-based scheme for staff mobility within an integrated structure of European RIs covering one, or several, research communities.** This would provide a solid framework within which staff mobility could occur, individual experts could follow a career path across a wide range of RIs and career development within a group of RIs, rather than within a single RI, could be envisaged.”

“**A financial scheme should be established to support this secondment-based mobility.** It is proposed to include a specific set of accompanying measures:

* A set of **financial measures** that include a living allowance and the reimbursement of removal expenses; exceptional solutions may be considered to cover education expenses or the loss of a partner’s job; existing European-level financial rules should be examined for applicability;
* An additional funding mechanism should be established to provide the **budget needed to cover the supplementary costs associated with these measures.**”

(EIROforum/ERF, 2011, 2, 4, 5)

1. **Other**
2. **Unforeseen challenges during the construction phase (e.g. developments in science and technology)**

“**Uncertainty about Development**: there is significant uncertainty regarding the direction of technological development and standardisation in e-Infrastructure technologies (e.g., the recent shift from OGSI [Open Grid Services Infrastructure] to WSRF [Web Services Resource Framework], cf. Czajkowski *et al*. 2004). **Response**: provision of forecasting reports and roadmaps for technical development by experts in the field and increased outreach activities by institutions such as the Open Grid Forum.” (Voss, et al. 2007, 4)

1. **Legal framework**

“The continuity and steady progress of intergovernmental RIs is guaranteed through their founding treaties, which offer a regulatory framework that is both flexible and reliable. All EIROforum organizations [CERN, EMBL, ESA, ESO, ESRF, EUROfusion, European XFEL, ILL] are based on arrangements amongst member states, such as intergovernmental conventions or treaties, although they have opted for different legal models as regards their implementation. These vary from an international organization, a non-profit company model established under national law or a joint undertaking and a multi-party agreement. These legal models ensure that the administrative workload within a particular RI is minimized.” (EIROforum, 2015, 3)

“For pan-European RIs, the host country - or in distributed RIs the host countries - play a vital role in ensuring the smooth establishment and functioning of the RI. The relationship between the RI and the host country(ies) is often regulated in a separate legal document.” (EIROforum, 2015, 4)

“The European Research Infrastructure Consortium (ERIC) legal entity has been identified as the most appropriate legal entity to support the distributed operation of the BBMRI. BBMRI-ERIC is established for an unlimited period under the Council Regulation (EC) No 723/2009 of 25 June 2009 on the Community legal framework for an ERIC. The ERIC is set up to sustainably establish and operate, on a non-economic basis, the distributed pan-European Research infrastructure “Biobanking and Biomolecular Research Infrastructure, European Research Infrastructure Consortium” (BBMRI-ERIC).” (BBMRI, 2012, 37)

1. **Bibliography**
2. **Literature cited**

* Bany Mohammed AA, Altmann J. 2010. [*A funding and governing model for achieving sustainable growth of computing e-infrastructures*](https://ideas.repec.org/p/snv/dp2009/201062.html). Seoul National University, Technology Management, Economics and Policy Program. (Discussion Paper, 62) & *Annals of Telecommunications*, 65(11): 739-56.
* Barbera R, et al. 2009. [Approach to sustainable e-infrastructures: the case of the Latin American grid](http://www.ist-africa.org/conference2009/default.asp?page=secure-doc&docid=3370&paperid=859&paper.refno=45&paper.siteid=5&versionid=1924&number=), IST-Africa Conference, Kampala, Uganda, May.
* Barbosa D, et al. 2014. [A sustainable approach to large ICT science based infrastructures: the case for radio astronomy](http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=6850498&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxpls%2Fabs_all.jsp%3Farnumber%3D6850498), IEEE International Energy Conference, Dubrovnik, Croatia, May.
* BBMRI, European Biobanking and Biomolecular Resources Research Infrastructure. 2012. [*Biobanking and biomolecular resources research infrastructure BBMRI: business plan*](http://bbmri-eric.eu/documents/10181/49443/BBMRI+Business+Plan.pdf/25e8e6e0-c97f-40b2-91fb-ba1b4bf3184b). Graz, Austria.
* Chandras C, et al. 2009. [Models for financial sustainability of biological databases and resources](http://database.oxfordjournals.org/content/2009/bap017.full.pdf+html), *Database: the Journal of Biological Databases and Curation*.
* e-IRG, Infrastructures Reflection Group. 2015. [Best practices for the use of e-Infrastructures by large-scale research infrastructures](http://e-irg.eu/documents/10920/277005/Best+Practices+for+the+use+of+e-Infrastructures+by+large-scale+research+infrastructures.pdf). The Hague, Netherlands. (Guidelines Document)
* EIROforum, European Intergovernmental Research Organisations / ERF, European Association of National Research Facilities ERF. 2011. [*Research Infrastructures Staff Exchange (RISE): a new scheme for staff mobility within European research infrastructures*](http://www.eiroforum.org/downloads/201111_mobility_proposal.pdf).
* EIROforum, European Intergovernmental Research Organisations. 2015. [*Long-term sustainability of research infrastructures*](http://eiroforum.org/downloads/20150325_discussion-paper-research-infrastructures-sustainability.pdf). (Discussion Paper)
* ERICON, European Polar Research Icebreaker Consortium. 2011. [*Business planning perspective and financial models of participation for the research icebreaker AURORA BOREALIS*](http://www.europeanpolarboard.org/uploads/tx_ameospublication/ericon_del_4-2_01.pdf). European Science Foundation ESF: Strasbourg.
* ESA, Ecological Society of America. 2010. [*Strategies for sustainability of biological infrastructure*](http://www.esa.org/esa/wp-content/uploads/2014/02/Strategies-Sustainability-Biological-Infrastructure-Workshop-Report.pdf). (Workshop Report)
* European Commission. 2010. [*Cost control and management issues of global research infrastructures: report of the European expert group*](https://ec.europa.eu/research/infrastructures/pdf/cost_control.pdf). Brussels.
* European Commission, DG Information Society and Media, Unit F3 „Géant & e-Infrastructures. 2012. [*Skills and human resources for e-infrastructures within Horizon 2020*](http://cordis.europa.eu/fp7/ict/e-infrastructure/docs/report_human_skills.pdf). (Report on Consultation Workshop)
* Helmholtz Association of German Research Centres. 2013. [*The cost of large RIs: comments*](https://www.helmholtz.de/fileadmin/user_upload/03_ueber_uns/organisation/Internationale_Bueros/Bruessel/stellungnahmen/2013_Helmholtz_Statement_on_Indicrect_Cost_RI.pdf). Brussels.
* Katz D, Proctor D. 2014. [A Framework for discussing e-research infrastructure sustainability](http://openresearchsoftware.metajnl.com/articles/10.5334/jors.av/), *Journal of Open Research Software*, 2(1): 1-4.
* Lee S, et al. 2013. [*Financing UK biobanks: rationale for a national biobanking research infrastructure*](http://stratumbiobanking.org/docs/STRATUM%20COST%20MODEL%20FINAL%20REPORT%20MAY%202013.pdf). STRATUM, Strategic Tissue Repository Alliances Through Unified Methods, UK. (Final Report of Work Package 7 “Cost Model” of STRATUM).
* Norwegian Association of Higher Education Institutions. 2014. [*A Norwegian research infrastructure resource model: a methodology for declaring the costs and pricing the use of research infrastructure in externally funded projects at universities and colleges*](http://www.uhr.no/documents/A_Norwegian_Research_Infrastructure_Resource_Model_270214.pdf). Oslo.
* NRIC, National Research Infrastructure Council, Government of Australia, 2013. [*Strategic framework for research infrastructure investment*](http://docs.education.gov.au/node/34417). Canberra.
* OSIRIS. 2012. [The business models for ICT research infrastructures: model for public authority – research infrastructure interaction](http://www.ictresearchinfrastructures.eu/communicraft-cms-system/uploads/Deliverable-4.1-final.pdf). Final report of the project “Towards an Open and Sustainable ICT Research Infrastructure Strategy” funded under FP7.
* [Ramiri handbook](http://www.ramiri-blog.eu): Chapter 4 “[Finance](http://www.ramiri-blog.eu/index.php?n=Main.Fina)”. 2013. (The online tool from the project Ramiri (Realising and Managing International Research Infrastructures) was funded under a grant agreement of FP7, the 7th Framework Programme for Research and Technological Development of the European Union)
* Rannis, Icelandic Centre for Research. 2015. [*Infrastructure fund: rules for the grant year 2015*](http://en.rannis.is/media/innvidasjodur/Infrastructure-fund-rules-and-guidelines-2015.pdf). Iceland.
* Vaught J, et al. 2011. [Biobankonomics: developing a sustainable business model approach for the formation of a human tissue Biobank](http://www.ncbi.nlm.nih.gov/pubmed/21672892), *Journal of the National Cancer Institute Monographs*, 42: 24-31. (2.4)
* Voss A, et al. 2007. [Sustainability of e-infrastructures (for the Social Sciences)](http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.126.4642&rep=rep1&type=pdf), 3rd International Conference on e-Social Science, Ann Arbour, MI.
* Watson PH, et al. 2014. [A framework for biobank sustainability](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4150367/pdf/bio.2013.0064.pdf), *Biopreservation and Biobanking*, 12(1): 60-8.

1. **Literature consulted, but not cited**

* Atakan K, et al. 2015. [The European Plate Observing System and the Arctic](http://pubs.aina.ucalgary.ca/arctic/Arctic68-S-1.pdf), *Arctic*, 68(1), Supplement 1.
* BBMRI, European Biobanking and Biomolecular Resources Research Infrastructure. 2015. [*Biobanking and biomolecular resources research infrastructures BBMRI-ERIC: annual and financial report 2014 on activities and achievements of BBMRI-ERIC*](http://bbmri-eric.eu/documents/10181/49443/Annual+and+financial+Report+2014_august_webissn_low_reso.pdf/e19739fc-9fc7-4852-9610-e11c7c5b006d). Graz, Austria.
* Becker R, van Dongen GAMS. 2011. [EATRIS, a vision for translational research in Europe](http://www.researchgate.net/profile/Alan_Bank/publication/51905961_Right_Ventricular_Pacing_Mechanical_Dyssynchrony_and_Heart_Failure/links/559a802d08ae21086d27264a.pdf), *Journal of Cardiovascular Translational Research*, 4(3): 231-7.
* Calzolari A, et al. 2014. [The European research infrastructures of the ESFRI roadmap in biological and medical sciences: status and perspectives](http://www.scielosp.org/pdf/aiss/v50n2/12.pdf), *Annali dell’Istituto Superiore di Sanità*, 50(2): 178-85.
* ESF, European Science Foundation. 2013. [*Research infrastructures in the European Research Area: a report by the ESF Member Organisation Forum on Research Infrastructures*](http://www.esf.org/fileadmin/Public_documents/Publications/mof_research_infrastructures.pdf). Strasbourg.
* Flyvbjerg B, Garbuio M, Lovallo D. 2009. [Delusion and deception in large infrastructure projects: two models for explaining and preventing executive disaster](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2229781), *California Management Review*, 51(2): 170-93.
* Halban PA, Boulton AJM, Smith U. 2013. [A new paradigm for improved co-ordination and efficacy of European biomedical research: taking diabetes as a model](http://link.springer.com/content/pdf/10.1007%2Fs00125-012-2790-z.pdf), *Diabetologia*, 56(3): 439-43.
* NCRIS, National Research Infrastructure for Australia. 2015. [*National collaborative research infrastructure strategy: programme guidelines*](http://docs.education.gov.au/system/files/doc/other/national_collaborative_research_infrastructure_strategy_programme_guidelines_2015-16.pdf).
* NRF, National Research Foundation / DST, Department of Science and Technology. 2011. [*Research infrastructure support programmes (RISP) grants*](http://www.ul.ac.za/application/downloads/RISP%20Manual%202011-12%20Final.pdf). Pretoria, South Africa.
* Péro H. 2011. [Research infrastructures of pan-European interest: the EU and global issues](https://apps.webofknowledge.com/full_record.do?product=UA&search_mode=MarkedList&qid=4&SID=N2Q2NdsAkCYtGRCnNJs&page=1&doc=10&colName=CCC), *Nuclear Instruments and Methods in Physics Research, Section A*, S69-S71.
* Péro H, Faure JE. 2007. [European research infrastructures for the development of nanobiotechnologies](http://www.ncbi.nlm.nih.gov/pubmed/17368840), *Trends in Biotechnology*, 25(5): 191-4.
* Reichel J., et al. 2014. [ERIC: a new governance tool for biobanking](http://www.nature.com/ejhg/journal/v22/n9/pdf/ejhg20146a.pdf), *European Journal of Human Genetics*, 22(9): 1055-7.
* Reiter G, Hadjichristidis N, Möller M. 2003. [Chances and challenges in Europe](https://apps.webofknowledge.com/full_record.do?product=UA&search_mode=MarkedList&qid=4&SID=N2Q2NdsAkCYtGRCnNJs&page=2&doc=12&colName=CCC), *Nature Materials*, 2(2): 67-9.
* Shanghai Supercomputer Centre. *Annual Reports, 2010, 2011, 2012, 2013, 2014*. Shanghai. (available only in Chinese)
* SHARE, Survey of Health, Ageing and Retirement in Europe. *Annual activity reports,* [*2012*](http://www.share-project.org/fileadmin/pdf_documentation/SHARE-ERIC/ERIC-Committee_Report2012_15Okt2012.pdf)*,* [*2013*](http://share-dev.mpisoc.mpg.de/fileadmin/pdf_documentation/SHARE-ERIC/share_eric_report.pdf)*,* [*2014*](http://www.share-project.org/fileadmin/pdf_documentation/SHARE-ERIC/share_eric_report_2014_web.pdf). Munich Center for the Economics of Aging MEA, Germany.
* Wilcox A, et al. 2014. [Sustainability considerations for health research and analytic data infrastructures](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4371522/pdf/egems1113.pdf), *eGEMs*.
* Witt A. 2014. [Sustainability of research infrastructures: some lessons learned from TextGrid and CLARIN-D](http://innet-project.eu/sites/default/files/InNet_Sustainability.pdf), 3rd inNET Conference, Budapest, Hungary, September.
* XFEL, European X-Ray Free-Electron Laser. *Annual reports,* [*2010*](http://www.xfel.eu/sites/site_xfel-gmbh/content/e63617/e123754/e123755/European-XFEL-Annual-Report-2010_eng.pdf)*,* [*2011*](http://www.xfel.eu/sites/site_xfel-gmbh/content/e63617/e123754/e157927/European-XFEL-Annual-Report-2011_eng.pdf)*,* [*2012*](http://www.xfel.eu/sites/site_xfel-gmbh/content/e63617/e123754/e212665/European_XFEL_Annual_Report_2012_eng.pdf)*,* [*2013*](http://www.xfel.eu/sites/site_xfel-gmbh/content/e63617/e123754/e234422/European_XFEL_Annual_Report_2013_eng.pdf)*,* [*2014*](http://www.xfel.eu/sites/site_xfel-gmbh/content/e63617/e123754/e255298/European_XFEL_Annual_Report_14_eng.pdf). Hamburg, Germany.

1. **Questions emerging from the literature review**

* What is understood by infrastructures (physical equipment, provision/availability of data, etc.)?
* Definition of sustainability (physical plant, data curation)?
* What makes an infrastructure “international”?
* Are biobanks a special case of RIs?
* Distinction between “large” and “small” RIs?

1. Formerly the Joint Information Systems Committee, JISC is a UK non-departmental public body whose role is to support post-16 and higher education, and research, by providing relevant and useful advice, digital resources and network and technology services. It is funded by all the UK post-16 and higher education funding councils. [↑](#footnote-ref-1)