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International Comparisons: Science Capital Appraisal and Evaluation

Appendix D - Case Study Compendium

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1 Introduction

The following country case studies were prepared as part of a study for BEIS on international practice in the governance, appraisal, monitoring and evaluation of science capital funding.

Based on an initial review of fourteen countries, Technopolis and BEIS selected a shortlist of eleven for further exploration. These were developed into full case studies, based on additional desk research, interviews and analysis, undertaken by a Technopolis researcher with country specific knowledge of research infrastructure policies and the corresponding language skills for the interviews. Case study drafts were sent to individual interviewees for validation before being submitted to BEIS for comment.

Final versions of each case are presented below. These provided the basis for cross-analysis of international practices and are drawn on heavily throughout the main body of the final report.

2 Australia

2.1 The process of allocating science capital funding

The key process in Australia for funding Large Research Infrastructures is the **National Collaborative Research Infrastructure Strategy (NCRIS)**, which was established by the Department of Education and Training in 2006. Through the NCRIS, the Government funds research facilities around the country that provide services to researchers. This funding has increased over recent years, from AU$80m in 2013-14, to AU$100m in 2014/15 and AU$150m in 2015/16.

The majority of lead partners ("lead agents") in the funded facilities are universities (15 out of 27). However, five publicly funded research agencies and six companies also act as lead agents.[1] The NCRIS aims to 'support major research infrastructure to encourage collaboration between the research sector, industry and government in Australia to conduct world-class research'[2]. It is not the only program that supports national research infrastructure, but it is the biggest. It also has the particularity of supporting research infrastructure which is collaborative and networked, meaning that it refers to more than one site and integrates a high proportion of collaboration between different research institutions. In that context, collaboration does not solely refer to the cooperation between researchers and facility operators. There is also a financial element: institutions involved in an NCRIS network must participate financially as well and make co-investments.

'National research infrastructure' in Australia is defined as 'comprising the nationally significant assets, facilities and services to support leading-edge research and innovation. It is accessible to publicly and privately funded users across Australia, and internationally[3]." NCRIS is addressing three levels of the Australian research infrastructure: National research infrastructure, landmark research infrastructure and global research infrastructure.

Since 2006, Australia has also been drawing up **national Roadmaps** for investing in large-scale research facilities. The establishment of NCRIS was an outcome of the initial 2006 Roadmapping process (described in more detail below). Hence, it can be considered as part of the Roadmap because the infrastructure reviewed during the last Roadmapping became the actual NCRIS-infrastructure.

The National Research Infrastructure Council supported the early Roadmapping exercises, while the latest (2016) Roadmapping process was led by the Chief Scientist for Australia. The process was also supported by an **Expert Working Group** (EWG), who's role was to consult widely with the key users of the research infrastructure and to take that advice on board in designing a 10-year vision for the research infrastructure necessary to serve the community. The group considered written submissions and consulted with a significant number of (580) stakeholders from the public and private research community, the university sector, research funders, governments, peak organisations, existing facility operators, publicly funded research agencies, international organisations, and users of research.

Members of the Expert Working Group are professors or chief executive officers from universities and research institutions operating in different thematic fields. For the

[1] National Collaborative Research Infrastructure Strategy Project Reviews - Overarching Report, KPMG 2014, p.25

[2] https://www.education.gov.au/national-collaborative-research-infrastructure

[3] Strategic Roadmap for Australian Research Infrastructure Draft 2016

2016 Roadmap, seven representatives participated from Monash University, CSL Ltd, James Cook University, the Australian National Fabrication Facility Ltd, Queensland Museum, the Australian Nuclear Science and Technology Organisation, and the ARC Centre of Excellence for Climate System Science.

The Expert Working Group was supported by the Department of Education and Training through a dedicated secretariat. Important selection criteria for members of the EWG were not only that they were experts in different fields, but also that they were well connected with the research sector (for example, being members in several different associations or having key functions across several different fields of research). Some members of the EWG are running very important infrastructures that will definitely receive funding (such as the Australian Nuclear Facility).

In addition to the EWG, National Research Infrastructure Roadmap Capability Expert Groups were built. Their members were operating in several different and scientific relevant thematic groups between the EWG and stakeholders of the scientific communities. The capability groups were also a means to expand the reach of the EWG as the members came from different subareas of the big group and could give a broader view on different topics and deliver information in a very rapid way.

The final **2016 National Research Infrastructure Roadmap** has not yet been published. So far, only the draft version has been released, with comments and feedback invited by January 2017. Government sources report that there is not yet a fixed data for the launch of the final roadmap, or indeed details as to the extent to which its contents will differ from the draft). Hence, all statements in this case study regarding the contents of the 2016 road map are only preliminary.

Five general **investment principles** were specified in the 2011 Roadmap, which also apply to the 2016 version. These principles are aspirational, rather than necessarily fully applied in practice[4]:

- The holistic funding principle means funding must also be available to support the *operation* of infrastructure (e.g. human capital, maintenance or infrastructure project planning).
- The principle of 'co-investment' aims to stress linkages with state / territory governments and industry to maximise opportunities for co-investment and encourage a broad user base. The co-investment can support networks and the quality of research.
- The access and pricing principle refers to the transparency of pricing regimes and that the infrastructure can be used by a broad range of excellent researchers. Hence, this principle seeks to foster access to data and research infrastructure.
- The principle of prioritisation means that investment must be channelled in the prioritised capability areas. However, previous investments should be taken into account. Also, 'high performing facilities remain national priority'.
- Excellence in research infrastructure refers to the importance of the effectiveness of the governance structures.

The overarching objective of NCRIS projects is to deliver high quality research and innovation outcomes to improve national well-being and enable Australian researchers to address key national and global challenges. The research strategy is therefore not

[4] Strategic Roadmap for Australian Research Infrastructure 2011

only focused on scientific outcomes, but designed as a challenge-driven strategy (similar to the Grand Challenges in Horizon 2020).

The process of allocating funding to infrastructure projects is characterised by a **collaborative, rather than competitive, approach**. This route was taken inter alia because of a recommendation in the 2004 Final Report of the National Research Infrastructure Taskforce. The report pointed to a previous study ("Should Government competitive research granting schemes contribute more to research infrastructure costs?"), which revealed that the growth in competitive grants can be linked to a decline of infrastructure funding ("in many cases, such grants fail even to cover even the direct costs of the projects they fund"). The shift to collaborative funding was finally made because in a pilot project in the 2000's, some research facilities where not able to meet the needs of research communities. They were focused too much on finding alternative funding rather than concentrating on providing services to the research community and so the funding wasn't considered as a success. Moreover, it was generally recognised in Australia and overseas that the collaborative approach regarding funding and investment was successful as it allows government to reduce the justification of investment and allows governments to work with stakeholders to identify opportunities to co-invest.

Besides NCRIS, there exist smaller funding schemes (that are not the focus of this case). The Australian Research Council (ARC) for instance administers the National Competitive Grants Programme (NCGP) through which funding is allocated to excellent research projects based on a competitive peer review process. One of these programmes (the Linkage Infrastructure, Equipment and Facilities (LIEF) scheme) provides funding for research infrastructure in universities. It is directed to higher education researchers to participate in cooperative initiatives with the aim that costly infrastructure, equipment and facilities can be shared between universities and industry. The average funding provided under LIEF is in the range of AU$400k to AU$500k per year.

2.2 The (ex-ante) appraisal approach

As indicated above, Roadmapping for research infrastructure has been conducted since 2006. However, the process has changed and evolved over time. During the first round in 2006 for instance, a committee that provided high level advice regarding research infrastructure needs in the future worked with facilitators and with the research communities to identify pieces of kit, locations and costs of kit. They determined the level of co-investment and the level and type of stakeholders involved. Facilitators then together developed an investment plan and identified the capability which was required for the future. Hence, the final recommendations given during that Roadmapping process were very specific and linked to concrete pieces of infrastructure.

By comparison, the 2016 Roadmapping process was slightly different from the previous exercises, as it was not clear how much money would be available. Moreover, participating stakeholders described it as 'more visionary' and 'more comprehensive' than previous ones. In contrast to the former Roadmaps (especially 2006), no specific indications were given as to *exactly* what infrastructure should be funded. The 2016 version had a longer time vision and for that reason it needed to be more flexible and allow for new opportunities. Hence, the outcome of the Roadmapping process 2016 was rather to point to specific areas which should be prioritised within NCRIS funding or should generally get more funding. The details will be decided on in the next steps by governmental bodies.

2.2.1 Determining capability focus areas and the capability issues discussion paper

As stated above, the whole process in 2016 was driven by the Expert Working Group who - in a collaborative approach - **determined specific capability focus areas** which are based on the National Science and Research priorities. These focus areas were:

- Health and medical science
- Environment and natural resource management
- Advanced physics, chemistry, mathematics and materials
- Understanding cultures and communities
- National security
- Underpinning research infrastructure
- Data for research and discoverability

The process of determining the capability areas involved several experts from across the research community called **'National Research Infrastructure Roadmap Capability Experts'**. In each of the areas mentioned above, around 3-4 experts were involved. These experts looked at what was already funded by NCRIS and what the future line of the specific capability area was (i.e. the expected developments in this areas), before coming up with some recommendations. To do so, the capability experts participated in workshops and had 'speed-dating-exercises' in which they had talks with people of the respective facilities and talked about their ideas and what was working and what wasn't.

All information gained during this process was fed into a discussion paper (Capability issues paper) which had the aim to 'set out the proposed capability requirements that will inform the development of the 2016 Roadmap[5]'. The issues paper was launched as a starting point and framework for the public consultations so that people were able to respond to something concrete rather than just to randomly give their opinion. Hence, the issues paper was about suggestions on where the EWG wanted to go and what they were thinking was the key priorities of the national research infrastructure were.

2.2.2 Feedback loop

The research community in Australia (as well as other interested stakeholders) were invited to put in submissions with their views on the Capability Issues Paper and these comments were also considered for developing the 2016 Roadmap. All in all, the stakeholder-feedback validated what was written in the paper, hence it confirmed the views that the EWG had formed. Based on the inputs, the Expert Capability Working groups was found to be developing the state of the art, and had made judgements regarding propitious research directions for the country. Criteria for the final suggestions were for instance whether the priorities would be in line with the country priorities, their relevance, quality and persuasiveness. For instance, there were some aspects which were generally considered as good ideas but at the time would be

[5] National Research Infrastructure Capability Issues Paper, July 2016

outdated. For example, there was one critical subgroup for which the experts could not see how this would fit in the bigger picture (the subgroup was more commercial than scientific) and so this group was not considered in the final recommendations.

2.2.3 Establishment of the Roadmap

Finally, all information and recommendations prepared in the single capability expert working groups were put together by the EWG following a presentation day on which all single capability groups could present their ideas. The EWG also undertook a series of infrastructure facility visits (51) during which all principle research sites in Australia were visited. The expert working group also spoke to a large proportion of the key stakeholders through open public consultations. Everybody who wanted to participate could register and come, and multiple consultation sessions were held in each location (with most EWG members in attendance at each).

From here they developed 'research infrastructure focus areas', in which the EWG identified a number of possible projects that could be funded. However, 'being chosen' in this context just meant that the concrete projects should be considered for further prioritization, not that they have to be funded. An important criterion used for assessment was not only the national significance of the project but also that its establishment was beyond the capabilities of one or two research institutions. Also, the international focus or impact of a certain facility or area was important. There needed to be a clear articulation of how a national need could fit in to the international context and be internationally excellent in terms of infrastructure and research.

The following infrastructure focus areas were identified in the Roadmapping process as underpinning the national research priorities and supporting the needs of the research community:

- Digital Data and eResearch Platforms
- Platforms for Humanities, Arts and Social Sciences
- Characterisation
- Advanced Fabrication and Manufacturing
- Astronomy and Advanced Physics
- Environmental Systems
- Biosecurity
- Complex Biology
- Therapeutic Development

The draft roadmap was then submitted to the country and, after further feedback, submitted to the government.

2.2.4 Project funding

When it comes to the step of funding concrete projects and infrastructure, one must differentiate between **two strings of funding**: funding through the Roadmap (direct at the creation of infrastructure and capital); and funding through the NCRIS programme (relating to the ongoing operations of the facilities that are part of the NCRIS network). The separation between the two illustrates that the approach of holistic funding has not been fully achieved yet. Under the 2008 Roadmap, there was a large amount of only capital funding but no operational funding. Facilities were consequently increased in size and new things were created but there was no operational funding available. What the government did in 2015 was to also provide ongoing operational funding for NCRIS. However, there is still no ongoing capital funding.

Facilities of the NCRIS network can receive operational funding based on each second year released and adapted 'NCRIS Programme Guidelines'. As described above, during the Roadmapping, the EWG also identified some projects which should be prioritised for the allocation of operating funding under NCRIS. The 'Programme Guidelines' state several criteria for projects to be eligible to receive funding. Eligible projects get an information note of their eligibility by the Department. In the 2016-2017 Guidelines, there was not much space for interpretation as the eligibility criteria are very straightforward. The indicative funding allocation for each project is calculated by a specific formula. To receive the final funding, Lead Agents of the eligible projects had to deliver specific business plans. These include several aspects/criteria which are assessed. The business plan includes[6] - among other features – an outline of governance and management arrangements, target performance measures and expected expenses on operation, management and governance costs, salaries and costs for technical staff, infrastructure maintenance, industry engagement and outreach activities. The funded infrastructures are asked every 1-2 years to submit new business plans for the upcoming period (NCRIS 2013 for funding in 2013-14 and 2014-15, NCRIS 2015 for funding in 2015-16, currently NCRIS 2016 for funds until 30 June 2017). Business plans of some institutions can be found online.

No specific investment plans have been developed yet for **funding through the 2016 Roadmap**. However, the 2016 draft version foresees a staged approach for the implementation of the Roadmap:

1. For each individual focus area, a strategy plan addressing the identified infrastructure requirements must be developed. These are considered to inform the development of an investment plan for the available government resources.
2. Facilitators should then help in moving from generic focus areas to specific investments (i.e. the best location, operating and governance arrangements), building on specific investments outlined in the submissions, consultations and advice in stage one of the appraisal process.
3. Based on the facilitation process, specific project business plans will be developed and 'set out how the research infrastructure needs will be delivered'[7].
4. Projects can either be implemented as a pilot (funding not longer than five years) or a 'greenfield project' (new establishment). Moreover, it is possible that an ongoing activity gets funding.
5. All projects are reviewed regularly for efficiency and effectiveness by an independent infrastructure advisory group.

Investment plans from previous Roadmaps are considered commercially sensitive and are not publically available.

[6] Attachment B to the National Collaborative Research Infrastructure Strategy Programme Guidelines, 2016-2017

[7] Draft 2016 National Research Infrastructure Roadmap, p.65

2.3 Monitoring and evaluation

In general, all funding recipients under the NCRIS are required to participate in project level evaluations and report at regular intervals.

The programme guidelines of the NCRIS funding rounds ask for mid-year **progress reports** and a yearly report on the conduct of the project as specified in the funding agreement. The monitoring reports detail project outcomes, short and long-term benefits/gains (quantitative and qualitative) and overall financial performance[8], and are intended to support evaluations of the overall benefits delivered by the project and the programme more broadly. Monitoring processes also require the funded organisations to advise the programme delegate if they are experiencing significant issues. Finally, the Department may select institutions or projects for site visits and/or programme audits.

Funded projects report against **performance indicators** for the NCRIS programme, as stipulated by the Australian Government Department of Education and Training. These indicators mainly cover – but are not limited to – three evaluation dimensions. These criteria and indicators include:[9]

- Effectiveness of financial, administrative and governance arrangements
  - Co-investment data, including amount and source
  - Philanthropic donations
  - Number and nature of any qualified audit findings
  - List of all collaborative delivery arrangements
  - Number and nature of external consultative mechanisms
  - Project employment breakdown by employment category and geographical location
  - Number of governance body meetings
- Infrastructure usage and other output measures
  - User numbers
  - Breakdown of user numbers by host and other institutions
  - User institution summary
  - Utilisation rates
  - Unmet demand measures and levels
- Impacts of all types, including outreach, industry and international engagement and where appropriate commercial outcomes.
  - Number and types of publications
  - List of outreach activities by key audience
  - List of all industry engagement activities
  - List of all international engagement activities
  - Number and types of commercial outcomes

[8] National Collaborative Research Infrastructure Strategy Programme Guidelines, 2016-2017, p. 9

[9] National Collaborative Research Infrastructure Strategy Programme Guidelines, 2016-2017, p. 9 and Attachment C

- List of contributions to the achievement of Australian Government policy objectives

There is no further information publically available on these indicators, or completed project reports.

In addition to the regular monitoring and reporting requirements there are also regular **overall evaluation exercises** for the NCRIS. A 2010 evaluation was carried out by an internal evaluation team from the then Department of Industry, Innovation, Science, Research and Tertiary Education, drawing on the work of a science panel and an economic consultant. In 2014, an external evaluator was then commissioned to undertake an independent "efficiency review" of the 27 research infrastructure projects funded under the NCRIS, drawing on project documents, site visits and various consultation activities. In both instances the evaluation dimensions included appropriateness, effectiveness, efficiency, integration into other public programmes, and strategic policy alignment. Additionally, the analyses addressed the ways in which performance assessment for NCRIS capabilities are carried out (2010 evaluation) and the financial management and compliance (2014 evaluation).
The evaluation of 2010 which was developed by the National Collaborative Research Infrastructure Strategy (NCRIS) Evaluation Team was looking at the whole programme. It addressed "the extent to which the NCRIS model — i.e. the approach, design and implementation of the program — has been appropriate, effective and efficient in establishing research infrastructure for Australia". With the assistance of an expert Science and Research Panel and an Economic Consultant, the framework of the evaluation was developed. The main methodologies applied were a stakeholder survey and consultations with NCRIS capability providers, users and key stakeholders.
The aim of the 2014 evaluation was "to undertake a review of the efficiency and effectiveness of each of the 27 individual projects and their lead agents". The evaluators visited each of the projects and then reviewed the projects also via desk research. The evaluation should assess the operational maturity of each project based on the following dimensions: governance, effectiveness, efficiency, financial management and compliance, integration and strategic policy alignment.
It is intended that more evaluations will be conducted in future but there is no information yet available on what these evaluations might look like. Moreover, there seem to be no specific approaches or plans towards future approaches to address difficult to measure aspects such as downstream, investments, spillover effects or local economic effects of research infrastructure.

2.4 Summary of key strengths and weaknesses

The Australian 2016 Roadmapping had a very inclusive character. At several stages of the process, the input of the research community, specific experts and other interested stakeholders was considered. The release of the issues paper for instance was followed by public consultations and open sessions that anyone could attend. Most of the major universities and the whole research sector engaged very heavily in this process. Then, the development of the draft Roadmap was followed by second public consultations. Overall, the inclusiveness was considered to be one of the strengths of the roadmapping process. It was perceived to have led to broad community support and a significant amount of information being taken on board from experts in the field.

The integration of different stakeholders in the appraisal and evaluation process of large research infrastructure are in principle transferable to other science systems. However, there may be barriers to be as inclusive with larger populations and more / bigger research institutions. There are also challenges to such an approach. For instance, one interview partner mentioned a risk that stakeholders might assume that their participation in the process meant their voice would automatically be reflected in the Roadmap or that there would be investment in the areas which were recommended. Handling vested interests seemed to be another challenge of the inclusive consultation process as there is the difficulty that a lot of people can't think beyond their own institutional interests. Hence, from an institutional and organisational perspective, the Roadmapping process had to be framed so that the participating stakeholders' views are channelled away from their institutional perspective to a broader view (the interest of the national community). Moreover, sectors had different degrees of organisation, which led to different levels of engagement and lobbying in the whole process. One sector for instance was very proactive and knew exactly which targets they intended to achieve during the process and how to articulate them. Hence, they requested specific meetings and had a peak group which was presenting their needs. Other sectors were harder to motivate to proactively participate in the discussions. Having said this, the general organisation and structuring of the process with the Chief Scientist as a manager (who is well respected in the research community, but not affiliated to a specific research institution) was described as quite effective in handling these issues and ensuring that the loudest voices didn't necessary dominate the conversation.

2.5 Sources

2.5.1 Documentary sources

- Strategic Roadmap for Australian Research Infrastructure 2011
- National Collaborative Research Infrastructure Strategy Programme Guidelines, 2016-2017
- 2016 National Research Infrastructure Roadmap Terms of Reference
- National Collaborative Research Infrastructure Strategy - Evaluation Report, 2010
- NCRIS Project Reviews - Overarching Report, KPMG 2014
- Size and Suitability, Investing Strategically in Large-Scale Research Facilities, Dutch Advisory Council for Science and Technology Policy (AWT), 2013

2.5.2 Interview Partners

- Ditta Zizi, Branch Manager, Research and Higher Education Infrastructure, Research and Strategy Group, Australian Government Department of Education
- Dr. Cathy Foley, Science Director and Deputy Director, CSIRO
- Prof. Andy Pitman, Director, ARC Centre of Excellence for Climate System Science
- Prof. Suzanne Miller, CEO and Director, Queensland Museum Network

3 Belgium (Flanders)

3.1 The process of allocating science capital funding

Both the region of Flanders and Belgium itself do not currently have a **roadmap for research infrastructures**. The Flemish government, however, has asked the (former) Hercules foundation and the department for Economy, Science and Innovation (EWI) to draft a Flemish roadmap for research infrastructures, in collaboration with the working group on infrastructures of the government's platform Europe policy development group. Principles for this roadmap are as follows:

- It should contain infrastructures that are of Flemish/regional importance for third parties, as well as ESFRI (European Strategy Forum on Research Infrastructures) infrastructures in which Flanders takes part or would like to take part.
- The infrastructures that are to be included should match certain criteria (without every facility having to answer to every criterion):
  - Maturity
  - The scientific quality of the infrastructure and of the consortium that manages the infrastructure
  - The strategic importance for the Flemish research- and innovation policy
  - Potential for innovation
  - Open access for at least researchers connected to the Flemish universities and Flemish public knowledge-institutes and companies located in Flanders
  - The provision of start-up funding from Flanders (e.g. through Hercules subsidies)
  - Support from the Flemish universities

The above are general principles, that have not yet been further developed. The development of the roadmap is currently on hold because of recent changes in the responsible funding organisations: the Hercules Foundation and the Research Foundation – Flanders (FWO).

The structural funding of research infrastructures started in 2007 with the establishment of **the Hercules programme**, as the Flemish Government acknowledged that it was almost impossible to redirect resources for research infrastructures without a structural channel in place, fuelled by fear that Flanders would significantly lag behind compared to other European countries if no concerted action was taken.

The Hercules programme has subsidised infrastructures for fundamental and strategic basic research, with the Flemish government providing between 70 and 100% of investment costs. It aimed to facilitate major investments in medium- and large-scale research equipment for both fundamental and strategic basic research.

The Hercules programme was originally executed by the Hercules Foundation with a board of directors that was nominated by the Flemish Government. However, with the reorganisation of the research funding agencies in 2016, when the IWT was integrated in a new Agency for Entrepreneurship and Innovation (AOI) in 2016, the Hercules Foundation was merged with the Research Foundation – Flanders (FWO), the main research funding organisation for fundamental research in Flanders. The FWO had previously only provided supplementary funding for international research infrastructure (through the Big Science Programme) but it now manages the key process in the Flanders region for funding large research infrastructures, funded by the Flemish government. Research infrastructure budget lines and tasks regarding the content have remained largely unchanged from those of the earlier Hercules foundation. However, several administrative procedures in the evaluation and monitoring process have now been aligned with general FWO programmes.

In 2016, FWO received a total of €321m from the Flemish government for fundamental research, strategic basic research, clinical scientific research and investments in medium-scale, large scale and special research infrastructure. For the funding period 2015-2016, €25.3m was available for the fifth call for proposals for infrastructures. Of this, €16.6m was available for mid-scale infrastructure and €8.7m for large scale research infrastructures.

Research groups from universities and universities of applied sciences can apply for medium-scale research equipment and large scale equipment through the FWO. For medium-scale equipment with an investment cost between €150k and €1m (including the non-recoverable part of taxes), the funds are divided between the different university associations. This is done using a distribution-key that incorporates the percentage of resources that the universities receive from the Special Research Fund (BOF) and the Industrial Research Fund (IOF), both of which are research funding budgets allocated to the universities by the Flemish Government. The better the achievements of the university, the higher its share in the total of BOF and IOF funding. Thanks to an a priori distribution-key, the associations can plan their investments more strategically and with a longer-term perspective.

Investment projects for large-scale infrastructure are selected based on open competitive calls in which all research fields are integrated. The selection of investments in large-scale equipment of more than €1m is done by two specific committees.

A **scientific evaluation committee**, consisting international experts, evaluates the investment based on its scientific qualities in a 2-step procedure. Within the committee, expertise regarding science and innovation policy and the management of major research facilities is also present.

Following the ranking of the scientific committee, a separate **strategic investment committee** considers the financial elements of the applications that were assessed as 'excellent'. It assesses whether the investment proposal is realistic enough and considers whether there are other collaboration agreements than the ones that were suggested in the proposals would have been possible or preferable. The committee in its actual configuration consists of members nominated by EWI, the Participation Company Flanders and the Hercules Foundation. Previously, the Flemish Minister of science- and innovation policy appointed the members of both committees for a new term of six years. Since 2016, the new responsible is the board of directors, who will make a first appointment in 2020, since the current committees are still in function for four more years.

The instalment of a separate committee to evaluate the financial side of the investment plan (Hercules Invest) was considered necessary because scientists - while good at elaborating on the scientific side of a proposal - are often inexperienced with writing a financial plan (e.g. accountability for costs, access policy, creditworthiness of a supplier). Furthermore, before the Hercules Foundation was in place, issues had also arisen when instruments had been delivered to a university, but the university did not have the resources to install and maintain the equipment. Among the members of the investment committee are financial experts that are nominated by the Flemish Participation Companies.

In the 2012 evaluation of the Hercules programme the selection and granting procedure for the large-scale infrastructure calls was considered of very high quality. One of the reasons for this was the involvement of the investment committee. Other aspects that were noted as contributing to the quality of the procedure were the use of external international expertise, the high profile and relevant expertise of the members of the scientific committee, the possibility of a rebuttal phase for applicants to comment on referee reports, the interviews with the applicants that have been selected after the first phase of the scientific committee's evaluation and the internal evaluation of the procedure that took place after each call and in which each of the different stakeholders was involved. A possibility for improvement that was named for the investment committee was the limited capacity available for the investment plan evaluation.

It is possible to apply for funding of multiple instruments that together total an investment cost of up to €100m. However, these instruments must show cohesion and applicants must prove that it is not possible to execute the research programme when one of these instruments is missing. Application for large scale equipment can be done by one or several research groups of a Flemish university, university of applied sciences, a strategic research centre, an institute for post-initial education, a collaboration of aforementioned institutes or a collaboration between one of the aforementioned institutes and one or several external partners.

When appointing funding the following **cost categories** can be accounted for:

- Costs for scientific investments
- Costs for the purchase of the infrastructure
- Costs for parts of the construction of the targeted research infrastructure
- Repair costs (*)
- Costs for adjustments to buildings and connection costs for the research infrastructure (*)
- Staff costs during the development and construction of the research infrastructure
- Maintenance costs during the entire depreciation period
- Costs resulting from maintenance agreements
- Costs resulting from upgrading of the research infrastructure
- Staff costs for the permanent maintenance and the operation of the research infrastructure (*)

For the cost categories with an asterisk (*) a 15% rule holds, whereby a maximum of 15% of the subsidy that was allowed for a proposal can be used for the named cost category, spread over the depreciation period. The following cost categories do not qualify for funding:

- Operating expenses regarding the research infrastructure
- Costs for infrastructural services, like costs for buildings, services that can be counted among the usual housing

The Hercules Foundation was also responsible for investments in supercomputers and contributed to the creation of a **Flemish Supercomputer Centre** (VSC), a virtual centre for academics and industry. The infrastructure is divided across four locations (Antwerp, Brussels, Ghent and Leuven) with an additional support office in Hasselt. Datacentres in Ghent and Leuven alternate housing and managing a Tier-1 supercomputer. FWO manages the centre together with the five Flemish university associations.

Furthermore, the FWO works together with EWI on the **European Strategy Forum on Research Infrastructures** (ESFRI). This is a strategic instrument to develop and strengthen the integration and impact of European Research. The FWO is responsible for setting out calls and evaluations, while policy matters are handled by EWI. The number of applications for ESFRI has vastly increased in the last year, which is the reason for including ESFRI in the roadmap for Flanders. The development of this roadmap will continue once a structural funding channel has been set up for international programmes and ESFRI.

3.2 The (ex-ante) appraisal approach

The two infrastructure categories - mid-scale infrastructures and large-scale infrastructures – each have a different appraisal approach.

For **medium-scale research infrastructure**, the boards of the university associations have an important role in the appraisal process. Every association organises a call for investment proposals and has an internal selection procedure, which proceeds in four phases:

- Proposals are submitted to the board, containing information on collaboration within the association or collaboration with different associations or with third parties and the content of the collaboration. It should also include a proposal of general financing of the infrastructure and a user plan that demonstrates the use of available capacity.
- In the second phase, the board evaluates the proposals based on the general research and collaboration regulations, including possible other inter- or intra-association collaborations, in any possible form.
- The third phase consists of bi- and multilateral meetings between the associations to come to maximal collaboration. The responsibility of the content lies with the association boards. However, the boards do not have to exchange information on all applications (e.g. when there is sensitive information in the proposal).
- In the fourth phase the Hercules committee of each university association evaluates the applications and ranks them on an indicative list according to the selection criteria. This is then sent to the FWO.

On receiving the lists from the different associations, the FWO evaluates the assessments that were performed by the associations. This is based on:

- The assessment per association of the indicative lists with consideration of the selection criteria.
- An evaluation of the way of working that the different associations have followed, aiming to enhance the intra- and inter-association collaboration as well as collaborations with third parties.

This evaluation is sent to the associations involved, who then have the possibility to adjust their proposal. Eventually, the board of directors of FWO takes a final decision based on the meta-evaluation of the assessments by the associations and the responses or proposals for improvement by the association boards.

By comparison, the appraisal process for **large scale research infrastructures** is performed by the two committees mentioned in detail above, the scientific evaluation committee and the strategic investment committee; this is a multi-stage assessment procedure. Frist, the scientific evaluation committee considers the scientific quality of the proposals and ranks them based on eleven criteria:

- The scientific quality and relevance of the research programme to be executed by means of the research infrastructure
- The importance of the research infrastructure for the research within the concerned scientific discipline
- The innovative character of the research programme to be executed by means of the research infrastructure
- The extent to which the research infrastructure can generate a large stream of new projects
- The innovative technological character of the research infrastructure
- In case the research infrastructure has to be constructed: the technical feasibility of the research infrastructure
- The quality and competences of the involved research group or groups, the scientific position of the involved research groups or groups in international context, and the involvement of policy of international research infrastructures.
- The extent to which the proposal can be fitted within the strategic research policy of the involved institute or institutes
- The extent to which the research infrastructure contributes to the strengthening of the Flemish or regional position in the specific research field
- The extent to which the proposal is aligned with initiatives at home and abroad and with research infrastructures within the specific research field
- The accessibility of the research infrastructure for researchers outside of the receiving institute and the quality of the access arrangements

The criteria are rated by the reviewers on a 5-point scale (ranging from below average – excellent). One exception is the scientific reputation of the applicants, which is assessed as: international leading, international competitive, national leading or national competitive. Reviewers can also tick a box with no opinion or insufficient knowledge and provide comments. There is no specific weighting per criterion. Only proposals that are judged as excellent continue for assessment by a strategic investment committee.

The strategic investment committee then considers the financial aspects of the applications, the feasibility of the proposal and whether other collaboration formats are possible beyond those suggested in the proposal. The criteria used for the assessment of investment plans (feasibility and financially) are:

- A description of the proposed investment
- A description of the manner of obtaining the infrastructure
- A user-plan

- A description of the quality of the infrastructure in which the research infrastructure will be located
- An estimation of the financial, personal and material costs
- A balanced budget

Apart from the above, the committee conducts a risk analysis, which considering (1) risks regarding the required building and environmental permits, (2) the financial position of companies and (3) the extent to which funding is available.

First, for the assessment of risks regarding building permits, the committee engages external technical consultants since there is not enough expertise on these permits within the committee. They consider whether enough thought has been given to the construction of the infrastructure, if all permits are in order and if the application is complete. Guidelines about the topics that need to be addressed are provided to the consultants.

Second, for the assessment of the financial position of companies, the committee uses a template with several questions to be answered. Part of this template is whether there are means foreseen for upgrades. Decommissioning is not yet considered in the assessment.

Third, for the assessment of available funding, the following criteria are taken into account by the investment committee:

- Availability of the proposed co-funding by the research and educational institute and/or third parties
- Viability of revenues from research grants and from selling user time on the infrastructure to outside users
- Availability of reserves to deal with shortcomings.

Finally, also collaborations as described in the proposal are scrutinized. The investment committee specifically explores whether there is enough collaboration among the different institutes. In practice, this is a topic that has been addressed in many other evaluations as well and therefore is not a lot of work for the committee. The investment committee may ask the applicants to provide additional information on certain aspects of the proposal in case this information is lacking.

If needed, based on the financial feasibility and collaboration assessment, the commission formulates a recommendation that is added to the list of selected proposals.

Eventually, the board of directors makes the final decision. If no restrictions regarding the investment and operation plan of an application ranked as excellent were made, projects will be funded until funding available for this call is exhausted. The board of directors can only ratify or decline the list as ranked by the scientific committee. When the list is declined, both committees are consulted again, possibly with notification of the elements that should be revised according to the board of directors. Regarding the recommendations, the board can:

- Reject the recommendations and accept the application as it was
- (Partially) accept the recommendations and turn these (partially) into funding conditions
- (Partially) accept the recommendations and ask researchers to amend their funding proposal

After finalisation of the selection procedure, subsidy agreements are drafted. Templates for these agreements have been developed in consultation with the institutes and in collaboration with a law firm. The depreciation term for the infrastructure, extended with a preparatory period and a period to complete the contract, determines the duration of the agreement. Each agreement also contains a payment calendar that consists of an advance payment, interim payments and a balance payment.

In most cases, the selected proposals are approved, with several conditions based on the advice of the two committees. These conditions need to be addressed in the implementation phase of the project, something which will be checked before providing the closing balance.

3.3 Monitoring and evaluation

When funding is allocated to a research infrastructure project, the host institution is also required to submit regular **financial and scientific reports**. The funding for the project is spread out over several years and in order to receive the next instalment of funding, an organisation must justify what previous expenditures took place. Furthermore, there are two moments of scientific evaluation:

- A progress report approximately one year after signing the agreement, that contains a short description of the project progress and, in case there is a delay in relation to the initial investment plan, a clarification of why this is the case. For commissioned infrastructure, a copy of the logbook with information on use of the infrastructure should also be submitted.
- An interim scientific report, approximately two years after commissioning of the infrastructure, that also describes collaborations that took place and publications. This report should be submitted by the Principal Investigator-spokesperson.

Every agency or institute that is part of the Flemish government is evaluated every five years by an **independent panel of experts**. The evaluations consider the following points:

- What is the yield of the investment, measured based on scientific breakthroughs, top-publications, valorisation results and gained industrial contracts?
- What is the effectiveness of the investment, where a portfolio is submitted by a joint venture specifically pays attention to the strength of that collaboration?
- What is the user intensity of the approved research infrastructure and what is the ratio of the user intensity and the total user costs?
- What is the accessibility of the infrastructure for the researchers? Attention is given to the level of occupation of the infrastructure. What is the share of the use by researchers of the receiving institution and what is the use by external parties (other universities, universities of applied sciences, research institutes, industry)?
- What is the international significance of the investment in the approved research infrastructure? To what extent is the research infrastructure used in international research programmes?
- What is the institute- and association-exceeding character of the approved proposals? What percentage of approved proposals is financed in a cooperative manner and what is the percentage of approved proposals in which a significant

part of the user time is taken by third parties outside of the receiving institution? Special attention will be given to the share of use by industry.

- What is the contribution of third parties, in specific the industry and foreign actors?

The independent experts for the evaluations are also asked to provide suggestions on possible adjustments to the financing mechanism to improve its efficiency.

The first **evaluation of the Hercules programme** took place in 2012, and focused on the programme's functioning and impact in terms of scientific, economic and societal value. With the Hercules foundation being integrated into the FWO in 2016, the infrastructure funding programme is now an element of evaluations of FWO. However, before the transfer to FWO, the Hercules foundation organised several internal evaluative exercises where people could indicate whether they agreed with the current structure and what changes were desired in the future.

3.4 Summary of key strengths and weaknesses

- One of the strengths of the appraisal and evaluation process in Flanders is the instalment of the strategic investment committee, a separate committee to assess the given resources and (financial) management. Whereas proposals are often very strong on the scientific aspects, often little thought has been given to the financial part. This is the added value of the investment committee, which is considered to play a pivotal role in the selection procedure.
- Another strength of the Flemish appraisal and evaluation procedure is the presence of international experts in the scientific committee. These experts are not involved in Flemish initiatives, and are therefore more independent. This independency might also be a minor weakness if committee members are not sufficiently aware of the Flemish priorities. This needs to be given thought when appointing the committee members and when they are briefed about the scope and aims of this funding programme.
- A weakness of the Flemish appraisal and evaluation procedures is the fact that decommissioning of the infrastructure is not yet considered. FWO is aware of this and would like to include this in future assessments.
- There are no country-specific characteristics in the appraisal and evaluation process in Flanders. In principle, the processes are transferable to other science systems.

3.5 Sources

3.5.1 Documentary sources

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3.5.2 Interview Partners

- Caroline Volckaert, FWO/Hercules Foundation, Advisor Research Infrastructure
- Professor Bart de Moor, University of Louvain, former chairman of the Hercules Foundation, former Head of Cabinet for the Federal Minister of Science Policy and former Head Socio-Economical Cabinet for the Minister-President of the Flanders Region.
- Bart van Beek, FWO, Science Policy Advisor

4 Canada

4.1 The process of allocating science capital funding

Canadian STI policy is formulated by the Prime Minister and Cabinet. This is then implemented by Industry Canada and the Department of Finance together with science-based departments and agencies. At the federal level, the Natural Sciences and Engineering Research Council (NSERC), the Social Sciences and Humanities Research Council (SSHRC) and the Canadian Institutes of Health Research all fund research and science infrastructure.

The main organisation responsible for providing funding to large research infrastructures on the federal level is the Canada Foundation for Innovation (CFI)[10] which is a semi-independent organisation. The approach of the CFI is the matching fund formula, meaning that the funds cover 40% of the costs and the additional 60% is to be covered by the funding mechanisms of the provincial governments who have a jurisdictional responsibility for supporting universities, research hospitals and colleges. While this means that there are individual funds for supporting the research infrastructures on the provincial level, these are overlapping in their aim and meant for backing up the funding provided by the CFI in their funds. There is a high synergy in the activity of CFI and the provincial government and the process relies on the appraisal, evaluation and monitoring activity of the CFI.

<u>Post-Secondary Institutions Strategic Research Fund</u>

The only national level fund in addition to CFI funds is the Post-Secondary Institutions Strategic Research Fund (SIF) which is a one-time investment in research infrastructures that are used to house, or increase the usability of CFI-funded equipment. As such, it is more complementary than overlapping to the activities of the CFI. Due to its limited scope and implementation time period, only a brief snapshot of the activities of the fund are given in the current case study. The total budget of the Post-Secondary Institutions Strategic Research Fund is up to CA$2 billion over the course of next three years. The aim of these investments is to modernize the research infrastructure facilities of the post-secondary institutions.[11]

SIF funds projects which are to a large part completed by April 30 2018 and fall into the following three categories:[12]

- improve the scale or quality of facilities for research and innovation, including commercialization spaces;
- improve the scale or quality of facilities for specialized training at colleges focused on industry needs; and
- improve the environmental sustainability of research and innovation-related infrastructure at post-secondary institutions and, college training infrastructure

The fund is operated by Innovation, Science and Economic Development Canada (ISED).

Detailed quarterly reports are the basis for providing the payments to the funds, which refers that the ongoing monitoring is integrated in the funding cycle of the fund.

[10] https://www.innovation.ca/

[11] Wesite of the the programme: https://www.ic.gc.ca/eic/site/051.nsf/eng/home

[12] http://www.ic.gc.ca/eic/site/051.nsf/eng/h_00001.html

The application and reporting requirements of the fund are outlined in the Program Guide[13]. The selection of the projects was done by the ISED in consultation with the Minister of Science and the provinces and territories. The selection was based on a set of assessment criteria – the scope, duration, outcomes and impact, user sector, number of potential users, number and profile of the project partners of the project. The applicants were expected to provide quantifiable impact measures where possible. In addition, the aboriginal considerations and the environmental impact were taken into account. The main aspects that were taken into account in the project selection were: the completeness of the application, readiness to complete the project, and merit based on the potential outcomes and impact. Selected projects where the SIF funding was above $50 million needed to undergo additional steps in the selection and approval process.

ISED reports on the ongoing implementation and effectiveness of this initiative through the Departmental Performance Reports. Periodic updates of progress will also be posted on the program website. Regular reporting allows for tracking the project progress as well as how much funding has been spent throughout the project implementation.

Canada Foundation for Innovation

The Canada Foundation for Innovation (CFI) is the central body providing the RI investments, the Canada case study will thus mainly outline the appraisal, evaluation and monitoring practices of this organisation. The Canada Foundation for Innovation was established in 1997 and aims to provide tools, equipment, laboratory spaces, and other facilities to help Canadian researchers to pursue their academic path and overcome challenges. Receiving funding from the government of Canada, the CFI uses its resources to support the construction of research facilities, installation of new equipment in universities, colleges, hospitals, research organisations and NGOs.

The CFI is funded by the government of Canada, however, it is not considered a government agency. Instead, the organisation has a science funding agreement with the government. The overseeing organisation of the CFI is the Innovation, Science and Economic Development Canada (ISED).

The budget of the CFI has increased over time – from CA$800 million (€560m) in 1997 to CA$ 1.33 billion (€930m) in 2015 – suggesting greater prioritisation of funding for research infrastructures by the Canadian government.

Overall, it is estimated that the Foundation has invested more than 12 billion Canadian dollars (€8bn) in Canadian research infrastructures since it was founded in 1997, with individual projects ranging from tens of thousands of dollars to tens of millions[14].

CFI invests in state-of-the-art research infrastructure through a wide range of funds which address the full spectrum of infrastructure: projects to attract a leading researcher; team-led innovative projects that have a structuring effect for an institution or a region; and large-scale national projects.

The interviews revealed that a dual approach is used in determining the main priorities of the CFI funding activity. Being an independent organization the CFI is not entirely interlinked to federal government activities. However, the general national priorities are taken into account in the top-down prioritizing process. At the same time, the CFI gathers regular feedback and input from the partners on provincial level in order to

[13] http://www.ic.gc.ca/eic/site/051.nsf/eng/h_00002.html

[14] In terms of research support to private sector, see the National Research Council of Canada which links businesses to existing research infrastructure.

better understand their development needs. It is important to note that CFI has designed its funds such that they are limited in number but are able to respond to the regionally different development and support needs. This is further described below.
The CFI funds that specifically target science capital investments are:

- **Innovation Fund** - An instrument aimed at supporting transformative research infrastructure projects. A call was launched in January 2016 with a budget of CA$ 425 million (€298m) for infrastructure costs and CA$ 127 million (€89m) for operating costs
- **The Major Science Initiatives Fund -** This fund contributes to the maintenance and operating costs of the national research facilities to allow them to operate on an optimal level, to adopt best practices in governance and management and to support the researchers in their academic pursuit. It currently funds a share of maintenance and operating costs of 12 national large research institutions – four of these funded in 2012 and eight chosen in 2014. In 2016, another round of CA$ 400 million (€280m) was initiated to cover a share of maintenance and operating costs of Canadian research infrastructure facilities in 2017-2022.
- The **Cyberinfrastructure Initiative** – This provides infrastructure for data-intensive institutions in Canada. The CFI organised two competitions in 2015-2016 and allocated a total of CA$ 40 million (€28m) as part of these.
- The **Infrastructure Operating Fund** - Helps to cover the costs of the projects which have been funded by CFI in order to ensure the optimal use of the infrastructure. The fund provides some flexibility in terms of costs that should be covered in order to allow organisations to allocate them to the costs of the highest priority. In 2015-2016 the fund shared CA$24 million (€17m) to help with operating and maintenance costs of research infrastructure facilities across Canada.

The typical funding cycle of the CFI starts with the budget announcement by the government. The foundation then establishes competitions and schedules, working in cooperation with their stakeholders. The competitions (open calls) are then launched and the research institutions apply through a particular CFI fund. A panel of international experts are then invited to review the proposals and analyse the project propositions, before making suggestions to the CFI Board of Directors. The longer analysis of the appraisal process is elaborated further in the next chapters.
The funding process is supported by the **CFI Awards Management System (CAMS)** which is a secure online portal allowing the recipients to apply for funding and manage pre- and post-funding activities. It is therefore an important tool throughout the stages of application and appraisal, monitoring as well as evaluation to facilitate the funding process and also communicate with the recipients effectively.[15]

4.2 The (ex-ante) appraisal approach

The selection process of projects to fund is called the multi stage review process. The Canada Foundation for Innovation relies in the process on the document called Policy and Program Guide from May 2013 and about to be renewed in the upcoming summer. The main change in the approach in the past few years has been the increase in the importance of the sustainability of the projects.

[15] https://www.innovation.ca/apply-manage-awards/apply-funding/cams

The document outlines the eligibility restrictions and criteria for different types of research organisations. Furthermore, there are a certain set of costs that can be covered with the investment from the CFI funds and some costs that do not qualify as being covered by the CFI. For example, the funds cover research equipment and components, laboratory furniture, software licences etc. costs which occur with acquiring or developing research infrastructure. At the same time, the purchase of property, office supplies, consumables, conference travel etc. items not directly related to research infrastructure are not covered by the funds.

The application process starts off even before submitting the official proposal. Before submitting a proposal, the applicants must issue a strategic research plan outlining their major objectives and focus areas. The university, college or research hospital must also demonstrate that it has met the eligibility criteria[16] and is asking funding for eligible costs only. Furthermore, depending on the area of research, the applicants must adhere to the specific guidelines which they confirm by signing the *Institutional Agreement*.

It is important to note that as the Canada Foundation for Innovation only covers 40% of the eligible project costs, the organisations need to find a partnering organisation to cover the rest of their costs occurred with the research infrastructure investment already before submitting their application. It is very often the provincial government which has set up an additional fund to support projects receiving funding from the Canada Foundation for Innovation funds. For this, the Canada Foundation for Information has agreed to share the necessary application information with the provincial governments as well as take into account their views on the project which also ask for their funding.

The supporting partners could also be companies, departments or agencies of the federal governments, non-profit organisations and individuals. As it was revealed in the interviews, the partnering companies may often decide not to provide monetary support, but supply their products at a great discount rate for the research infrastructure organisation. The organisations may receive this kind of in-kind contributions to cover the capital items or non-capital items that are needed to bring the infrastructure into service. The in-kind contributions to the operating costs of the research cannot be accepted.

The CFI funding decisions are based on the **merit-review process** which involves researchers, research administrators and public sector officials. The main criteria are:

- Quality of the research and its need for infrastructure;
- Contribution to strengthening the capacity for innovation;
- Potential benefits of the research to Canada.

The more specific assessment criteria of individual funds vary, but might include:

- Scientific excellence;
- International competitiveness;
- Need for CFI funding;
- Excellence in governance;

[16] The organisation must have: 1) established the research and training mission, 2) capacity to support and conduct research, 3) full qualification to carry out independent research, 4) sufficient time, facilities and services that enable researchers conduct their work, 5) no institutional constraints on the publication of their results, 6) willingness and ability to administer CFI funding in accordance with the CFI's requirements.

- Excellence in management and operations;
- Institutional capacity and track record;
- Research or technology development;
- Team;
- Infrastructure;
- Sustainability;
- Benefits to Canadians.

As the research focus and future plans of the applying institutions may vary, the specific assessment criteria need to be project-specific. The first stage of review involves the assessment of proposals by Expert Committees who review small groups of related proposals. Expert Committees assess the strengths and weaknesses of the proposals in relation to the six assessment criteria:

- Institutional capacity and track record
- Research or technology development
- Team
- Infrastructure
- Sustainability
- Benefits to Canadians

This is a crucial stage in determining the true potential of each of the submitted applications. As the CFI operates only a small number of funds which are aimed to cater the varying needs and research areas in different provinces, it is the task of the Expert Review Committee to assess the suitability and potential of the funding application. This is a condition which means that the Committee members are identified and invited on board specifically for each of the funding rounds and depending on the focus area of the applications. After the project proposals are received from institutions they are then combined together by research field. Committees of experts around the world then assess proposals depending on their area of expertise. Following that, they will submit a report to the CFI on the strengths and weaknesses of each proposal, depending on the research focus. The responsibility for the members of the committee is even larger due to the fact that they follow a policy document *Conflict of Interest and Confidentiality*[17] in their work and also have strict guidelines given by the CFI in performing the review[18].

The second stage of the appraisal process involves Multidisciplinary Assessment Committees (MAC), where multidisciplinary individuals from across the globe with a deep understanding of the research and innovation landscape perform yet another review on the submitted proposals[19]. As a result, 40 proposals will be left to be investigated in terms of which of these could best fit the set criteria of the specific funding competition. The criteria generally include the excellence of the proposed research activities, the expertise of the research team and the partnerships developed,

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[17] Conflict of Interest and Confidentiality, Government of Canada: http://www.science.gc.ca/eic/site/063.nsf/eng/h_90108244.html?OpenDocument

[18] For example, the Guidelines for Expert Committees serves this purpose: https://www.innovation.ca/sites/default/files/Funds/2017_guidelines_for_expert_committees_final.pdf

[19] They are assisted by special guidelines, called Guidelines for Multidisciplinary Assessment Committees: https://www.innovation.ca/sites/default/files/Funds/2017_guidelines_for_mac_en.pdf

the innovativeness capacity enhancement aspect of the proposal, and the potential benefits to Canadians.

The MACs will review proposals grouped with others of similar size and/or complexity, on the basis of the three competition objectives:

- Objective 1: Strive for global leadership by conducting world-class research or technology development activities in areas of institutional strategic priority.
- Objective 2: Enhance research capacity by forging productive partnerships within and among institutions, sectors and disciplines for the effective and sustainable use of the research infrastructure and facilities.
- Objective 3: Generate social, health, environmental and/or economic benefits for Canadians, including better training and improved skills for highly qualified personnel, through appropriate pathways.

The third and final stage involves the Special Multidisciplinary Assessment Committee (S-MAC). The S-MAC is charged with ensuring consistency among the MACs, and in instances where MAC recommendations exceed the available resources, the S-MAC recommends to the CFI Board of Directors the proposals that most effectively support the CFI's mandate, meet the objectives of the competition and represent the most effective portfolio of investments for Canada.

While the general objectives and criteria of the CFI funds are mostly similar, each of the funds may have some more specific objectives with their respective criteria and indicators for reflecting the level of achieving the results.

For example, the objectives, criteria and criteria standards (can be compared to indicators) for the Innovation Fund are following:

Table 1 Objectives, criteria and standards for criteria of the CFI Innovation Fund

Objective 1: Strive for global leadership by conducting world-class research or technology development activities in the areas of institutional priority	
Institutional capacity and track record	Criterion standard: The proposal builds on existing capacity and track record of key investments in people and infrastructure in the area of institutional priority
Research for technology development	Criterion standard: The research or technology development activities are innovative, feasible, have the potential to lead to breakthroughs, and will enhance international competitiveness
Team	Criterion standard: The team is comprised of established or emerging leaders and has the expertise and breadth, including relevant collaborations, to conduct the research or technology development activities
Objective 2: Enhance research capacity by forging productive partnerships within and among institutions, sectors and disciplines for the effective and sustainable use of the research infrastructure and facilities	
Infrastructure	Criterion standard: The infrastructure is necessary and appropriate to conduct the research or technology development activities

Sustainability	Criterion standard: The infrastructure is optimally used within and among institutions, sectors and disciplines and is sustainable through tangible and appropriate commitments over its useful life
Objective 3: Generate social, health, environmental and/or economic benefits for Canadians, including better training, improved skills for highly qualified personnel, through appropriate pathways	
Benefits to Canadians	Criterion standard: The research or technology development results will be transferred through appropriate pathways to potential end users and are likely to generate social, health, environmental and/or economic benefits for Canadians

4.3 Monitoring and evaluation

The Board of Directors plays a key role in the directions and actions of the CFI. It consists of 13 individuals with different backgrounds. The Government of Canada appoints six members while the rest are appointed by the members of the CFI. The members of the Board have tasks in four committees: audit and finance, investment, governance and nominating, members' governance and nominating committees. It also reports to a higher governing body, consisting of members of the CFI. The CFI is governed by a Board of Directors, seven of whom are appointed by the CFI members (a group of accomplished individuals drawn from all sectors of Canadian society), and six of whom are appointed by the Government of Canada (also accomplished individuals drawn from all sectors). The Board of directors holds fiduciary responsibility for all CFI awards and oversight of both strategic decisions and general operations. This governance structure is specified in the CFI's founding legislation; the Budget Implementation Act of 1997. The management of CFI is the responsibility of the President and CEO, supported by three vice Presidents and the professional program staff.

To best support the recipient organisations in managing the funded projects the CFI has issued guidelines and provides assistance to the organisation. However, all recipient institutions are considered responsible for timely implementation of their CFI-funded project as well as providing necessary input to monitoring and evaluation activities.

An integrated strategy is used at CFI to monitor and assess the risk and performance. On the one hand, it involves monitoring the achievement of established outcomes and outputs. The other side of the monitoring activities concentrate on the institutional compliance and project results through operational and financial procedures.

A risk-based approach has been adopted by CFI in the oversight and monitoring of the financed projects. A Tool for Risk Assessment and Management (TRAAM) has been adopted for this purpose. The tool has two components: the CFI's risk assessment and a summary of the CFI's oversight activities commensurate with the identified project-related risks. In order to identify the project-related risks, the CFI works closely with the managing team of each of the funded organisation. As such, the most relevant risks are identified and incorporated in TRAAM. The risk assessment is revisited annually for each of the funded projects or more frequently if there is a need. The oversight and monitoring activities are adjusted accordingly. For example, if the result of the risk-based approach shows that the project falls into a higher risk category, it is monitored more closely and the organisation may need to report on its activities more frequently. The aspects which may place the project in a higher-risk category include the large funding size, delays in award finalization and project implementation, deviations in the financial performance when compared to the plan etc.

These monitoring activities depend on the risks of specific projects and can include meetings, financial reporting, project status reports, site visits, contribution audits etc.

In order to make sure that the organisations that have received funding are accountable to CFI, they must submit various reports and overviews. For all projects above CA$ 1 million, the financial report must be submitted every year by June 15th (every second year for smaller projects). For certain projects, quarterly or semi-annual financial reports may be requested by the CFI. The organisations that have received funding are also required to develop and periodically update their strategic research plans, as well as submit their communications plans.

One of the main sources of information that contributes to both monitoring and evaluation activities are the project process reports submitted by the recipient organisations. The projects above CA$ 1 million will start submitting these reports three years after finalising the awarding process and must submit the yearly report for four or five years, depending on the scale of funding. The project process reports provide information about a number of indicators: attraction and retention of researchers; training of highly qualified personnel; research productivity; partnerships and collaborations; and social and economic benefits. The report also provides information on issues such as operation and maintenance and the useful life of the infrastructure. This information is compiled annually on *the Report on results* of CFI[20].

CFI outlines the importance of site visits in their oversight and monitoring activities. The visits help to understand whether the funds have been used for their intended purposes, confirm sound project management practices at the institution and provide input to monitoring. In addition to the oversight activities, the monitoring visits provide value for the institutions by helping to disseminate the information on the CFI activities and policies and sharing the knowledge.

All of the projects that have an approved budget of more than CA$ 10 million, will be subject to a contribution audit of the institution. A selection of other projects is audited based on the risk-based audit approach, which considers criteria such as the value of CFI contribution or the complexity of the project.

The evaluation approach of the Canada Foundation for Innovation has changed over time. While at the times of its start, measuring the impacts of their investments focused primarily on the brain drain, the Canada's infrastructure deficit and reversing the brain drain, nowadays the focus of impact evaluation is much wider. The interviews revealed that there is a growing expectation in Canada as elsewhere in the World to seek understanding of the wider impacts of the research infrastructure investments – the tangible outcomes and results of the investment, the societal impacts, economic impacts and impact on the quality of life.

The CFI has a thorough evaluation approach in place which is based on the *Performance, evaluation, risk and audit framework (PERAF)*[21] from March 2015

[20] For example, the 2015 Report on results is available here: https://www.innovation.ca/sites/default/files/essential_documents/cfi-2015-report-on-results-en-web.pdf

[21] Performance, evaluation, risk and audit framework, 2015, https://www.innovation.ca/sites/default/files/pdf/PERAF%202015%20-%20Final.pdf

(initially introduced in 2008). This is a toolkit and a guide on managing the risks and assessing the performance of CFI in relation to its objectives and outcomes. The PERAF thus approaches to the whole organisation of the CFI and outlines the profile, risk assessment and management plan, collecting information and reporting on the CFI's performance and an evaluation strategy.

The Evaluation and Outcome Assessment (EOA) team in CFI analyses the outcomes of the CFI investments to ensure the most appropriate policy and programme design. The EOA team also tracks the economic and social outcome of the CFI's investment to ensure the organisation's accountability in face of its stakeholders – the general public, the Board of Directors, the Government of Canada etc. The data is gathered and analysed using the Overall performance evaluation and value for money audit, the outcome measurement studies, the evaluations of CFI's programs and special studies.

The tasks of the EOA is not limited to planned systematic performance evaluations only. The department also has ongoing evaluation projects which look into specific outcomes and impacts of the funding. For example the national thematic assessments which concentrate on a certain field and be more large-scale, such as the ongoing study about the funding impacts on the agriculture sector. They may also be more limited in the implementation time and scope, for example touch upon the impacts of the funding on attracting students and scientists in certain institutions which have received funding from the CFI. The representatives of the CFI emphasised that these project-based evaluations and outcome assessments follow the need of their stakeholders and the topics are agreed upon mutually.

An important challenge for the EOA is the communication of the results of the CFI internally and externally. In time, the organisation has started to use a shorter and more visual format of presenting the outcomes and impacts of the CFI. One example of this is the recently adopted approach to provide brief one-page overviews of the outcomes in different aspects on the intervention logic framework outcome and impact level[22].The approach entails giving a graphic and detailed overview in one particular aspect, be it the gained networking effects, skills and expertise or knowledge advancement targets on the level of outcomes or the impact level outcomes of innovation supported or general social, economic and environmental benefits of the activities of the CFI.

This kind of visualisation approaches provide important stakeholders with quick snapshots of the current status and developments in specific areas, instead of giving them obligation to find information from long information-heavy reports. This serves well the Board of Directors of the organisation who are able to grasp the most important aspects easily and quickly, pointing out the specific fields themselves where more information is needed. This characterises once again that the engagement and discussions with the stakeholders hold an important place in the work of CFI.

In time the approach towards monitoring and evaluation activities in the CFI has changed. Previously the monitoring system relied on the organisations participating extensively in the process. The institutions had to write their own assessment report which was then reviewed by an international panel. It started to appear that the approach may not serve its purpose, as many of the institutions receiving funding were overwhelmed with the requirements. Another criticism toward the approach was the fact that the resulting reports were not made public. Since then, the approach has changed. The CFI is mostly making their final reports public or sharing them with the

[22] CFI logic model: https://www.innovation.ca/sites/default/files/pdf/cfi_logic_model.pdf

relevant stakeholders. Since the monitoring requires extensive reporting by the receiving institutions anyway, the evaluation and outcome studies now entail more data collecting activities by the CFI itself.

Another aspect to point out in the outcome assessment and evaluation as well as monitoring activities is the cooperation with the provincial governments that partner with the institutions to provide additional funding. Some of the government cooperate with the CFI in gathering the oversight and monitoring data, as well as in performing evaluations. There are some which rely on the CFI sharing the most crucial information with them. However, some of the provincial governments have put in place their own monitoring and oversight systems. This can double the administrative burden of the funding recipients.

Between 2010 and 2015 the CFI was obliged to perform *Overall performance evaluation and value-for-money audit* (OPEA) at least every five years to evaluate the effectiveness and efficiency of the use of its funds. This was part of CFI's agreement with the Government of Canada. The first OPEA was performed in 2010 and the second one in 2015[23]. However, since the renewal of the CFI's Contribution Agreement with the Government of Canada in 2015, the OPEA is no longer required.

4.4 Summary of key strengths and weaknesses

- Making the decisions on the field of innovation (and other fields) is characterised by bottom-up approach. Instead of following long term development and implementation plans, the action plan is being adjusted based on the consultations and input of the stakeholders on the regional level. For example, the research institutions in Canada regularly submit their research plans to Canada Foundation for Innovation who reviews their approach and opportunities based on that. Consultations with stakeholders are held on a regular basis to understand that the activities of the CFI best meet their needs.
- The CFI evaluation and appraisal system focuses to a large extent on an individual and cooperative approach. In the appraisal process, the focus and potential of each of the applications is being assessed separately and involving the field experts. At the same time, the risk-based monitoring system also requires an individual approach to each of the organisations, their needs and potential shortcomings.
- The individual approach throughout the funding cycle meets well Canada's needs – a small number of RI funds are able to accommodate a large variety of organisations and needs which differ based on regional economies and research focus. Good ideas are not left out due to unnecessary limits.
- The CFI Evaluation and Outcome Assessment (EOA) department is built up on the approach of serving the needs of the ones who need the information they provide. The department chooses the project based research topics based on the consultations with their stakeholders. This means that the approaches of the outcome assessment and evaluation is evolving constantly.
- In addition to choosing their topics based on the needs of their stakeholders, the EOA puts a lot of emphasis on the presentation of the outcomes and impacts of the

[23] The reports of these general evaluations and audits can be found here: https://www.innovation.ca/results-impacts/assessing-risk-performance/framework-evaluations

CFI's activities. In recent years a more concise and visual approach has been adopted.

- A drawback of the system is the aspect that the monitoring and outcome assessment activities are not always in line with the requirements and expectations of the provincial governments. Many of the provincial governments have good cooperation ties with the CFI in sharing monitoring and oversight information about the projects funded by both of the parties. At the same time, some of the provincial governments have their own oversight and monitoring system which can double the burden of the institutions receiving funding.

4.5 Sources

4.5.1 Documentary sources

Policy and Program Guide, 2013
The Budget Implementation Act, 1997
CFI, Results and impacts: https://www.innovation.ca/results-impacts
CFI, Performance evaluation, risk, and audit framework (PERAF)
CFI Logic model: https://www.innovation.ca/sites/default/files/pdf/cfi_logic_model.pdf

4.5.2 Interview Partners

Mr. David Moorman – Senior Advisor, Policy and Planning, Canada Foundation for Innovation
Ms. Laura Hillier – Director, Evaluation and Outcome Assessment, Canada Foundation for Innovation
Mr. Tim Franklin – Senior Advisor, Science & Research Branch, Ministry of Research, Innovation and Science
Mr. Mohammad Nasser-Eddine – Director of Programs

4.6 Supporting Material

In the following, the performance measurement framework of CFI is presented. This table is taken from Appendix C of the Performance, evaluation, risk and audit framework (2015).

	PERFORMANCE MEASURE	DATA SOURCE(S)	RESPONSIBILITY FOR DATA COLLECTION
Context			
Research funding environment	Federal granting agency funding (000's)	Government of Canada, main estimates	Evaluation and outcome assessment (EOA)
	CFI disbursements as a percentage of federal granting agency funding (%)	Finance database	EOA and Finance
	CFI commitments as a percentage of federal granting agency funding (%)	Finance database	EOA and Finance
Inputs			
Financial and non-financial resources	Annual federal payments to the CFI ($)	Finance database	Finance
	CFI's annual operating budget ($)	Finance database	Finance
	Number (#) of fulltime staff	Human resource database	Human Resources
Activities			
Engage stakeholders, adapt program architecture, manage application and review process, administer awards, monitor and track performance and report on results	Number (#) of formal interactions, by audience	Various	EOA, External relations and communications (ERC), Finance, Programs, senior management
	Number (#) of full applications received, in total and by fund	Programs database/ CFI Award Management System (CAMS)	Programs
	Number (#) of monitoring visits completed	Finance database	Finance
	Number (#) of contribution audits performed	Finance database	Finance
	Proportion (%) of financial reports received by CFI deadline	Finance database	Finance
	Proportion (%) of project progress reports received by CFI deadline	CAMS	EOA
Outputs			
Deliver new and ongoing Funds through competitions	Number (#) of active Funds	Programs database/ CAMS	Programs
	Number (#) of new Funds and competitions launched	Programs database/ CAMS	Programs
	PERFORMANCE MEASURE	DATA SOURCE(S)	RESPONSIBILITY FOR DATA COLLECTION
Awards and disbursements for research infrastructure and operations and maintenance	Number (#) of new awards, by Fund (new commitments)	Programs database/ CAMS	Programs
	Value ($) of new awards, by Fund (new commitments)	Programs database/ CAMS/Finance database	Programs and Finance
	Number (#) of awards, by Fund (on-going disbursements)	Programs database/ CAMS	Programs
	Value ($) of awards, by Fund (on-going disbursements)	Programs database/ CAMS/Finance database	Programs and Finance
Communicate information for decision-making and accountability	Number (#) of published editorials	Communications database	ERC
	Number (#) unique visitors to Innovation.ca, by page	Communications database	ERC
	Number (#) of subscribers to Innovation Now	Communications database	ERC
	Number (#) of newsletters sent and opened by group/population	Communications database	ERC
	Number (#) of click-throughs to Innovation.ca content by social media platform	Communications database	ERC
Outcomes and impacts			
World's top researchers attracted and retained	Number (#) of researchers attracted to the institution due to the infrastructure, by sector and by country	Project Progress Report (PPR)	EOA
	Number (#) of researchers retained by the institution due to the infrastructure	PPR	EOA
	Percentage (%) of CRC holders among above researchers	CCV data	EOA
Capacity to conduct world-class research and technology development enhanced	Rating of the quality of the infrastructure, by type	PPR	EOA
	Useful remaining life of the infrastructure, by type	PPR	EOA
	Extent to which the infrastructure was utilized	PPR	EOA
Training environment enriched	Level of the impact the infrastructure had on the quality of the training environment	PPR	EOA

	PERFORMANCE MEASURE	DATA SOURCE(S)	RESPONSIBILITY FOR DATA COLLECTION
	Number (#) of distinct types of research disciplines	CCV data	EOA
Productive teams, networks and collaborations established	Number (#) of researchers at the institution advancing their research (# internal users)	PPR	EOA
	Number (#) of researchers outside the institution advancing their research (# external users), by sector and region	PPR	EOA
	Research collaboration enabled by the infrastructure, number (#), type, region and sector	PPR	EOA
Skills and expertise acquired by highly qualified personnel	Number (#) of trainees using the infrastructure as a key resources	PPR	EOA
	Number (#) technical personnel trained on the use and maintenance of the infrastructure	PPR	EOA
	Number (#) highly qualified personnel completed training	PPR	EOA
Knowledge advanced	Number (#) of research outputs, by type	PPR	EOA
Innovation supported	Number (#) of research agreements, by type and region	PPR	EOA
	Number (#) of intellectual property rights, by type	PPR	EOA
	Number (#) of licensing agreements	PPR	EOA
	Number (#) of spin-off companies	PPR	EOA
Canada benefits socially, economically and environmentally	Number (#) of benefits, by type	PPR	EOA
	Number (#) of new job creation	PPR	EOA

5 Denmark

5.1 The process of allocating science capital funding

The Danish National Fund for Research Infrastructure is a specially designed programme for funding large-scale research infrastructure. It was established in 2006 using funding from the Danish Globalisation Fund. The Minister for Higher Education and Science is the responsible authority and it allocates money to the Fund each year through the national budget. The purpose of the Fund is to establish and promote national strategic research infrastructure.[24]

The Danish Ministry of Higher Education and Science invested €104 million in 2015 in large research infrastructure (i.e. that exceeding €1 million). According to the Danish Roadmap for Research Infrastructure 2015, the general trend has been for the Ministry to increase its investment in this area over recent years. This is mainly a result of recent investments in large international research infrastructures, such as European Spallation Source (ESS), as at the same time the funds for open investments for research infrastructure have been reduced from 32% of the Ministry’s investments in research infrastructure in 2007 to just 9% in 2015.[25]

Since its establishment, the National Fund for Research Infrastructure has gone through three different phases.[26] In the first phase (2007-2009) the Danish Research Coordination Committee along with international panels of experts made recommendations for allocations. The second phase (2010-2014) was a roadmap-model, influenced by models of other European countries, whereby proposals were examined by six expert panels before establishing a roadmap in 2011. The third phase (2015-present time) is based on the current Danish Roadmap for Research Infrastructure 2015. The proposals from the management of universities and research institutes for specific research infrastructure supports decisions and prioritisations regarding investments in research infrastructure. Contrary to the second phase, the third phase does not involve expert panels.

According to the interviewees, one experience from the first phase was that too many proposals were received and that no clear strategies or criteria were in place for the allocation and appraisal process. In addition, no scientific national strategy was in place for the research infrastructures. Therefore, it was decided for a shift towards a roadmap model in line with other European countries with a national priority setting and decision support for the Minister´s allocations. For example, the introduction of the six expert panels supported scientific prioritisation within six research areas. The experiences from the second phase was that even with the introduction of the scientific panels no clear national strategy was in place. In addition, many of the applicants were individual researchers or research groups without a clear support from the management of the universities. For the third phase, based on the previous experiences a National Committee for Research infrastructure (NUFI) was introduced for the purpose of advising on national priority settings. In addition, proposals for the 2015-

[24] Danish Agency for Science, Technology and Innovation (2015). Danish Roadmap for Research Infrastructures 2015. Danish Agency for Science, Ministry of Higher Education and Science.

[25] Danish Agency for Science, Technology and Innovation (2015). Danish Roadmap for Research Infrastructures 2015. Danish Agency for Science, Ministry of Higher Education and Science.

[26] Danish Agency for Science, Technology and Innovation (2015). Danish Roadmap for Research Infrastructures 2015. Danish Agency for Science, Ministry of Higher Education and Science.

roadmap were submitted by university management and typically signed by the rectors of the universities.

The interviewees state that each phase has been an improvement compared to the previous phase. Furthermore, the interviewees mean that one of the main advantages with the current phase compared to earlier phases is that it is more efficient and fast. Further on, the commitment of the universities has improved in the current phase (more about this in section 1.2).

In 2013, the Danish Agency for Science, Technology and Innovation also appointed the National Committee for Research Infrastructure (NUFI). This committee includes representatives from Danish universities and the Danish Council for Independent Research, while the Danish National Research Foundation has an observing role. NUFIs role is to prepare for decisions and agreements on establishment, prioritisation, financing and continuation of research infrastructures (international and national), as well as to promote optimal usage of the research infrastructures.[27]

Proposals for research infrastructure investments are submitted in open competition. These investments should promote excellent research and have a high scientific value for the involved actors. Co-funding of 50% is required, and this funding usually stems from the main target groups of universities and/or research institutes. The projects should have open access and promote the entire Danish research and innovation-community and optimal usage.[28] Thus, the objectives of the funding scheme are to promote scientific, industrial and societal added value.

In recent years, there has been an increased focus in Denmark on national level commitment (interinstitutional collaborations) and international collaborations with regard to research infrastructure investment.

5.2 The (ex-ante) appraisal approach

The ex-ante appraisal process is based on the catalogue in the Danish Roadmap for Research Infrastructures 2015. The catalogue consists of concrete proposals for public investments in research infrastructure. The process consists of four stages: priority settings by the research institutions; recommendation from NUFI to the Ministry of Higher Education and Science; deliberations by the Ministry of Higher Education and Science; and a final decision and selection of proposals from the catalogue by the Ministry of Higher Education.

In the first stage, the management of the universities and research institutes were invited to submit proposals for national research infrastructures as part of national consortia. The management of universities and research institutes were involved in the proposal process and in making decisions to ensure that investments in research infrastructure for the following five years (2015-2020) are in line with the strategies of the research institutions. The submitted proposals could either be upgrades of existing research infrastructure or the establishment of new research infrastructure. All main research fields and all kinds of research infrastructure were eligible in the proposals.

The proposals had to meet the following five criteria:

- To be of national interest and support the research institutions strategies as well as being of a great scientific value

[27] Danish Agency for Science, Technology and Innovation (2015). Danish Roadmap for Research Infrastructures 2015. Danish Agency for Science, Ministry of Higher Education and Science.

[28] Danish Agency for Science, Technology and Innovation (2015). Danish Roadmap for Research Infrastructures 2015. Danish Agency for Science, Ministry of Higher Education and Science.

- To be long term and scientifically, financially and technologically mature enough within five years
- To be open for access (as in non-exclusive consortia) for all interested researchers no matter their research institution
- Co-funding of 50% from research institutions, and when established the research institutions have the operational responsibility for the research infrastructures
- If relevant, a linkage with international research infrastructure

In addition, proposals were asked for societal, industrial and scientific prospects.

In the next stage NUFI reviewed the submitted proposals and advised the Danish Agency for Science, Technology and Innovation to include 27 proposals in the catalogue. Then the Ministry evaluated the proposals and had their own prioritisation process based on industrial and innovation value. The outcome of the independent evaluation was that 22 of 27 recommended proposals were listed in the catalogue. NUFI and the Ministry of Higher Education and Science used the five criteria as the basis for their evaluation of the proposals. Finally, the Ministry ensured that all of the 22 proposals covered all main research areas and were supported by an average of at least four research institutions.[29]

According to the interviewees, NUFI qualitatively assessed the proposals by the five criteria. NUFI ranked the proposals on a three-grade scale (A = Need to be discussed further, B = More information needed before further discussions and C = Rejected without further discussion needed). NUFI discussed and ranked (using same A to C-scale) the proposals on two occasions before making recommendations to the Danish Agency for Science. The interviewees state that the assessment of the proposals is based on the plan described in the proposals and is solely a qualitative assessment without any scoring mechanisms. The following content of the proposals is used to assess the proposals: character, purpose and context; scientific perspective; societal and business perspective; project organisation and consortia; project and time schedule; budget and funding of the infrastructure; host institution and partners; leadership of the infrastructure. For example, the scientifically, financially and technologically maturity of the infrastructures are qualitatively assessed case by case based on the information in the proposals. According to one interviewee, this can regard an assessment and qualitative analysis of the matureness of the ideas and plans presented in the proposals.

One interviewee adds, the prioritisation of the proposals was not only based on the scientifically, financially and technologically maturity but also on evolvement and future impact. The same interviewee explains that if the assessment was only based on scientific quality, the same infrastructures would be funded over a long period of time and the development would stagnate. Instead, the proposals were also qualitatively assessed regarding evolvement and possible future impacts.

According to one interviewee, the initial assessment made by the universities is probably the best measure to assess the matureness of the infrastructures. The same interviewee explains that considering the high requirement of co-funding it is in the

[29] Danish Agency for Science, Technology and Innovation (2015). Danish Roadmap for Research Infrastructures 2015. Danish Agency for Science, Ministry of Higher Education and Science.

universities self-interest to make a proper assessment of the proposals and to fund mature infrastructures to ensure good investments.

The five criteria used to assess the proposals cover non-market impacts such as scientific value. According to the interviewees, the proposals are qualitatively assessed case by case. Since the five criteria need to be met by the proposals, they are not strictly weighed against each other. One interviewee explains that maturity of the proposals is important along with scientific quality have been important when assessing the proposals. Furthermore, the same interviewee means that it is important that the research infrastructure is not only assessed by scientific excellence and that it also should contribute to evolvement.

The interviewees explain that the portfolio of the research infrastructures have to cover all scientific areas. The scientific areas are: biotech, health and life sciences; energy, climate and environmental sciences; physical sciences; humanities and social sciences; materials technology and nanotechnology. However, the number of proposals can differ between the different scientific areas. All interviewees explain that the current portfolio meet the demand of covering all scientific areas. In addition, the Ministry of Science and Education expects that on average each infrastructure should have support from at least four universities. This to ensure that all relevant research groups in Denmark are represented in the infrastructures. One of the interviewees adds that it was clear that the overall portfolio of infrastructures also promoted industrial impacts (are of relevance for the industry) and job creation.

The only hard criteria for assessing whether the infrastructures are in line with the strategies of universities and research institutions is the pledged co-funding of 50 %. According to the interviewees, the requirement of 50 % co-funding is a very good indicator that the infrastructures are aligned with the strategies of the universities and research institutions. One of the interviewees states that the internal assessment of the infrastructures made by the universities as well as the co-funding requirement are both crucial to ensure a strong commitment of the universities. The involvement of the top management of the universities and of the rectors ensures that the infrastructures are in line with the strategies of the universities. One interviewee means that if an infrastructure was not in line with the strategies it would simply not be submitted considering the high requirement of co-funding. According to the interviews, the universities have been forthcoming regarding the rather high requirement of co-funding.

According to the interviewees, one concrete example of an infrastructure proposal in line with the strategies of the universities is a proposal submitted last year regarding drones. The establishment of a centre for drones has for a while been a top priority for one of the Danish universities. Last year the university along with others submitted a proposal about establishing a research infrastructure for developing the drone technology as well as using drones in research.

The rationale behind the change from expert panels towards a stronger involvement of the top management of the universities was to ensure the commitment of the universities as well as increasing the scope of the assessments. One interviewee explains that the experts that assessed the proposals in the previous phase had a good position within their research field and scientific expertise. However, the expert panels focused on their specific research area when assessing the proposals. Therefore, other important aspects such as societal challenges and industrial aspects were partly missed in the assessment of the proposals. One interviewee mentions that to the next phase an international expert group might be involved when assessing the proposals for infrastructure investments.

The catalogue serves as a tool for the decisions and prioritisations of allocations for research infrastructure to 2020, although the proposals listed in the catalogue are not guaranteed funding. (During the period 2015-2020, one of the main objectives for the Ministry of Science and Education is to fund 15 of the catalogue's research infrastructure projects.[30]) NUFI advises the Ministry of Higher Education and Science of allocating funds to the prioritised research infrastructures, the Ministry then makes the final decision using the same criteria as for the proposals. The Ministry's funding of the research infrastructures together with the 50 % co-funding goes to the implementation and construction of the research infrastructures. The involved university and research infrastructure partners in the consortium of a given research infrastructure are expected to cover operational costs after the implementation phase.

5.3 Monitoring and evaluation

Each of the granted research infrastructures is obliged to report annually the Ministry of Higher Education and Science in order for the Ministry to monitor the progress of the research infrastructure. In addition to financial information, the main parts of the annual reporting scheme are:[31]

- The Research Infrastructure
- – Construction, establishment and purchase (for example machines and software)
- – Project plan and time plan
- – Access policy (all infrastructures must have a defined access policy for academic and industrial users)
- – Data management and availability
- – User support (for academic and industrial users)
- – Competence building (courses, information and educational material)
- – Outreaching activities (meetings, newsletter etc.)
- – Operational plans for the research infrastructure when the programme period has ended (only in final report)
- Scientific return
- – Number of users (if possible share of institutional users and international users)
- – Publications (based on use of data from the infrastructure)
- – International cooperation (for example within ESFRI)
- – Mobility, training and recruiting (for example PhD and postdocs)
- Added value for society and industry
- – Cooperation with other than the research institutions (for example enterprises, GTS-institutes and innovation networks)

[30] Danish Agency for Science, Technology and Innovation (2015). Danish Roadmap for Research Infrastructures 2015. Danish Agency for Science, Ministry of Higher Education and Science.

[31] http://ufm.dk/forskning-og-innovation/tilskud-til-forskning-og-innovation/administration-af-bevilling/skemaer/rapportskemaer/filer/afrapportering-forskningsinfrastruktur.pdf

- Users other than research institutions (for example enterprises, GTS-institutes and innovation networks)
- New technologies, methods and processes based on results from the research infrastructure
- New products based on results from the research infrastructure
- New enterprises based on results from the research infrastructure
- Added value for society (for example cooperation with authorities and other organisations)

- Other
- New applications for research infrastructure or research projects based on results of the infrastructure (for example for EU-funds or private foundations)
- New funds to research infrastructure or research projects based on results of the infrastructure (for example from EU-funds or private foundations)
- Requests for changes that require approval
- Changes in the research infrastructure
- Changes of professional contact
- Changes of the consortia
- Other changes

The final reports from the research infrastructures serve as the main evaluation tool. The final reports are similar to the annual reports, but with an additional 1,000 words of scientific, societal and industrial impacts. No quantitative evaluation system is in place. One interviewee means that the annual reports serve as basis for monitoring the infrastructures and to check if they are on the right track by the initial plan. The Ministry of Higher Education and Science may request a meeting with the responsible for the infrastructure if the infrastructure is considered to not be on the right track. According to the interviewees, it is difficult to evaluate any impacts of the infrastructures since most impacts are only visible after a long time and the funding only covers the implementation and construction period, typically 5 years. The interviewees mention that the spillover effects and other effects are not specifically evaluated. However, each infrastructure is ex-ante asked to describe the expected future impacts and spillover effects generated by the infrastructure.

5.4 Summary of key strengths and weaknesses

In general, the Danish system (allocation, ex-ante appraisal and monitoring/evaluation) for research infrastructure investments are well-developed and thoroughly measured. The Danish roadmap is influenced by other European roadmaps for research infrastructure investments, but with some own characteristics. One characteristic is the involvement of the top management of the Danish universities in the prioritisation and appraisal processes. Based on two country characteristics, this is suitable for Denmark. First, the university management is considered to be strong in Denmark and therefore it is important to involve the top management of the universities to ensure their commitment and support of the infrastructures. Second, Denmark is a small country with a small number of universities in comparison to most other countries. This means that it is a manageable task for the Ministry of Higher

Education and Science to involve all the universities and to ensure their commitment. The process for prioritising and funding infrastructure has become faster since the introduction of peer reviewing by universities instead of using expert panels. The conclusion is that the main strengths of the Danish system for infrastructure investments are the fast and smooth appraisal and allocation processes and that the appraisal processes ensures the commitment of the universities.

One potential weakness of the Danish system for infrastructure investments is that the peer review of the infrastructures is made by the universities themselves. Even if this promotes the commitment of the universities as well as maturity of the infrastructure, it is likely that the academic needs are promoted before societal and industrial needs. However, the primary purpose of the Ministry's funding of research infrastructure is to cover the academic need. Another potential weakness is that the assessment of the infrastructures is solely qualitative. This means that a consistent assessment relies on the expertise by the members of NUFI. On the other hand, the members of NUFI and in the Ministry itself have a thorough knowledge and experience of infrastructure investments that should ensure a consistent assessment.

One aspect that makes it difficult to transfer the Danish system for research infrastructure to other countries is that the Minister of Higher Education and Science makes the final decision of prioritisations and allocations. However, certain parts of the Danish system are transferable to other countries with smaller modifications regarding the final decisions. For example, the involvement of top management of the universities in the appraisal process is likely to fit other smaller countries.

5.5 Sources

5.5.1 Documentary sources

- Danish Roadmap for Research Infrastructures 2015, the Ministry of Higher Education and Science
- Danish Roadmap for Research Infrastructures 2011, the Ministry of Higher Education and Science
- Report documents
- ufm.dk
- dst.dk

5.5.2 Interview Partners

- Interview with Lars Christensen at the Ministry of Higher Education and Science
- Interview with Katinka Stenbjørn at the Ministry of Higher Education and Science
- Interview with Henrik Bindslev Dean at the Faculty of Engineering at the University of Southern Denmark, also member of NIFU.

6 Finland

6.1 The process of allocating science capital funding

The first Finnish **research infrastructure roadmap** was published in 2009. This roadmap and its recommendations resulted in a broader discussion of Finland's research infrastructures. In autumn 2011, Finland's Ministry of Education, Science and Culture assigned the task of administering the country's national research infrastructure policy to the Academy of Finland (a funding agency for basic research). The Academy was to establish a broad-based committee of experts for this purpose. Accordingly, the Finnish Research Infrastructure Committee (FIRI Committee) was established in spring 2012 and its tasks were included in the Act of the Academy of Finland in summer 2014. The current roadmap for 2014-2020[32] was approved and published in December 2013.

The **FIRI Committee** at the Academy of Finland monitors and develops Finnish and international research infrastructure activity, provides funding to infrastructure projects and monitors funded projects. FIRI comprises key actors in research infrastructure policy, such as representatives of the Academy of Finland; the Ministry of Education, Science and Culture; the Ministry of Employment and the Economy; the Ministry of Social Affairs and Health; Tekes – the Finnish Funding Agency for Innovation; Finnish universities; Universities Finland UNIFI; state research institutes; the Council of Research Institute Directors; and the Rectors' Conference of Finnish Universities of Applied Sciences.

Specific provisions have been made in the state budget for the funding of research infrastructures to implement the roadmap and to give the possibility to develop new initiatives. This **earmarked infrastructure funding** is allocated to the budget of the Academy of Finland and administered by the FIRI committee. The annual earmarked budget for research infrastructures is currently €18.5m, while in 2014 and 2015, funding decisions amounted to €17.0m and €17.8m respectively. The Academy of Finland strategy indicates targeted increases in research infrastructure funding in the future. However, budget allocations have not allowed this so far.

This earmarked funding covers only a part of total research infrastructure funding, which is estimated to have been at least €200m per year over the 2014-2018 period overall. Within this, membership fees in international research infrastructures alone account for almost €40m, while other funding for research infrastructures is provided by host organisations, different ministries and Tekes – the Finnish Funding Agency for Innovation.

The earmarked infrastructure funding is allocated based on **annual calls**[33]. The calls are partly open (proposals aligned with the national roadmap, and proposals for new non-roadmap initiatives) and partly targeted (proposals invited only from organisations responsible for Finnish coordination of international research infrastructures where Finland is a member[34]). Eligible applicants are hosts of research infrastructures (national roadmap infrastructures call, new non-roadmap infrastructures call), or invited national coordinators (call for international research

[32] http://www.aka.fi/globalassets/awanhat/documents/firi/tutkimusinfrastruktuurien_strategia_ja_tiekartta_2014_en.pdf

[33] The latest call was in April, 2016. The next call will be in 2018, i.e. no call in 2017. For details of the 2016 call, see chapter 4.1 in http://www.aka.fi/globalassets/10rahoitus/hakuilmoitukset/huhtikuun_hakuilmoitus_2016_en.pdf

[34] Finland is a member in CERN, EMBL, ESO, ESA, ITER, IIASA, several ESFRI infrastctures, and other, see http://www.aka.fi/en/research-and-science-policy/research-infrastructures/

infrastructures where Finland is a member). The calls cover all size infrastructures, although a recommended minimum is given[35]. The calls have no other size, thematic or other similar restrictions.

Selection of research infrastructures to the national strategy is based on **criteria**[36], which include: 1. Scientific quality and potential, 2. Open access and utilisation, 3. Relevance to the strategies of host institutions, 4. National and international relevance, and 5. Feasibility. The April 2016 call further defines the objectives of funding as: to upgrade the quality and improve the renewal, competitiveness and interdisciplinary approach of Finnish research, to increase the appeal of Finnish research environments and boost the national and international collaboration of Finnish universities, research teams and researchers, to support researcher training and the creation and application of scientific knowledge and intellectual capital, and to address funding needs arising from memberships in national and international research infrastructures (e.g. membership fees).

6.2 The (ex-ante) appraisal approach

The appraisal of research infrastructure funding applications is organised by FIRI Committee, which also makes the final decisions. The appraisal is based on a **single step international peer review** process[37]. Applications are submitted through the Academy's online services[38] (the same online services are used for reporting).

In addition to the general principles of the Academy of Finland, the **appraisal** covers: national and international scientific significance and added value of the research infrastructure, the project's links to the research strategy of the host organisation(s) and the commitment by the organisation(s) to the project, links to projects that have been presented in Finland's strategy and roadmap 2014–2020 or ESFRI's 2016 strategy report on research infrastructures, and openness in the use of the infrastructure. Attention is also paid to: systematic and broad utilisation of the infrastructure, quality and scope of potential user community, technological and other advancement of the infrastructure, and economic capacity and stability of the infrastructure during its lifespan.

More concretely, the documentation of the Academy of Finland shows that each research infrastructure project proposal is evaluated individually and separately in 5 dimensions as well as in comparison to the other infrastructures in all other areas of science. The appraisal dimensions are[39]:

- Scientific quality and potential
- Open access and utilisation,
- Relevance to the strategies of host institutions
- National and international relevance

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[35] In the 2016 call, the recommended minimum was 400 000 EUR per project, or 600 000 EUR for a consortium project with 200 000 EUR minimum for a consortium sub-project. Smaller infrastructure needs can typically be addressed through other funding channels, such as normal budget funding and project based competitive funding.

[36] For a detailed description of the selection criteria, see Appendix 4 in http://www.aka.fi/globalassets/awanhat/documents/firi/tutkimusinfrastruktuurien_strategia_ja_tiekartta_2014_en.pdf

[37] For more details, see http://www.aka.fi/en/review-and-funding-decisions/how-applications-are-reviewed/

[38] http://www.aka.fi/en/funding/how-to-apply/online-services/

[39] for a description of the evaluation criteria see http://www.aka.fi/globalassets/20arviointi-ja-paatokset/liitteet/firi2016_evaluation_criteria.pdf

- Feasibility.

Each dimension is appraised using a 6-level scoring system[40]:

- 6: Outstanding: stands for exceptional novelty, innovativeness and enabling of renewal of science at a global level,
- 5: Excellent: extremely good in international comparison – no significant elements to be improved
- 4: Very good: contains some elements that could be improved
- 3: Good: contains elements that could be improved
- 2: Unsatisfactory: in need of substantial modification or improvement
- 1: Weak: severe flaws intrinsic to the proposed infrastructure project or the plan

The same rating system is used for the overall appraisal of the project. There are no references in the official documentation to weighting of the criteria. However, given the appraisal process and funding objectives, dimensions 1 and 2 may have higher impact on the overall rating. Rating below 3 in any criterion would most likely result in rejection.

When positively assessed, the earmarked infrastructure funding is primarily allocated to investment **costs** (acquisition of equipment and systems and creation of services) at the construction phase and to significant upgrading of existing infrastructures. The equipment must be incorporated into an existing or upcoming national or international research infrastructure that is open to use by the scientific community. Permanent operating expenses should mainly be covered by funding from the host organisations. Funding for salary costs is granted only in special cases, however, taking into account research-field-specific differences. The costs must be justified in the application. The Academy does not fund operating costs of research infrastructures.

The funding contribution must come to no more than 70% of the total costs of the acquisition, establishment or strengthening of a research infrastructure. If applicants have ongoing funding for research infrastructures, they can be granted funding for the same infrastructure only for very special reasons. The need for concurrent funding must be justified in the action plan.

While there are no explicit economic impact criteria for the earmarked infrastructure funding, the scope of the potential user community, openness in the use, and economic capacity and stability of the infrastructure during its lifespan may all help to promote the use of research infrastructures in collaboration with industry or to support commercialisation of public research (e.g. innovative start-ups), and thereby enhance economic impact. Other infrastructure funding, especially that coming from Tekes includes explicit economic impact criteria.

6.3 Monitoring and evaluation

There are no explicit requirements as to how the **governance** of research infrastructures should be organised. Depending on the funding source, there are requirements related to the management of funding and a possible project the funding is linked to. However, application guidelines clearly indicate that the governance structures and processes must be sufficiently described in the application, including:

[40] for the evaluation form used in the appraisal of proposals see http://www.aka.fi/globalassets/20arviointi-ja-paatokset/liitteet/firi2016_evaluation_questions.pdf

organisation chart of the research infrastructure, organisational activities of the research infrastructure, distribution of work between its units, and competence of the PI (coordinator) and key personnel in terms of project implementation. This information is used in the assessment and thereby the appropriateness of the governance structure and processes is confirmed.

Reporting requirements depend on the funding source. In the case of the earmarked research infrastructure funding, reporting is done at 4 month intervals (3 times per year). Payment of funds is done afterwards based on the accumulated, reported and verified costs. Reporting is done using the Academy's online service.

The application requirements[41] clearly indicate that in addition to financial reporting, the reporting should cover also e.g. services provided by the research infrastructure for users, quality and scope of (both real and potential) user base both nationally and internationally, plans for expansion of user base, open access to use the research infrastructure (Open access provided to all researchers? Does the infrastructure charge a fee for using its services? Are the users selected based on a set of criteria? What are the criteria?), research infrastructure utilisation rate and results over the last five years described, for instance, as scientific publications, patents, products, applications or business initiatives, and data management plan.

The reporting of research infrastructures is currently being renewed and the new reporting practice will be adopted in spring 2017. Previously, the reporting was done using the normal reporting guidelines applied for all research projects funded by the Academy of Finland. These guidelines were not tailored to the specific needs of monitoring the implementation and impact of research infrastructure projects. The earmarked funding for research infrastructures and the respective governance processes are relatively new. Priority was to launch and establish the funding and governance processes. The next logical step is to focus more on the monitoring and evaluation.

The Academy of Finland is currently in the process of renewing its **monitoring systems**. This covers all funding and will put more emphasis on systematic collection of impact data. The renewal of the monitoring of research infrastructure funding is part of this overall monitoring reform. The monitoring reform will also have an impact on the information requested during application for funding, as these must be closely aligned.

The **new monitoring model** was designed at the Academy of Finland by the people responsible for supporting the FIRI committee. The decision to launch the new monitoring practice was made by the FIRI committee. During the development of the new monitoring system, experiences and models were studied from several other countries. These included e.g. UK, Netherlands, Austria, the neighbouring Nordic countries, as well as European level requirements applied in the context of ESFRI.

The new reporting practice is significantly more demanding than the old generic one used for all research projects. It is based on systematic collection of data focusing on the impact of science infrastructures at 5 different levels (with key indicators in brackets): Scientific quality and relevance (numbers and quality of publications, scope and quality of users, openness to scientific community), Technological relevance (number and funding of collaborative projects with industry, number of developed new technologies, number of patents, number of start-ups and spin-offs), Economical relevance (versatility and sustainability of funding, number and funding from

[41] http://www.aka.fi/en/funding/how-to-apply/appendices-required/firi-call-action-plan/

commercial users, number of direct and indirect jobs created, business volumes), Relevance to skills and international collaboration (number of users, utilisation rate, number of degrees, students and programmes, number of international events), and Societal relevance (public openness of knowledge, knowledge distribution to industry and public, regional impact).

The actual data collected with respect to these five areas of impact is in the form of selected key performance indicators and free text. The same approach is used in the new monitoring for research projects. The Academy of Finland is already using text mining tools for other purposes and later on these tools can be also used for analysing the free text impact descriptions collected via the new monitoring system.

The FIRI committee at the Academy of Finland is responsible for the data collection. The data is collected using a web-based form and application. The form is pre-filled by the Academy of Finland with application and other information already available at the Academy databases. The Academy is also developing automatic links between the new monitoring system and other relevant data sources, such as the publication database Virta[42].

One of the most challenging aspects of monitoring the impact of research infrastructures is the fact that only part of the funding comes from earmarked funds through the FIRI committee. The monitoring system attempts to capture the full impact of the infrastructures. The owners of infrastructures are required to report the implementation and impact of the whole infrastructure, not only the part funded from funds managed by FIRI committee. To what extent the new monitoring system is able to capture all relevant infrastructures and their impact remains to be seen after the new monitoring system starts to provide the data and the first analyses become available.

The other challenging aspects of research infrastructure monitoring, such as downstream impacts of investments, spillover effects and effects on local economy are being covered in the new monitoring system. Similar to the challenge of capturing all relevant infrastructures sufficiently, the extent to which these aspects can be sufficiently addressed will become clear once the new monitoring system starts to provide results. Currently, there are no specific plans to address these difficult to measure aspects.

The national research infrastructure strategy and roadmap identifies **evaluation** of the impact and significance of research infrastructures as one of the 5 main activities necessary for implementing the strategy. The concrete actions consists of the following: (a) The impact, significance and collaborative use of research infrastructures will be subject to regular evaluation, (b) Decisions on the continuation of international and national research infrastructures of importance to Finland will be based on a systematic evaluation method, and (c) Evaluations will be performed of the direct or indirect benefits of national or important international research infrastructures to Finnish research, business and society. In developing such evaluations, account will be taken of the fact that the nature of research infrastructures may change due to developments in science and technology such as new digital breakthroughs.

The national strategy also states that the implementation of the research infrastructure strategy and the progress of research infrastructures selected for the roadmap will be reviewed every three years. This periodic and systematic review process allows stocktaking of all relevant recent evaluations. Evaluation outcomes are also analysed

[42] https://confluence.csc.fi/display/VIR/VIRTA-julkaisutietopalvelu. CSC which manages this database is currently developing a system to link publications to specific science infrastructures.

and discussed at FIRI Committee, allowing an even more direct link to decision making.

A mid-term evaluation of the national science infrastructure strategy and roadmap has been recently launched. The mid-term evaluation is experimental and combines several approaches. On the one hand, it will be largely based on the data collected using the renewed reporting practice. On the other hand, the evaluation will be supported by two international expert panels, one focusing on the scientific dimension and another focusing on governance and impact. These panels have not yet been formally nominated. No interviews with research infrastructure owners are planned. However, benchmarking will be done against selected countries of interest. Countries have not yet been decided, but are likely to include countries where evaluations regarding research infrastructures have been implemented and published recently. These are Sweden and the Netherlands, but benchmarking may also include other relevant countries.

The mid-term evaluation will follow the same approach and use the same framework as the new monitoring system with regards to impact. In this way, the mid-term evaluation provides an excellent testing ground for the new monitoring system. The evaluation should reveal if any parts of the monitoring system require improvements or amendments. One particular concern is how the monitoring system is able to capture all relevant science infrastructures regardless of to what extent they may have received funding from FIRI committee.

During the mid-term evaluation, the science infrastructures are required to report their funding, activities and impact for the period of 2013-2017. In addition to the recent past, they are also required to indicate their plans for the period of next 5 years. The information should cover both funding from FIRI committee and funding from any other source.

The mid-term evaluation is based on the same approach than the new monitoring system. This means that it will reveal to what extent difficult to measure aspects such as downstream impacts, spillovers and impacts on local economy can be captured by the evaluation. As the evaluation is experimental in nature, experiences from it will give an indication as to how the monitoring and evaluation approaches need to be developed in the future.

Results from monitoring and evaluation will eventually have an impact on future science infrastructure funding. The first response to the evaluated (or monitored) infrastructure is likely to be a notice indicating that the poor performance or impact has been identified and manager of this infrastructure is encouraged to take appropriate steps to rectify the situation. If the performance or impact remains poor, future funding is not likely. The earmarked funding is only for investments in new infrastructures or enlargement of existing ones, and doesn’t include any support for managing and operating the infrastructure. Therefore, the impact of the monitoring and evaluation results will show in terms of funds available for extending existing science infrastructures or building new ones (in case the infrastructure governance was particularly poor). However, once the monitoring and evaluation system starts to provide sufficient evidence of especially impact, it is likely that this information will have an impact on the behaviour of other funding sources. This may reduce resources available for managing and operating a poorly performing infrastructure.

6.4 Summary of key strengths and weaknesses

Both the appraisal and governance systems seem to work well. However, the link to research activities is still weak. This has been recognised, and the new monitoring system is partially addressing this issue. Further efforts are being made to link science infrastructures to scientific output (e.g. publications) and socio-economic impacts using other data sources.

The monitoring system (and the mid-term evaluation as it builds on the same approach) is based on good European practice. The fundamental approach can be transferred to other science systems. However, there are two specific points that need to be addressed when considering a transfer.

One is the approach to capture all relevant infrastructures by a committee that is responsible only for a limited amount of earmarked science infrastructure funding. The FIRI committee (or the Academy of Finland under which it resides) does not have a formal mandate to request the extensive information regarding the whole infrastructure, its activities, and impact. Giving this information therefore relies partly on voluntary action on behalf of the managers of science infrastructures. The quality and extent of data also depends on understanding the downstream impact pathways, which may in some cases be limited. Furthermore, the link between infrastructures and research activities may not always be clear.

The other point is related to the digitalisation of the data collection and the overall monitoring system. The system can be very effective and efficient if it can be linked to other relevant data sources automatically via appropriate interfaces. This depends on the level of digitalisation and quality of IT systems used by the funding agency as well as managers of science infrastructures. The more the data can be automatically collected and analysed using state-of-the-art tools, the more efficient, effective and timely can the system be. Although the impact of science infrastructures is typically not so much short term, automatization of the monitoring practices can ensure data quality and avoid unnecessary duplication of efforts.

One further challenging aspect related to science infrastructures is how to identify relevant future scientific research directions, so that new infrastructures could be built to support and enhance these. While the monitoring and evaluation systems don't provide answers directly, mining the free text collected from research and infrastructure projects may provide some indication of future needs, especially when combined with other similar data sources.

It is too early to say how the new monitoring system will be able to capture science infrastructures and their impact to a sufficient extent. However, the experimental approach combining the launch of the new monitoring system with the mid-term evaluation should provide a good platform for identifying any challenges and/or problems related to the monitoring and evaluation approach. Furthermore, the analysis and conclusion from the international expert panels may be later compared against monitoring data. This may allow further insight into what kinds of guidelines could be given e.g. for the free text impact descriptions.

The new monitoring and evaluation systems represent good international practice. Their main new feature is an increasing emphasis on impact, both scientific and socio-economic. Both systems are being introduced simultaneously, i.e. the first round of data collection using the new monitoring approach is being used in the mid-term evaluation. This can be regarded as an experimental approach, where the monitoring supports the evaluation and the evaluation supports the verification and development of the monitoring system by providing feedback from the two international expert panels (and the FIRI committee). This experimental approach provides an excellent basis for establishing a solid basis for future monitoring and evaluations.

6.5 Sources

6.5.1 Interview partners

Dr. Merja Särkioja, Senior Science Adviser, Academy of Finland

7 Germany

7.1 The process of allocating science capital funding

Overall, there are three main funding mechanisms for research infrastructure in Germany, *plus* a national roadmap process for very large RIs that does not fit into one of the three regular mechanisms. The general *Research infrastructure* programme and the "*Large research infrastructure*" programme are co-funded by BMBF and the state ministries, which oversee their regional higher education institutions due to Germany's federal structure. The states match the federal funding of research infrastructures at their universities in an equal proportion (50:50). In addition, the states receive more than €695m each year of so-called "compensatory funding" to fund investments in their higher education sectors, of which a major share is dedicated to fund research infrastructures at universities.

The following table provides an overview of budgets, responsible organisations and funding mechanisms for the three programmes. For the Research infrastructures and Large research infrastructures funding programmes, the executing organisation for budget allocation is the German Research Foundation (*DFG*). The Joint Science Conference (GWK) makes the final decision on grants. For the "compensatory funding", the state ministries themselves oversee the allocation and funding decisions. The underlying funding mechanism is implemented through open competitive tenders.

Table 1 Overview of the three federal research infrastructure funding programs in Germany

Programme	**Organisation(s) responsible**	**Amount of budget (2016)**	**Funding mechanism**	**Scope**
Research infrastructures according to Article 91b of the Basic Law (Großgeräte-forschungsprogramm)	• Funding: BMBF • Allocation: DFG • Decision: DFG	• Overall: € 213m (plus matched state funding of about 100 %) • Per funding: €200k to €5m (for applied universities minimum threshold is only €100k	• Funding Scheme: Open tenders • Objective(s): Scientific quality and national importance • Target group(s): Public and private HEI	• All parts of the research infrastructure (without construction), including software
Large research infrastructures according to Article 91b of the Basic Law ("Forschungs-bautenprogramm)	• Funding: BMBF • Allocation: DFG • Decision: GWK	• Overall: € 85m (plus matched state funding of about 100 %) • Per funding: From €5m		
"Compensatory funding" for higher education institutions in the states (*Länder*)	• Funding: BMBF • Allocation: State ministries of education or research) • Decision: State ministries	€ 695,3m (provided by BMBF, allocated by state ministries at their own discretion)	• Funding Scheme: Open tenders • Objective(s): Not specified • Target group(s): Public and private HEI	• Use in Research, Education and Teaching as well as health care • Includes IT appliances, libraries as well as HEI and health care administration tools

DFG[43]

[43] http://www.dfg.de/download/pdf/foerderung/programme/wgi/fuenf_jahre_grossgeraeteprogramme.pdf (in German)

7.1.1 The National Roadmap Process for Research Infrastructures

The German Federal Ministry of Education and Research (*BMBF*) has put in place a "National Roadmap Process for Research Infrastructures", which is dedicated to planning and establishing new Research Infrastructures. BMBF adopted the idea for a national roadmap in 2010, when it concluded that the processes in place were not adequate anymore for the challenges resulting of new RI investments. At that time, BMBF had several major RI investments in the pipeline and decided to implement a national roadmap process. Two main reasons guided this decision. On one hand, the roadmapping process could serve as a basis for "rational prioritisation" of future RI. On the other, it offered the opportunity to implement valid cost and risk assessments of RIs based on a unified decision and criteria framework. In addition, the work of ESFRI had illustrated to German policy makers the advantages of formalising the assessment of RIs through a Roadmap process.

Based on these considerations, BMBF launched the "Roadmap for Research Infrastructures Pilot Process", which was implemented from 2011 to 2013. The German Council of Science and Humanities (*Wissenschaftsrat*), consisting of university professors and national / regional policymakers, was involved. The Wissenschaftsrat had already dealt with the scientific assessment of RI long before the pilot, notably in the context of its statement on nine Large-scale Facilities for Basic Scientific Research in 2002 and of his recommendations concerning the funding of research ships in Germany in 2010. Thus, it was a natural decision to involve the Wissenschaftsrat in the new Roadmap pilot process.

Furthermore, the previous experience from assessing the funding of different types of research infrastructures had demonstrated the need for a thorough economic evaluation of RIs. A strong increase in the cost of a research ship over its planning time or an accelerator facility showed policy makers the importance of a more consistent and extended economic evaluation of RIs. Therefore, in the pilot process, while the Wissenschaftsrat conducted a science-driven evaluation of the RIs, a BMBF project management agency was asked to implement and oversee the economic evaluation process.

As a follow-up to the pilot, in August 2015 BMBF established the "Roadmap Process for Research Infrastructures" to prepare and prioritise future and long-term investments in national and research infrastructures with German involvement. All interested universities and non-university research institutions planning to establish new Research Infrastructures are eligible to participate. As a conclusion from the pilot, it was decided to further integrate the science-driven and the economic evaluation. Now, in the first phase of the Roadmap process that began in 2013, a representative of the science-driven evaluation attends the meetings of the economic evaluation, and vice-versa.

Besides BMBF and the responsible state ministries, the German Council of Science and Humanities implements the appraisal process and contributes to the overall research infrastructure roadmap and decision making process. BMBF's project management agency PT-DLR oversees economic evaluation.

7.2 The (ex-ante) appraisal approach

With the National Roadmap Process, BMBF has developed a st**ructured three-stage assessment process** to appraise new research infrastructures.

In the first stage, universities submit their proposals to the relevant state ministry for education or research, which perform the eligibility check. All public universities as well as private, accredited higher education institutions may submit proposals, while research infrastructures must be of significant size (estimated cost of at least €200,000).

In stage 2, the state ministries forward the proposals to BMBF. All proposals are assessed based on three evaluations (science-driven, economic and societal importance):

1. Science-driven evaluation -

The science-driven evaluation is implemented by the German Council of Science and Humanities (Wissenschaftsrat), which appoints a mandated committee. Generally, three international reviewers are mandated independently from each other to perform the assessment of the RI in question. The three individual assessments serve as the foundation for the assessment committee, which consists of the three international reviewers and the responsible programme officials. In an interactive and open discussion, the three assessments are put together and the committee produces a common assessment. This is then presented to the Wissenschaftsrat's Expert Committee on Large-Scale Research Facilities. The Expert Committee consists of appointed researchers of all scientific domains.

Because assessing RI from different fields of science within a common framework is difficult, the Wissenschaftsrat has introduced four dimensions. The logic behind that procedure is that an assessment of one RI always involves an implicit comparison between RIs, even though RIs can differ enormously in area, approach and scope (one RI could be a research ship while another could be an electronic laser. One RI could be distributed, while another is only existing in one location). Therefore, in order to add substance to the assessment process, the Wissenschaftsrat performs four distinct assessments in each of the following four dimensions:

- The "Scientific potential" dimension includes the assessment of the importance of the project to access existing or develop new research areas. This assessment also includes planned, as well as existing potentially competitive and complementary research infrastructures.
- The "Usage" dimension assesses the size and origins of user groups as well as modalities that regulate the access to the research infrastructure. This dimension also includes the data concept as well as quality assurance measures ("sound academic practice")
- The "Realisation" dimension includes technical preconditions as well as personal and institutional requirements of the host organization (including the governance concept).
- Finally, the "Relevance" dimension refers to the proposed research infrastructure's relevance to Germany and its effects on visibility and attractiveness of German research

Once the RI-specific common assessment is completed by the mandated committee, the Wissenschaftsrat's Expert Committee on Large-Scale Research Facilities performs an assessment along these four appraisal dimensions. It awards 1 to 5 points in each dimension. Out of this procedure results a table, listing the points for each of the dimensions. No specific indicators are used, as Wissenschaftsrat's experience has shown that quantitative indicators such as the number of publications or other bibliometric indicators are not satisfying in assessing RIs in a coherent way.

2. Economic evaluation

The economic evaluation of new RI is conducted through a cost and risk assessment, which is implemented by an appointed project management agency, the German Aerospace Center Project Management Agency (PT-DLR).

In a first step, PT-DLR appoints independent experts from industry and science. Through its various project management activities, PT-DLR has broad experience in appointing and conducting review and assessment committees. The set-up of committee members depends largely on the RI in question. For most RIs, experts with specific knowledge of RI cost factors are needed (for example, the costs of mirrors for a solar telescope). These experts are usually scientific managers from large research institutions (usually the head of the institution and/or administrative directors). But committee members can also be scientists from various research fields or other experts with substantial competences in project organisation, management and cost planning. These experts may include, for example, engineers who specialise in propulsion engines for research vessels or in the load-bearing capacity of large concrete structures for an accelerator. Their assessment allows for a thorough evaluation as to whether proposals are financially sustainable but also feasible from a technical perspective.[44]

Thus, the set-up of the cost and risk assessment committee depends largely of the nature of the RI assessed. One of the main difficulties is to identify scientists and experts with no attachment to the RI in question, as generally six to eight scientists and experts take part.

Once the committee is appointed, PT-DLR provides all available information and the proposal to the committee members. Each one of them receives an individual access code to a dedicated online platform. On this, each committee member is invited to provide his or her individual cost assessment for several cost items that have been prepared by PT-DLR. The cost items are shown in a large cost table covering all major cost factors of the RI in question. This procedure is meant to provide an aggregated cost assessment in advance of the cost and risk assessment committee meeting. Before the physical committee meeting, PT-DLR aggregates the committee member's individual cost assessment.

Subsequently, the cost and risk assessment committee meeting is held with participation of all committee members, BMBF and PT-DLR. The main purpose of the meeting is to agree on the aggregated cost assessments and to perform a qualitative risk assessment. The aggregated cost assessment lays the foundation for a procedure build on the Delphi-method. PT-DLR presents the aggregated cost assessment, allowing all committee members to provide further input to it and agree on the final cost assessment for the RI. It is important to note that no formal indicators or rankings are used for the cost assessment. In a second step, the meeting participants hold a discussion on risks to the RI, especially focused on potential factors that could increase overall costs in the lifetime of the RI. Similar to the cost assessment, the risk assessment is conducted through an open, qualitative discussion. Finally, PT-DLR writes down the results of both the cost and the risk assessment in a formal protocol, that is in turn open for review to all committee members.

Thus, the main outcome of the economic evaluation is an extensive cost table with all costs as assessed by the committee members as well as a qualitative risk assessment.

[44] BMBF. Verfahren zur Durchführung von Kostenschätzungen (in German).

The agreed protocol is sent to BMBF for further consideration in the Roadmapping process. The cost and risk assessment is the first building block of an accompanying financial controlling process and serves as an early available research policy decision tool.

3. Evaluation of societal relevance

The evaluation of societal relevance is carried out internally by BMBF. It examines socio-economic, societal and research policy impacts of the proposals. The most relevant units in BMBF are contacted and receive the concepts of the scientific and economic evaluations. They look at whether the project fits to the overall BMBF strategy and program, which is generally the case. Furthermore, they look at how the project's future impact may look like. They also look at exclusion-arguments: For instance, the German government would not fund nuclear-based RIs because it has decided to quit nuclear energy. On this basis, a cumulative assessment of the societal relevance of the projects is written. The minister decides at the end, which projects are retained on the roadmap. The process is highly qualitative and BMBF did not provide more information on this.

Finally, in the third stage of the Process, the BMBF makes the final decision on inclusion in the National Roadmap. Beside the results of the three evaluations, this also takes other criteria into account, such as international obligations and the possible contribution of the project to the development of innovative research areas or relevant research policy strategies. Inclusion in the Roadmap signifies a fundamental intention to provide funding. Unless infrastructures are funded under institutional budgets, funding is provided by the relevant ministries within the framework of a regular application procedure and subject to the availability of the necessary budgetary funds.

7.2.1 Governance and project management requirements

BMBF provides a structure called 'minimum requirements for projects' ('Mindestanforderungen an Projekte', MAP) for the implementation of large-scale projects; this structure is the basis for the lifecycle phases described above[45]. The terminology used is based on the BMBF's key management process of controlling. The MAP process was developed based on the relevant DIN standards (DIN 69900 and DIN 69901), and in accordance with the Lehman process (US DOE Order 413.3A). Its aim is to ensure an efficient project management structure within a project that, among other things, enables quick orientation and is relatively independent of the individual persons involved.

The requirements are overseen by the BMBF Controlling unit. The BMBF controlling unit adds to the project-specific controlling unit and assesses project development regarding costs, timing and progress. Furthermore, the BMBF Controlling unit assesses governance and management structures of the projects in question. All RIs are subject to the oversight by the BMBF Controlling unit.

The MAP structure is a phase model for the planning and implementation of (large) projects. The aim is to enable efficient management information and to implement an efficient project management structure within the project. MAP is based on a project life cycle model with successive phases.

Within the individual project phases, phase-dependent and project-specific key management processes are executed. MAP can be adapted to the project-specific

[45] BMBF (2015). BMBF Controlling approach.

conditions. At the end of the phases, a decision about the continuation of the project (continuation, continuation with rework or abort) is to be decided by means of a release report. Based on this approval protocol, BMBF checks whether all relevant key management processes have been processed and allows the project explicitly to enter its next phase. If the project cannot be released, the respective phase can be extended or the project can be stopped. MAP is binding for project participants according to the stipulations in approval permits / contracts (phase approvals, release procedures).
The following table summarises the different phases of MAP as well as associated key management processes that are required from the projects in question.

Table 2 Different phases of the BMBF Minimum Requirements for Projects (MAP), Germany

Phase	Key management processes
Initialisation phase	Outline goals in a strategic plan Clarify responsibilities
Definition phase	Build the project core team Define goals Analyse the project environment and stakeholders Create a preliminary structure Rough estimate of project costs Define milestones Define information, communication and reporting processes Determine risk control processes Evaluate overall feasibility
Planning phase	Plan project organisation Plan costs and financial resources Create schedule Create a resource plan Determine personnel requirements Detail information, communication and reporting processes Analyse and control risks Create a project plan Determine contract content with vendors Describe work packages Create a project structure plan Describe and plan operations Plan quality assurance Carry out an external cost estimate
Control phase	Perform kick-off meeting Trigger operations Schedule appointments Perform controlling costs and funding Develop team structure Deal with contracts Assess project targets Approval of the project
Final Phase	Terminate contracts Create ex-post cost assessment Create final report Conduct final meeting Return resources End the project

7.3 Monitoring and evaluation

BMBF's Guidelines for outlining proposals for the National Roadmap for Research Infrastructures requires applicants to implement an extensive governance system "that is adequate to the task".[46] The governance concept must be laid out in a dedicated annex to the utilisation and realisation concept, and should include a description of the fundamental system of enterprise management and governance. Furthermore, the concept needs to specify envisaged governance bodies, such as scientific advisory boards, supervisory boards, the composition of the board of directors and the

[46] BMBF (2015). Guidelines for outlining proposals for the National Roadmap for Research Infrastructures.

management board. If the research infrastructure at hand is decentralised, applicants must also outline the added value of having a functionally integrated research infrastructure with common standards in order to allow for an evaluation of the whole unit. In addition, the type of ownership, its location and the associated rules determining tasks and decision-making powers are further elements to include.

In its controlling requirements, BMBF suggests the usage of Key Performance Indicators (KPI) to represent, measure, assess and set action standards and thereby determine critical success factors. As a general procedure, the requirements foresee: (1) the definition of goals; (2) assess existing KPIs; (3) set target/reference values; (4) enter actual KPI values; (5) analyse deviations and make recommendations; and finally (6) implement control decisions.

The requirements mention the following KPIs:

- KPIs for Earned Value Analysis
  - Schedule Performance Index (SPI): "Earned Value/Planned Value", in order to assess the relationship between the value of the work done and that of the planned work.
  - Time Estimate at Completion (TEAC): "Time at Completion/Schedule Performance Index", in order to estimate project duration.
  - Cost Performance Index (CPI): "Earned Value/Actual Cost", in order to determine whether the project's cost planning meets its targets.
  - Estimate at Completion (EAC): "Budget at Completion/Cost Performance Index", in order to perform a revised cost estimate at a given date.
- Personnel-related KPIs
  - Overtime rate: "Amount of overtime hours in each timeframe/Overall amount of regular work hours in a given timeframe", to assess personnel loading limits.
  - PhD quote: "Amount of PhD students/Amount of overall personnel", to assess the intensity of scientific activities.
- Bibliometrics
  - Publication rate: "Amount of relevant papers/Amount of relevant journals", in order to assess the project's scientific contributions in a given timeframe

Interviewees highlighted, that project applicants generally make use of KPIs, as they acknowledge the funder's interest in calibrating time, costs and expected impacts. The overall monitoring mechanism is described as a fluid process, given that BMBF's dedicated controlling unit communicates frequently with project leaders to require and/or assess additional information. In turn, the controlling unit reports two times a year to the relevant units inside BMBF.

The Guidelines for outlining proposals also foresee a management concept for all necessary phases in the life of the research infrastructure. Applicants must cover the organisation of management and business administration as well as HR management and reporting. BMBF's Controlling requirements specify what the management concept should include. It requires the following two elements:

- The Product Structure Plan (PdSP) details the technical structure of the individual components of the product. The PdSP contains the product components in a hierarchical arrangement. The configuration depends essentially on the complexity of the underlying product. It constitutes the framework for further project planning. All planned and actual data for the project-specific (dates and costs) and the product-specific basic variables have a direct relationship to the product structure. The product structure forms the bridge between commercial cost structuring, the functional task structuring (project structure) and the development results. It enables the synchronisation of the deadline and cost monitoring and facilitates a joint project planning of the various actors within the project.

- The Project Structure Plan (PSP) forms the foundation for project planning and implementation. The structure of the project is defined in the PSP; It contains all the project activities to be carried out in the respective project phases. In general, there are three forms of PSPs:
  - Object-oriented PSP: The definition of the work packages depends on the technical structure of the object to be developed. The underlying project is systematically decomposed into its individual parts to be developed, e.g. for an IT workstation system in "control unit", "drive", "aggregates" and "software".
  - Functional PSP: The work packages are subdivided according to the development functions (for example: construction documentation, contracting, construction work); It is not oriented at the individual parts of the project, but at the functional areas of a project.
  - Process-oriented PSP: The work packages are determined and structured according to the development process (for example, planning, development, production). The top level of such a PSP reflects the process sections of the organizations; The individual process steps are displayed on the lower levels. This type of PSP is only useful where strictly sequential developments are carried out in a process sequence.

In practice, mixed forms of the PSPs described previously are used. The PSP treats the project in its entirety, while its level of detail depends on the projects' complexity. In a typical Top-Down process, the project is analysed regarding its task structure (structural analysis). The activities are divided into independent and controllable tasks. The lowest common layer are the work packages.

As confirmed by BMBF, its project management agency PT-DLR as well as the Wissenschaftsrat, no "standardised" monitoring system is required by the projects. It remains at the discretion of the project applicants to propose a monitoring system. For BMBF, the controlling process based on the MAP requirements (see above) are sufficient and are in place since 2009.
Regarding an ex-post evaluation of the Roadmapping process, interviewees indicated that the German Council of Science and Humanities might be mandated with an extensive ex-post evaluation of the Roadmap process. However, such an evaluation will only be conducted once the second phase of the National Roadmapping process is completed. Probably only after the next Roadmap process that is due in two years, there will be an overall evaluation.

7.4 Summary of key strengths and weaknesses

Although Germany's Roadmap Process for RI represents a recent policy development, its decisive building blocks – the science-driven and the economy evaluations – are well developed and profit from BMBFs and the associated agencies' broad experience in funding RIs. The main stakeholders in the ex-ante appraisal approach, BMBF's project management agency PT-DLR and the Wissenschaftsrat, both provide longstanding experience in the scientific evaluation and cost assessment of RIs, respectively.

The science-driven evaluation recognises the core difficulty of finding a common assessment framework of diverse RIs. Through the four distinct appraisal dimensions (Scientific potential, Usage, Realisation and Relevance) as well as the committee process with international reviewers, the science-driven evaluation is conducted in a coherent way. By awarding points specifically for the four dimensions, the evaluation process takes into account the different nature, scope and approaches of RIs. Nevertheless, it seems that the science-driven evaluation relies strongly on qualitative means, making it difficult to transfer the process to other science systems.

The economic evaluation foresees an extensive cost and risk assessment, conducted by PT-DLR. A notable feature of the assessment is the inclusion of technology and sectoral industry experts, which increases the likelihood of valid cost assessments. In addition, the "blind" cost assessment by the experts preceding the actual assessment committee meeting highlights potentially high deviations between the individual cost assessments.

Regarding governance and project management requirements, BMBF has laid out general principles and minimum requirements for RI projects. A dedicated Controlling unit inside BMBF monitors the development in the different RIs. This procedure recognises the different project-specific conditions in RIs, where pre-defined and/or standardised governance requirements could prove to be inefficient.

Nevertheless, substantial external or internal impact evaluations are – for the moment – not part of the German Roadmapping process. Given the substantial financial volumes of German RI funding, however, it can be expected that an extensive evaluation process (probably through the Wissenschaftsrat) will be launched in the upcoming 2 or 3 years.

7.5 Sources

7.5.1 Documentary sources

- DFG (2012). Fünf Jahre neue Großgeräteprogramme 2007-2011 Rückblick und Ausblick http://www.dfg.de/download/pdf/foerderung/programme/wgi/fuenf_jahre_grossgeraeteprogramme.pdf (in German)
- BMBF. Approach to conduct cost and risk assessments (in German). https://www.bmbf.de/files/Verfahren_zur_Durchfuehrung_von_Kostenschaetzungen_deutsch.pdf
- BMBF Controlling approach (2015) https://www.bmbf.de/files/Controlling_im_BMBF_(1).pdf
- BMBF (2015). Guidelines for outlining proposals for the National Roadmap for Research Infrastructures. https://www.bmbf.de/pub/Guidelines_for_outlining_proposals.pdf

7.5.2 Interview Partners

- Mr. Peter Wenzel-Constabel, Head of Unit 'research infrastructures', German Ministry of Research and Education (BMBF). Responsible for National Roadmap Process for RI.

- Dr. Annette Barkhaus, Deputy head of research department, German Council of science and humanities (Wissenschaftsrat). Overseeing the science-driven evaluation of roadmap projects.
- Dr. Johannes Janssen, Research infrastructure and information technology, German Research Foundation (DFG). Responsible for allocating funding for the two major RI funding programmes.
- Dr. Peter Sliwka, Head of Unit Research Infrastructures, German Aerospace Centre. In charge of economic evaluation in the context of the roadmapping process.

8 Ireland

8.1 The process of allocating science capital funding

8.1.1 RI roadmap / strategy

Ireland currently has no specific roadmap for research infrastructure, nor a centralised permanent committee on research infrastructures, such as exist in certain EU countries. However, there have been several national exercises and publications in recent years of relevance to this topic.

A **national review** of research infrastructure in Ireland[47] was published in 2007. Its purpose was to internationally benchmark the research infrastructure (facilities, equipment, associated human resource and soft infrastructure) in the higher education sector and to identify gaps in the national platform for research infrastructure, which could be addressed in the short to medium term. The findings and recommendations effectively provided a basic roadmap for the further development of Ireland's research infrastructure, and have informed subsequent policy and investment.

The review found that weaknesses and gaps remained in the higher education and national research infrastructure, and that the country was still in 'catch up' mode following a lack of investment prior to 1998. Amongst other things, the report called for: (i) a restructured PRTLI (programme for research in third-level institutions – see below) that would accommodate support for new proposals and existing investments, as well as for pre-determined infrastructures, disciplines or areas, on an open competitive basis; plus (ii) the reinstatement of the mechanisms formerly operated by the Higher Education Authority for replacement, updating and renewal of research equipment.

In 2010 (and partly in response to the economic/financial crisis), the Irish Government initiated a wider top-down priority setting exercise for research funding, based on Ireland's needs. It established a **Research Prioritisation** steering group, tasked with undertaking detailed analysis and making recommendations to the Government on focus areas for the next phase of Ireland's science, technology and innovation strategy, as well as future public investment in STI. Contributors included Government departments and agencies that fund R&D, as well as the research community, the enterprise sector and other stakeholders. The resulting report of the Group[48] concluded that it was now appropriate to move towards a more top-down, targeted approach, and to focus investments to achieve critical mass in areas that link more precisely to current and likely future societal and economic needs. It also set out 14 priority areas[49] for the Irish Government to steer its €500m scientific research budget. These priority areas have gone on to influence the themes and budget allocations within the funding agencies, including in relation to infrastructure investments.

In relation to infrastructure specifically, the steering group concluded that there would be significantly less investment required in *new* buildings and equipment in the coming years, and that investment should instead be targeted at the maintenance of

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[47] Research infrastructure in Ireland – building for tomorrow (HEA/Forfas, 2007)

[48] Report of the Research Prioritisation Steering Group, 2011

[49] Priority areas: future networks and communication; data analytics management, security and privacy; digital platforms, content and applications; connected health and independent living; medical devices; diagnostics; therapeutics; food for health; sustainable food production and processing; marine renewable energy; smart grids and smart cities; manufacturing competitiveness; process technologies and novel materials; innovation in services and business processes.

equipment and specific integrating infrastructure required for the priority areas. It recommended that "funding programmes for physical infrastructure should adapt to recognise the current priority to maintain and support the operation of existing infrastructure, while also incentivising the sharing of resources, thereby utilising their full capacity".

Ireland's current **national strategy** for research and development, science and technology (Innovation 2020)[50], was published in December 2015. This identifies 'infrastructure' as one of the targets for increased public and private investment in research, and in particular through the introduction of a successor to the PRTLI in order to provide investment in new facilities and equipment, and the maintenance and upgrading of existing ones. Specifically, it states that by 2016 DJEI (with DES, SFI, HEA and other departments, funders, HEIs and others) would scope out and develop a successor to PRTLI to support new investment in research infrastructure in the wider research base and to allow for maintenance and upgrading of existing facilities and equipment. However, by April 2017, no official details of a successor programme had yet been released.

The strategy also sets out a series of guiding principles to be applied in making future investment decisions around research infrastructure. These are:

- Excellence with impact will be the core funding driver. Funding for infrastructure will be awarded via a competitive process and will include the potential for co-funding with industry and other private sources.
- Research investment and facilities must align (and drive synergies) with Ireland's talent development at higher education level (i.e. coherent campus development)
- The infrastructural needs of the wider research base must be recognised in order to tackle global challenges and to be internationally competitive, including the growing importance of big data / data analytics and other associated e-infrastructures
- The importance of international links, such as ESFRI must be acknowledge through the funding of large-scale research infrastructure
- There must be long-term commitment to the maintenance, operational and upgrade costs of facilities to ensure their future viability, including implementation of access charges for all large pieces of research infrastructure by all national funders of research
- System efficiencies must be continuously sought, for instance through shared access to equipment through inter- and intra-institutional collaboration, and through the provision to industry of access to infrastructure promoted through online resources such as the HEA's Large Items of Research Equipment (LIRE) database.

8.1.2 Main RI funding schemes

It is estimated that the Irish Government has invested €60m-€80m per year in research infrastructures over the past 15 years[51]. Much of this was through the Higher Education Authority (HEA) Programme for Research in Third-Level Institutions

[50] Innovation 2020 – Excellence, Talent, Impact: Ireland's strategy for research and development, science and technology (Department for Jobs, Enterprise and Innovation, 2015)

[51] Irelands future research infrastructure needs (Technopolis, 2015)

(PRTLI) and (to a lesser extent) through the Science Foundation Ireland (SFI) Research Infrastructures (RI) Programme. Both these schemes are explored further in the following sub-sections.

Beyond the PRTLI, the HEA also launched a Research Equipment Renewal Grant in 2007 and Research Facilities Enhancement schemes in 2008. Together these grants and schemes provided €88m of exchequer funding for research facilities and equipment. In addition, several other government departments (e.g. Agriculture, Food, Marine), public agencies (EI and IDA) and research councils have provided grants for research equipment and infrastructure. Research performing institutions have also used core funding and block grants to invest in Research infrastructure.

8.1.3 Main RI funding schemes - PRTLI

Launched in 1998, the **Programme for Research in Third-Level Institutions (PRTLI)** has been the main government-financed intervention in research infrastructure in Ireland. It was initially funded by the Department of Education and Skills (until 2010) and then the Department of Jobs, Enterprise and Innovation. The management of the Programme and the allocation of funds was coordinated by the HEA on behalf of the Irish Government.

Although the overall motivation for PRTLI investment was the achievement of sustainable, long-term economic benefit, the programme itself was focused on developing basic research capability and did not seek to secure immediate commercial benefits from the funding. Specifically, the specific objectives set for the programme were:

- To enable a strategic and planned approach by third-level institutions to the long-term development of their research capabilities, consistent with their existing and developing research strengths and capabilities and national goals;
- To promote the development of high quality research capabilities in third-level institutions, so as to enhance the quality and relevance of graduate outputs and skills;
- And, within the framework of these objectives, to provide support for outstandingly talented individual researchers and teams within institutions and the encouragement of cooperation between researchers both within the institutions and between institutions, with a particular focus on promoting inter-institutional cooperation within Ireland, the EU and internationally

The PRTLI awarded €1.2 billion in exchequer and private match-funding over five cycles (five funding periods from 2000 to 2015), largely to support new research infrastructure (65% for buildings, research centres and equipment, and 35% for research programmes, training and other activities). However, in the later cycles there was more emphasis on research platforms/communities and collaborative research programmes.

The last cycle of PRTLI funding was awarded in 2010, covering the period up to 2015. Despite the national R&D strategy (2015) stating that a successor PRTLI would be scoped out and developed by 2016, no official information on any successor programme has yet been released (as of April 2017). We understand that the scheme, if/when it re-emerges, may look somewhat different – for example to take account of the research prioritisation exercise that has been conducted since the last cycle in 2010, and possibly with the programme devolved to a separate agency or body, rather than the HEA.

As no recent information is available on the framework or processes for the PRTLI scheme, and because it may evolve considerably in the coming years, this case study does not focus further on this programme. It looks instead at the (only) other significant RI scheme currently operating in Ireland.

8.1.4 Main RI funding schemes – RI Programme

Substantial investments in Research Infrastructures have also been made by Science Foundation Ireland (SFI), since it was established in 2003. This was reinforced by its **strategic plan for 2013-20**[52], in which SFI set out its intention to continue to invest in research infrastructure over the coming years, using exchequer funds and leveraging other resources, and ensuring that infrastructure is sustained through good access and charging models.

It launched the **Research Infrastructure (RI) Programme** in 2004, with further calls for proposals subsequently issued in 2007, 2012 and (most recently) in 2015.

There is no set budget for the programme (i.e. money is not ring-fenced). This is partly because SFI operates on an annual budgeting basis and so cannot necessarily be certain at the launch of a call about the funds that will be available at the end of the call/selection process. But more importantly, SFI wants to have the flexibility to consider the opportunities arising through this programme alongside other spending options in any given year. This flexibility means that proposals are not just funded because there is budget to be spent, but also that a case can be made for spending more if the number and quality of proposals put forward is greater than anticipated.

It is estimated that around €150m-€200m in grants have been awarded to-date (mostly in the latter two calls), with many of the individual grants exceeding €1m in value. For example, in 2016 SFI announced €28m in investments in research equipment and facilities across 21 different projects, with nearly half of these (13) receiving grants in excess of €1m each[53].

Aims and objectives of the programme

The RI programme aims to build, enhance and maintain national infrastructural capacity, in order to support the research community in accomplishing high quality, high impact and innovative research in areas of science, technology, engineering and mathematics that demonstrably enhance and underpin enterprise competitiveness and societal development in Ireland. It encourages the efficient use, renewal and development of existing infrastructure, whilst also recognising the need for continued investment in cutting-edge equipment and infrastructure in areas of national priority.

The key objectives of the programme currently include:

- To enhance activities and outputs of SFI researchers and other research groups
- To facilitate a more rapid commercialisation of research
- To encourage strategic infrastructural planning by research bodies
- To foster collaboration and partnership between researchers

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52 Agenda 2020 (SFI, 2013)

53 http://www.sfi.ie/news-resources/press-releases/28-million-research-infrastructure.html

- To encourage partnership with industry through collaborative initiatives or through provision of access to infrastructure (growing the utilisation of the infrastructure by industry is a key focus)
- To encourage good negotiation with equipment vendors resulting in cost-effectiveness
- To promote future sustainability through the development of access charge plans

A new requirement for 2015 was that proposals should also (where relevant) consider two further programme objectives that relate to maximising the impact of investments. These were:

- Funding key Research Infrastructures that will enable Irish researchers to compete for Horizon 2020 research funding calls, and in particular the EU Programmes for Integrated Research Infrastructures, Societal Challenges and Leadership in Enabling and Industrial Technologies.
- Encouraging bids that fund large infrastructures including testbeds, which have the potential to increase the Technology Readiness Level of research activities.

Further, applicants are also asked to include in their submission consideration of:

- Inter/intra-institutional partnerships, to ensure maximal usage and alignment with strategic plans
- Industry links, to support technology development, innovation and commercial impact
- International links, enabling participation in wider research programmes
- Access charge plans, to strengthen sustainability and maximise utility

In the following sections we examine the SFI RI programme in more detail, reviewing the appraisal, monitoring and evaluation processes, frameworks and approach.

Eligibility and eligible funding

Calls are open to all eligible research bodies (a set list of 34 organisations that includes research institutes, universities, colleges, institutes of technology, and others[54]), or collaborations between these. The research body is the body in charge of the financial and administrative coordination of the award received from SFI. It is considered the lead / primary applicant, and is responsible for the oversight and management of the research infrastructure. The Research Body must also specify a Key Responsible Investigator, who is responsible for the submission of the application and has primary fiduciary responsibility and accountability for the management of the infrastructure award and all associated monitoring and reporting.

The RI programme funds research infrastructure based on the definition derived from ESFRI. This covers major equipment or smaller individual items of equipment, in addition to knowledge-containing resources such as collections, archives, data banks, e-infrastructure and test beds. Research Infrastructures may be "single-sited", "distributed", or "virtual" including technology based infrastructures such as Grid, computing, software and middleware. Importantly, it does not fund the construction of the facilities (i.e. the buildings), but rather the equipment (large or small) within it.

Eligible costs include:

[54] Eligible bodies: http://www.sfi.ie/funding/sfi-eligible-research-bodies.html

- New equipment or equipment upgrades (including VAT, transport and installation)
- Maintenance or service contracts (for up to 2 years from purchase)
- Software
- Materials and consumables required to set-up/operate equipment (up to 2 years)
- Training for key personnel required to operate equipment
- Opportunistic funds

Human resources are not considered as eligible costs that can be covered by programme funding. However in-kind contributions (see below) can take the form of personnel to operate infrastructure.

Other ineligible costs include:

- Indirect costs / overhead
- Buildings and construction
- Contingency or miscellaneous
- Costs for programmes of research
- Access charges
- Costs to industry partners
- Hospitality and entertainment
- Office equipment and supplies
- Technology transfers of patent
- Conference / workshop organisation

Individual items of infrastructure to be supported through the RI programme must cost at least €50,000, and in most cases are expected to exceed €200k. Cost share is also mandatory for all requests, with minimum requirements for cash or in-kind (dedicated personnel to operate infrastructure) contributions from other sources. Infrastructure costing between €50k and €200k must achieve at least 40% cost share, while that costing more than €200k must achieve at least 10%. Other in-kind contributions are also encouraged, with SFI suggesting that a figure of 30% is desirable. The call documentation highlights that above-minimum levels of cost share will be looked on favourably as part of application review.

All infrastructure requests are required to align with one of the 14 National Research Priority areas (as defined by the Research Prioritisation Group in 2011), or any area under SFI's legal remit where strong evidence can be provided of significant relevance and strong economic impact.

8.2 The (ex-ante) appraisal approach

The SFI RI Programme launches **open competitive calls** for proposals every few years. The most recent call process invited proposals under four distinct categories (see below), with a call for Categories A and B launched in 2015 and a call for Categories C and D launched the year after.

- Category A: H2020 Research Infrastructure – Integrating Activities – Advanced Communities
  - Funding for key items of research infrastructure (an identified infrastructural gap), so as to strengthen the opportunities of Irish researchers (who are already within H2020 Advanced Communities) to lead / join a consortium submitting a bid to the H2020 INFRA-IA Advanced Communities call. The H2020 programme itself does not fund infrastructure, but rather supports its sustainability and efficient operation by funding transnational access, networking and joint research. (SFI has funded 7 proposals in this category – all

of which went on to successfully bid to H2020, resulting in significant financial drawdown to Ireland).

  - Infrastructure requests in this category must support STEM-based research. There is no cap on the number of requests accepted from individual research bodies.

- Category B: Large Scale Research Infrastructures for SFI Research Centres
  - Funding to support the expansion and sustainability of SFI Research Centres through the addition of new capabilities and partnerships.
  - Each of the existing twelve SFI Research Centres are permitted to submit up to two requests under this category.
- Category C: Large Scale Research Infrastructures for Research Bodies
  - Funding to address large scale infrastructural needs in the research community (beyond SFI Research Centres). (There were 68 proposals submitted to this category in 2016, of which just under half have been awarded funding).
  - Infrastructure requests should focus in areas of national priority or strategic opportunity that are aligned with the strategic research objectives of the relevant research body. Each research body is permitted to submit a prioritised list of up to six requests.
- Category D: Opportunistic Funding
  - Funding to address ongoing infrastructural needs of the community through "value for money" opportunities (i.e. funds that may be used for the acquisition of equipment when a value for money opportunity arises, e.g. through online auction buying). This category is for smaller infrastructure, with grants usually of a few hundred or a few thousand Euros each.

All bids (except for Category D) were required to express interest initially (for information and planning purposes only), one-month in advance of submitting a full proposal through the online SESAME system. The requirements for information at the EoI and Full Proposal Stage are set out in the box below. Category D applications are made via email and, given the nature of the call, need only include a (1 page) description and (1 page) listing of the types of equipment to be acquired.

Figure 1 Information requirements for expressions of interest and full applications, Ireland

The requirements for the **expressions of interest** vary by category, but generally necessitate brief information in each of the following areas:

- Details of key responsible investigator, including current SFI/eligible awards and contact details
- Primary National Priority Area of relevance
- Most appropriate (max 15) Research Keywords of relevance
- Total cost of infrastructure and requested funding from SFI
- Details of other bids relating to the same infrastructure that are outstanding
- Where equipment will be located
- Lay summary (150 words) – context and motivation for infrastructure request
- Technical summary (250 words) – technical details on the proposed infrastructure (components, function, alignment with objectives of call)
- Plus, depending on relevant category:
  - Category A: A statement on planned submissions to H2020 (250 words)
  - Category B: Details of the relevant SFI Research Centre
  - Category C: A ranked list of infrastructure requests for research body

The **full proposals (Category A-C)** require additional information under the following sections:

- Detailed description of infrastructure request (2 page per request)
  - Description of infrastructure requested
  - Justification for why new / updated infrastructure is needed
  - Overview of proposed user groups
  - How it would enable emergent areas of research (where relevant)
  - Link with research body strategic planning
  - How it would facilitate industrial collaboration and partnership (where relevant)
  - How it could be used to leverage other funding (where relevant)
  - How it will increase the TRL of research activities (where relevant)
- Detailed description of key users and how the requested infrastructure will enhance the activities of their group / collaborators / partners (1 page)
- Management and sustainability plan (1 page)
- Access charge plan (see below)
- Proposed budget and justification (1 page)
- Letters of support (2 pages each)
- Additional budget information
- Vendor quotes

It is worth noting the requirement for **access charge plans** as part of the proposal submission, as this is regarded as an important innovation within SFI. This was introduced in the 2012 call to encourage the community to think more professionally and help ensure the longer-term sustainability of infrastructure investments. Science Foundation Ireland recognises the importance of sustainability planning to enable research bodies to maintain research infrastructure. It is therefore critical that maximum usage of infrastructure is planned, and an appropriate access charge plan is put in place. At the same time, SFI allows grant applications under its various programmes to include requests for infrastructure access charges. But, it will only fund such charges once a pre-approved access charge plan is in place. A list of infrastructure with an approved access charge plan is available online[55], with over 100 listings currently. A copy of the access plan template is appended at the end of this case.

The submitted proposals are assessed through a rigorous international **panel-based peer review process**. The reviewers are selected at the sole and exclusive discretion of SFI and their identity is confidential. However, SFI have indicated that they select top-quality international scientists in the relevant areas for RI programme peer review, but also (where possible) that they look to identify reviewers with broader CVs as well (e.g. scientists with experience managing similar infrastructure themselves), as they are also expected to be able to comment on the technical validity of the bid.

Applications to the 2015 Call were evaluated by the review panels based on set criteria, which largely reflect the objectives set out for the programme (as mentioned above). These **criteria** were:

- The strength of the justification of need
- The proposed use of infrastructure by the named investigators
- Intra- and inter-institutional usage and access
- Potential long term benefits and impact of the infrastructural investment to enhance current research activities of SFI funded researchers and the wider research community
- Alignment to 14 National Research Priorities
- Contribution to the overall research strategy of the research body(ies) concerned
- Quality of sustainability and management plans, including access charge plans (that might incorporate cash / in-kind institutional contributions to reduce charges and maximise usage
- Favourable negotiation with suppliers for discounts, maintenance and technical support. There will be an expectation of industry cost-share in this regard.

In addition, where appropriate, consideration will also be given to **additional criteria**:

- Ranking of the infrastructure request with respect to priority as provided by the Research Body (Category C applications only)
- Strength of case made for leveraging non-exchequer funding if infrastructure investment is made

[55] http://www.sfi.ie/assets/media/files/downloads/Funding/grant_policies/Approved-SFI%20Access-Charges-18-01-17-web%20(002).pdf

- Relevance of investment to industry and proposed use by industry (from SMEs to MNCs)
- Development of existing centralised or national research facilities
- Quality of case for increase in TRL through the acquisition of, for example, a testbed.

The review process is conducted entirely virtually, with each reviewer assessing 5 or 6 proposals each (and each proposal being reviewed by 3 or 4 reviewers), based on a set of detailed guidelines provided by SFI[56]. **Reviewers provide a score** from 1-5 against each criterion (from very poor, weak, low potential, etc. to outstanding, justifying each score with additional comments. Each of the criteria and each of the reviewers have equal weighting, and an average score is calculated across review panel members. These scores and comments are collected through the online SESAME system and fed back to the programme management staff.

High-level review summaries are then produced internally for each proposal, providing basic details on the applicant, the proposed infrastructure and the review scores and comments (main pros and cons). These summaries then form the basis for a **two-day SFI internal panel**, where the programme management team report back on the proposals and panel reviews and come to a position on recommendations for funding. Predominantly this is based on the ranking of average scores provided by the panel review process, and if there is any deviation from this it needs to be justified.

The outcome of the internal panel then goes to the executive committee, who make a recommendation to a sub-group of the board for **final approval**. In addition, any individual investment above €250k must go through full board approval. Applicants are then informed of the outcome.

8.3 Monitoring and evaluation

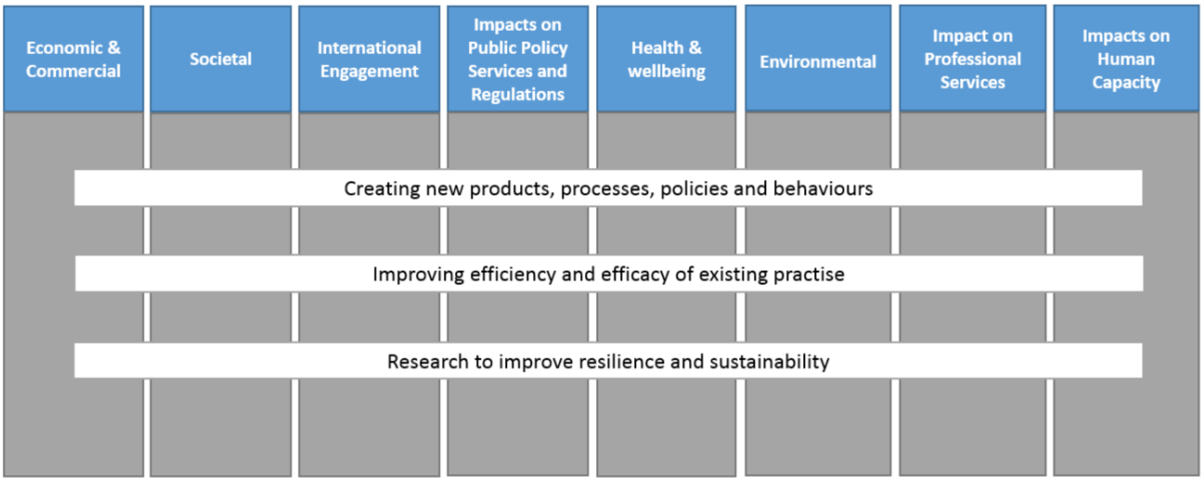
SFI notes on its website[57] that it is both desirable and necessary to show value for money from public spending and, within this, to demonstrate and articulate the impact and benefits of investing in scientific research. It adds that, as Ireland's scientific infrastructure and capacity matures, there is an even greater focus on demonstrating the economic, societal and other benefits of publicly-funded research to the wider society.

SFI Agenda 2020 sets out a vision for Ireland to be the best country in the world for both scientific research excellence and impact. While SFI continues to focus on scientific excellence, it also now applies equal focus on impact (which it defines as "the demonstrable contribution that excellent research makes to society and the economy") across its portfolio of programmes. SFI classifies the impacts of scientific research according to eight pillars, which are underpinned by three thematic areas. A summary of the pillars / areas is shown below. Full details of the 'types of impact' defined by SFI can be found appended at the end of this case.

[56] A copy of these guidelines have been shown to the study team, but cannot be shared.

[57] http://www.sfi.ie/funding/sfi-research-impact/

Figure 2 Classification of the impacts of scientific research, SFI, Ireland



SFI has always asked applicants to articulate the *value* of their research to Ireland, but it has been expanding and refining this aspect of requirements (both in terms of pre-funding appraisal and post-award evaluation of progress), as well as using experts in the translation, commercialisation and development of scientific research to evaluate research impact as an important and integral part of the review process. The intentions here are manifold, including:

- To stimulate researchers to consider how best to maximise the impact of their research, including the engagement of users in their research
- To actively demonstrate the contributions and benefit to society and the economy of publicly funded investment in R&D
- To better understand the transfer of scientific knowledge into practice, allowing the strengthening of the system and structures for this transfer, as well maximising the use and benefits of publicly funded research.

Monitoring arrangements / requirements

Reporting requirements

Successful awardees of the SFI Research Infrastructures Programme (as well as all other SFI programmes) are required to complete an annual report. For the RI programme this is a requirement each year for at least five years – but potentially longer, given the time required to assess and report on the outcomes of large infrastructure investments.

The SFI Grants and Awards Management System, SESAME, is the primary conduit for all SFI reporting, with the majority of programmes making use of a standard reporting template. The RI award, however, employs a bespoke template, specifically designed for this programme and first introduced for awards made in the most recent (2015/16) call.

The new template was designed by the post-award team, but working in close collaboration with pre-award staff, and in advance of the launch of the call. This was to ensure that reporting requirements align with the aims and objectives of the programme (as well as associated Key Performance Indicators set out in SFI's Strategic Plan "Agenda 2020"), but also to ensure that the aims and objectives initially set out in call documentation are appropriate for subsequent measurement.

The new template includes the following sections:

- Details of the Research Infrastructure

- Management of the Research Infrastructure
- Usage and accessibility
- Academic outputs (publications and proceedings)
- Outreach, media, education and public engagement
- Academic collaboration
- Strategic impact (more below)
- Industry engagement
- EU activities
- Knowledge transfer and commercialisation activities
- Funding diversification

Additional detail on each section of the annual reporting template for the RI award is appended at the end of this case[58]. This includes a more detailed look at the 'strategic impact' section, which requires awardees to select at least one (and up to 5) impact declarations from a given list (each of which aligns with one or more of the 'areas of impact' defined by SFI, and shown in the previous figure). Awardees are also asked to provide narrative and refer to metrics in support of the statements that they have selected, justifying their choice. The list of impact declaration statements that awardees can choose from is also appended to this case.

SFI are currently collecting the first annual reports using the bespoke template (these relate to the awards made for the 2015 call), and so it is too early to comment extensively on their use or usefulness. There is also an expectation that at this stage some of the award holders will have only made limited progress in terms of output, outcome and sustainability metrics – indeed some may still be in the process of purchasing and installing the equipment. This is why it is important to repeat the annual reporting process over a number of years, and to continue to capture and analyse the emerging data.

Post award site review

In earlier calls (pre-2015), each RI programme awardee was also subject to a site review following the acquisition and installation of the infrastructure. This was performed by SFI staff (possibly engaging international reviewers for certain – larger – awards) and involved examination of infrastructure installation and operation, management systems and access charging plans, and accessibility. Other areas that might be addressed included demonstration of partnerships, sustainable planning, links with industry, intra-/inter-institutional collaboration to ensure maximal usage and alignment with institutional strategic plans.

However, the future use of site-review is currently unclear. The new annual reporting template for the RI programme has attempted to amalgamate the collection of data on outputs with key information previously obtained through site review. As the first annual reports are only now coming through to SFI and have not yet been analysed, it is not clear to what extent these will prove sufficient. It is likely that after analysis of annual reports the programme manager will take a view as to whether or not (and in which particular cases) a site review would still be useful. In some cases, a follow-up

[58] However, this is still just a publically available summary. The full template has been provided to the study team, but cannot be shared.

phone discussion may be sufficient to clarify points from the annual report, while in others no further action may be needed at all. As the number of site visits had gradually increased over the years, the programme management team is keen to be able to use the new annual report to limit staff time on site visit activities where this is no longer necessary – focusing only on priority cases (be that the biggest grants, those showing a lack of progress or those that raise other concerns through their annual report).

Evaluation

The annual reporting process described above is in part to check on individual awards and award holders, including whether further checks are needed (e.g. site visit) or awards should be rescinded. But it is also intended to provide the basis for programme-level analysis (monitoring progress of investments, measuring outputs and outcomes achieved, and considering how the programme might best evolve in future calls). The reporting templates have been designed such that information can be easily extracted, aggregated and analysed – across projects and across years. While it is only the start of the first round of annual report analysis, the expectation is that over time SFI will be able to see investments gathering momentum and contributing increasingly to the original programme aims and objectives. Over the longer term it may also provide indications of infrastructure becoming obsolete, or requiring further investment, which will be important to understand for future rounds of funding.

Currently a summary overview analysis of the first annual reports are planned for internal circulation and consideration, but there is an expectation that the type and depth of analysis will build over time.

At some stage the RI programme will also be subject to a full external evaluation. One or two of SFI's programmes are evaluated each year by an external contractor, with the results reported to the Board. It is expected that the RI programme will be subject to such an evaluation in the coming years.

8.4 Summary of key strengths and weaknesses

- SFI has been working to improve the appraisal and monitoring processes associated with its Research Infrastructures programme. For instance:
  - Designing aims and objectives that are measurable
  - Looking to include proposal reviewers with broader expertise and knowledge of managing infrastructure investments
  - Developing new bespoke application and reporting templates that are specifically designed for the programme and the needs of the appraisal and monitoring process
  - Introducing new requirements to encourage broader access to infrastructure and longer term sustainability of its investments
  - Improving its ability to measure progress and achievements across the programme and over time.
- It now has well established and documented assessment and reporting criteria, templates and guidelines that have been improved over the course of a decade to reflect learning, new opportunities and changing policy and context.
- Other than some specific elements of criteria and objectives, much of the wider approach and process employed by the RI programme appears transferable to other countries and contexts.

- The longer-term monitoring and evaluation process is still a work in progress, in that the exact intentions here are not yet finalised. However, the programme management team (with pre-award and post-award collaboration) have worked hard to ensure the structures are in place to enable meaningful and useful analysis will be possible moving forward, which can feed back into future investment decisions and programme processes.

8.5 Sources

8.5.1 Documentary sources

The call documentation for the 2015 round of the RI programme:
http://www.sfi.ie/assets/media/files/downloads/Funding/Funding%20Calls/research_infrastructure/SFI_Research_Infrastructure_Call_Document_2015_12_10_15.pdf (Section 3.8)
Presentation: SFI Impact Webinar, May 2015, Aisling McEvoy, SFI:
http://www.sfi.ie/assets/media/files/downloads/Funding/Impact/Impact%20Webinar.pdf
SFI Research Infrastructure reporting guidelines:
http://www.sfi.ie/assets/media/files/downloads/Funding/sfi%20reporting%20procedures/SFI%20Research%20Infrastructure%20Reporting%20Guidelines.pdf

8.5.2 Interview partners

- Nicola Stokes, Pre-award programme manager for the Research Infrastructure Programme, SFI
- Yvonne Halpin, Post-award manager for the Research Infrastructure programme, SFI
- Marion Boland, Head of Post-Award, SFI

8.6 Supporting material

8.6.1 Types of Impact (as defined by SFI)

Economic Impacts: Impacts where the beneficiaries may include businesses, either new or established, or other organisations which undertake activity that creates jobs and revenue. Beneficiaries may also include graduates, employees, trained scientists and the general public. The following are examples of Economic Impacts:

- A new business sector or activity has been created or expanded through new or improved products/services or a significantly improved technology or process
- A spinout or start-up has been created around a new product, service or licence
- Research has attracted and nurtured developing businesses, for example, through the licensing of technologies.
- Industry or other organisations or charitable foundations have invested in their own research and development through research collaboration.
- Performance has been improved, or new or changed technologies or processes have been adopted, in companies or other organisations through highly skilled people having taken up specialist roles that draw on their research, or through the provision of consultancy or training that draws on their research.
- Employment has been created or increased through the production of a highly educated and relevant workforce in demand by industry and academia.

Societal Impacts: Impacts where the beneficiaries may include individuals, groups of individuals, organisations or communities whose quality of life, knowledge, behaviours, creative practices or other activity have been influenced positively. The following are examples of Societal Impacts:

- Public debate has been stimulated or informed by research.
- Public interest and engagement in science, engineering and mathematics (STEM) has been stimulated, for example, through the enhancement of STEM related education in schools and the increased number of children taking up STEM subjects at 3rd level
- The awareness, attitudes, education and understanding of the public have been enhanced by engaging them with research activities
- The work of an NGO, charitable or other organisation, including international agencies or institutions, has been enhanced by the research, for example through improved access to healthcare or improved water quality
- Quality of life has been improved through improved access to healthcare.
- Research has contributed to community development and regeneration
- Research supports creativity and increases appreciation and/or design of cultural services, for example, museums, galleries, libraries, through improving cultural awareness or improving the design and accessibility of public facilities thereby having a positive impact on cultural life of population and/or national identity.
- Mitigation of risks to public health, for example, through preventative measures for communicable and non-communicable diseases

International Engagement Impacts: Impacts where the beneficiaries include Irish based research scientists who are striving to improve their international reputation and international scientists who wish to relocate their research groups to Ireland. Irish businesses and Irish headquarters of MNCs may also benefit from increased international engagement._The following are examples of International Engagement Impacts:

- Significant contribution to global challenges, for example in the areas of health, the environment and poverty reduction
- Contribution to international relations and the international profile and reputation of Ireland
- Attraction of international scientists and talented people
- Leveraging of international funding through industrial and collaborative research
- New connections to international expertise have been developed providing access to new markets and state-of-the art knowledge

Policy & Public Service Impacts: Impacts where the beneficiaries may include government, non-governmental organisations (NGOs), charities and public sector organisations and society, either as a whole or groups of individuals in society. Impact can occur top-down through policy changes and bottom up, through changing behaviours at the delivery level. The following are examples of Policy & Public Service Impacts:

- Implementation, revision or verification of policy to improve efficiency, efficacy and responsiveness of public services and / or Government regulation
- Policy decisions or changes to legislation, regulations or guidelines have been informed by research evidence
- Changes to education or the school curriculum have been informed by research.
- Improvements in best practice of those delivering public services, have been made
- Risks to national security have been reduced
- Improvements in risk management in public services/public sector

Health and Wellbeing Impacts: Impacts where the beneficiaries may include individuals (including groups of individuals) whose health outcomes have been improved or whose quality of life has been enhanced (or potential harm mitigated) through the application of enhanced healthcare for individuals or public health activities. The following are examples of Health and Wellbeing Impacts:

- Patient health outcomes have improved through, for example, the availability of new drug, treatment or therapy, diagnostic or medical technology, improvements to patient care practices or processes, or improvements to clinical or healthcare guidelines.
- Public mental and social health and well-being has improved.
- Increased efficiency of delivery of public health services.
- Decisions by a health service or regulatory authority have been informed by research.

- Quality of life in a developed or developing country has been improved by new products or processes through, for example, improved water quality or access to healthcare.
- Animal health and welfare has been enhanced by research.
- Reduction in cost for treatment for an equivalent outcome through a new drug, device or improved diagnostics
- Mitigation of risks to public health, for example, through preventative measures for communicable and non-communicable diseases
  - Disease prevention or markers of health have been enhanced by research
  - Public awareness of a health risk or benefit has been raised
  - Improved nutrition and food security

Environmental Impacts: Impacts where the key beneficiaries are the natural and built environment with its ecosystem services, together with societies, individuals or groups of individuals who benefit as a result. The following are examples of Environmental Impacts:

- Debate on the environment, environmental policy decisions or planning decisions have been stimulated or informed by research and research outputs
- The management or conservation of natural resources, including issues around global competition for energy, water and food resources, has been influenced or improved.
- The management of an environmental risk of hazard has been improved (e.g. risk to stakeholders/community has been decreased and or resilience of community has been increased)
- The operations of a business or public service have resulted in the meeting of relevant environmental objectives
- New/improved technology or process has led to direct reduction in pollution and/or reduction of impact of pollutants on ecosystems and humans
- Improvement in sustainable use of resources and reduced overall consumption of constrained resources
- The management of natural resources, including issues around global competition for energy, water and food resources, has been improved.
- Understanding of health risks to livestock and disease risks to crops have improved, enabling improved health and increased security in food production.
- In the built environment, infrastructure or housing quality and/or longevity have been increased.

Professional Services Impacts: Impacts where beneficiaries may include organisations or individuals involved in the development of and delivery of professional service. The following are examples of Professional Service Impacts:

- Changes to professional standards, guidelines or training have been informed by research.
- Practitioners/professionals/lawyers have used research findings to improve the standard of their working practices

- The quality or efficiency or productivity of a professional service has improved.
- Professional bodies and learned societies have used research to define best practice.
- Practices have changed, or new or improved processes have been adopted, in companies or other organisations, through the provision of training or consultancy.
- Forensic methods/technologies have been improved as a result of research

Human Capacity Impacts: Impacts where beneficiaries cover the entire population, primary school students studying STEM subjects, the general workforce including science teachers, health professionals, policy makers, business leaders in SMEs and MNCs and the general public. The following are examples of Human Capacity Impacts

- The production of a highly educated and relevant workforce in demand by industry and academia
- Increased productivity of the workforce through improvements in health and general work environment
- Improved scientific and technical skills of current and future workforce
- Increased uptake of STEM subjects at secondary and University level
- Public interest, discussion and engagement in science, engineering and mathematics has been stimulated
- Attraction of international scientists and talented people to Ireland,
- Performance has been improved, or new or changed technologies or processes have been adopted, in companies or other organisations through the employment of highly skilled people having taken up specialist roles that draw on their research, or through the provision of consultancy or training that draws on their research
- Increased leveraged funding though programmes such as Horizon 2020 due to the increased number and level of highly skilled researchers in Ireland

8.6.2 *Research Infrastructure Award – Access Charge Plan Template (for applications)*

Access Charge Plan Template *(including examples)*			
(add rows or columns, for more years, as required)			
Item Requested			
Total Cost €			
Key Responsible Investigator			
Location (Dept., Centre)			
Category	***Examples of Line Items***	**2016**	**2017**
		€	€
Staff	*Technical staff*	€0	€0
Materials & Consumables	*filters, liquid Nitrogen*	€0	€0
Maintenance / Service Costs	*following warranty*	€0	€0
Other Costs	*user training*	€0	€0
Total Gross Operating Costs		**€0**	**€0**
Less Exchequer - Funded Costs	*research body Core staff, SFI awards, PRTLI awards, Other awards, consumables etc.*	€0	€0
Total Net Cost		**€0**	**€0**
Usage Hours		0	0
Cost per hour		€0	€0
Annual Charges	*Academic Users*	€0	€0
	Industry Users	€0	€0
	Other		
		€0	€0
Additional Notes			

8.6.3 *Research Infrastructure Award – Annual reporting template*

The annual reporting template for the RI programme requires information from award holders in the following eleven areas:

- Details of the Research Infrastructure - awardees are required to include all individual items which were purchased as part of their Research Infrastructure award (including the make and model of each individual item purchased as part of the overall research infrastructure).
- Management of the Research Infrastructure – awardees are to describe the plan for servicing and maintenance of the research infrastructure
- Usage and accessibility – to understand how users can access the research infrastructure funded through the award and how the associated access charges are calculated and managed. Awardees are also required to provide information regarding how the research infrastructure is advertised to the wider community. These details will inform the future sustainability of funded infrastructures and maximises utility and impact within the academic and industrial research community
- Academic outputs (publications and proceedings) – awardees are asked to report on all refereed journal and conference publications supported by the Research Infrastructure award, including both primary or secondary attributed outputs. (SFIs Agenda 2020 sets a target for Ireland to maintain its position in international bibliometric rankings)
- Outreach, media, education and public engagement – awardees are asked to input details on outreach, media and / or education and public engagement activities performed during the reporting period which are directly or indirectly related to the Research Infrastructure award, or similar activities that have involved the research infrastructure funded through this award. Awardees are asked to provide details on any engagement activities that were run as part of other programmes, but involved the infrastructure supported through their RI award.
- Academic collaboration – awardees are asked to input data on all academic collaborations, including intra- and inter-institutional national and international, which have arisen as a result (direct or indirect) of the RI award.
- Strategic impact* – awardees are provided with a list of 11 impact declarations or statements, of which at least one must be selected (although they are encouraged to rank up to 5, based on their relevance). Awardees are also asked to provide narrative and refer to metrics in support of the statements they have selected.
- Industry engagement – awardees are asked to input data on all industry engagement, including new collaborations with industry partners, which have arisen as a result (direct or indirect) of the RI award
- EU activities – awardees are asked to input details on any applications made to join a H2020 Research Infrastructure Advanced Community or ESFRI project as a result of infrastructure supported through this award
- Knowledge transfer and commercialisation activities – awardees are asked to input details on invention disclosures filed; patents filed, granted or exploited; licensing agreements signed; assignments; ICT standards / specifications; spin-out companies or start-up companies formed, which are directly or indirectly

attributable to the RI award. (This information is to enable SFI to report against the Agenda 2020 KPI of doubling (by 2020) the proportion of invention disclosures, patents, licences and spin outs recorded by Enterprise Ireland that are linked to SFI research).

- Funding diversification – awardees are asked to input data relating to any funding which has been leveraged as a result of the infrastructure supported through the RI award, including both national and international funding streams, for example H2020. (This information is to enable SFI to report against Agenda 2020 KPIs to (i) increase the average research income secured by Ireland based PIs from international funding entities and so reduce the number of researchers that rely on SFI for the majority of their funding; (ii) to increase the level of leadership roles held by Ireland-based PIs in major European initiatives; and (iii) to increase the number of ERC grants secured by Ireland-based PIs.)

Impact declarations

*For the 'strategic impact' section of the RI programme reporting template, awardees are provided with a list of 11 '**impact declarations'**. Each aligns with one or more areas of impact defined by SFI (shown in parenthesis):

1. The research conducted through my award has enabled me to leverage international funding through industry/collaborative research (Economic and Commercial, International)
2. The research conducted through my award has resulted in the start or expansion of a company which has resulted in the creation of high value jobs (Economic and Commercial)
3. The research conducted through my award has attracted developing and nurturing businesses (Economic and Commercial)
4. The research conducted through my award has attracted international scientists and talented people (Human Capacity; International Engagement)
5. The research conducted through my award has resulted in a new policy being implemented and/or an improvement to the delivery of a public service (Public Policy and Services)
6. The research conducted through my award has enhanced the quality of life and health of Irish citizens (Health & Wellbeing, Societal Impact)
7. The research conducted through my award has improved the environment and/or the sustainable relationship between society, industry and the environment (Environmental Impact)
8. The research conducted through my award has increased the knowledge, appreciation and understanding of science, engineering and technology amongst the general public. The research conducted through my award has developed the country's international reputation (Societal Impact, International Engagement)
9. The research conducted through my award has resulted in the creation of employment through directly influencing and inspiring the future workforce and/or the production of a highly educated and relevant workforce in demand by industry and academia (Human Capacity, Economic and Commercial)

10. The research conducted through my award has impacted in other areas not reflected in the choices provided, for example by enhancing the creative output of Irish citizens (Environmental, Professional Services, Societal)
11. The research conducted through my award has not yet realised any significant Impact

At least one statement must be selected, although awardees are encouraged to rank up to five of these statements according to relevance, as well as provide more details justifying the declarations they have selected.

9 Netherlands

9.1 The process of allocating science capital funding

The first National Roadmap for Large-Scale Research Facilities in the Netherlands was published in 2008. Following an initial process to identify preliminary ideas, a national roadmap committee invited 16 consortia to elaborate their proposals – with the majority submitted by the Universities of the Netherlands, the Royal Netherlands Academy for Arts and Sciences (KNAW) and the Netherlands Organisation for Scientific Research (NWO).

Then, after several years, the State Secretary for Education, Culture and Science requested that the NWO organise a review of the Roadmap. Several research facilities that had not yet reached sufficient maturity in 2008 had developed further in the interim, while other new research facilities had arisen. More generally there was felt to be a need to periodically review the Roadmap. The national roadmap was updated in 2012. The latest update of the National Roadmap took place in 2016 and the aim is to update the roadmap every four years.

The funding for large research infrastructures started earlier (in 2006), with the then Minister of Education Culture and Science, Maria van der Hoeven, deciding to invest €100m in the development of five large-scale research facilities. The available budget was oversubscribed about 15-fold with proposals that were usually of a high quality. This was an indication of the considerable demand for large-scale research facilities and NWO requested that the Minister provide structural funding in this area. In 2008 the Minister of Education, Culture and Science set aside €20m in NWO's budget – a figure that has since risen to €40m per annum. With this budget, bi-annual funding rounds are organised, with a budget of €80m now available for each round. The most recent funding rounds were in 2012 and 2014. In 2017, a new call was issued based on the National Roadmap of 2016, with funding decision expected in 2018. For this latest round, NWO funds for large-scale research infrastructure totalling about €110 million will be deployed, of which €5 million is earmarked for bridge funding.

In 2006 an advisory committee (the "committee Van Velzen") was also established to advise the Minister of Education Culture and Science about policy regarding large research infrastructures. This temporary committee was followed by the Taskforce Large Scale Research Facilities. Then, in 2015 the Permanent Committee for Large-Scale Scientific Infrastructure was appointed by NWO, in accordance with a request from the Ministry of Education, Culture and Science based on advice of the AWTI. This committee consists of 12 members (from several scientific organisations) and was tasked with formulating a national strategy for investment in large-scale research infrastructures. In particular, the committee has focused on formulating a more strategic approach to research infrastructure in the Netherlands. To realise its task, the committee has made an inventory of all large-scale research facilities in the Netherlands. This inventory has guided the update of the National Roadmap for Large-Scale Scientific Infrastructure 2016.

For the assessment of applications submitted under the Call for Proposals National Roadmap for large scale Research Infrastructure, the Governing Board of NWO appoints ad hoc selection committees. These committees are made up of researchers with a strong track record and expertise in research facilities.

9.1.1 Funding round 2017

Earlier funding rounds were completely bottom-up. This changed in 2017, when the new Permanent Committee developed a strategic framework that includes strong cooperation between facilities. The committee also decided to divide funding over different fields of science.

The main aim of the funding for large research infrastructures is to strengthen science. Large-scale research infrastructures are considered vitally important for carrying out innovative scientific research. In addition, they can play an important role in boosting social and economic innovation. Furthermore, the committee aims to secure continuity in both the assessment and the investment opportunities in scientific infrastructure.

The funding in the National Roadmap assessment procedure is competitive. However, applications may only be submitted by facilities that have been included in the National Roadmap. The competitive funds available are open for all scientific fields. The following framework for distributing funds applies: 10% is available for infrastructure within the humanities and social sciences, 45% is available for infrastructure within the natural sciences and engineering sciences, and 45% is available for infrastructure within the life sciences.

In order to obtain funding, applications must comply with the following conditions:

- The size of the infrastructure, in terms of the total capital investment and the exploitation costs for a period of 5 years, is at least €10m. This amount excludes the cost for accommodating the research facility. The exploitation costs concern solely the costs needed to make the research facility accessible. It does therefore not concern the costs for the research programme.
- For distributed research infrastructure, a single point of access for researchers from external organisations and a single board of management (or consortium agreement) are required.
- Infrastructure must implement an access policy for research that is in agreement with the European Commission's European Charter for Access to Research Infrastructures.

Funding can include the following elements:

- The costs for the development and acquisition/construction of the intended research facility, or the costs of a modification to the existing research facility that enables scientific breakthroughs. This also includes the membership contributions of the Netherlands to an international research facility or an international research project if these are intended for the costs stated above. Costs of accommodation of the research facility are not eligible for funding and do not count as co-funding.
- The costs (personnel and material) for the running of the facility can be requested on a one-off basis for a maximum of 5 years (if the operational life is 10 years or more) or proportionately less (if the operational life is shorter than 10 years). This also includes the membership contributions of the Netherlands to an international research facility or an international research project if these are intended for the costs stated above. Running costs are understood to mean those needed for keeping the facility operational and the facilitation of external users.
- The costs for realising the required ICT infrastructure insofar as these are in addition to the typical existing ICT infrastructure of the institutions involved or that are already available nationally, such as SURF (the national computer centre).

The following costs are not eligible for funding: costs for accommodation; costs that have been incurred or for which obligations have been entered into before the grant is awarded; costs that have previously been funded or have been financed in another way from university or public funds and costs for research that can be conducted with the infrastructure.

The following knowledge institutions are allowed to submit applications:

- Dutch universities and university medical centres
- Academic research institutes (e.g. NWO and KNAW institutes; the Netherlands Cancer Institute; the Max Planck Institute for Psycholinguistics in Nijmegen, Advanced Research Centre for NanoLithography (ARCNL) and NCB Naturalis)
- Researchers from the DUBBLE Beamline at the ESRF in Grenoble.
- Academic libraries
- Institutes for applied research like TNO, Large Technological Institutes (LTIs), Governmental Knowledge Institutes and DLO. However, their applications must mainly be motivated from the perspective of tools for science

In summary, in the last ten years the Dutch Government secured a permanent funding stream for large research infrastructures (currently around €40m annually), the present National Roadmaps for large research infrastructures provides a strategic framework for investments and the establishment of a permanent committee provides a longer-term vision on large research infrastructure in the Netherlands.

9.2 The (ex-ante) appraisal approach

For the assessments of applications, NWO appoints an ad-hoc **selection committee**, which will carry out the assessment of current applications within the frameworks established in the Call and the National Roadmap. The selection committee will be composed of experienced senior researchers with a broad knowledge of scientific developments and experience with large scientific consortia/institutes. There will not be any overlap between this committee and the Permanent Committee for Large-Scale Research Infrastructure, who will be involved in assessing the admissibility of the applications.

The selection committee will assess applications according to the following **criteria** and sub criteria, with each of the three headline criteria accounting for one-third of the final assessment:

- Science and excellence case
  - The importance for science and the potential to attract researchers
  - Embedding of the investment
  - Urgency of the investment for Dutch science
- Innovation and strategic case
  - The importance for society and industry and the connection with societal developments
  - National interest
- Technical, business and management case
  - Technical feasibility

- ICT infrastructure
- Organisation and governance
- Accessibility
- Financial aspects
- Risk analysis

The three criteria (science and excellence case, innovation and strategic case and technical, business and management case) each weigh for 33,3% in the final assessment of the proposal.
The first step in the assessment procedure is to test whether an **application is admissible**. To this end, the Permanent Committee for Large-Scale Research Infrastructure will have a role in assessing the applications (in as far as these concern the strategic framework and conditions defined by the Permanent Committee) and advise the Executive Board of NWO, who will then take a final decision.
The next step is a **peer review procedure**. For all eligible applications, at least four referees' reports will be requested. Applicants will then give their response. The applications and information obtained will then be studied by the selection committee, who will then select the applications in two phases:

- During the first phase, the committee will prioritise all applications on the basis of the assessment criteria and will invite applicants of the highest ranked applications for an interview or site visit.
- During the second phase the committee has the opportunity to pose questions during an interview or site visit. These are an important part of the selection process and may lead to an adjustment of the original assessment. After the interview or site visit, the committee will then draw up a final ranking of applications and submit this ranking advice to the Executive Board of NWO.

The Executive Board of NWO will take a **funding decision** about the applications.

9.2.1 Changes in the appraisal-process

Since the first financing round in 2006, the financing of large research infrastructure funding has seen a change from ad-hoc funding to more structural funding. This is a process that is still ongoing.
The major changes to the appraisal-process have taken place between 2013 and 2016, following advice from the AWTI. The AWTI was asked by the Ministry of Education, Culture and Science and the Ministry of Economic Affairs to investigate the best strategy for the Netherlands regarding investment in large-scale research infrastructure, both for the national, European and global level. One of the recommendations was the instalment of the 'Permanent Committee Large Research Infrastructures' to oversee and coordinate investments. Other recommendations included a phased selection process involving different areas of expertise at different stages, and the consideration of:

- European and global playing fields for possible public and private sector partners
- The entire life span of facilities and their lifetime costs
- The required quality of facilities, given their intended purpose
- The possibilities for public-public and public-private cooperation in the development and use of infrastructure

- How facilities fit with the specialisation pattern and development strategy of universities, research institutes and regions

Finally, the report urged ministers to create the necessary preconditions for the work of the Committee on Large-Scale Research Facilities in the form of an inventory of large-scale research infrastructures in the Netherlands, as well as a specification of strategies regarding large-scale research infrastructure of universities, research institutes and 'top sectors' and the regular monitoring and evaluation of the use and performance of these facilities.

Based on the advice by the AWTI, a Permanent Committee has been installed, which has resulted in a more structured approach to the funding of large research facilities. The committee also ensures more coordination between facilities that apply for funding. This led to clustering of facilities because they require comparable equipment or cover a similar scientific field. The current roadmap contains 19 clusters of facilities, which are based on the inventory of large-scale facilities in the Netherlands, and that consist of facilities that would like to purchase or develop similar research infrastructure and aims to stimulate collaboration between research areas. These clusters were asked by the Permanent Committee to each propose an investment agenda. The current roadmap also contains 14 individual facilities, in addition to these clusters.

Since the instalment of the Permanent Committee that sets the framework for the assessment and the instalment of the cluster-approach a change has also taken place in the **composition of the selection committee**: previously, this committee consisted of members from Dutch research organisations. With the clustering of research facilities and the establishment of the Permanent Committee, finding independent experts in the Netherlands has become near to impossible. For that reason, the selection committee will exist of foreign experts only.

Another change that has taken place is a **shift in focus in the appraisal of proposals**, from being solely interested in the scientific contribution, to also taking into account the long-term sustainability, possible risks and the governance of the research facility.

9.2.2 Reception of the new model

At the moment, the new financing model has not received many comments from the field. Organisations will have to get used to the new structure, in which institutes that compete with each other must also now collaborate in clusters. Because the first financing round since the instalment of the Permanent Committee is still ongoing, the outcomes of the new model are still unknown.

In 2016, the AWTI published further advice to the Dutch government, where it was mentioned that the current bi-annual €80m is not enough to keep large research infrastructure in the Netherlands at a good standard. NWO is advised to increase the budget and assign the Permanent Committee with the task to make the resources better available to public knowledge institutes other than universities. Part of the resources should also be made directly available for the facilities of the institutes of applied science (TO2-institutes). Furthermore, structural investments should be made in digital research infrastructure. The follow-up of these recommendations is to be decided by the next cabinet.

9.3 Monitoring and evaluation

The emphasis in the Netherlands with regards to the assessment of large research infrastructures is focused more on ex-ante appraisal than monitoring and evaluation, and so the Permanent Committee (and NWO) have no requirements regarding the governance (e.g. supervisory board) for the latter.

However, for the monitoring of the investments in large research facilities the Permanent Committee asked all funded projects to submit a progress report in 2015. The form was to be submitted by the board or director of the organisation/institute leading the project and contain information about:

- General information (name, contact, hosting organisation, type of infrastructure, key words)
- Governance (organisation, participants, governance)
- Users (Dutch-based / international research and institutes, type of user groups)
- Access policy
- Results (outputs, other results)
- Financial aspects
- Recent developments
- Future developments

In addition to the progress reports, the Permanent Committee made an inventory of all the large research infrastructures in the Netherlands. The committee also invited boards of public research institutions to register their operational facilities and future investment plans for the coming five years. The results of this are made available online (http://www.onderzoeksfaciliteiten.nl).

The target group for the website are people that use or are looking for facilities in the Netherlands, as well as policy makers that need an overview of major research infrastructure. The data on the website will in the future be automatically transferred to the Mapping of European Research Infrastructure Landscape (MERIL) database. Furthermore, the website is being developed to allow for the visualisation of the clustering of facilities and the ordering of the roadmap facilities based on their development-progress.

The progress reports and the inventory of large scale research infrastructures in the Netherlands were used as input for the inclusion of facilities on the roadmap. There is no structural monitoring process in place. However, the current call for proposals for the 2017-2018 period does ask for applicants that have previously received funding to include information on the progress of their project.

The roadmap itself will receive an end-evaluation every four years, before the instalment of a new roadmap. In addition, the Permanent Committee consults with the different institutes on the reception of the roadmap, while at every meeting of the Committee it considers the effectiveness of the current roadmap structure.

9.4 Summary of key strengths and weaknesses

- The appraisal- and evaluation procedure in the Netherlands has seen several changes in the last few years. As of the 2017 funding round, the new procedure pays more attention to the financial aspect and organisation of large scale research facilities, as well as to the commitment of the institutions and organisations involved.

- The instalment of a Permanent Committee and the introduction of cluster-coordination are also seen as major improvements to the process that lead to a more stable and strategic approach of research infrastructure policy in the Netherlands.
- The regular updating of the roadmap for research infrastructures and the input it receives from a Permanent Committee can be considered a strength of the Dutch appraisal and evaluation process.
- A weakness in the Netherlands is the fact that monitoring and evaluation of projects is still in an early stage. There is no structural monitoring of projects, while aspects such as the dissemination of infrastructure are also not taken into account. This process is being developed at the moment and will possibly also depend on future (longer term) resources for large-scale infrastructure.
- The appraisal and evaluation process in the Netherlands could largely be transferable to other science systems, for example the instalment of a Permanent Committee and selection committee. However, it is unclear how the current cluster-approach - which works well for a small country such as the Netherlands – would function in a larger country.

9.5 Sources

9.5.1 Key documentary Sources

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- http://onderzoeksfaciliteiten.nl/permanente-commissie
- http://www.onderzoeksfaciliteiten.nl
- National roadmaps large-scale research infrastructure
- Call for Proposals National roadmap large-scale research infrastructure 2017
- AWTI report, *Size and Suitability. Investing strategically in large-scale research facilities* (2013)
- AWTI report, *Houd de basis gezond* (2016)

9.5.2 Interview Partners

- Professor Emmo Meijer, AWTI, Chairman of AWTI report *Size and Suitability*.
- Isabel van der Heiden, NWO, Policy Officer responsible for the roadmap 2017/2018.
- Kas Maessen, NWO, Coordinator of infrastructure activities and Permanent Committee.

10 Norway

10.1 The process of allocating science capital funding

The key organisation in Norway for funding large research infrastructures is the Research Council of Norway (RCN), which operates under the responsibility of the Norwegian Department of Education and Research. The RCN is the single most important advisor to the Government in research policy-making. The RCN creates meeting places, provides a platform for dialogue between researchers, users of research and research funders and works to promote international cooperation.[59]

The RCN comprises of four research divisions, one division for administrative affairs and an executive staff organised directly under the Chief Executive. The RCN has some 400 employees. The Chief Executive's staff has the overall responsibility for coordinating activities relating to budget planning, strategic initiatives, statistics, annual reports, international cooperation and media contact. The shape of the research divisions ensures that relevant institutions (e.g. universities, university colleges, independent research institutes, organisations and industry) are adequately represented. Annually, the RCN distributes roughly NOK nine billion to research and innovation activities.[60]

National Financing Initiative for Research Infrastructure (INFRASTRUKTUR) was introduced in 2007 and is the only national funding scheme in Norway. Hence, all decisions regarding funding of research infrastructure projects of national importance are made by the RCN, with the intention to support the development of nationally prioritised research areas. If a project exceeds the budget managed by the RCN, the project needs financial support by nationally prioritised research areas and national key industries. INFRASTRUKTUR is managed within the RCN and handles applications ranging from NOK 2 million to NOK 200 million (€220k to €22m). Applications exceeding NOK 200 million are decided by the responsible Ministry based on advice from the Research Council.[61]

The Norwegian Government allocated NOK 24.8 billion (€2.7bn) for R&D investments in 2014.[62] The resources allocated by the RCN in 2015 totalled NOK 7.8 billion (€860m), up from NOK 6.3 billion (€700m) in 2011.[63] RCN funding specifically for research infrastructure was NOK 451 million (€50m) in 2015, an increase of NOK 100 million from the previous year.[64] The funding of research infrastructure has steadily increased each year since 2010, when funding was around NOK 100 million (€11m).[65]

The RCN has been drawing up national road maps for investing in large-scale research infrastructure in Norway since 2010. It looked to roadmaps existing and under development in other countries in order to establish a strategic basis for investments. The roadmap for 2016 constitutes the basis for RCN recommendations for increasing

[59] http://www.forskningsradet.no/en/The_Research_Council/1138785832539

[60] http://www.forskningsradet.no/en/Organisation/1138785841802

[61] The Norwegian Research Council (2012). Verktøy for forskning – del I Nasjonal strategi for forskningsinfrastruktur 2012–2017.

[62] http://www.ssb.no/en/teknologi-og-innovasjon/statistikker/foun/aar-endelige/2016-02-04

[63] http://www.forskningsradet.no/en/Key_figures_for_the_Research_Council/1254021049089

[64] The Norwegian Research Council (2015) Årsrapport 2015.

[65]https://www.forskningsradet.no/prosjektbanken/#/explore/statistics/query/querystring=&view=stats&dist=pbaarbelopcalcnav&counttype=sum&chart=trend&lang=no&sortby=%20pbaarstart%20pbaarslutt&offset=0&navigators=pbsokntypefornav,S,%5EForskningsinfrastruktur$,S,S%C3%B8knadstype,S,Forskningsinfrastruktur,C,pbaar,S,%5E2017$,S,%C3%85r,S,2017,OR,%5E2016$,S,2016,OR,%5E2015$,S,2015,OR,%5E2014$,S,2014,OR,%5E2013$,S,2013,OR,%5E2012$,S,2012,OR,%5E2011$,S,2011,OR,%5E2010$,S,2010,C,pbkilde,S,FORISS,S,kilde,S,FORISS&lang=no

the volume of investments in research infrastructure and aiming for a long-term sustainable financing of research infrastructure.[66] The roadmap covers strategies for eleven different research areas. The infrastructures included are of national importance, which means they have to be of national interest, be public and accessible for relevant research areas and practitioners, construct a foundation for further international research and be limited to one or a few institutions/places. The purpose of the last criteria is to locate coinciding interests on a national level and promote collaboration between stakeholders.[67]

The roadmaps are a product stemming from the 2009 research White Paper *Klima for forskning* (Climate for research). In *Klima for forskning*, it was stated that the RCN should be set with the task of creating a roadmap in which large-scale research infrastructure projects would be presented. The roadmap will work as a recommendation for Norwegian investments in research infrastructure in the nearest future. The demands were strict on what should be included in the roadmap. In order for the roadmap to meet its purpose of achieving the overall targets of the Norwegian research policy, only investments matching the requirements of producing high scientific quality and are of societal relevance were to be included in the roadmap.[68]

One interviewee states that before the Norwegian government decided to introduce the roadmaps, Norway was falling behind other countries regarding research infrastructure. Consequently, INFRASTRUKTUR was introduced. The same interviewee explains that it has been difficult for the RCN to determine what specific effects the roadmaps have entailed. The same interviewee means that the roadmap has contributed to a strategic approach to investments in infrastructure and that this could be an effect of the roadmaps highlighting projects and certain prioritised research areas. In addition, the EU are making links specifically to every national roadmap that further promote the Norwegian projects. According to one interviewee, this attracts additional attention from interested parties and financiers.

In terms of target groups, the majority of the research infrastructure resources allocated by the RCN in 2016 has mainly been to research institutes (NOK 438.8 million or 68%) and universities or university colleges (NOK 145 million or 22%). A small proportion of funding has been allocated to the private sector (NOK 59.6 million or 9%) and investments in other unspecified research infrastructures (NOK 1.9 million or 0.3%).[69]

The RCN highlights certain projects in the roadmap after every major announcement of allocations. For a project to get on to the roadmap three criteria all need to be met:

- The infrastructure has to be of national importance (12 areas)
- The infrastructure needs to be appraised both scientifically and strategically
- The scope of the infrastructure has to be extensive

The objectives of the funding scheme are therefore both scientific and societal. For the project to be of national importance, the establishment of a given research infrastructure has to generate an added value for Norway as a nation. The second

[66] The Norwegian Research Council (2016). Norsk veikart for forskningsinfrastruktur 2016.

[67] The Norwegian Research Council (2012). Verktøy for forskning – del I Nasjonal strategi for forskningsinfrastruktur 2012–2017.

[68] St.meld. nr. 30 (2008–2009), *Klima for forskning*.

[69]https://www.forskningsradet.no/prosjektbanken/#/explore/statistics/query/querystring=&view=stats&dist=pbaarsektorbelopcalcnav&counttype=sum&chart=bar&lang=no&sortby=%20pbaarstart%20pbaarslutt&offset=0&navigators=pbsokntypefornav,S,%5EForskningsinfrastruktur$,S,S%C3%B8knadstype,S,Forskningsinfrastruktur,C,pbaar,S,%5E2016$,S,%C3%85r,S,2016,C,pbkilde,S,FORISS,S,kilde,S,FORISS&lang=no

criteria is linked with the appraisal approach (for a detailed description see part 1.2). In short, the projects highlighted in the roadmap need to have received high professional praising from the expert groups. In addition, the RCN need to anticipate that the establishment of the research infrastructure have a great strategic value for Norwegian research. The third criteria regarding the extensive scope specifically means the project needs to be compatible with other research infrastructures within the given research area in order to further increase the usage of the infrastructure.[70]

One interviewee states that one interesting aspect of the Norwegian roadmap is that not all projects included in the roadmap have been granted money. The three criteria described above are the only formal demands a project have to meet in order to be included. This is due to the RCN wanting to be able to highlight certain projects that have received high praising, but have not been granted money for example due to insufficient funds. According to one interviewee, this enables RCN to both encourage these projects to reapply during the next call for appraisals and highlighting the need of an infrastructure in a specific research area to other applicants and financiers.

10.2 The (ex-ante) appraisal approach

The allocation process for funding large research infrastructure projects is competitive and encompasses the projects in the roadmap, even though not all granted projects are included in the roadmap. The RCN is responsible for the ex-ante appraisal process in collaboration with the National Financing Initiative for Research Infrastructure. The process is the same for all types of research infrastructure, including large-scale infrastructure. First, applications are assessed by committees consisting of external experts (expert panels), which consider whether the infrastructure will contribute to research of high scientific quality. This process provides an overview of the specific areas in need of research infrastructure improvements. The assessment of the expert panels is advisory to the RCN's assessment of the applications in the second part called the administrative process. In addition, the administration of the RCN conducts an assessment encompassing all research infrastructures of national and strategic importance, and prepares a recommendation to a board committee consisting of qualified members of the Executive board and division boards. This invites a possibility to take action in areas in which a few major, nationally important research infrastructures are favoured in the allocation process. The work is carried out to identify prioritisations in specific research areas and how the infrastructure corresponds to those priorities.[71]

This approach is enables the RCN to make appropriate strategic priorities, and to target specific subjects and topics where necessary. Those eligible for science capital funding for research infrastructures are universities, university colleges and research institutes. Also, publicly managed administrations are able to apply for funding if their work is closely linked to one of the different research institutions in Norway.[72]

Criteria used for assessment include: relevance to the announcement, a research infrastructure of national importance, scientific importance of the infrastructure, internationalisation, commercial relevance, societal relevance, national cooperation, national employment, feasibility, plan for the establishment and operation, administrative management of the infrastructure, ethics, environmental consequences

[70] The Norwegian Research Council (2016). Norsk veikart for forskningsinfrastruktur 2016.

[71] The Norwegian Research Council (2012). Verktøy for forskning – del I Nasjonal strategi for forskningsinfrastruktur 2012–2017.

[72] The Norwegian Research Council (2012). Verktøy for forskning – del I Nasjonal strategi for forskningsinfrastruktur 2012–2017.

and lastly the overall quality of the application. These criteria are mainly developed to match the future national and global needs within given research fields, as well as to make sure the projects meet the demands on quality necessary for the infrastructure to produce research of high quality. Actors that are part of the project have through a bottom-up process actively contributed to the shaping of the criteria.[73]

The strategic assessment of the applications are guided by the notion of what is being prioritised in certain research areas and how the infrastructure corresponds to these priorities. The expert panels have an advisory purpose to the RCN, but the RCN reviews the applications by the aforementioned criteria to make an overall assessment, which then constitutes the final decision. The applications must fulfil the requirements, but the criteria are not weighted against each other in any specific manner. Instead, the RCN funds the research infrastructures with the highest average score, all criteria included.

After all applications have been submitted, a two-step evaluation process begins. First, an expert panel is assembled according to the professional profile in the application base. To ensure an impartial assessment, almost all the panellists are located abroad. The expert panels evaluate each application based on given criteria. The application must obtain a grade of five or better in both the expert panel's overall assessment and in the evaluation of the feasibility criteria. An average of every criteria constitutes the final grading of a 1-7 scale. Although every criteria is not formally graded from 1-7, the final grading is an overall assessment of all criteria taken into account. The most important part in the assessment is to estimate how the research infrastructure will be used in the coming ten years. This is conducted through analysing what the priorities are in a given research area and how the infrastructure will meet these priorities.[74] One interviewee states that the plans for operational costs are very important and must be included in the project description, and that the users should contribute to the operational costs of the infrastructures.

The panels that consist of employees of the RCN with a vast knowledge and experience of the given scientific area and their respective Norwegian researchers undertake the first step in the administrative process. The administration panels are divided in the same manner as the expert panels. The administration panels evaluate all applications that have received high marks (5, 6 or 7 on the 1-7 scale) from the expert panel. Applications that need high investments and/or are considered to be of particularly great national importance (i.e. large-scale infrastructure), are evaluated regardless of the ratings by the expert panels. In this step of the process, all the projects, regardless of research area, compete against one another and the panels make an overall assessment of the applications that best meet the above-mentioned criteria.[75]

In general, the RCN's funding for research infrastructure covers capital costs but not operational costs. Thus, the users are expected to cover operational costs. The RCN's funding supports upgrades, establishment of research infrastructures and occasionally the long term operation if some specific prerequisites are met.[76] One interviewee states that a characteristic element of the Norwegian model is that the money granted are not upfront payments. Instead, the projects has to get started and later on RCN makes the payments when receiving the invoices. This method was established in order to shorten

[73] The Norwegian Research Council (2012). Verktøy for forskning – del I Nasjonal strategi for forskningsinfrastruktur 2012–2017.

[74] The Norwegian Research Council (2012). Verktøy for forskning – del I Nasjonal strategi for forskningsinfrastruktur 2012–2017.

[75] http://www.forskningsradet.no/no/Forskningsinfrastruktur/1186753746616

[76] Norwegian Research Council (2012). Verktøy for forskning – del I Nasjonal strategi for forskningsinfrastruktur 2012–2017.

the start-up phase as well as to streamline the budgetary use. According to the same interviewee, it appears to have been a success thus far.

10.3 Monitoring and evaluation

In general, all funding recipients under the RCN are required to participate in project level evaluations and report at regular intervals. The RCN has a general responsibility for satisfactory control of the allocated funding to ensure the results of the projects correspond to the initial plan.[77] The programme guidelines of INFRASTRUKTUR also request an annual progress report. In addition, an early follow-up meeting within six months from the signing of the contract monitors the establishment of the project and observes the progress of the project as specified in the funding agreement, aiming to reduce the start-up phase. Thereafter, annual meetings are arranged. A final report is to be delivered within one month after the end of a project.[78]

Both the progress reports and the final reports detail project outcomes, and financial performance, both regarding the project as a whole and per participant. The aim of the reports is to support evaluations of the overall benefits from the project, and in consequently from INFRASTRUKTUR as a whole on an aggregated level.[79]

There are no specific indicators to monitor the progress other than economic ones. Instead, the monitoring of the projects focuses on the capacity of the infrastructure, and how the capacity corresponds to the economic schemes mapped out in the contracts. Three parts are mandatory to include: the main targets and the interim targets for the specific report, an economy scheme for the project as a whole and an economy scheme per partner.[80]

The project leader is to deliver a comprehensive, separate report based on the template available at the website of the RCN, which shall contain all relevant subjects of the report, such as costs and financing plans etc. Furthermore, subjects that should be included is the operation of the infrastructure, identification of the users and what capacity the infrastructure holds. These are used to define what type of research the infrastructure contributes to.[81]

According to one interviewee, the administrative responsibility of the project is important and extensive. The rationale behind this is to create sustainable projects that work in the long-term perspective, beyond the scope of the contract. Consequently, the RCN has been very clear that the management of participating institutions, institutes or companies has to be involved in the projects. Since the economic and administrative elements are so extensive, it is considered highly important that the management of the involved actors is included in the projects. Several of the interviewees has mentioned the need for an increased economic awareness within the projects in order to make them long-term sustainable.

The evaluations of the aggregated reports are commissioned almost exclusively by the RCN and are meant to strengthen the knowledge base of research and innovation policies, strengthen the efficiency and accuracy of the allocations, reveal the results and effects of the investments and contribute to internal learning and organisational development. The evaluations have an advisory purpose to the relevant political

[77] http://www.forskningsradet.no/no/Artikkel/Om_prosjektrapportering/1182736868212

[78] http://www.forskningsradet.no/prognett-infrastruktur/Prosjektoppfolging_og_rapportering/1253990140745

[79] http://www.forskningsradet.no/prognett-infrastruktur/Prosjektoppfolging_og_rapportering/1253990140745

[80] http://www.forskningsradet.no/prognett-infrastruktur/Prosjektoppfolging_og_rapportering/1253990140745

[81] http://www.forskningsradet.no/prognett-infrastruktur/Prosjektoppfolging_og_rapportering/1253990140745

departments, for example regarding adoption of more efficient and accurate strategies. In order to fulfil these objectives, the RCN centres its evaluating work on three principles.[82]

First, through the implementation of a "process wheel", the RCN expects that the systematics of the evaluations will increase. The process wheel is a system established for planning, implementation and follow-up and is invented to ensure appropriate standardisation, integration, efficiency and anchoring of the evaluation work. The starting point is the planning, next up is implementation and the final part is the follow-up. The follow-up part is a tool used to enhance the planning of new projects, thereby also enhance the implementation part, and in turn generate stronger overall projects.[83]

Second, a strategic approach is expected based on long-term and targeted initiation and monitoring of evaluations. The strategic approach aims to strengthen the efficiency and accuracy of the evaluation instruments in the research and innovation policy area. Thus it is expected to contribute to a greater knowledge of the future needs and thereby enhancing the implementation of future projects.[84]

Third, evaluation activities must increasingly reflect a changing research and innovation policy, which the RCN strives to achieve through renewal of methods and targets of the evaluations. The RCN aims to further legitimise public investments in research, development and innovation through developing the methods of the impact evaluations, increasing the focus on wide impact evaluations, confirming the effects of the evaluations carried out by the RCN, investigating the possibility of using ex ante evaluations and developing result- and impact indicators.[85]

According to one interviewee, the RCN is constantly balancing the methodological approach of how different projects are to be evaluated. Decisions whether qualitative or quantitative evaluations should be used are made with regard to the design of the project. Decisions regarding the most appropriate methodological approach are based by looking at the purpose of the infrastructure and how it is used. The same interviewee states that the evaluations are often conducted similarly within the same research area since projects within the same research area often have similar characteristics.

One interviewee states that the evaluations are primarily supposed to support the development of the scientific community. The scientific effects are clearly the focus of the evaluations, but some of the users of the infrastructure projects spend much of their time on issues within applied sciences that generates spillover effects in the society. However, the same interviewee explains that it is difficult to confirm the spillover effects and there are no standardised instruments yet for evaluating the spillover effects.

According to several of the interviewees, one effect from INFRASTRUKTUR has been a big knowledge bank. The knowledge bank has been created through the rigorous information sharing between the vast amounts of users of the research infrastructures. This is beneficial for the scientific community as well as to the society.

However, one interviewee states it has taken a long time to grasp the effects of the infrastructures. Since the first discussion regarding the investment was initially initiated back in 2007, it is only now that the effects are starting to appear. Actions

[82] Norwegian Research Council (2013). Evalueringspolicy for Norges forskningsråd, 2013–2017.

[83] Norwegian Research Council (2013). Evalueringspolicy for Norges forskningsråd, 2013–2017.

[84] Norwegian Research Council (2013). Evalueringspolicy for Norges forskningsråd, 2013–2017.

[85] Norwegian Research Council (2013). Evalueringspolicy for Norges forskningsråd, 2013–2017.

taken to promote the long-term targeted initiation and monitoring of the evaluations are for instance user surveys as the RCN, as agreed in the contract, can order from the projects 'managements. The aim of the user surveys are to collect additional information of how the infrastructures are used. Hence, the RCN can make more well-founded decisions in their future strategic activities.

In 2016, the RCN published a portfolio analysis of the national investments in research infrastructure. The portfolio analysis regards all by then granted projects on an aggregated level sorted by research area and summarises number of applications, amount of money applied for, amount of money granted and share of granted projects from the total number of applications. In addition, the portfolio analysis covers types of costs, funding sources and size of the projects. In conclusion, the portfolio analysis contains both general and detailed information about all the aggregated granted projects from 2009-2015 based on four calls for appraisals.[86]

The portfolio analysis covers scientific impacts, industrial impacts, international cooperation, sustainability and future challenges. The portfolio analysis contributes to the assessment of future applications by addressing the challenges of increasing the capacity and the systematic approach in the evaluations of the portfolio of infrastructure projects. The portfolio analysis is part of an increased budget for INFRASTRUKTUR in which an extra NOK 400 million (€42m) were to be allocated during the period of 2014-2018.[87]

The effects and challenges described in the portfolio analysis are based on data from the first four calls for appraisals of INFRASTRUKTUR. The mentioned effects have increased the quality of the research, the overall quality of the research system, the international cooperation and have developed more sustainable operating regimes. The challenges for the coming years were to establish a long-term budget, to provide open access to research data, to specify legitimate costs in relation to the projects, to further improve the monitoring and evaluations of the projects and to relate to new financial laws regarding research from the EEA.[88]

10.4 Summary of key strengths and weaknesses

In general, the entire process from announcing prioritised research areas, to granting projects that meet these priorities, to evaluating the aggregated reports from the projects overall seems coherent and well-functioning. The purpose of the entire process is to strengthen the long-term scientific quality in Norway. Through the introduction of a roadmap, the RCN has established a platform for channelling the information necessary to meet this purpose as well as to strategically govern the Norwegian infrastructure investments. RCN has as an organisation established routines for monitoring and evaluating investments. This enables RCN to have a clear strategy and purpose of the monitoring and evaluation activities. In addition, there is also room for flexibility, for example regarding the methodological approach and for using user surveys.

Only a few weaknesses can be identified in the current system. One weakness is that it still seems to be difficult to measure the impacts of the infrastructures. Furthermore,

[86] Norwegian Research Council (2016). Porteføljeanalyse for Nasjonal satsing på forskningsinfrastruktur. Avdeling for forskningsinfrastruktur, Norges forskningsråd.

[87] Norwegian Research Council (2016). Porteføljeanalyse for Nasjonal satsing på forskningsinfrastruktur. Avdeling for forskningsinfrastruktur, Norges forskningsråd.

[88] Norwegian Research Council (2016). Porteføljeanalyse for Nasjonal satsing på forskningsinfrastruktur. Avdeling for forskningsinfrastruktur, Norges forskningsråd.

given the fact that there are no standardised instruments for measuring potential spillover effects. The RCN has tried to address these issues through several actions. For instance developing the process wheel, ordering user surveys and publishing the portfolio analysis. It has to be recognised that these issues are not exclusive for Norway, since determining impacts always is a delicate matter. In general, user surveys might be a good idea measuring the hard caught impacts, even if there might be a bias problem (positively) as well as general issues related to dealing with perceptions.

In Norway, the overall R&D field is very well financed. The overall infrastructure system has many positives and seems well structured and organised considering the use of roadmaps and the extensive strategies for monitoring and evaluating the infrastructure investments. RCN is a big actor with a lot of funds as well as a vast experience of different research systems. This means that the established and extensive routines for RCN regarding infrastructure investments, for example regarding evaluating and monitoring processes, are more transferable to other bigger organisations with the right infrastructure in place. However, organisation with similar characteristics as RCN are likely to be successful adopting a similar system to the Norwegian.

10.5 Sources

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The Norwegian Research Council, Årsrapport, 2015
http://ssb.no/
Consulting Kirsti Solberg Landsverk at the Norwegian Research Council

10.5.2 Interview partners

Norway Solveig Flock (Special advisor, Infrastructure, The Research Council of Norway)
Norway Svein Stølen (Principal of UiO)
Norway Tor Grande (Vice Dean for Research at Department of Materials Science and Engineering, NTNU)
Norway Unni Steinsmo (former CEO of SINTEF)

11 Sweden

11.1 The process of allocating science capital funding

The Swedish Research Council is the national coordinator of large research infrastructure in Sweden. Since 2014, it has reviewed the processes involved in the organisation, prioritisation and financing of research infrastructures, and as a consequence is gradually implementing a new model. For instance, calls for applications are now released every other year and the applicants must be listed within the inventory of needs priority list, whereas previously annual open-competitive calls took place.[89] In addition, the universities apply for funds of infrastructures instead of the given research group as in the previous model.

In 2012, Kåre Bremer (then, rector of Stockholm University) was contacted by the Swedish Research Council to study and assess the forms for organisation, governance and funding of Swedish national infrastructure funded by the Swedish Research Council. The outcome of the study is based on meetings and discussions with all then host universities of the national infrastructures and other stakeholders. For example, the Swedish Research Council, the Council for Research Infrastructure (RFI) and the Association of Swedish Higher Education (SUHF). In the report, it was suggested that annual calls were too often considering that infrastructures of national importance are long-term commitments and are few in number. In addition, the report recommended an extension of the five year period of grants.[90] Consequently, the Swedish Research Council now fund national infrastructures for eight years. Generally, many of the recommendations in the report was taken into account when developing the new model.

Besides the Swedish Research Council, other research funding agencies and universities fund large research infrastructure projects. For example, infrastructures owned by the Swedish Energy Agency and the Swedish National Space Board (SNSB) are not channelled by the Swedish Research Council.[91] Annually, the Swedish Energy Agency distributes SEK 15 million to new projects within the basic energy research.[92] No information is available about SNSB's contributions to research infrastructure.

In total, the Swedish Government invested SEK 34.4 billion (€3.6bn) in R&D during 2016.[93] This included SEK 1.8 billion (€190m) invested by the Research Council in research infrastructure, of which SEK 800 million (€84m) was to support national research infrastructure.[94] The research infrastructure funding is mainly targeted at universities and other research performers, but other organisations are also free to

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[89] The Swedish Research Council (2014). THE SWEDISH RESEARCH COUNCIL'S GUIDE TO RESEARCH INFRASTRUCTURES: The Swedish Research Council

[90] Kåre Bremer (2013) SYNPUNKTER PÅ PLANERING, ORGANISATION, STYRNING OCH FINANSIERING AV SVENSKNATIONELL INFRASTRUKTUR för forskning med stöd från Vetenskapsrådet genom Rådet för infrastruktur: The Swedish Research Council

[91] The Swedish Research Council (2014). THE SWEDISH RESEARCH COUNCIL'S GUIDE TO RESEARCH INFRASTRUCTURES: The Swedish Research Council

[92] https://www.vr.se/forskningsfinansiering/sokabidrag/vetenskapsradetsutlysningar/stangdautlysningar/projektbidraginomenergiriktadgrundforskning.5.63a8cc152634fa8b6ec2a9.html

[93] http://www.scb.se/hitta-statistik/statistik-efter-amne/utbildning-och-forskning/forskning/statliga-anslag-till-forskning-och-utveckling/pong/statistiknyhet/statliga-anslag-till-forskning-och-utveckling-2016/s

[94] Vetenskapsrådet, (2017). Vetenskapsrådets årsredovisning, 2016: The Swedish Research Council

apply. At least three organisations should apply together as a consortium[95] with one selected host organisation (most often a university or a research performing public agency).[96]

The Council for Research Infrastructure (RFI) announces calls every other year and is responsible for processing the applications. From 2015, existing research infrastructure has competed with new infrastructure projects for funding, so as to ensure both continuity and renewability. The granted projects should be of the highest scientific quality and used by the best researchers in the field.

The calls are based on the scientific and strategic prioritisations developed through the 'inventory of needs', a process that develops proposals for research infrastructure that align with the Swedish Research Council's Guide to Research Infrastructures. This guide is an important part of the model and is published every four years by the Swedish Research Council. It aims to direct Swedish investments in research infrastructure and increase awareness of challenges that need to be addressed in the coming years. An appendix to the guide is published every other year, and presents information and updates about the prioritised areas.

The general principles for the Swedish Research Councils investments in research infrastructure are: open-access for researchers, national importance and the scientific value. The objectives of the funding scheme are to both promote high quality science and to meet national challenges.

11.2 The (ex-ante) appraisal approach

The Swedish Research Council´s old model for prioritisation, funding and organisation of national research infrastructure was in place during the years 2006 – 2015. The old model had annual open calls and allocated four different types of grants: project grants, planning grants, grants for investing in equipment or databases and operational grants. Then, the Swedish Research Council used experts for assessing the applications. The main criteria for assessing the applications was the scientific quality of the infrastructures. In addition, the Swedish Research Council used the criteria of societal development (technological development, knowledge formation and internationalisation), feasibility (organisational maturity, costs and technology), strategic research considerations and open access.[97] According to the interviewees, the old model had less criteria for assessing the applications. According to the interviewees, the Swedish Research Council had less tools in the old model to assess if the infrastructures were of national importance and used by others than the research groups of the infrastructures. The criteria of national importance as well as the criteria of implementation, organisation and leadership of the infrastructure have been added to the new model.

In short, the differences between the new model and the old model regard the involvement of the universities (prioritisation process and strategic involvement), a narrower scope of national importance and establishing a long-term perspective of infrastructure investments as well as renewability. According to the interviewees, the

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[95] http://www.vr.se/forskningsfinansiering/sokabidrag/vetenskapsradetsutlysningar/aktuellautlysningar/bidragtillinfrastrukturavnationelltintresse.5.6b078ee51581835cea274c4b.html

[96] http://www.vr.se/forskningsfinansiering/sokabidrag/vetenskapsradetsutlysningar/aktuellautlysningar/bidragtillinfrastrukturavnationelltintresse.5.6b078ee51581835cea274c4b.html

[97] The Swedish Research Council (2012). THE SWEDISH RESEARCH COUNCIL'S GUIDE TO INFRASTRUCTURES 2012: The Swedish Research Council

process of implementing the new model is still ongoing. One early learning is the importance of clear instructions for the applicants.

The Swedish Research Council initiated the reform behind the new model. As mentioned previously, Kåre Bremer assessed the forms for organisation, governance and funding of Swedish national infrastructure funded by the Swedish Research Council. The main recommendation of the report was that the universities should have a more central role when prioritising the needs for infrastructure of national importance. The report specifically points to the weakness that the managements of the universities was not involved in the planning of the Swedish Research Council´s guide to research infrastructure. Concretely, the report suggested that the management of the universities should form a body for infrastructure that together with the Swedish Research Council make prioritisations regarding infrastructure of national importance. According to the report, the information in the guide were limited regarding which university had the biggest need as well as capacity for hosting an infrastructure within specific research areas. In addition, the universities were recommended to develop their internal organisation for planning and prioritising infrastructures.[98]

Under the Swedish Research Council's new model, ex-ante appraisal is a two stage process. According to the interviewees, the universities had a central role when developing the new model.

The first stage is the inventory of needs, which is compiled by universities, research actors and research groups submitting proposals for research infrastructure, based on identified research needs. In the latest inventory of needs, the Swedish Research Council received 150 proposals from higher education institutions (HEIs), research performing public agencies, research groups and research funding bodies.

The Swedish Research Council then makes a strategic and organisational prioritisation of the submitted proposals from the inventory.[99] In this process, the Research Council considers the opinions of universities, a reference group for research infrastructure (representatives from the management of the ten largest HEIs and a representative for the Association of Swedish Higher Education) and other scientific committees and councils of the Swedish Research Council.[100]

According to the interviewees, the introduction of the inventory of needs provided an overview of the current needs of infrastructure of national importance. Since the infrastructures listed in the Swedish Research Council´s guide to infrastructure are not guaranteed funding, other financiers can use the guide to fund infrastructures that have not yet been granted funds.

Submitted proposals are categorised by thematic area and then divided into seven different grades (A1-D). The groups A1 (mature enough for call for application and considered to be an infrastructure of national interest) and A2 (not mature enough for call for applications but an infrastructure of national interest) are listed in appendix to the Swedish Research Councils Guide to Research Infrastructure. The areas in A1 are prioritised but not guaranteed funding, while the areas in A2 can only apply for grants

[98] Kåre Bremer (2013) SYNPUNKTER PÅ PLANERING, ORGANISATION, STYRNING OCH FINANSIERING AV SVENSKNATIONELL INFRASTRUKTUR för forskning med stöd från Vetenskapsrådet genom Rådet för infrastruktur: The Swedish Research Council

[99] The Swedish Research Council (2014). THE SWEDISH RESEARCH COUNCIL'S GUIDE TO RESEARCH INFRASTRUCTURES: The Swedish Research Council

[100] The Swedish Research Council (2016). APPENDIX TO THE SWEDISH COUNCIL'S GUIDE TO INFRASTRUCTURES: The Swedish Research Council

in 2019 at the earliest.[101] The criteria used for assessing the submitted proposals are national importance, scientific relevance, and strategic considerations. The assessment is made by advising groups connected to the RFI.[102]

The next phase in the process concerns the calls for infrastructure, which are issued every other year, and only open to the prioritised projects. RFI has the overall responsibility for announcing calls and evaluating the applications.[103] The applications are assessed by an expert panel considered possessing extensive infrastructure competence. The expert panel assess the applications based on the seven criteria listed below.

Joint applications are generally requested (by at least two universities that forms a consortia) in order to ensure a wide national interest as well as financial stability for the infrastructure. The consortia need to at least co-fund 50 % of the total costs of the infrastructure. The applications need to include a realistic and sustainable financial plan and a contract that ensures binding financial support to the infrastructure by the involved actors. The applications also need to have a scientific, technical and organisational plan. In addition, applications need a plan to support e-infrastructure. The template for the financial plan covers: costs (management and equipment operation support), contributions (by the Swedish Research Council, the consortium members and other funders), user fees, management costs (manager, salary, rent of premises, other costs and indirect costs), activity (function staff, function science support per staff, equipment, construction/development/installation, other depreciable costs, adaptation of premises, rent of premises, other costs and indirect costs) and existing resources that is available through the consortium. In general, the financial plan address costs or other financial information distributed per year and per module within the infrastructure.[104] The technical and organisational plans are covered by the criteria listed below (for example implementation, organisation and leadership).

The interviewees states that the applications are assessed regarding socio-economic impacts. The assessment of socio-economic impacts is based on innovation aspects and considers if the industry can absorb the expected results of the infrastructures. The applicants are asked to motivate how the infrastructure is going to promote Swedish and international innovation. In addition, the applicants can exemplify with key references and with patents.[105]

Five evaluation panels (which are being merged into one in 2017) assess the applications based on scientific, technical and organisational aspects. The following seven criteria are used in the assessment of the applications:[106]

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[101] The Swedish Research Council (2016). APPENDIX TO THE SWEDISH COUNCIL'S GUIDE TO INFRASTRUCTURES: The Swedish Research Council

[102] https://www.vr.se/forskningsinfrastruktur/saprioriterasinfrastruktur/behovsinventering2017.4.5b5331114b70e41aef3ffc4.html

[103] http://www.vr.se/inenglish/aboutus/organisation/scientificcouncilsandcommittees/scientificcouncilsandcommittees/councilforresearchinfrastructures.4.69f66a93108e85f68d4800011615.html

[104] https://www.vr.se/forskningsfinansiering/sokabidrag/vetenskapsradetsutlysningar/stangdautlysningar/bidragtillinfrastrukturavnationelltintresse.5.6b078ee51581835cea274c4b.html

[105] https://www.vr.se/forskningsfinansiering/sokabidrag/vetenskapsradetsutlysningar/stangdautlysningar/bidragtillinfrastrukturavnationelltintresse.5.6b078ee51581835cea274c4b.html

[106] http://www.vr.se/forskningsfinansiering/sokabidrag/aktuellautlysningar/bedomningssidor/bedomninginfrastruktur.4.44d83f3a14c55dafc4b1a58.html

- Ethical consideration (only text):
  - The criteria is used to comment on potential ethical dilemmas that the application has not taken into consideration.
- Scientific impact (the assessment is based on 1-7 scale: poor, weak, good, very good, very good to excellent, excellent, and outstanding):
  - The criteria is used to assess the scientific impact of the infrastructure. This includes how the infrastructure: meet the needs of the research; promote world-leading research; long term synergy effects; scientific, organisational, technical and operational comparison to similar European and international infrastructures; merits of the Swedish scientists connected to the infrastructure as well as the merits of the Swedish scientists who participates through in-kind contributions; dissemination of research results and competence.
- Societal impact (the assessment is based on a 1-3 scale: insufficient, sufficient and excellent):
  - The criteria is used to assess the non-academic impacts of the infrastructure: This includes: contribution to innovation and societal development; possibilities for the industry.
- Implementation, organisation and leadership (the assessment is based on 1-7 scale: poor, weak, good, very good, very good to excellent, excellent, and outstanding):
  - The criteria is used to assess: competence of the leadership and the partners (both scientific/strategic and leadership); cooperation with other infrastructures; realistic time plan considering construction, development and operation of the different modules of the infrastructure; accessibility, communication and user support towards current and new users.
- E-infrastructure (the assessment is based on a 1-3 scale: insufficient, sufficient and excellent):
  - The criteria is used to assess e-infrastructure aspects, such as: calculations (visualisations, simulations and analysis); databases; networks; development and implementation of software; user support.
- Prioritisation between modules (only text):
  - The criteria is used to suggest a prioritisation between different functions and modules within the infrastructures. This regards: the modules contribution to the scientific objectives of the infrastructure; assessment if the budget of the modules is reasonable.
- Final grade (the assessment is based on 1-7 scale: poor, weak, good, very good, very good to excellent, excellent, and outstanding):
  - The final grade is the seventh criteria and is used to assess the overall capacity of the infrastructure. This regards: to what extent the infrastructure fulfils the Swedish Research Council´s criteria of being an infrastructure of national importance; promoting Swedish researchers to perform excellent research (added value of the coordination and synergy effects of the infrastructure); to what extent the organisation and operation of the infrastructure support Swedish researchers to perform excellent research; missed risks or obstacles.

The final grade is an overall assessment based on the six other criteria. The six criteria include elements of assessing non-market impacts. The description of the final grade suggest that it is important that the research infrastructures promote scientific excellence. According to the interviewees, the panel´s assessment of the research infrastructures is mostly based on the scientific contribution. In addition, RFI in collaboration with the advisory groups assess the research infrastructures contribution to the overall strategies of research infrastructure investments. According to the interviewees, ethical considerations have been highlighted in this year´s call.

According to the interviewees, the latest call (2017) was the first call where the applicants in advance could check the criteria used for assessing the applications. This was done to increase the applicant's chances of meeting the criteria. The method used to assess the applications is peer review. In this process, the experts assess the applications by their experience and competence of infrastructures. In addition, the RFI has the possibility to exclude certain modules of the infrastructures if they are required to not meet the criteria. The applicants are also asked to make their own prioritisation of the modules of the infrastructure. According to the interviewees, the number of modules can shift between the infrastructures.

Panels then make recommendations to the RFI. However, the final decision on funding the infrastructures is made by the Swedish Research Council in dialogue with the involved consortia.[107]

The funding is holistic and covers both capital and operational costs (planning, development, operation and decommissioning). Funding is limited to an eight-year period, however if the infrastructure is considered to still be of national interest, additional funding can be applied for.

In general, the new model has enabled a better coordination on a national level. The interviewees explains that the universities have through the new model an increased understanding of the long term costs of the infrastructures which means that they are better equipped planning future costs of the infrastructures. This is especially important since the universities are required to co-fund 50 % of the total costs. In addition, the new model has improved the Swedish Research Council´s capacity to strategically govern the national infrastructure investments. One example mentioned by the interviewees is that different databases have been coordinated within one infrastructure. A result of this is that researchers can use bigger datasets and more tests (for example regarding biobanks) that provides more accurate results (statistical significance).

11.3 Monitoring and evaluation

The granted research infrastructure has a board with overall responsibility for the infrastructure. The boards consist of highly qualified experts as well as national and international researchers that are not part of the university management or have a position with a similar degree of influence.[108]

In general, all funded researchers need to send in annual financial reports and in most cases scientific reports to the Swedish Research Council.[109] The granted research

[107] The Swedish Research Council (2014). THE SWEDISH RESEARCH COUNCIL'S GUIDE TO RESEARCH INFRASTRUCTURES: The Swedish Research Council

[108] The Swedish Research Council (2014). THE SWEDISH RESEARCH COUNCIL'S GUIDE TO RESEARCH INFRASTRUCTURES: The Swedish Research Council

[109] http://www.vr.se/forskningsfinansiering/beviljadebidrag/aterrapportering.4.6b078ee51581835cea2ae106.html

infrastructure projects need to report according to the general terms of reporting, which focuses on key numbers in terms of usage, national reach, equality and scientific results/impacts. Granted research infrastructure projects (from 2015-onwards) also have to annually report against the following indicators:[110]

- Equipment (costs, supplier and explaining text)
- Salary costs, for the construction and modifying of instruments (names of individuals and hours)

In addition, the scientific reports of the infrastructure that have been granted funds from 2015 report through (a selection from) the following criteria:

- Contribution to databases and social science or medicine with focus on individual data
  - Scientific report of 1-2 pages: explaining what the funds have been used for, usage of the infrastructure and publications from the infrastructure
- Contribution to national and international research infrastructure
  - Key numbers in line with specific terms
  - Number of users in terms of thematic area, gender, researchers, others, per module of infrastructure
  - Number of research projects that uses the infrastructure
  - Number of publications and patents, by contribution from the infrastructure (after 2-3 years and is mandatory for applications by existing infrastructures)
  - Number of datasets that the infrastructure has produced
  - Extent of usage per user
  - Number of applicants that have been denied access (total and gender)

In 2012, the Swedish Research Council released an interim evaluation of eleven national research infrastructures. The focus of the evaluation was on accessibility, organisation and management. The overall objective of the evaluation was to assess the performance and outcome of the research infrastructures. The interim evaluation was carried out by three international expert panels. The evaluation was based on self-evaluations by the infrastructures, business plans, organisation plans, strategic plans, a user survey and a hearing with representatives of the infrastructures. The Swedish Research Council highlighted five specific aspects of the evaluation: the general development of the infrastructures (e.g. activities and management), national accessibility, cooperation between national and international infrastructures and nodes, user perspective (e.g. support and training) and the host university and its role to the infrastructure. Economic impact was not directly one of the aspects evaluated. The outcomes of the evaluation supported the Swedish Research Council on decisions for continued funding and recommended improvements for the infrastructures.[111] Thus, the evaluation had implications on both learning and budget re-allocations.[112]

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[110] http://www.vr.se/forskningsfinansiering/beviljadebidrag/aterrapportering/infrastrukturbidrag.4.5b71f982159f91b7a7c89ecd .html

[111] The Swedish Research Council (2012). Interim Evaluation of 11 national research infrastructures 2012. VETENSKAPSRÅDETS LILLA RAPPORTSERIE 10:2012.

[112] The Swedish Research Council (2012). Interim Evaluation of 11 national research infrastructures 2012. VETENSKAPSRÅDETS LILLA RAPPORTSERIE 10:2012.

11.4 Summary of key strengths and weaknesses

The allocation, ex-ante appraisal and the monitoring and evaluation are all well-developed processes within the new Swedish model for research infrastructure investments and prioritisations. The Swedish Research Council has been successful involving the universities in the creation and in the processes of the new model. Consequently, the universities have a more central role in the prioritisation settings of national infrastructure investments. The introduction of the inventory of needs have improved the strategic national coordination of the infrastructures. Another advantage of the inventory of needs is that other financiers have an overview of infrastructures of national importance, which can attract further investments. In general, the Swedish Research Council´s model for appraisal and prioritisation of national infrastructure is well-developed considering the previous identified weaknesses in the report by Kåre Bremer. Further on, the Swedish model is well balanced regarding the limited funds available for national infrastructure investments. For example, it has been important to establish the universities involvement in the national strategies for infrastructure investments, especially since the universities are required to co-fund 50 % of the total costs. Other strengths of the Swedish model is that it both promotes long-term investments (grants funds for eight years) and renewability (through the competition between existing infrastructures and those proposed in the inventory of needs). It is an advantage that the applicants beforehand can check the criteria. In general, the criteria used for assessing the applications are extensive and cover many aspects.

The main weakness of the Swedish system is that only limited funds are available for research infrastructure. For example, it is arguable if the eight period for granting funds is reasonable considering the limited available funds for national infrastructures. Another potential weakness is that even if the new model has increased the dialogue and commitment of the universities, an industrial perspective seems to be somewhat missing. It would be beneficial with a clearer involvement of the industry in the prioritisation processes of national infrastructure investments. Not least to promote the infrastructures to have positive future impacts, such as job creation and new products, services and processes.

The Swedish Research Council´s model is mostly transferable to other countries facing similar challenges as Sweden, such as limited funds for national infrastructure investments.

11.5 Sources

11.5.1 Documentary sources

- The Swedish research council's guide to research infrastructures (2014)
- Appendix to the Swedish council's guide to infrastructures (2016)
- The Swedish Research Council´s annual report (2016)
- Interim Evaluation of 11 national research infrastructures 2012
- vr.se
- Report documents

11.5.2 Interview Partners

Tove Andersson, Research Officer at the Swedish Research Council (Infrastructure)

Susanna Bylin, Research Officer at the Swedish Research Council (Infrastructure)

12 USA

12.1 The process of allocating science capital funding

12.1.1 Overview

Much policy in the United States is decentralised to different Federal departments and agencies, with research infrastructure strategy embedded within wider strategic plans across each scientific domain. However, steps are being taken centrally to better monitor investments in research infrastructure.

The White House's Office of Science and Technology Policy (OSTP) is responsible for advice on the scientific, engineering and technological aspects of the economy, national security and other topics. It also leads interagency science and technology efforts, and assists the Office of Management and Budget (OMB) with an annual review of the Federal R&D budget. The OSTP and Federal agencies, coordinated by the OMB, are also taking steps towards a national strategic coordination of research infrastructure inventories and good practices. This will be undertaken by the National Science and Technology Council (NSTC), through its Committee on Science (CoS), which addresses significant national and international policy, program and budget matters across agency boundaries. It will monitor the progress of research facility construction, as well as the procurement of major instrumentation and maintenance projects.

Through the annual budget process, Federal agencies must indicate to the OMB what their budget requests are for the coming year. Congress is then responsible for approving this financing. In 2016, it was proposed that $2.8 billion (£2.2bn) be invested in research infrastructure in 2017 (see Table 3). This includes support for the construction of research and development (R&D) facilities, as well as the renovation and purchase of major capital equipment for R&D.

Funding for the construction of R&D facilities in the Department of Defence (DOD), the Department of Agriculture (USDA), the National Institutes of Health (NIH), the Smithsonian Institution (SI), and the National Institute of Standards and Technology (NIST) are mainly devoted to Federally-managed facilities or Federally Funded Research and Development Centre (FFRDC). By comparison, National Science Foundation (NSF) funding supports the construction and operation of projects managed by the extramural research community. Department of Energy funding is primarily devoted to FFRDCs but some funding is also managed by the extramural research community.

Table 3 R&D Expenditure on Facilities and Equipment (in million US dollars)

Departments / Agencies	2015	2016	2017 proposed	2016 to 2017 % change
Energy	990	1,112	1,138	2%
NSF	375	424	459	8%
Commerce	231	400	331	-17%
Agriculture	168	357	225	-37%
Health and Human Services	173	180	223	2%
Defence	116	33	195	491%
NASA	64	137	137	0%
Transportation	25	35	35	0%
Smithsonian Institution	36	32	33	3%

Departments / Agencies	2015	2016	2017 proposed	2016 to 2017 % change
Environmental Protection Agency	5	5	5	0%
Interior	36	2	2	0%
Homeland Security	315	8	0	-1%
Total	**2,527**	**2,723**	**2,783**	**2%**

Office of Management and Budget (FY 2017) Analytical Perspectives – Budget of the U.S. Government

12.1.2 The National Science Foundation (NSF)

One of the most important agencies involved in large research infrastructure in the United States is the **National Science Foundation** (NSF), and it is the only federal agency with a mandate to support fundamental research and education across all fields of science and engineering. The NSF director oversees 2,100 NSF staff, who's responsibilities include programme creation and administration, merit review, budget, planning and day-to-day operations of the agency. Furthermore, the NSF has a National Science Board (NSB) that meets six times a year to establish the overall policies of the foundation.

The importance of NSF's support for large research infrastructure is embedded in its founding legislation from 1950, as well as in its current (2014-18) strategic plan (which has a strategic goal to "*provide world-class research infrastructure to enable major scientific advances").* The NSF also argues that to fulfil its mission of "promoting the progress of science", the research community must be provided with advanced and powerful tools and capabilities. As such, approximately 15% of the NSF's portfolio is comprised of large research infrastructure, while significant further funding is provided for smaller or mid-scale infrastructure and major instrumentation. In the past, the NSF has also invested in large multi-user research facilities such as research vessels, particle accelerators, astronomical observatories, the U.S. Antarctic stations, advanced cyberinfrastructure and more.

The approach of the NSF differs from 'mission agencies' like the Department of Energy (DOE) and the National Aeronautics and Space Administration (NASA). While these agencies tend to have long term roadmaps for infrastructure and a much larger investment in infrastructure designed specifically to support the purpose of the agency itself, the NSF approach is more balanced. It does have long term commitments to existing research infrastructure, but it is also more reactive to research community initiatives, with nearer-term plans and the possibility to respond to opportunities and different scientific discipline roadmap recommendations in multiple ways.

The NSF has several funding schemes for research infrastructure, executed by its different departments, agencies and offices. This includes multiple discipline-specific programmes for the acquisition and development of instruments and facilities (e.g. Chemistry Research Instrumentation and Facilities, Computing Research Infrastructure, Biological Field Stations, Marine Laboratories), as well as several NSF-wide schemes for research infrastructure funding. The latter includes the **Major Research Instrumentation (MRI) Programme**, which is managed by the Office of Integrative Activities (OIA) and aims to catalyse new knowledge and discoveries through state-of-the-art research instrumentation.

The goals of the MRI programme are to:

- Support the acquisition of state-of-the-art instrumentation
- Foster the development of next generation instrumentation

- Enable academic departments, (cross-/) disciplinary units and multi-organisation collaborations to create well-equipped research environments that integrate research with education
- Support the acquisition and development of instruments that contribute to existing investments in cyberinfrastructure, while avoiding duplication of services already provisioned by NSF investments
- Promote substantive and meaningful partnerships for instrument development between academic and private sectors.

The MRI programme focuses on mid-range instrumentation, with proposals usually limited to between $100,000 and $4 million (£77k and £3.1m) – although disciplines of social, behavioural, economic and mathematical science and organisations that do not award doctoral degrees can also submit proposals requesting less. Proposals requesting less than $2 million can support the acquisition of a single instrument, a large system of instruments, instrument development or multiple instruments that share a common or specific research focus. Requests for more than $2 million must be for a single instrument.

Other NSF-wide funding programmes for facilities, equipment and infrastructure include two business programmes - the Small Business Technology Transfer (STTR) programme and the Small Business Innovation Research (SBIR) programme – which stimulate partnerships for innovators. There is also the Research Infrastructure Improvement (RII) initiative that is part of the Experimental Programme to Stimulate Competitive Research (EPSCoR). This supports jurisdictions within the U.S. that have historically received lower amounts of NSF research and development funding.

There are three NSF "funding accounts" for large research infrastructure facilities:

- The Major Research Equipment and Facilities Construction (MREFC) account, which was created in 1995 to fund the acquisition, commissioning, construction, and upgrading of major science and engineering infrastructure projects that could otherwise not be supported by Directorate level budgets without a severe negative impact on funded science. Construction of most large-scale facilities is supported through this account. The MREFC funds cannot be mixed with funds for activities other than construction. MREFC projects generally range in cost from $300m, expended over a multi-year period. The lower threshold is determined by NSF and is currently $70 million.
- The Research and Related Activities (R&RA) account, which generally supports the construction and acquisition of additional, smaller scale, facility or infrastructure projects (usually between $1m and $50m). The R&RA account also supports the annual operations and maintenance of large multi-user facilities, including those developed through the MREFC account. Examples of activities supported by the R&RA account are initial development, design, routine maintenance, operations and the associated scientific research. Each directorate has its own share of R&RA funding and can fund projects on a case-by-case basis based on research community priorities.
- The Education and Human Resources (EHR) account, which can also be used to fund facility or infrastructure projects of a smaller scale. In practice, this rarely happens.

The NSF also publishes a yearly '**Large Facilities Manual'** that describes the policies that apply to all large facility projects funded by the MREFC, R&RA and EHR account. In the 2016 manual it states that the NSF makes awards (usually in the form of cooperative agreements) to external recipient entities (universities, consortia of universities or non-profit organisations) to undertake construction, management and operation of facilities. Facilities are defined as "shared-use infrastructure, equipment and instrumentation that are accessible to a broad community of researchers and/or educators."

12.1.3 Other key organisations (DoE and DoD)

Beyond the NSF, other important organisations in the US regarding research infrastructures include:

- **The Joint Science and Technology Enterprise Steering Committee** (Department of Defence). The primary task of this committee is to strengthen the laboratory enterprise and the connections with industry and academia. The Committee periodically reviews the department's laboratories, the Federally Funded Research and Development Centres (FFRDCs), University Affiliated Research Centres (UARCs), the defence industrial base and universities conducting research in support of department programmes.
- **The Facilities and Infrastructure Division** (of the Department of Energy). This division serves as a focal point for the Facilities and Infrastructure policy, planning and performance of the Office of Science (SC). The SC operates 10 national laboratories that together have over 1,800 operational buildings and property trailers, with 20 million square feet of space. The division provides technical and subject matter expertise on the management of Facilities and Infrastructure. Every year, the DOE national laboratories engage in a strategic planning activity to define a long-term vision for the future. The Office of Laboratory Policy and Evaluation develops, manages and coordinates the implementation of the annual laboratory planning process on behalf of the SC. The DOE is also the Management System Owner of the SC facilities and infrastructure management system.

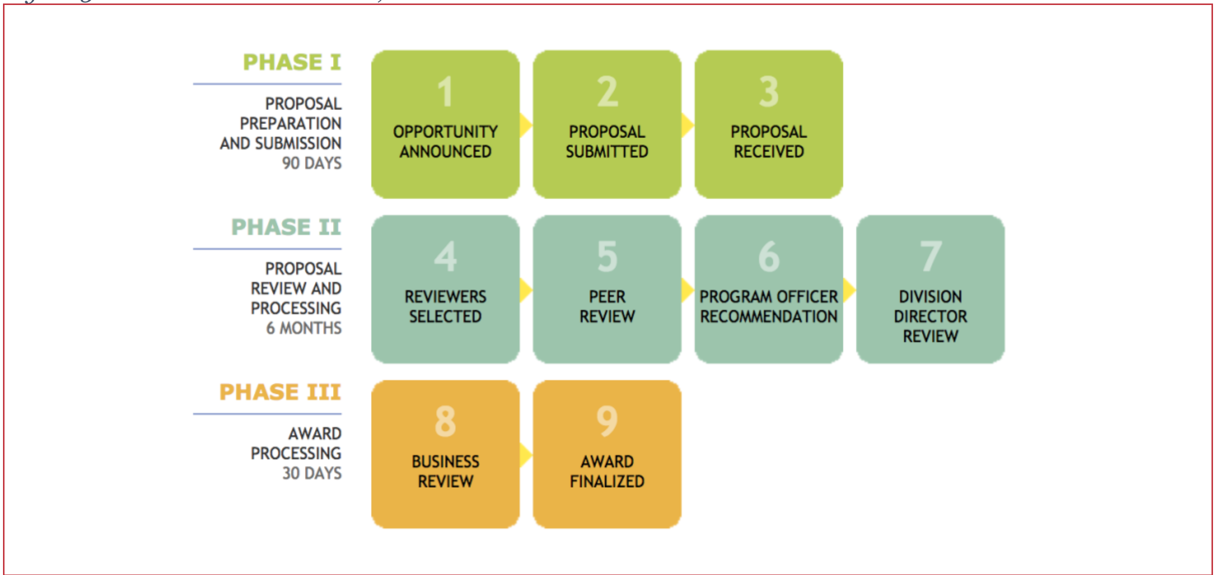
12.2 The (ex-ante) appraisal approach

Every NSF candidate project is reviewed according to two review criteria: Intellectual Merit and Broader Impacts. The merit review process ensures that submitted proposals are reviewed in a fair, transparent, competitive and in-depth manner. For large facilities (those funded through MREFC, as well as large projects funded from R&RA), there is an extended sequence of increasingly detailed development and assessment steps, called the "Stage-Gate" design review process. The two different review processes are described in detail below.

12.2.1 The Merit Review Process

The Merit Review Process applies to every proposal submitted to NSF. It consists of three phases: the proposal preparation and submission phase; the proposal review and processing phase; and the award processing phase (see Figure 3).

Figure 3 The Merit Review Process, US



Source: NSF (2017)

In **Phase I**, proposals that are received by NSF are assigned to the appropriate NSF programme for acknowledgement and, if they meet NSF requirements, for review and technical evaluation. All MREFC proposals (for large scale infrastructure) are also subject to several administrative and technical checks before being accepted for review. This includes meeting the following conditions:

- Be consistent with the goals, strategies and priorities of the NSF strategic plan
- Have long term tool capability, accessible to an appropriately broad community of users
- Require large investments for construction/acquisition, over a limited period
- Have received strong endorsement of the appropriate science and engineering communities
- Have coordination with other organisations, agencies and countries to ensure complementarity and integration of objectives and potential opportunities for collaboration and cost-sharing
- Involve an MREFC-funded investment for construction and/or acquisition exceeding $70 million.

In **Phase II**, the review is led by the NSF programme officer, with a review panel composed of external, community experts in the science and engineering fields related to the proposal (proposers may suggest eligible reviewers). They evaluate the proposals through use of two merit review criteria;

- Intellectual Merit: the potential to advance knowledge
- Broader Impacts: the potential to benefit society and contribute to the achievement of specific, desired societal outcomes.

Both Merit Review criteria are to be given full consideration during the review and decision-making processes. There is no weighting of one criterion over the other.

After scientific, technical and programmatic review, the NSF Programme Officer determines whether the proposal should be recommended for an award or declined for funding.

Projects that have passed phase II are then submitted to the Grants & Agreements Officer in the Division of Grants and Agreement go into **Phase III**, where a review of business, financial and policy implications takes place by the Grants and Agreements Officer and the award is finalised. Each NSF award notice identifies certain conditions that are applicable to that award.

12.2.2 The Stage-gate Design Review process

For the largest facilities, there is a more extensive sequence of increasingly detailed development and assessment steps (see Figure 4), which incorporates the Merit Review process as one small element.

The Stage Gate process includes multiple opportunities for input from the research communities, while NSF programme officials and senior management, including the National Science Board (NSB), also play key roles in the process.

For each MREFC project an Integrated Project Team (IPT) is assembled. This is the coordinating body, comprised of NSF personnel with knowledge and expertise in areas related to the scientific and technical, award management and strategic aspects of a project. The core members of the team, who interact frequently to carry out NSF's oversight and assurance of projects, are:

- The Programme Officer (PO) - a scientist or engineer that has the primary oversight responsibility of all aspects of the project, and may not be an employee of the NSF
- The Grants/Agreements Officer (G/AO) – who has as legal responsibility and authority for the business and financial management of grants, cooperative agreements and/or award contracts
- a Large Facilities Office Liaison (LFO) – who advises the PO on policy, process and procedural issues related to the development, implementation and oversight of the project.

In addition, there is an MREFC panel that is comprised of Senior Management representatives and offices of the NSF.

Figure 4 MREFC Life Cycle, US

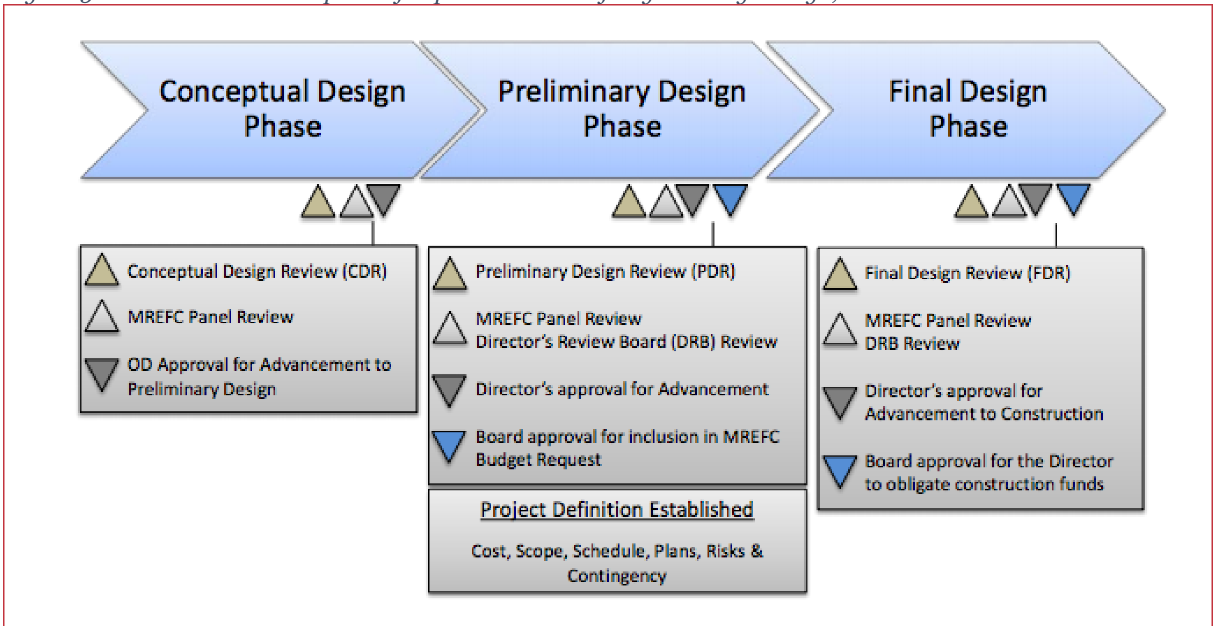
Source: BFA-LFO (2017) Large Facilities Manual

First in the MREFC life cycle is **Development Stage**, in which research communities alert NSF programme staff of the most promising questions that need to be explored, and the necessary research equipment for this. NSF uses studies by the National Academy, professional societies, community workshop reports, Directorate advisory committees and other methods to receive input about opportunities. NSF programme staff also often take a proactive role in facilitating submissions.
It is important in the development stage that a project is well described, such that it can receive recommendation by the MREFC panel and written approval of the NSF Director. Criteria for recommendation by the MREFC panel are:

- A compelling science case with well-articulated project goals
- A fit within the mission and strategic plans of the NSF and the sponsoring Directorate or Division, and within the broader NSF facility portfolio
- Consistency of the conceptual design plan with the guidelines in the Large Facilities Manual
- A preliminary timeline for development and implementation (including programmatic, NSB, budget and any necessary partnering milestones)
- Consideration of potential opportunities for internal and or external partnering
- Other major challenges regarding this project that need awareness of the Director

Recommended projects then enter the **Design Stage**, which consists of three phases (shown in Figure 5). This stage generally lasts 3 to 5 years and, depending on the nature of the infrastructure, costs at least 10% of the estimated construction cost.

Figure 5 Review and decision points for phases in the Life Cycle Design Stage, US



Source: BFA-LFO (2017) Large Facilities Manual

In the Conceptual Design Phase an NSF Programme Officer is assigned as primary contact with the Project Manager and develops an Internal Management Plan with a strategy for NSF oversight during pre-construction planning, funding and safety nets in case the project does not progress as planned.

Furthermore, the NSF conducts a Conceptual Design Review (CDR). During the CDR, the Conceptual Design package is subjected to external review, using standard NSF criteria for merit review (Intellectual Merit and Broader Impacts, as above) as well as extra programmatic and technical criteria that are assessed by a review panel. The review panel consists of external experts, consulting firms and in-house expertise in science, technology and business communities that assess the scientific, technical and project-management aspects of the project. The PO in consultation with the LFO organises and reviews the CDR process. Projects that rank well in the external review are subjected to a second ranking, where strategic criteria are assessed across related fields (e.g. greatest impact on scientific advances, opportunities to serve the needs of researchers from multiple disciplines, greatest potential for education and workforce development).

The initial ideas or concepts from the Development Stage are further developed into the conceptual design which defines the infrastructure necessary to answer the key research questions. The conceptual design package at CDR must include:

- A definition and (relative) prioritisation of the research objectives and science questions that the proposed facility will address
- A statement of the science requirements to be fulfilled by the proposed facility
- Descriptions of the functional requirements of the major subsystems of the proposed facility that are essential to achieve the research objectives
- A Project Execution Plan (PEP) describing how the proposing organisation will manage the project
- A top-down budget estimate, risk assessment and corresponding contingency budget for risk mitigation and a budget for operation of the proposed facility
- A projection of future partnerships possible during development, construction and operation

An initial Cost Analysis is then performed by NSF when the CDR is complete. A project can exit the Conceptual Design Phase when it has successfully completed the CDR, has received recommendation for advancement by the sponsoring Directorate and approval by the Director of NSF.

When the CDR is positive and a project is selected for more detailed development and planning, it enters the Preliminary Design Phase. The NSF asks proponents to begin refining the PEP, which details the management practices, scope, schedule and budget needed to develop the project's Preliminary Design. The Preliminary Design is then developed, including detailed descriptions of all major facility subsystems, a bottom-up cost estimate and resource loaded schedule.

Then the NSF again reviews the Preliminary Design in a Preliminary Design Review (PDR). The PDR is organised and conducted, like the CDR, by the PO and LFO liaison. External experts, consultants and firms can be used to evaluate proposed plans and budgets. The review focuses on:

- The robustness of the technical design and completeness of the budget and construction planning.
- The effectiveness of project management through this phase of development
- The plans for completion of final design, construction and operation.
- The management structure and credentials of key staff

Following the PDR, a second, more detailed NSF Cost Analysis will be initiated and conducted together with key assurance members of the IPT. A project is ready to move to the final design phase once:

- A successful PDR has been submitted, with subsequent support from the Directorate.
- The project has received a review and recommendation by the MREFC panel and the DRB for advancement to the Final Design Phase.
- The project has received approval from the NSF Director and subsequent recommendation to the NSB for inclusion of the project in a future year budget request
- The NSB has authorised the budget request.

As part of advancement to the Final Design Phase a third ranking is applied where national criteria across all fields are assessed (e.g. projects in new and emerging fields, most current windows of opportunity, greatest degree of community support), particularly when multi projects are being considered. The MREFC-panel prioritizes major research infrastructure projects based on six questions (Large Facilities Manual, 2017, p. 2.1.6-19):

- Which projects are in new and emerging fields that have the most potential to be transformative? Which projects have the most potential to change how research is conducted or to expand fundamental science and engineering frontiers?
- Which projects have the greatest potential for maintaining U.S. leadership in key science and engineering fields?
- Which projects produce the greatest benefits in numbers of researchers, educators and students enabled?
- Which projects most need to be undertaken in the near term? Which ones have the most current windows of opportunity, pressing needs and international or interagency commitments that should be met?
- Which projects have the greatest degree of community support?
- Which projects will have the greatest impact on scientific advances across fields taking into account the importance of balance among fields for NSF's portfolio management in the nation's interest?

There is no information available on whether weighting per question takes place.

If the NSB authorises advancement to the Final Design Phase, a final pre-construction design is prepared and reviewed (the Final Design Review) by NSF to assess readiness to obligate funds for construction. The final design should be construction-ready and the final PEP should include descriptions of: the scope, tools and technologies needed for construction, a capable project management organisation, fully implemented project management controls and other business systems, updated construction budget and schedule, up-dated operational cost estimates, updated educational outreach and broader societal impact plan, all necessary partnership agreements, plans for risk management, quality assurance and safety management.

After successful review of the final design project definition and PEP, the Director recommends an approval of construction awards to the NSB. The NSB then authorises the granting of the award. A Contract Agreement or a Cooperative Agreement is negotiated between the Recipient and the NSF and the construction phase is started.

Because of the Federal appropriations process, there is at least eighteen months between the Preliminary Design Review and the start of construction, including successful completion of the Final Design Review. If construction funds are not appropriated as planned, the NSF can continue annual project reviews to ensure the continued viability of the project's plan and budget for eventual construction. If the construction plans become inconsistent with the pending budget request, the NSF may include a revision of the project's budget or scope in a future budget or withdraw the request for funding.

In most cases, the entity responsible for construction and commissioning of the facility also has responsibility for a period of initial operation. NSF is responsible for encouraging excellence and efficiency in operation of the facility and may decide to re-compete operations once the facility has reached a stable operational tempo or if the managing organisation is not performing adequately.

12.2.3 Design of non-MREFC projects

When a project is below the threshold of $70 million, it is not subject to the same requirements of Conceptual Design, Preliminary Design and Final Design reviews and not subject to review by the MREFC panel. However, the NSF recommends the use of the stage-gate review approach as a toolkit for the Directorate or Office that is planning and managing the facilities and infrastructure, especially if these proceed through a similar design and construction process.

All projects are still required to follow a proposal-driven process with external and internal merit review and are assigned a programme officer (PO). The PO is then encouraged to organise an IPT to help coordinate oversight and assurance. NSF utilises a rotating, temporary staff from the science community to a large extent. The POs of non-MREFC funded projects are not required to be permanent NSF-employees. Furthermore, the Large Facilities Working Group is also available to review and comment on the internal management plan for smaller-scale projects and the LFO is available in an advisory capacity to NSF staff for best practices regarding project management and business oversight. Unlike large facilities, this involvement is not mandatory.

12.3 Monitoring and evaluation

Large facility projects are routinely monitored by the NSF throughout their construction and operation. The NSF itself is also evaluated on a regular basis as described in its Performance Plan. Both kinds of monitoring and evaluation are described below.

12.3.1 Monitoring of MREFC projects

There are a number of mechanisms that are used for NSF's programmatic management and oversight of Large Facilities, starting early-on in the MREFC project life. These are:

- The NSF Internal Management Plan, which is developed by the NSF PO in the Design Stage. It states how the NSF will oversee the development, construction, operation, divestment and closeout of large facilities and provides budgetary estimates and a strategy for financing these activities
- The Project Execution Plan, which is produced by the recipient and details how the management and execution of design and construction will be accomplished.

- The Annual Operations Plan, which is produced by the recipient and covers all aspects of operations, upgrades, maintenance and research and education programmes.
- Monthly and Annual Reporting
- Periodic expert panel reviews (generally annually)
- An NSF Facility Plan is also presented to the NSB each year, containing an exposition of the status and intensions for the NSF portfolio of existing and candidate MREFC facility projects.

Returning to the MREFC lifecycle (introduced in the previous section), most monitoring activities take place once a project enters the **Construction Stage**. On average, this stage lasts two to six years and costs between $100m and $600m. Projects need to report progress following the approved PEP and the terms and conditions in the Cooperative Agreement or contract. The project status is periodically reviewed to ensure the project is capable of finishing within budget and schedule and delivering the envisioned scope. Reviews examine the schedule, costs, technical performance and management performance of the project. Based on the project's performance against plan using Earned Value Management (EVM) or any other technical or management issues that arise, more frequent reviews may be scheduled. The reviews are conducted by an annual review panel, whose members are external experts covering all technical and management aspects of the project. The panel reports directly to the NSF and provides advice on project direction and necessary changes. The reviews are organised by the Programme Officer in consultation with the LFO liaison.

The day-to-day work to operate and maintain the Research Infrastructure and perform research then takes place during the **Operations Stage.** This lasts 20 to 40 years, with total costs often exceeding the costs of construction. Well before the operations stage is entered, an annual operating costs and operations plan is established. The operation stage then normally includes a series of periodic status reviews. In general, there are three key aspects of oversight in the operations stage:

- Annual work plans, that describe what will be accomplished in the next fiscal year
- Annual reports, describing in detail the activities of the facility over the last twelve months, including an explanation of progress on each goal
- Annual operations reviews, organised by the NSF utilising an external panel of experts

The operations stage may also include reviews and decisions on further investment, refurbishments, capability-upgrades and the final decision on divestment. The final decision to divest is made when the scientific community or the NSF determines that the facility is no longer an operational priority regarding the advancement of science.

The **Divestment Stage** starts when the first financial investment is made to decommission or divest the research infrastructure. Plans are drafted that address the specific issues that are part of the divestment and closeout of a facility. This plan should be kept up-to-date during the facilities divestment, along with its associated budget liability.

12.3.2 The NSF framework for self-evaluation and assessment

For the foundation itself, the NSF developed a 'Performance Plan' with performance goals that are each connected to one or more strategic objective(s) in the Strategic Plan. In the Performance Plan, a framework is established for evaluation and assessment. There are several NSF processes on which the framework is built:

- All NSF funding decisions are based on merit review by subject matter experts, which functions as a leading indicator of performance and should ensure the impact of NSF's programmes.
- A Committee of Visitors (COV) - consisting of external experts - performs an external assessment of the NSF programmes every three years. They consider the merit review process, programme operations and technical and managerial matters at programme level. For example, for the MRI programme the following aspects are reviewed by the COV:
  - The quality and integrity of the merit review process (e.g. are the review methods appropriate and are both merit review criteria addressed, do reviewers provide substantive comments, do the panel summaries and the documentation provide the rationale for panel consensus and award/decline decision)
  - The selection of reviewers (e.g. appropriate expertise, balanced, recognition and resolving of conflicts of interests)
  - Portfolio of awards (e.g. quality of research activities, integration of research and education, balance of innovative projects)
  - Management of the programme (e.g. planning and organisation, responsiveness to previous COV comments
- Independent audits on NSF's financial performance provide accountability to Congress. The Office of the Inspector General (OIG), conducts independent audits, reviews and investigations to provide oversight of the different NSF activities. Audits can have an internal or external focus. Internal audits focus on the efficiency and effectiveness of programmes and operations, whereas the external audits consider the compliance of awardees with NSF and federal requirements. The audits and reviews are focused on issues that are of substantial importance for the NSF and its goal, for example the Large Facility Projects (including the cooperative agreements used to construct and operate these). Projects are selected based on risk assessments and the likelihood that an audit or review would result in improvements. Reviews consider:
  - Programme, management and financial risks
  - Government standards and the assistance in the NSF mission
  - Effectiveness and efficiency

  Affected parties of the reviews are kept informed and are given the opportunity to provide feedback.

  The investigations conducted by the OIG investigate possible wrongdoing by organisations and individuals that submit proposals, receive awards, conduct business with or work for the NSF.
- A database of metrics is maintained by NSF that are used as indicators for the performance goals. For this, data on several specific performance indicators is held

as well. In their performance plan 2017, the OIG lists a range of qualitative and quantitative indicators for performance, including:

- Percent of audit products issued during the performance year
- Weekly tracking and monitoring of the status of the investigations
- Completion of budget requests in compliance with established deadlines
- Number of update meetings with the NSF Director and Deputy Director
- Number of participations with other federal and international agencies
- Number of outreach activities to the research community
- Number of semi-annual reports, performance reports, and other reports completed by prescribed target dates.

- Benchmarking against similar organisations worldwide can take place by external subject-matter experts for programmes whose ultimate outcomes occur over timeframes that are longer than grant periods. The benchmarks are based on self-assessments and general knowledge of the assessment team, who have knowledge of the international context of a given programme.
- The NSF has a Federal Advisory Committee for every directorate, and additional committees that advise several agencies on selected fields or crosscutting activities. The NSF also pays attention to advice offered in reports by National Academies, national and international science organisations, professional societies, workshops, interagency working groups, and the NSB.

Furthermore, NSF has launched the NSF Evaluation Initiative to expand the capability of the agency in evidence-based evaluation. An annual Strategic Review now also takes place that is submitted to OMB as part of the annual budget process. The NSF also has an Evaluation and Assessment Capability (EAC) that is part of the OIA and provides the NSF with support and resources for data collection, analytics and the design of evaluation studies. This way, the NSF should be able to make evidence-based policy decisions. During the 2014 – 2018 period, investments are made to develop portfolio analysis tools that can support portfolio analysis, evaluation and the use of evidence and data for programmatic decision making. The EAC is also tasked with the development and implementation of a coordinated evaluation framework.

Finally, there is a continual ongoing dialogue with other Federal agencies on the state of research infrastructure in Federal intramural and contractor-operated facilities.

At the end of each financial year, the NSF prepares an annual performance report, an agency financial report and a summarizing Performance and Financial Highlights report. These documents are prepared to provide performance and financial management information and are all included in the subsequent Budget Request to Congress.

- The Annual Performance Report (APR) presents the results of that year's performance goals, including the agency priority goals that are related to the Government Performance and Results Act (GPRA) and the GPRA Modernization Act. The report states whether the goals and objectives have been achieved or not, and discusses why this is the case.
- The Agency Financial Report (AFR) focuses on financial management and accountability and includes the results of the NSF's annual financial statement audit, the management challenges defined by the Inspector General and the

progress made on these management challenges as well as a management assurance statement.

- The Performance and Financial Highlights report present an overview of the key financial and performance information from the APR and the AFR. The report also contains several core numbers on the NSF, for example:
  - Sort of institutions receiving NSF funding
  - Proposals evaluated through competitive merit review process
  - Competitive awards funded
  - Estimated number of people directly supported by NSF

12.4 Summary of key strengths and weaknesses

- All projects financed by the NSF are focused on the needs expressed by the scientific community and should fulfil the requirements of Intellectual Merit and Broader Impacts. The merit review process ensures that submitted proposals are reviewed in a robust, fair and transparent manner.
- A strength of the NSF process is the fact that MREFC projects and large projects funded from R&RA are also required to go through a formal stage-gate review process. As part of this process, consideration is given to the entire facility life cycle (including decommissioning) and formal, well-documented progress monitoring that ensures the delivery of high quality research facilities.
- The rigorous evaluation and review process of the NSF, which considers the entire life cycle of a project, might be relatively demanding for smaller science systems and requires good internal knowledge management by the organisation. However, since the process also relies on a lot of external expertise and is easily scalable (even by NSF), it should also be possible for smaller organisations to manage this kind of process. Therefore, the appraisal and evaluation processes of the NSF are in principle transferable to other science systems.

12.5 Sources

12.5.1 Key documentary sources

- BFA-LFO (2017) Large Facilities Manual (NSF 17-066); https://www.nsf.gov/pubs/2017/nsf17066/nsf17066.pdf
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- NSF (2014). Strategic Plan for 2014 – 2018.
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12.5.2 Interview Partners

- Matt Hawkins – Head of the Large Facilities Office (NSF)
- Graham Harrison – Office of International Science and Engineering (NSF)
- Brian Midson – Program Director Division of Ocean Sciences (NSF)
- Robert Hengst – Large Facilities Advisor (NSF)

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