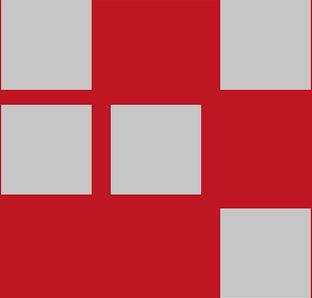




Rat für
I n f o r m a t i o n s
I n f r a s t r u k t u r e n

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AN INTERNATIONAL COMPARISON OF THE DEVELOPMENT OF RESEARCH DATA INFRASTRUCTURES

Report and Suggestions

ABOUT THIS PUBLICATION

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The RfII prefers to use gender-sensitive language. The male form used in individual cases applies equally to females. We have forgone the consistent use of two designations to improve readability.

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1 PREFACE

In conjunction with the digital transformation, the key question of how to organise the established information infrastructures in a national scientific system – with its regional, sectoral, and international contexts – to create a sustainable research data infrastructure landscape has become a political issue. While global competition in the sciences thus far has focused on top researchers and successes in research as well as on research infrastructures, the focus nowadays is increasingly being directed towards research *data* and its *storage* and *availability*, as well as on its *usability* and *use*. For this reason, the question of which country currently has an established, high-quality research data infrastructure is of particular interest.

In its 2016 position paper PERFORMANCE THROUGH DIVERSITY, the RfII not only pointed out the general importance of research data management and information infrastructures to the development of science in Germany, but also took a brief comparative look at neighbouring countries.¹ The comparison showed that even the initial situations and general conditions (education system, financing, laws, policies, research administration, closeness of the relationship between science and industry, etc.) differ greatly from country to country, and therefore that comparing their research policies – and especially their research data infrastructure policies – is extremely difficult.

A general finding of the paper is that there is *inequality and non-simultaneity in terms of information infrastructure developments* in the European states as well as worldwide. In addition, the international environment can be referred to as *dynamic* – whereby technology developments in the strict sense as well as the development of research methods (including the changes to networks of scientists/community structures, publication cultures, etc.) are advancing extremely rapidly. New data processing and communication technologies lead to radical changes and disruptive innovations that alter research processes without regard to national boundaries.

It is questionable, though, if the corresponding digital scientific infrastructures will be able to keep pace in this case. Few countries are actively pursuing the topic of research data. The importance of infrastructure policy to the quality and sustainability of digital research processes is not always recognised, and science and data sovereignty are not always thought of in conjunction. How to maintain proper control over the continuous development of a scientific infrastructure landscape under today's conditions – once digitality has simply become a part of every discipline – still appears to be an unanswered

¹ Cf. RfII (2016) – Performance through Diversity. Online: <http://www.rfii.de/download/rfii-recommendations-2016-performance-through-diversity/>, Section 2.4: “Germany by international comparison”.

question. The search for successful paths is just beginning, and action usually lags behind. In many countries, the funding of individual projects, self-organisational processes resulting from research, or market-based solutions dominate. In any case, initiatives under political control are complex and fraught with risk. Scientific information infrastructure projects must be designed to be dynamic to prevent them from failing.

Only high-performance and networked data infrastructures can strengthen data-based research achievements, expand global competitive advantages, and increase a scientific or economical lead over the long term. Data-intensive science also leads to competition in infrastructures – regardless of whether or not this is desired. Having access to data, being able to use digital resources, and receiving training or working at digitally creative research locations is also essential in the era of global interconnectedness. Although digital services allow many tasks to be performed regardless of location, it is still crucial to know who creates, uses, saves, secures, and maintains research data; who designs and operates (and possibly licenses and utilises) data services; and who grants access to the data – and where this is done.

How much do we in Germany need to know from our neighbours, partners, or from countries that obviously have completely different data infrastructure policies or those with similar data infrastructure policies in order to control our own data infrastructure well? From the perspective of German science and scientific policy, it is important to monitor and study the heterogeneous international environment, which itself handles the dynamics of digitisation dynamically, looking specifically at *the paths taken* in research data infrastructure policy and *the corresponding decision-making processes*. The RfII recommends more systematic activities in this regard.

Pragmatic aspects should be used as guidelines in this case. It would seem reasonable, and certainly important, to examine our own potential deficits as well as ideas and good practices implemented elsewhere. Furthermore, we can and should examine which paths should be avoided or which are deemed to be risky, to require discussion, or to be unsuitable due to research policy considerations or other general considerations. Data protection deficits, the privatisation/economisation of science, governmental influence on research results, as well as the drastic inequality between how users from various disciplines are handled mark the borders of what can be considered plausible for Germany.

The RfII does not provide a general recommendation on whether or not Germany or German stakeholders need to catch up – and in comparison to which country. In any case, the RfII has recommended the creation of a national research data infrastructure (NFDI). This infrastructure should be designed like a network. As a structure that grows step-by-step and whose

standards are based on the needs of researchers – i.e. users – the NFDI should lead to science that is more digitally sustainable than is currently the case, especially in terms of interoperability and shared, efficient services.

Referring to the NFDI as an *infrastructure* indicates that digital science requires an expanded definition of the term infrastructure: information infrastructures and research data infrastructures comprise data and services, human resources, and finally the research processes themselves. Regarding the question of how the development of such a widely relevant infrastructure can be managed within a national framework – and how it is being designed in the countries examined below – the RfII considers the following aspects in particular:

- What are the differences and the common challenges being faced by all countries at the level of policymaking, and especially at the level of research funders?
- Which national and subnational policies have been created in the past few years or are being created to organise the infrastructure landscape from a conceptual perspective?
- What sources of financing will be used to fund information infrastructures and at what scale?
- Which stakeholders and groups of stakeholders are driving developments at the level of information infrastructures?

In most countries – and in Germany as well – the relevance of goals such as interoperability (for data models, metadata, service interfaces, etc.), the open use of scientific data, and the integration of national efforts (namely in a European framework) into a transnationally coordinated environment is being emphasised strongly and in similar terms. The extent to which these goals will be reached directly at the level of governance and policies or remain merely declaratory in nature would need to be examined separately.

Efforts at the level of international cooperation also need to be monitored separately. In this case as well, the countries involved and their domestic stakeholders choose different paths – and either take action or remain passive.

The following country analyses and subsequent conclusions and suggestions which path to take are based on the results of the first monitoring effort of the RfII (as of February, 2017). The countries initially classified as important and for which adequate data was available were examined in more detail. The RfII does not claim to have full knowledge of the observed processes; it simply desires to highlight certain aspects. The research focused on such efforts of other countries which exhibit certain parallels to the establishment of a national research data infrastructure (NFDI) in Germany. Nevertheless, a variety of

additional aspects are also described and touched upon. Here, a further need for monitoring is indicated.

The international comparison is intended to serve as a rough guide. Each country has developed solutions according to their own national system and political style. For this reason, direct applicability of such approaches to the German scientific system cannot be expected. Nevertheless, relevant strategies or information infrastructure components, best practices, blueprints, or gaps identified in this international comparison can serve as an inspiration, confirmation, or impetus to stakeholders in Germany.

Based on a comparison between countries, it is possible to derive ideas as to where international and transnational networking counts, how national solutions can be integrated into a higher – European or international – level, or where there is simply a need for more involvement or harmonisation. Fully answering questions on the international dimension of national research data policy remains a complex as well as a political task.

This English translation is an abridged version of the original German report.²

² Rfll (2017) – Entwicklung von Forschungsdateninfrastrukturen im internationalen Vergleich. Bericht und Anregungen.

2 INTERNATIONAL DEVELOPMENTS IN THE AREA OF RESEARCH DATA INFRASTRUCTURES – THE RESULTS OF THE COUNTRY ANALYSIS

The considerations and suggestions presented here are based on research and consultations with the following four countries, each of which is advanced in terms of the development of research infrastructures and research data management:

- Australia,
- Canada,
- Netherlands,
- United Kingdom.³

Each country was analysed in terms of how national strategies for the governance of information infrastructures and research data are being developed and who is developing them.

In all of the countries examined, structures are being developed at the national level that, at least in terms of their objectives, exhibit certain parallels to the national research data infrastructure (NFDI) proposed for Germany. Canada, for example, is working on a “Digital Research Infrastructure Ecosystem”, the Netherlands on a “National Open Science Cloud”, the United Kingdom on an “e-Infrastructure Ecosystem” and more recently on an “Open Research Data Infrastructure”, and Australia on an “Australian Research Data Cloud”. The different origins and types of initiatives arise in this case from differences in the organisational forms of the corresponding national scientific systems and forms of research funding. The implementation of the initiatives has progressed to varying degrees and is being driven by different stakeholder groups depending on the country.

2.1 PUBLIC FUNDING OF RESEARCH

Three of the cases studied – Australia, the United Kingdom, and Canada – exhibit similarities in terms of science culture and research funding due to the similarities of their political systems.

Differences here are due to geopolitical conditions, among others. The vast, egalitarian, and confederated country of Australia views digitisation and internationalisation as appropriate means considering their geographic

Different initial situations

³ Research on other countries, and especially on countries outside of the Commonwealth tradition (France, Scandinavian countries, Russia) would also be interesting from the point of view of the RfII.

location and as a way to promote a structural transformation that would create new business sectors in their economy, which has traditionally been based on the export of raw materials. In the area of research data, Australia was one of the first countries to specify the objective of making data a *national strategic resource* (according to the current mission of the Australian National Data Service founded in 2009).⁴ Canada, another large, federated – and bilingual – country in which the provinces have a high degree of political autonomy views digitisation as one way to bring citizens in the expansive territories together and retain Canadian culture, even in the multilingual and multinational age of uninterrupted digital communication.⁵ The United Kingdom can be characterised as a decentralised unitary state because it is composed of legally separate states. It views the advance of digitisation as a way to strengthen its own economy – even in a post-Brexit UK.⁶

Research councils in the Commonwealth countries

The three Commonwealth countries fund their research in similar ways. In the United Kingdom, there are seven research councils specific to a certain discipline or group of disciplines as well as three in Canada (Research Councils UK and Tri-Agencies) that provide public funding. A majority of the funding for research and information infrastructures in Canada comes from the Canada Foundation for Innovation (CFI). In Australia, there is the multidisciplinary Australian Research Council (ARC) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) as well as a National Health and Medical Research Council (NHMRC) for funding medical research at universities.

Structures similar to the German Research Foundation in the Netherlands

The Netherlands is a small, decentralised unitary state with clear political emphasis on top-down approaches. The Dutch educational and scientific system places particular emphasis on multilingualism, and especially on the use of English as the language of science, and is also highly international by tradition, which is demonstrated by their very active involvement in various international initiatives and policies at the EU level. In the Netherlands, the Netherlands Organisation for Scientific Research (NWO) is the most important public funder of research. The internal organisation of the NWO is similar to that of the German Research Foundation (DFG).

Instruments for coordinating investments

All of the scientific systems examined have reacted to the challenge of enabling data-based interdisciplinary research through adequate infrastructure funding. The community-oriented establishment of information in the United Kingdom is promoted by research funding from the Research Councils UK (RCUK), which is organised into scientific areas. However, to coordinate investments in information infrastructures serving multiple disciplines, the

⁴ <https://data.gov.au/user/ands>.

⁵ Cf. Government of Canada (2015) – Digital Canada, p. 17.

⁶ <https://www.gov.uk/government/publications/uk-digital-strategy/uk-digital-strategy>.

United Kingdom established a *National e-Infrastructure Group* in 2010/11 under the auspices of the RCUK – probably also to counteract the pillarisation of infrastructure development resulting from having seven Research Councils. Investments are coordinated in this case through a common E-INFRASTRUCTURE ROADMAP. In the other countries examined as well, funders have established or are planning to establish committees with the goal of developing the tools required for better control and coordination of the investments in such an infrastructure. In Australia, the foundation of an independent *Research Infrastructure National Advisory Group* was proposed in late 2016. One of its tasks is to formulate recommendations for investments and periodically update a corresponding roadmap.⁷ In the Netherlands, the NWO established a Permanent Committee for Large-Scale Scientific Infrastructure in 2015, whose first task was to itemise all existing research infrastructures and determine which facilities are lacking. The results of the committee's work were included in the National Roadmap for Large-Scale Scientific Infrastructure published in late 2016. In Canada, the Canada Foundation for Innovation (CFI) recommended in late 2015 a better coordinated, holistically designed Digital Research Infrastructure Ecosystem.⁸

This means that in all four countries, research funders have recently begun to account for the new requirements in terms of the overall control and coordination of research and information infrastructures.

In addition to public research funding, there is also considerable private sector expenditures for research and development in all countries examined as can be seen in Table 1.

Private sector research
funding

⁷ Australian Government. Department of Education and Training (2016) – National Research Infrastructure Roadmap.

⁸ CFI (2015) – Developing a digital research infrastructure strategy for Canada.

Table 1: Expenditures in the field of research and development (R&D) in the countries examined, listed in order of the size of their gross domestic product

Country (Year)	Netherlands (2015)	Australia (2013)	Canada (2013)	UK (2015)	Germany (2015)
Indicator					
GDP (in billions of USD)	838.9	1,092.8	1,556.7	2,662.6	3,858.5
Public Sector Expenditure on R&D – PSERD (in billions of USD)	7.2 (2014)	9.4	13.0	15.0 (2014)	35.4 (2014)
Business Enterprise Expenditure on R&D – BERD (in billions of USD)	9.4	13.0	13.1	30.4	76.4
Gross domestic expenditure on R&D – GERD (in billions of USD)	16.9	23.1	26.2	46.3	112.8
Percentage of GDP spent on R&D (GERD in % of GDP)	2.01	2.11	1.68	1.70	2.87

Source: OECD: Gross domestic product and spending on R&D.⁹

2.2 NATIONAL AND SUBNATIONAL POLICIES

National strategies for digital research (data) infrastructures

The need for control and coordination in scientific policy, between the funders of research, and between other infrastructure stakeholders is being addressed at the national level as well as at the subnational level through new policy approaches or initiatives for strategy development.

At the national level, there would appear to be a tendency in some countries to include the aspect of digital research infrastructures in their strategies for research infrastructures, use this aspect to differentiate their strategies, or pursue separate strategies for digital research infrastructures. Recent developments include dedicated concepts for research data infrastructures or data clouds.

For example, Australia’s Roadmap for Research Infrastructures, updated in late 2016 under the auspices of the Department of Education and Training, contained a section on digital research data infrastructures, including an

⁹ <http://stats.oecd.org/>. The most recent data available for each country was used. Minor inconsistencies in the table are due to data availability.

“Australian Research Data Cloud”.¹⁰ The Roadmap is linked to the National Collaborative Research Infrastructure Strategy (NCRIS) initially formulated in 2004, whose programme was recently extended for another ten years after receiving a positive evaluation (see 2.4).

The Dutch roadmap for research infrastructures explicitly includes research data infrastructures as well.¹¹

The Open Science Paradigm is also a driving force in the two EU member states, the United Kingdom (for now) and the Netherlands. In the United Kingdom, for example, a task force will be established in late 2017/early 2018 on the suggestion of the UK Department for Business, Energy and Industrial Strategy (BEIS) to create an action plan for a national open research data infrastructure. In February of 2017, the Dutch Ministry of Education, Culture and Science (OCW) published a NATIONAL PLAN OPEN SCIENCE with the declared goal of establishing a national open science cloud. Representatives from the groups who participated in creating the document and from groups affected by open science (such as researchers, universities, science academies, infrastructure providers, research facilities, libraries, and research funders) issued in parallel a common declaration on open science expressing their intention to become involved in such a national cloud initiative. In the meantime, a national platform has been established together with these stakeholders.

Open Science
as a driver

In Canada, the Department of Innovation, Science, and Economic Development is overseeing the development of a strategy for digital infrastructures. One of the goals of this strategy is to position Canada as a global pioneer in the area of big data.¹² It can be seen in the international comparison that the areas of responsibility and compositions of the ministries (economics/research) in Canada and in the United Kingdom are focused more on programmatic statements regarding innovation and the involvement of industry as the goals of research data infrastructures.

The development of policies happens not only at the national, but also from the bottom up at the subnational level, and these approaches are understood to be partial solutions to a systematic approach. In this case, stakeholders who are themselves primary users and providers of information infrastructures participate in the formulation of concepts. Such stakeholders include data archives, large-scale research facilities, science academies, and universities, for example. Such initiatives are characterised, especially in the Netherlands, by a

Stakeholder-driven
concepts and initiatives

¹⁰ Australian Government. Department of Education and Training (2016) – National Research Infrastructure Roadmap.

¹¹ NWO (2016) – National Roadmap Large-Scale Scientific Infrastructure.

¹² Cf. Government of Canada (2014) – Seizing Canada’s Moment, Section 6.2.3: Supporting Cutting-Edge Infrastructure.

great determination among the relatively small number of participants to use a unified approach and develop initial implementations together. A prime example of this is the Dutch coalition of data archives *Research Data Netherlands (RDNL)* and the systematic introduction of data management plans by the Dutch research organisation NWO.

In the United Kingdom, the universities, in association with the Higher Education Funding Councils (HEFCEs), RCUK, and the Wellcome Trust formulated a common CONCORDAT ON OPEN RESEARCH DATA in July, 2016.¹³ This document declares a total of ten principles, including open access to research data, recognition of the rights of data creators to reasonable first use, good data management, data curation, and the development of appropriate data skills. The national academy of science, the Royal Society, has – like other British stakeholders – already been active for several years in the area of data culture. In a comprehensive report from 2012, for example, it points out the value of data gathering, analysis, and communication; the need for common standards for sharing information; a requirement to publish data in reusable formats; and the need for training of data experts.¹⁴ In Canada, under the auspices of the Research Data Canada (RDC) initiative, a STATEMENT OF PRINCIPLES: RESEARCH DATA MANAGEMENT IN CANADIAN UNIVERSITIES was developed in 2016 that is based on the British model.¹⁵ These examples show how mid-level initiatives create coordinated concepts or policies as a common basis for the activities of the corresponding stakeholders.

For Germany, the Rfll pointed out in its position paper PERFORMANCE THROUGH DIVERSITY how infrastructure policy processes have proceeded in a phase of relative deregulation and what coordination mechanisms could or should look like for an infrastructure system that has become fragmented as a consequence.¹⁶ The four countries analysed here are meanwhile also pursuing systematic, national approaches with the goal of integrating the relevant stakeholders and interest groups through comprehensive concepts (cf. 2.10).

2.3 FINANCING

The four countries analysed are smaller – measured according to gross domestic product (GDP) – than Germany and spend a lower percentage of their GDP on research and development (see Table 1 for an illustration of

¹³ HEFCE et al. (2016) – Concordat on Open Research Data.

¹⁴ The Royal Society (2012) – Science as an open enterprise. See also: The Royal Society (2014) – Science 2.0 Consultation.

¹⁵ RDC (2016) – Research Data Management in Canadian Universities.

¹⁶ Rfll (2016) – Die Entwicklung von Konzepten für Informationsinfrastrukturen in der Bundesrepublik Deutschland seit den 1960er Jahren (The Development of Concepts for Information Infrastructures in the Federal Republic of Germany since the 1960's).

the public and private sector expenditures for research and development). In most cases, though, it is only possible to estimate the actual amount spent on information infrastructures and on activities in the area of research data management, especially in light of the fact that the definition of what an information infrastructure is differs from country to country.

The Research Data Cloud model proposed in Australia is integrated into the National Roadmap for Research Infrastructures for which progressive funds are allocated by the government. The three key stakeholders of the planned Australian Research Data Cloud – the Australian National Data Service (ANDS), the Research Data Services (RDS) project, and the National eResearch Collaboration Tools and Resources (NeCTAR) project – emphasise that the national cloud should be established based on existing investments.¹⁷ Whether or not the national cloud itself should receive additional funding and which governance structure will apply to it could not be determined.

The three stakeholders themselves are in turn financed through the national research infrastructure strategy NCRIS. After substantial initial investments of over 720 million AUD (536 million USD)¹⁸ between 2006 and 2014/15, NCRIS will receive annual funding of 150 million AUD (112 million USD) starting in 2015/16.

According to a report published in 2015, the Australian government has over the past ten years invested an average of eight percent of the total research and development expenditure in research infrastructures.¹⁹ In addition, the partners participating in the predominantly collaborative roadmap projects also make a contribution.

Portions of the funding for the roadmap are being distributed by the project to other stakeholders in the scientific system. The ANDS, which plans to embed the use of data throughout the entire Australian scientific system, invested resources in infrastructure construction projects at universities, among others, during the first funding phase starting in 2009. Starting around 2013, it has primarily financed the dissemination of best practices throughout the Australian scientific system.

In Canada, the Canada Foundation for Innovation (CFI) is the most important funder of research and information infrastructures, in addition to the non-

Australia's data cloud on the National Roadmap for Research Infrastructures

Australia invested about eight percent of its R&D expenditure in research infrastructures

¹⁷ <https://www.rds.edu.au/single-post/2017/02/15/National-Research-Infrastructure-Roadmap>.

¹⁸ The values specified in the currencies AUD, CAD, and GBP were converted for the purpose of comparison based on the current exchange rate (on 18 May 2017).

¹⁹ Cf. Australian Government. Department of Education and training (2015) – Research Infrastructure Review, p. ix.

profit corporation CANARIE²⁰ and the Tri-Agencies. In late 2014 the CFI started the Cyberinfrastructure Initiative, which is a fund containing specific budgets for financing research data infrastructures as well as computer and data storage infrastructures.

Canadian fund supports the operation of infrastructures

In addition to the Cyberinfrastructure Initiative, an Infrastructure Operating Fund (IOF) is available to complement other CFI funding lines. The IOF helps cover some of the operating and maintenance costs of CFI-funded infrastructures to ensure optimal use of the infrastructure. All projects approved by the CFI are eligible to receive 30 percent of the total budget approved from the IOF. In turn, the receiving institution is responsible for distributing the funds among the projects eligible to receive IOF funding. This allows institutions to distribute their IOF allocation among the projects based on the actual operating and maintenance costs. This offers institutions maximum flexibility in terms of supporting projects while ensuring full accountability to the funders of research. In its ECONOMIC ACTION PLAN 2015, the Canadian government budgeted a total of 100 million CAD (73 million USD) for investment in the digital research infrastructure. Furthermore, another 105 million CAD (77 million USD) will be invested over five years starting in 2015/16 to support the research network operated by CANARIE.²¹

Cost estimates of the Research Councils UK for investments in the e-Infrastructure

In the United Kingdom, the Research Councils UK (RCUK) made a rough estimate of the cost of future investments in the British e-Infrastructure in their e-Infrastructure Roadmap published in 2014. For the six year period from 2015 to 2021, potential investments of 595 million GBP (770 million USD) are forecast.²² The RCUK estimates the future operating costs of the e-infrastructure for the six year period to be 210 million GBP (272 million USD). This does not include spending by Research Councils in the area of post-graduate studies and professional training, which is planned to be several hundred million pounds per year. Furthermore, there will also be several tens of millions of pounds for funding projects in online training, a training repository/marketplace, or the integration of security and authentication systems across infrastructures. It is unclear, though, how much of the costs for

²⁰ CANARIE operates a publically financed optical fiber-communication network for government facilities and for science (NREN – National Research and Education Network).

²¹ Cf. CFI (2015) – Consultation; Department of Finance Canada (2015) – Economic Action Plan 2015, p. 98 f.

²² This amount is almost identical to the amounts actually invested in the e-infrastructure calculated by the Joint Information Systems Committee (Jisc) in their retrospective for the five year period from 2011 to 2015 (606 million GBP (785 million USD)). This amount was invested in HPC and research network infrastructures, in big data projects, the Centre for Cognitive Computing at Hartree Centre, a 10 Pflop supercomputer at the Met Office, and the Alan Turing Centre for Data Science, see <https://www.slideshare.net/comth/uk-einfrastructure-for-research-ukusa-hpc-workshop-oxford-july-2015>, Slide 4 ff.

the necessary operating personnel have been taken into account in these figures.

In the United Kingdom, the industry also makes a considerable contribution to the financing of research infrastructures (cf. also section 2.6). This is in line with the generally established close cooperation between the public and private sector when financing research and development projects. For example, the Alan Turing Institute, founded in 2015 by universities, received 42 million GBP (54 million USD) from the government and 35 million GBP (45 million USD) from the private sector and partner organisations.²³ In the Netherlands and Canada, no such strong commitment to the financing of research information infrastructures by business stakeholders could be identified. In 2015, an Australian government commission considered a significant commitment from the industry to invest in the national research infrastructure unlikely.²⁴

Strong financial investments from private companies in the United Kingdom

The Dutch government is providing a total of 110 million EUR for calls for proposals for research infrastructures in the framework of the National Roadmap 2016.²⁵ The main provider of scientific information infrastructures in the Netherlands, SURF, estimates total revenues of 75 million EUR for 2017, 45 million EUR of which will come from services financed through fees.

SURF is a cooperative that is supported in particular by Dutch research universities and universities of applied science. It acts as a central ICT service provider and operates the Dutch research network, among others. Such member-financed service structures of universities and research facilities can also be found in the United Kingdom (Jisc – Joint Information Systems Committee, cf. 2.5) and in Germany (DFN-Verein, which promotes the German National Research and Education Network, although with a significantly smaller budget and service portfolio).

The important role of flexible funding is notable. Several funding models allow the stakeholders to control their own funding budgets (e.g. the Australian National Data Service ANDS or the Dutch eScience Center NLeSC) so the stakeholders themselves can initiate projects for integrating users or developing new technologies. The British Joint Information Systems Committee (Jisc) also allows the independent allocation of funds for small projects, with

Higher impact of infrastructure stakeholders due to having their own funding budgets

²³ <https://www.gov.uk/government/publications/uk-digital-strategy/uk-digital-strategy>.

²⁴ “Furthermore, there is no evidence that industry will be a major funding source for the National Research Infrastructure in Australia.” Cf. Australian Government. Department of Education and Training (2015) Research Infrastructure Review, p. 12.

²⁵ Budgets are planned for five to ten years. Information and calls for proposals can be found at <http://www.nwo.nl/en/funding/our-funding-instruments/nwo/national-road-map-large-scale-research-infrastructure/national-road-map-large-scale-research-infrastructure.html>; see also The Netherlands EU Presidency (2016) – The Netherlands’ contribution to the European Research Area, p. 6.

the advantage that needs can be met quickly and the threshold for testing potential solutions is as low as possible.

The ability to control their own funding budgets therefore increases the impact of the infrastructure stakeholders when disseminating best practices for research data management and data culture throughout a particular scientific system.

Long-term planning and joint financing

Overall, the international analysis reveals a wide range of funding levels in research data and information infrastructure policies. Whereas Australia is characterised by long-term planning as well as long-term financing, the United Kingdom and the Netherlands illustrate how financial resources or other monetary benefits can be obtained through cooperation with business stakeholders or using member-financed business models as well as through public investments.

2.4 SUCCESSES AND INDICATORS OF SUCCESS

The impact of the Australian National Collaborative Research Infrastructure Strategy (NCRIS) has been studied in depth. The findings of the assessments conducted in 2014 illustrate the effects of a nationally coordinated approach and are therefore described below as an example.²⁶

KPMG evaluation of the Australian NCRIS

A study of 27 NCRIS projects conducted by KPMG came to conclusion that the projects were generally of a mature nature and made a substantial contribution towards scientific research capability as well as research outcomes in Australia. This effect was achieved due to the greater availability of resources that were previously inaccessible or highly fragmented as well as due to the constructive support provided to researchers by the qualified personnel of the infrastructures. The strategic allocation of investments through the NCRIS Roadmap process contributed to the success of the programme. The NCRIS programme addressed a form of market failure since most of the facilities and resources could not be maintained in a comparable form by the private sector alone or by the scientific research facilities alone. In the area of e-Research in particular, another report came to the conclusion that NCRIS has accelerated and improved collaborative activities between infrastructure operators and researchers.²⁷ The KPMG report emphasises the continued need for government funding since the scientific system would fall

²⁶ A similar systematic evaluation was conducted in 2013 for the projects on the ESRFI Roadmap. The findings showed, among other things, how much time is actually needed to develop international infrastructures. Cf. RfII (2016) – Performance through Diversity, p. 22.

²⁷ Australian Government. Department of Education and Training (2015) – NCRIS Status Report.

back to the inefficient status quo ante if NCRIS were to be terminated. A regular portfolio review is recommended for the future in which the infrastructure projects funded would be evaluated in terms of whether or not the portfolio as a whole is meeting the national needs for research and innovation. This therefore includes the possibility that individual projects may not receive any more funding and the money will be invested in other resources instead.²⁸

The KPMG analyses were included in the final report of a government commission that was commissioned to create a review of the national research infrastructures.²⁹ However, the commission stated that in spite of the successes of NCRIS, central problems such as fragmentation, competing ministerial authorities, and funding cycles that are too short still remained. A primary measure suggested was the establishment of an Australian Research Infrastructure Fund and project financing cycles spanning seven years.

The lack of development on indicators for measuring the success and impact of infrastructure funding is pointed out in both reports. The government commission criticised the lack of data and pointed out fundamental problems it encountered while attempting to create an inventory of existing research infrastructures.

KPMG determined that many NCRIS projects had difficulties quantifying the impact of their project. In the meantime, a reporting system for the projects has been introduced specifically for this reason. It requires statements regarding the “impacts of all type, including outreach, industry, and international engagement and where appropriate commercial outcomes”.³⁰

Suitable criteria for measuring the impact – e.g. quantitative measurements as compared to qualitative reports in the form of project-related success stories – were also discussed intensively and critically in the United Kingdom in preparation for the nationwide research assessments (Research Excellence Framework (REF) 2014). At all levels of the British research landscape, this has led to the dissemination of good practices in terms of accountability. This is why many case studies of impact can now be found in UK institutions.

Discussion on
measuring impact in
the United Kingdom

²⁸ KPMG (2014) – NCRIS Projects Review 2014. The review examined the governance, effectiveness, efficiency, management and compliance, integration, and strategic policy alignment of each project.

²⁹ Australian Government. Department of Education and Training (2015) – Research Infrastructure Review.

³⁰ Cf. Australian Government. Department of Education and Training (2016) – NCRIS Programme Guidelines, p. 9.

2.5 THE STAKEHOLDERS DRIVING IMPLEMENTATION AND NETWORKING

Looking at actual operational development of infrastructures, meaning development outside of political platforms, it can be seen that there are different groups of stakeholders in these countries driving them.

Libraries as a driving force in Canada

In Canada, the involvement of the Canadian Association of Research Libraries (CARL) is particularly noticeable. It has designed and established PORTAGE, a national service network for research data management. In addition, the non-profit corporation CANARIE, the Canadian University Council of Chief Information Officers (CUCCIO), and the publicly financed Compute Canada are the driving forces at the level of the development of information infrastructure services and have joined to form a leadership council (see also 2.10).³¹

High level of cooperation and networking in the Netherlands

In the Netherlands, it is the DANS data archive, among others, supported by the national research organisation NWO and the Royal Netherlands Academy of Arts and Sciences (KNAW) which together with SURF, the central service provider for information and communication technology in Dutch education and research, are present in various research data initiatives. In general, there appears to be a willingness in the Netherlands to establish and provide centrally coordinated information infrastructures (in addition to DANS, there is also the Netherlands eScience Center – NLeSC). SURF is a cooperative of the Dutch research universities and universities of applied science and is therefore able to adequately represent the perspective of universities in various IT infrastructure initiatives.

A role similar to that of SURF, i.e. oriented towards shared services, has been played in the United Kingdom for many years by the Joint Information Systems Committee (Jisc), jointly financed for several years now by a community of over 270 colleges and universities as well as other users, following a restructuring programme. In the framework of a research data shared service pilot programme, Jisc offers various services relating to research data management, that aim to bundle existing services in order to increase efficiency.

User integration as a critical factor for success

In consultations held by the RfII with experts from the countries analysed, the integration of scientific users was repeatedly stated as a factor critical to success and as an obstacle to the establishment of high-performance infrastructures that has only been partially overcome in most cases. In the Netherlands and the United Kingdom, attempts to conduct a structured survey of the needs of users were undertaken in order to better understand the status quo to be managed, but these attempts are insufficient to handle the dynamic developments in the area of research methods and research data.

³¹ Cf. CFI (2015) – Developing a digital research infrastructure strategy for Canada, p. 6.

Overall, a tendency can be seen in the countries examined to (in some cases structurally) network/integrate a variety of stakeholders and stakeholder groups – including in particular the users. In Australia this networking/integration takes place at an early stage through project funding provided by the national data service ANDS. In this context, local data experts were trained at those facilities that were initially sceptical of research data management (RDM) for cost reasons. These data experts are now able to implement RDM independently.³² Currently, ANDS is focusing especially on establishing best practices for RDM throughout the Australian scientific system – and always based on the needs of the particular institution. In the Netherlands, a centre for e-Science (NLeSC) was established in 2011 with a similar intention. In addition, the three data archives that have joined forces in the Research Data Netherlands (RDNL) alliance designed and implemented the so-called front office/back office model in 2014. The core goal of the model is to offer users of the three data archives a common service model. The front offices act locally as an intermediary service that is supported by the back offices in the data archives. The quality of the services is ensured through networking and by providing the employees in the front offices across all facilities with training. In the United Kingdom, the Collaborative Computational Projects (CCPs) offer a scalable and transferable software infrastructure for researchers in the sciences and engineering. Easy-to-use tools and services are intended to make data analysis easier, and cost-intensive parallel developments are also avoided.³³

Tendency to integrate different stakeholders and stakeholder groups

2.6 INVOLVEMENT OF INDUSTRY

In Canada and the United Kingdom, infrastructure developments have a focus on innovation and thus exhibit a clear connection to industry – and this applies to business enterprises as users and producers of data for research and innovation, but also as providers of services.

The goal of the collaborative connection of public research data infrastructures to research and development in the private sector is prominent, especially in the United Kingdom. In the UK, the Catapult Centres were founded in 2010/11 and the Open Data Institute (ODI) was established in 2012 as formats for cooperation with business and industry. While the topical Catapult Centres generally focus on the commercialisation of research through infrastructures

Companies as research partners and users of data infrastructures

³² The reason for scepticism was the uncertain cost calculation for RDM, which may have also resulted in the tendency in all countries analysed to invest in hardware, which is easier to calculate.

³³ An illustration of the funding line can be found at <https://www.epsrc.ac.uk/research/ourportfolio/themes/researchinfrastructure/subthemes/einfrastructure/software/ccprojects/>.

and are national in scale³⁴, the ODI focuses on the use of data. The ODI therefore actively promotes a change in (data) culture and brings together companies from many sectors as well as non-commercial organisations and government institutions – including universities – that are interested in the use of data. Meanwhile, a global network of nodes has been established.³⁵ The ODI is an example of how networking at the national level can be complemented by simultaneous international involvement. An example of the importance of information infrastructures to innovation policy is high-performance computing and supercomputing. For example, in the framework of a strategic partnership with the Science and Technology Facilities Council (STFC), IBM provided the Hartree Centre with technologies and services valued at up to 200 million GBP (259 million USD).³⁶ The mission of the Hartree Centre is to provide industry as well as public research facilities with the latest digital technologies in the area of data-centric computing, big data, and cognitive computing technologies. Another partner of the Hartree Centre as well as of the UK Research Data Facility³⁷ is the company OCF, which operates in the area of HPC, data storage, and data analysis and also cooperates with other companies.³⁸

In Canada, for example, the Open Data Exchange (ODX) institute was founded as a public-private partnership in the framework of implementing the national innovation strategy. The institute is intended to play a key role in the aggregation of large amounts of data, the development of standards for interoperability, and stimulation of the commercialisation of open data apps.³⁹

Companies as providers: increasing number of commercial offers in the area of scientific information infrastructures

When providing science with digital services, there is a basic conflict between the development of products and services proprietary to the scientific community and the use of commercial products and services. A study commissioned by the Australian government on the status of e-Research capability in Australia came to the conclusion that the national e-Research infrastructure would be a mix of publicly financed leading-edge technologies and commercially provided facilities and services. Since the conception, funding, and implementation of projects using public resources often proceeds at a slower pace than the rapid developments on the open market, commercial products and services enabling the use of the latest developments in technology are becoming increasingly important in science. Commercial providers are already turning their attention to this market. A publicly financed offering is necessary, though, in the area of high-performance computing and

³⁴ Cf. Technology Strategy Board (2011) – Technology and innovation centres, p. 4.

³⁵ <http://theodi.org/nodes>.

³⁶ Warrington Guardian (2015) – Town to benefit from ‘huge’ economic boost (video).

³⁷ <http://www.rdf.ac.uk/about/>.

³⁸ <http://www.ocf.co.uk/partners>.

³⁹ Government of Canada (2014) – Seizing Canada’s Moment.

its associated infrastructure since such facilities are impossible to operate economically due to their very nature.⁴⁰ The British government is also taking a subsidiary approach to public funding. In view of the preparation of a European Open Science Cloud, it strongly advocates ensuring the market options of private companies are not compromised by public offerings and is also implementing this policy in the UK.⁴¹ However, there are also strong arguments in favour of services proprietary to scientists such as ensuring data sovereignty in data hosting services.⁴²

2.7 DEVELOPMENT OF SKILLS AND PERSONNEL

It is not only a need for policies for scientific infrastructure development that is being articulated in all countries studied. Meeting the demand for personnel and skills development in connection with the establishment of high-performance research and information infrastructures is also stated as a challenge. There is a lack of scientifically qualified personnel as well as of users with data skills because the development of personnel, skills, and services is not keeping up with the growing amounts of data nor with the growing complexity and heterogeneity of the tasks arising in connection with data-intensive research.

The development of personnel, skills, and services is not keeping pace with technology developments

A series of initiatives in the countries analysed are attempting to tackle the problem of a lack of users with data skills. In the Netherlands, the Netherlands e-Science Center (NLLeSC) established in 2011 intends to promote the use of existing databases through its own projects and fellowships. Its task is to build bridges between the heterogeneous components of the information infrastructures and to entice researchers to use the e-infrastructure. The British government has started numerous initiatives for training digital skills, including for example the Digital Skills Partnership with business enterprises or the National College for Digital Skills opened at the end of 2016, which receives a total of 31 million GBP (40 million USD) in public funding. Libraries are also explicitly assigned a special role in training data skills in society.⁴³ In Australia, the National Data Service ANDS is involved in particular in disseminating best practices in research data management throughout the Australian scientific system through its project funding programmes (cf. 2.5).

Cross-sector initiatives for training users in data skills

⁴⁰ Australian Government. Department of Education and Training (2015) – NCRIS Status Report.

⁴¹ <http://www.publications.parliament.uk/pa/cm201617/cmselect/cmeuleg/71-ii/71119.htm>.

⁴² Cf. Australian Government. Department of Education and training (2015) – NCRIS Status Report, p. 13.

⁴³ <https://www.gov.uk/government/publications/uk-digital-strategy/uk-digital-strategy>.

Incentives for attracting highly qualified personnel in Canada

One of the strengths of the Canadian scientific system according to numerous press reports is the ability to successfully recruit and retain highly qualified personnel from foreign countries and within Canada. The large number of research infrastructures in Canada also plays a role in this regard. The John R. Evans Leaders Fund, for example, provides funding to new researchers for special data infrastructures, instruments, or other equipment.⁴⁴

2.8 CURRENTLY EXISTING OPERATIONAL INFRASTRUCTURES

The four countries studied already run operational infrastructures, some of which have become the driving stakeholders in the development of research data management in their particular countries (cf. 2.5).

Basic technical infrastructure

In the Netherlands services for (physical) storage, backup storage, and archive storage for research data are coordinated at the national (SURFsara), regional (Target), and local level (university computer centres). SURFsara also offers functions in the area of high-performance computing and supercomputing. SURFnet is involved in the development of a national research network (NREN – National Research and Education Network) for the optimisation of data transfers. Both are subsidiaries of the ICT service provider SURF, which is a cooperative comprising Dutch universities and research facilities (and organised in a similar manner to the German DFN-Verein which provides the National Research and Education Network).

The Advanced Research Computing High End Resource (ARCHER) is currently the United Kingdom's largest national facility for high-performance and supercomputing. It is managed on behalf of the RCUK by the Engineering and Physical Sciences Research Council (EPSRC). The UK Research Data Facility (RDF), which functions as a high-performance, stable, and long-term data store, is also located there but is financed separately. The Science and Technology Facilities Council (STFC) runs the Hartree Centre for high-performance computing and supercomputing (see also 2.3). The British research network Janet is operated by the Joint Information Systems Committee (Jisc), which like SURF and the German DFN-Verein is supported by colleges and universities. The national research networks in Europe are part of GÉANT, the pan-European research network.

In Australia, the Research Data Services (RDS) project financed within the framework of the National Collaborative Research Infrastructure Strategy (NCRIS) has been establishing a national network of distributed nodes for the storage of, analysis of, and simplified access to research data as well as its reuse since 2010. The Pawsey High Performance Computing Centre founded

⁴⁴ Cf. CFI (2016) – Annual Report 2015-16, p. 11.

in 2000 is a central component of the Australian high-performance and supercomputing infrastructure. The member-financed Australian Academic and Research Network (AARNet) is responsible for establishing the Australian NREN. AARNet also offers interfaces to the Trans-Eurasia Information Network (TEIN), which connects Asia's and Europe's research communities to each other and is co-financed by the EU Commission.⁴⁵

In Canada there is Compute Canada, which is partly financed by the Canada Foundation for Innovation (CFI) and operates in the area of data storage as well as in the area of high-performance computing and supercomputing. Furthermore, the non-profit corporation CANARIE operates an optical fibre communication network for government institutions and science that is financed primarily with public money.

The Dutch data archive DANS (see also 2.5) offers researchers from all Dutch research facilities various services for archiving and reusing their data.⁴⁶ In addition to DANS, the other two partners that form Research Data Netherlands are also active in the area of data archiving/data management: SURFsara and the 4TU.Centre for Research Data.

Research data centres
and data archives

In the United Kingdom, the Economic and Social Research Council (ESRC), together with the Medical Research Council (MRC), Jisc, and the University of Essex, finance the UK Data Archive, which in turn realises the UK Data Service together with Jisc. The vision of the UK Data Service is to integrate existing data services for social and economic data into a comprehensive, national service. A pioneer in data curation is the Digital Curation Centre (DCC), which is financed by Jisc. Jisc also organises a *Shared Data Centre Service* for long-tail data for its member organisations.⁴⁷

In Australia, the National eResearch Collaboration Tools and Resources (NeCTAR) – a project founded in 2011 and financed by NCRIS – provides a data cloud, various tools for data analysis, and virtual research environments. The offer is directed explicitly towards researchers and their international cooperation partners.

Furthermore, there are numerous discipline- and community-specific research data infrastructures in the countries examined. These infrastructures are planned and (co-)financed in some cases through national roadmaps for research infrastructures. In all countries, such infrastructures are typically present in data-intensive research areas like genomics and biomedicine, environmental and Earth system research, astrophysics, or empirical social

⁴⁵ TEIN CC (2014) – Connecting Asia and Europe's Research and Education Communities (Map).

⁴⁶ <https://easy.dans.knaw.nl>, <http://dataverse.nl/>, <http://www.narcis.nl/>.

⁴⁷ <https://www.jisc.ac.uk/shared-data-centre>.

sciences. Data collections in these areas are often already networked across national borders.

In the Netherlands and in the United Kingdom, the member-based infrastructure facilities SURF and Jisc are engaged in numerous activities for supporting research data management and the use of research data from facilities connected to them: from offers for consulting and advanced training to the foundation of specialised facilities like the Digital Curation Centre (by Jisc) or the Netherlands eScience Centre (by SURF).

The front offices in the Dutch collaborative model (cf. 2.5) include university libraries and discipline-specific research infrastructures. They act as link between researchers and data archives (back offices). In addition, they support the research process in terms of data storage, provide training to researchers, and acquire data.

In Canada, the research data management network PORTAGE launched in 2015 by the Canadian Association of Research Libraries (CARL) is intended to provide support to researchers and other stakeholders. For this purpose, a network spanning all stakeholder groups, national platforms for advice, and platforms for storing and searching through research data have been created. PORTAGE is still in the development phase. In a pilot project, working groups, the first services (e. g. for the simplified creation of data management plans), and a functional coordination unit were established.⁴⁸

The Australian National Data Service (ANDS) is a project that has been in existence since 2009 and receives long-term financing in the context of the National Collaborative Research Infrastructure Strategy (NCRIS). It is listed there in the category “Platforms for Collaboration”. Its stated goal is to make Australia’s research data collections more valuable. This is done through projects relating to the management, linking, and retrieval of data and to supporting a wide variety of uses of the data.

2.9 INTERNATIONAL NETWORKING

Infrastructure developments in the countries analysed have always had an international component – in some cases for reasons of self-interest because access to international resources is needed by the national science system, and in other cases because communities of states like the EU or international organisations like the OECD have agreed to take a community approach (with very high obligations like in the area of geodata or with an opt-in option as

⁴⁸ Cf. CARL/Portage (2017) – Portage Business Plan 2017 and 2018, p. 4 ff.

in the case of the trans-European research infrastructures in the ESFRI programme).⁴⁹

Science itself is an important driver of international networks of *research data infrastructures* – which are generally community-based or discipline-based. Funding for many of these infrastructures comes from national project funds through the participating partner organisations and nodes. Depending on the business model, securing a budget requires a more or less intense national negotiation process. To become a member of the GEOSS or ELIXIR transnational infrastructures, for example, it is necessary to sign a government agreement, and to found a *European Research Infrastructure Consortium* (ERIC) under the ESFRI programme, formal commitments from each of the participating states are required. In cases where a financial commitment is obtained, the commitment is often bound to a specific project. For this reason as well, the scientific and infrastructure facilities involved urge national research funders and governments to develop a comprehensive and long-term strategy for participating in international infrastructure initiatives.

Science drives the international networking of research infrastructures

The Netherlands and the United Kingdom, like Germany, are very active participants in initiatives for the common European Research Area (ERA). The European Open Science Cloud – a pilot project is coordinated by a British council – is a notable example as well as the numerous transeuropean research and data infrastructure projects on the ESFRI roadmap.

Both countries – as well as Germany – have established national roadmap processes that serve to coordinate the national negotiation processes for participation in ESFRI. The Netherlands, in the context of their EU Council Presidency in 2016, have made the topic of Open Science a primary priority and research data management a secondary priority, and are directing their national efforts towards common European interests.⁵⁰ As an example, the planned *National Open Science Cloud* was significantly influenced by the concepts behind a *European Open Science Cloud*. Stakeholders in the Netherlands like the university-affiliated ICT service provider SURF and the national research organisation NWO are also very actively promoting participation in European initiatives.

National roadmaps and multi-stakeholder initiatives augment the international network

Australia and Canada want to maintain “world class research infrastructures”.⁵¹ A strong interest of science in obtaining access to resources outside their own continent was formulated by the government commission established in 2014

⁴⁹ Cf. the overview in RfII (2016) – Performance through Diversity, p. 22 ff. Additional statements in this section are based on an unpublished analysis of international initiatives and infrastructures conducted in 2015 by the Working Group on International Orientation of the RfII.

⁵⁰ European Union (2016) – Amsterdam Call for Action.

⁵¹ This phrase is used in various official statements issued by the corresponding governments.

to evaluate Australian research infrastructures, for example. In Australia, such access is realised in some cases from the bottom up through involvement in scientific networks, and in other cases access is supported by the government through cooperation and access agreements. An example of a formal alliance is the alliance between the Australian Microscopy and Microanalysis Research Facility (AMMRF) and the European Molecular Biology Laboratory (EMBL).⁵² A regular dialogue has been established between the Australian NCRIS programme and the European research infrastructure roadmap ESFRI.⁵³ At the Australian data service ANDS, funding for a separate programme for international collaboration has been allocated in the budget. ANDS is a co-founder of the Research Data Alliance (RDA), a global platform for exchanging best practices, and plays a significant role in its financing – next to stakeholders like the European Commission, Jisc (United Kingdom), and Research Data Canada (RDC).

Efforts to consolidate fragmented resources, individual institutional stakeholders, and investments can currently be seen in the countries analysed as well as at the level of unions of states.

2.10 OVERCOMING FRAGMENTATION – FROM CONCEPTS TO THE IMPLEMENTATION PHASE

The diversity of the stakeholders and their conceptual and operational activities discussed in the previous sections are also an expression of fragmentation in the infrastructure landscape, that is a side effect of the digital transformation – in part due to the speed at which it progresses, but also due to the bottom-up innovations typical in science and to financial constraints (i.e. project funding). The necessity to overcome this fragmentation – at the level of the technical system, financing, and governance, among others – appears to have been recognised across national borders.

Partial solutions predominate

The main recommendation for Germany, expressed by a Canadian expert in the spring of 2016, was: “Build a system first!” This meant an overall concept that goes beyond the technology alone since most countries have only presented partial solutions. The infrastructure experts from the Netherlands and the United Kingdom consulted by the RfII all came to the conclusion that coherent national systems with clear rules and coordinated infrastructure development are also useful in the area of research data management. The dedication of strong, individual institutional stakeholders has achieved a great

⁵² Australian Government. Department of Education and Training (2015) – Research Infrastructure Review.

⁵³ <https://www.education.gov.au/australia-s-relationship-european-union-research-infrastructure>.

deal, but the effort required is too great and exceeds the capabilities of self-organisation. For this reason, politicians – well-advised by scientists – are called upon to actively shape developments.

In all countries examined, various, and in some cases affiliated stakeholders and stakeholder groups who either provide policy advice or operate as infrastructure providers are currently attempting to further the use of information and data infrastructure services through visionary models and commitments. The goal is to promote research and innovation by increasing the value of data. This applies to research data management, but also to neighbouring fields such as the sustainable management of research software.

Visionary models and commitments

In all countries examined, new types of governance structure are being conceived, and there are some implementation concepts designed to enable research data management and the required infrastructures to be developed and networked holistically.

New types of governance structure and holistic approaches

In Canada, for example, the Leadership Council for Digital Infrastructure (LCDI) was tasked in 2016 by the Department of Innovation, Science and Economic Development with formulating recommendations on central aspects of a *Digital Research Infrastructure Ecosystem* with the intention of integrating the recommendations into the *Digital Research Infrastructure Strategy* currently being developed by the ministry. The LCDI, which has been in existence since 2012, is a coalition of stakeholders that was founded from the bottom up. Universities (incl. representatives of researchers), service providers, associations, and organisations are members as well as the Department of Innovation, Science and Economic Development and several funders of research as observers.⁵⁴ One national expert noted that its foundation was a reaction by national stakeholders to a regulatory “top-down vacuum”.

Leadership Council for Digital Infrastructure in Canada

In other countries, comparable consulting councils have been created top down, for example the e-Infrastructure Leadership Council (ELC) in the United Kingdom, which was established in 2012 on the initiative of the UK Department for Business, Innovation and Skills (BIS). In 2013 it formulated recommendations for the creation of an *e-infrastructure ecosystem*. Members of the ELC include representatives from science, industry, and society as well as from government departments, funding councils, and charitable organisations. The first report of the ELC already indicated a strong orientation towards implementation. It even suggests specific tasks for the stakeholders in the scientific system.⁵⁵

The e-Infrastructure Leadership Council in the United Kingdom

⁵⁴ The composition of the council is similar to that of the RfII, see also <http://digitalleadership.ca/about-the-leadership-council/participants/>.

⁵⁵ ELC (2013) – The ecosystem for innovation.

The Canadian LCDI and the British ELC were both commissioned by the ministry of economy in their corresponding country, and their programmes exhibit a strong focus on industry.⁵⁶ The Co-Chair of the ELC stated this succinctly as follows: “The E-infrastructure Leadership Council [...] is all about how industry can make appropriate use of this expensive research infrastructure.”⁵⁷

National coordination point in the Netherlands

While both Canadian and British leadership councils (LCDI and ELC) focus on the information infrastructure as such (digital research infrastructure and e-infrastructure, respectively), a national coordination point especially for research data management (National Coordination Point Research Data Management – LCRDM) was established in the Netherlands at the suggestion of universities. The coordination point is realised by the university-affiliated ICT service provider SURF, which works closely together with its Research Data Netherlands (RDNL) partners. Its task is to participate in the creation of a holistic national strategy for research data management while taking legal and financial aspects, the level of commitment of researchers, and questions regarding (data) infrastructures into consideration.

National data infrastructures and clouds

In the United Kingdom as well, there is one stakeholder specially reserved for research data management. On the initiative of the British government, a task force comprised of members from universities and the RCUK has been working on an action plan for an *Open Research Data Infrastructure* since 2016. This action plan is expected to be available by the end of 2017/early 2018 and stands as a prime example of the transition from the concept phase to the implementation phase observed in many countries in terms of the establishment of the suggested national research data infrastructures. This transition can also be observed in Australia, where the *Australian Research Data Cloud* has appeared as a merger of various preceding projects from the NCRIS programme in the recently updated roadmap for research infrastructures (see 2.2 and 2.3). The idea of a “national cloud” can also be found in the Netherlands.

In the end, the influence of the stakeholders and stakeholder networks striving for a holistic approach in their countries will depend on the extent to which their recommendations are integrated into national policies and governance processes. On the other hand, (governmental) top-down policy initiatives will not have the desired effect if they do not actively include the wide variety of different stakeholders in the concept phase as well as in the implementation phase. Here, as shown by a comparison of the individual development paths chosen, the information infrastructure model pursued in each country depends greatly on the composition of the stakeholder networks providing advice.

⁵⁶ *ibid.*

⁵⁷ Hey (2016) – We’re overwhelmed with data.

3 CONCLUSIONS AND SUGGESTIONS

3.1 FOR RESEARCH DATA INFRASTRUCTURES

In all countries examined, a new approach – directed towards the overall national system and oriented on research data management – is appearing in addition to the local provision of digital infrastructures and is even replacing these local approaches in some cases. However, in the Netherlands and Australia – and in contrast to Germany – an increased trend towards top-down measures in national initiatives can be recognised: The national funding paths for research infrastructures (roadmaps) are used to drive the development of the data infrastructures/e-infrastructures. For Germany, the RfII suggests a coordinated interplay of/with the development and operation of all research infrastructures while gradually establishing the national research data infrastructure (NFDI). The ability to interact should be guaranteed. In this manner it will be possible to ensure a regionally and institutionally coherent landscape for an overall network with adequately distributed nodes.

Research data infrastructures as a part of research infrastructures

The integration of scientific users has been recognised as a critical factor for the successful establishment of digital research data infrastructures. This was stated in all consultations with experts from the countries analysed. However, no country has developed a satisfactory national solution to this problem thus far. The sustainability of apparently advanced platforms – like those in the Netherlands – seems questionable when this aspect is considered. The RfII affirms its position in this case that only the permanent, structural integration of the users into the infrastructure development process will lead to sufficiently high-performance and sustainable solutions that meet the complex and changing needs of research. Such an approach is pursued by the consortia model suggested by the RfII for the NFDI in Germany.⁵⁸ It proposes the activation of general communities/scientific communities at an early stage who then join together with suitable infrastructure stakeholders, which should also enable interdisciplinary data use. There is no equivalent thus far to this innovative approach in any of the countries examined. Germany is therefore pioneering the concepts for this approach.

Integration of the users

Other countries are ahead of Germany in terms of the development of binding rules for the management of research data. Initially, Canada and the United Kingdom had only non-binding recommendations written in very broad terms from various locations, just like the current situation now in Germany where mainly options are discussed but no binding rules are adopted. In the meantime, overarching principles for good data management have been formulated in these countries, resulting from discourse between research

Rules for research data management

⁵⁸ RfII (2017) – Diskussionspapier 2017: Zur Nationalen Forschungsdateninfrastruktur.

fundings, libraries, and researchers. This creates a common basis for the actions taken by the stakeholders; the STATEMENT OF PRINCIPLES ON DIGITAL DATA MANAGEMENT of the Canadian Tri-Agencies or the CONCORDAT ON OPEN RESEARCH DATA in the United Kingdom can be considered exemplary in this regard. For Germany, the RfII suggests formulating binding principles for research data management. Although a series of institutional, discipline-specific, or community-specific guidelines for research data management exist in Germany in addition to the ten-year retention period requirement for data, these guidelines only reach specific parts of the scientific system. Only binding principles will create a basis for the kind of collaboration required in future to manage research data at all levels of the scientific system. The development of such principles for research data management in the form of a *charter*, for example, could be the first task to be performed by the initial members of the NFDI. Ideally, the members of the Alliance of Science Organisations in Germany as well as the German state and federal governments as research funders could participate in this case so that a common charter would be created for the German scientific system. In the Netherlands, these approaches have been put in concrete terms and developed into control mechanisms by requiring the submission of a data management plan as a mandatory prerequisite for receiving funding approval for a research project.

Flexible budgets for incentive funding and innovations

The countries analysed have successfully experimented with allowing greater funding flexibility in order to finance innovative approaches. In the context of infrastructure projects, the stakeholders can use a portion of the funding they receive to fund projects relating to user integration or to finance smaller, tailor-made technical developments. Examples of this can be found at the Australian Data Service ANDS, the Dutch e-Science Center NLeSC, and at Jisc in the United Kingdom. The advantages of this form of financing are that needs can be fulfilled quickly and unbureaucratically, and that the threshold for testing potential solutions is as low as possible. It increases the impact of initiatives oriented towards the scientific system as a whole. The RfII suggests providing large initiatives in Germany as well with funds for user grants and smaller development projects more frequently in order to firmly anchor best practices throughout the scientific system or to initiate interoperability projects. Transparency and good communication of results must be ensured in this process.

Promoting the use of data in a variety of ways

The problem of skills development and the need for personnel are being handled in very different ways in the countries examined. In addition to training digital skills or offering advice on research data management to (individual) scientists, stakeholders are also turning to the question of how to provide researchers with easier access to complex data analyses using user-friendly software and tools. Overall, small projects and fellowships for research on existing data, in cooperation with experts who curate the data, can make a

substantial contribution to the development of digital skills and would not be difficult to implement as tools – e.g. by allowing grants to be awarded independently within the framework of larger funding projects or within the NFDI.

Securing budgets over the long term and increasing demand are two of the conditions that need to be considered in future financing schemes. Remarkable in this respect is the recommendation of the Australian government commission to increase the minimum duration of infrastructure projects to seven years. In Australia, projects also receive a significant portion of their funding through co-investments from partners. In Canada, there is a fund available for subsidising the operating costs of research infrastructures. In its position paper *PERFORMANCE THROUGH DIVERSITY*, the RfII called for strategies for the long-term financing of services that were previously funded as projects – primarily using a phase model and through systematic evaluation. Matching funds from partners would be one way to transfer projects to the permanent operating phase. The managed provision of operating cost subsidies from a separate fund created especially for this purpose would be another way to ensure long-term financing and to link preservation of the infrastructure to regular evaluations.

Participatory financing models

For the evaluation of initiatives and infrastructures in the area of research data management, the countries analysed have developed methods whose applicability to Germany should be examined further. The evaluations of the Australian NCRIS programme and the resulting documentation of the impact of public investments, the appropriateness of the selected governance structures, and the improvement of strategies and services can be considered exemplary. They not only evaluated the quality of science, but were also able to provide evidence supporting the hypothesis that public investment in a coherent national strategy is useful.

Evaluation methods and criteria

In its position paper, the RfII already pointed out the great importance of systematic evaluations of infrastructures for analogue and digital data and suggested including a quality assurance system in the NFDI. The Australian strategy can thus serve as a model for the development of criteria after it has been analysed in more detail.

Individual stakeholders like the coalition of data archives in the Netherlands (Research Data Netherlands), Jisc and the Digital Curation Centre in the United Kingdom, or the Australian Data Service ANDS provide model educational services to universities and research facilities, offer training to researchers and data managers, and more. The service model of Research Data Netherlands (front office/back office or *FO-BO model*) offers a good example of how local structures can be linked to research data repositories serving numerous

Federated and collaborative models for user integration

institutions⁵⁹ as recommended by the RfII. The RfII suggests that universities and research facilities in Germany, in collaboration with infrastructure providers, offer their researchers similar support and services for research data management. Discussion of whether or not FO-BO models are plausible should not only take place in the consortia of the NFDI, but also in the research facilities themselves. Can advisory functions – especially those supporting better management of long-tail data – for university libraries and computer centres be professionalised based on the FO-BO model?

The decision to include business stakeholders in concepts for public research data infrastructures has had a lasting impact on developments in the United Kingdom and Canada. In its position paper *PERFORMANCE THROUGH DIVERSITY*, the RfII critically examined several aspects of the relationship between science and industry with respect to the use of data and the provision of digital services (including the existence of dependencies and the uncontrolled use of data by third parties, but also the codification of laws regarding the sharing of data among scientists). The RfII endorses the development of services by the scientific community so that it retains sovereignty over its research data. However, in order to capitalize on opportunities presented by cooperations between science and industry, it would appear reasonable to investigate new paths of development without endangering the sovereignty of science over research data.

In view of the recent international developments, it is also recommended to initiate a more vigorous exchange regarding how the controlled commercial use of information infrastructure solutions and corporate participation therein should be arranged in the framework of the National Research Data Infrastructure (NFDI), in collaborations at the European level (e.g. the European Cloud Initiative), or in other transnational collaborations. Thus far, specific aspects of this have only been alluded to in the countries analysed. Central issues include: access by industry to publicly funded data infrastructures, the use of data from industry research by public research facilities, criteria for the procurement/use of commercial products and services vs. investment in products and services offered by the scientific community itself. Internationally as well, these issues are far from being clarified or resolved. When developing binding rules and regulations, the issues stated above (and here in particular: guidelines for the controlled commercial use of research data at the national and international level) should be discussed in the framework of an NFDI.

⁵⁹ Cf. RfII (2016) – *Performance through Diversity*, p. 36.

3.2 ON THE ROLE OF GERMANY AS AN INTERNATIONALLY NETWORKED PLAYER

The countries examined (and certainly Germany as well) can be considered strong in science and “potent” global players in terms of investment. Not all countries will provide similar capacities, exhibit the will to continue developing their research infrastructures and research data management solutions, or contribute to shaping open science. In the four countries analysed, questions regarding the interconnectedness of their research data infrastructures as well as the decisions associated with the role of a potential, internationally active contributor to the development of global information infrastructure policies become even more important.

The challenge for politics, science, and industry is to integrate their national resources into international and transnational networks. However, this also leads to potential opportunities. The organisation of the ESFRI Roadmap and the European high-performance computing resources are models of shared structures in which Germany is already playing an important role.

In the area of research data infrastructures, strategies for integrating and linking the NFDI into the European and international environment could be developed and implemented in a similar fashion. To accomplish this, it is also necessary for German representatives in the corresponding committees to be able to act in a more coordinated manner and receive wider support for their involvement. This applies especially to the NFDI representatives because they are involved in the development of resources that will become extremely important in the future.

The European Cloud Initiative (ECI), which includes a science cloud and a data infrastructure, will be an important focal point in the European Research Area. Based on the current status, it is unclear if the services will be provided using the conventional model by a network of strong individual national stakeholders or if it is possible to create a network of national research data infrastructures step by step using a process similar to the ESFRI process. In the near future, there will probably only be a limited number of countries with such structures, but they will have at least come to an understanding in this regard. In addition, it is necessary to examine networks outside of the European context. Globally distributed and networked data infrastructures have already been founded for individual research areas, but they depend on a stable national commitment and have not realised their full potential yet. These infrastructures would also benefit from high-performance national research data infrastructures. The RfII initially suggests continued and more intense exchanges with the initiatives arising in other countries. Furthermore, the international initiatives currently underway (for example GO-FAIR) offer the opportunity to come to an

International
integration of the NFDI

The European Cloud
Initiative as a focal
point for national
initiatives

Intensify
communication with
the driving forces in
other countries

agreement on how the roles of the national research data infrastructures being developed could be defined so they are conducive to international networking.

The RfII has observed before that German stakeholders are already active at international level. This applies to their participation in data infrastructures as well as to their participation in standardisation and best practice networks like the Research Data Alliance and CODATA or in activities in the international associations and platforms existing in all sectors (libraries, universities, academies, research funders, etc.).

Coordination of the international activities of German stakeholders

As noted in the position paper PERFORMANCE THROUGH DIVERSITY, these activities need to be much more closely coordinated at the national level.⁶⁰ Through the establishment of an NFDI, Germany would be able to speak with a stronger voice at the international level. This could ensure the ability of scientific policy to influence the development of the international landscape and promises to put Germany strategically in an even better position than before.

Resources for international networking

Finally, the RfII suggests providing the projects and initiatives funded in Germany with resources dedicated to international networking. In Australia, the data service ANDS has a programme for networking its activities internationally, and the UK Open Data Institute (ODI) maintains branch offices in numerous countries (see 2.9). The RfII considers it exemplary to integrate the task of international networking into the programme of a facility and to provide the facility with its own resources. This approach is also recommended as useful for recruiting skilled specialists.

3.3 ON THE FUTURE MONITORING ACTIVITIES OF THE RFII

“How is the German scientific system positioned with respect to the international competition?”⁶¹ In 2014, the Joint Science Conference assigned the RfII the task of answering this question by monitoring the international situation. The comparative analyses presented here show that other countries are in an experimental phase – not unlike the situation in Germany – with regard to their structures, processes, and results in terms of new ways of managing research data, as well as in terms of organisational and structural questions and the financing of research data management.

International support for the idea of an NFDI in Germany

The strategy devised for Germany of gradually establishing a “network-like” NFDI was met with interest and received very positive reactions from the consulted experts from the various countries in the discussions the RfII was able to hold with them.

⁶⁰ Cf. RfII (2016) – Performance through Diversity, p. 43.

⁶¹ GWK (2013) – Drucksache 13.48.

The development of integrated research data infrastructures may follow different paths in the future, including the paths for cooperation – also for cooperation with industry – chosen by individual stakeholders. The question of whether priority should be given to national or international approaches for specific disciplines remains open, though. It is possible that security aspects as well as questions relating to data integrity will become increasingly important in the future. It will also be necessary to observe what form Open Science eventually takes.

In the short and medium term it is therefore important to provide the Joint Science Conference, and the German scientific system in general, with information on international and transnational developments using various methods. Additional countries should also be monitored because a wide variety of very different approaches are conceivable for harnessing the digital transformation of science and industry to improve the quality of science and research. The different cultural and legal approaches also play a role in this regard and are also politically interesting.

Continue monitoring
of international
and transnational
developments

Countries with which Germany maintains particularly close scientific relations are of interest in this context, but also countries which are pursuing unusual paths of development in terms of the digital transformation due to the particularities of their political systems. The first objective in this regard would be to create a dossier providing a basic overview of the main stakeholders, programmes, and initiatives involved in the areas of research (data) infrastructures and research data management for digital and analogue data. The legal form of these approaches is highly relevant in this case since it determines the feasibility of many data-oriented approaches to research. For this reason, how other countries resolve the central legal issues in the areas of data protection and copyrights in particular is a matter of great interest. In various and sometimes new transnational cooperation formats (e. g. GO-FAIR) and coordination forums (e. g. the Research Data Alliance or the Belmont Forum), stakeholders are discussing their particular national approaches and merging them together. This transnational dimension should also be a subject of further systematic monitoring. Monitoring should eventually also focus on the activities of large corporations in areas relevant to information infrastructures.

The governance structures currently being developed internationally and exhibiting certain parallels to the objectives of the National Research Data Infrastructure (NFDI) suggested for Germany should be observed further. In addition, those committees identified as fulfilling a task similar to that of the RfII should be contacted. If contact has already been made, it should be maintained. This represents an immediate opportunity for learning, but also an opportunity to participate in developments.

Continued and more in-depth monitoring of the countries initially analysed can be expected to provide practical information on the development of the legal framework, the management and quality assurance of data and information infrastructures, and the skills and expertise that need to be developed in this area. The analyses presented here only touch on these topics – although they will play a central role in the design and development of the German research landscape in the upcoming years.

In future monitoring activities performed by the RfII, duplication of work is to be avoided – which means that international analyses performed by the RfII must include and build on parallel activities of other stakeholders in the scientific system.

BIBLIOGRAPHY

- Australian Government. Department of Education and Training (2015): NCRIS National Research Infrastructure for Australia. Status Report on the NCRIS eResearch Capability. Summary. A Report to the Australian Government Department of Education and Training, Canberra/Melbourne, available online at: https://docs.education.gov.au/system/files/doc/other/abridged_eresearch_status_report_-_web.pdf, last checked on: 25/04/2017.
- Australian Government. Department of Education and Training (2015): Research Infrastructure Review. Final Report. September 2015, available online at: https://docs.education.gov.au/system/files/doc/other/research_infrastructure_review.pdf, last checked on: 25/04/2017.
- Australian Government. Department of Education and Training (2016): 2016 National Research Infrastructure Roadmap (Draft), available online at: https://docs.education.gov.au/system/files/doc/other/draft_2016_national_research_infrastructure_roadmap_2.pdf, last checked on: 25/04/2017.
- Australian Government. Department of Education and Training (2016): National Collaborative Research Infrastructure Strategy. Programme Guidelines 2016-2017, Canberra/Melbourne, available online at: https://docs.education.gov.au/system/files/doc/other/minister_approved_ncris_2016-17_guidelines_no_watermark_2.pdf, last checked on: 25/04/2017.
- CARL – Canadian Association of Research Libraries / Portage – Services partagés pour les données de recherche (2017): Portage Business Plan: 2017 and 2018, available online at: https://portagenetwork.ca/wp-content/uploads/2016/03/Portage_Business_Plan_Final-e-2017.pdf, last checked on: 25/04/2017.
- CFI – Canada Foundation for Innovation (2015): Consultation on the Canada Foundation for Innovation's fund architecture. A discussion paper, Ottawa, available online at: <https://www.innovation.ca/sites/default/files/Funds/2015%20CFI%20Consultation%20discussion%20paper.pdf>, last checked on: 25/04/2017.
- CFI – Canada Foundation for Innovation (2015): Developing a digital research infrastructure strategy for Canada. The CFI perspective, Ottawa, available online at: <https://www.innovation.ca/sites/default/files/Funds/cyber/developing-dri-strategy-canada-en.pdf>, last checked on: 25/04/2017.
- CFI – Canada Foundation for Innovation (2016): Innovation is our nature. Annual Report 2015-16, Ottawa, available online at: https://www.innovation.ca/sites/default/files/file_uploads/final-cfi-ar-en.pdf, last checked on: 25/04/2017.
- Department of Finance Canada (2015): Economic Action Plan 2015, available online at: <http://www.budget.gc.ca/2015/docs/plan/budget2015-eng.pdf>, last checked on: 25/04/2017.
- ELC – e-Infrastructure Leadership Council (2013): E-infrastructure: The ecosystem for innovation: One year on. Department for Business, Innovation and Skills, London, available online at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/249474/

bis-13-1178-e-infrastructure-the-ecosystem-for-innovation-one-year-on.pdf, last checked on: 25/04/2017.

European Union (2016): Amsterdam Call for Action on Open Science (website), Amsterdam, available online at: https://anfdonnees2016.sciencesconf.org/conference/anfdonnees2016/pages/amsterdam_call_for_action_on_open_science.pdf, last checked on: 25/04/2017.

Government of Canada (2014): Seizing Canada's Moment. Moving Forward in Science, Technology and Innovation, available online at: [https://www.ic.gc.ca/eic/site/icgc.nsf/vwapj/Seizing_Moment_ST_I-Report-2014-eng.pdf/\\$file/Seizing_Moment_ST_I-Report-2014-eng.pdf](https://www.ic.gc.ca/eic/site/icgc.nsf/vwapj/Seizing_Moment_ST_I-Report-2014-eng.pdf/$file/Seizing_Moment_ST_I-Report-2014-eng.pdf), last checked on: 25/04/2017.

Government of Canada (2015): Digital Canada 150. Version 2.0, Ottawa, available online at: [https://www.ic.gc.ca/eic/site/028.nsf/vwapj/DC150-2.0-EN.pdf/\\$FILE/DC150-2.0-EN.pdf](https://www.ic.gc.ca/eic/site/028.nsf/vwapj/DC150-2.0-EN.pdf/$FILE/DC150-2.0-EN.pdf), last checked on: 25/04/2017.

GWK – Gemeinsame Wissenschaftskonferenz (2013): Ergänztter Bericht des Ausschusses (GWK Drucksache 13.48, unpublished), Bonn.

HEFCE – Higher Education Funding Council for England et al. (2016): Concordat on Open Research Data, n.p., available online at: <http://www.rcuk.ac.uk/documents/documents/concordatonopenresearchdata-pdf/>, last checked on: 25/04/2017.

Hey, Tony (2016): "We're overwhelmed with data" – interview with Digifest speaker Tony Hey (website), n.p., available online at: <https://www.jisc.ac.uk/news/were-overwhelmed-with-data-22-feb-2016>, last checked on: 25/04/2017.

KPMG (2014): National Collaborative Research Infrastructure Strategy Projects Review. Overarching Report. December 2014, available online at: https://docs.education.gov.au/system/files/doc/other/ncris_project_reviews_final_report_web.pdf, last checked on: 25/04/2017.

NWO – Netherlands Organisation for Scientific Research (2016): National Roadmap Large Scale Scientific Infrastructure, available online at: <http://www.nwo.nl/en/documents/nwo/permanent-commission/roadmap-large-scale-scientific-infrastructure>, last checked on: 25/04/2017.

RDC – Research Data Canada (2016): Research Data Management in Canadian Universities. A Statement of Principles, n.p., available online at: <http://www.rdc-drc.ca/download/rdm-statement-of-principles/?wpdmdl=709>, last checked on: 25/04/2017.

Rfll – German Council for Scientific Information Infrastructures (2016): Enhancing Research Data Management: Performance through Diversity. Recommendations regarding structures, processes, and financing for research data management in Germany, Göttingen, available online at: <http://d-nb.info/1121685978>.

- RfII – German Council for Scientific Information Infrastructures (2016): Die Entwicklung von Konzepten für Informationsinfrastrukturen in der Bundesrepublik Deutschland seit den 1960er Jahren. RfII Berichte No. 2, Göttingen, available online at: <http://d-nb.info/1106392086>.
- RfII – German Council for Scientific Information Infrastructures (2017): Ein Diskussionsimpuls zu Zielstellung und Voraussetzungen für den Einstieg in die Nationale Forschungsdateninfrastruktur (NFDI), Göttingen, available online at: <http://d-nb.info/1131083113>.
- RfII – German Council for Scientific Information Infrastructures (2017): Entwicklung von Forschungsdateninfrastrukturen im internationalen Vergleich. Bericht und Anregungen, Göttingen, available online at: <http://d-nb.info/1136758240>.
- Technology Strategy Board (2011): Technology and innovation centres: a prospectus. Maximising the commercial impact of UK R&D, Swindon, available online at: <https://catapult.org.uk/wp-content/uploads/2016/04/Technology-and-innovation-centres-a-prospectus-2011.pdf>, last checked on: 25/04/2017.
- TEIN CC – Trans-Eurasia Information Network Corporation Center (2014): Connecting Asia and Europe’s Research and Education Communities. Map, available online at: https://www.aarnet.edu.au/images/uploads/resources/TEIN_Backbone_MAP_Normal_style_%28JUN2014%29.pdf, last checked on: 25/04/2017.
- The Netherlands EU Presidency 2016 (2016): The Netherlands’ contribution to the European Research Area, Brussels, available online at: https://era.gv.at/object/document/2763/attach/NL_Final_draft_The_Netherlands_contribution_to_the_European_Research_Area.pdf, last checked on: 25/04/2017.
- The Royal Society (2012): Science as an open enterprise, London, available online at: <https://royalsociety.org/topics-policy/projects/science-public-enterprise/report/>, last checked on: 25/04/2017.
- The Royal Society (2014): Science 2.0 Consultation: Royal Society response, n.p., available online at: <https://royalsociety.org/~media/policy/Publications/2014/science-2-0-consultation-response-290914.pdf>, last checked on: 25/04/2017.
- Warrington Guardian (pub.) (2015): Town to benefit from ‘huge’ economic boost after unveiling £313m partnership deal (video), available online at: http://www.warringtonguardian.co.uk/news/13313681.Town_to_benefit_from__huge__economic_boost_after_unveiling_of__313m_partnership_deal/, last checked on: 25/04/2017.

LIST OF ABBREVIATIONS

AUD	Australian Dollar
CAD	Canadian Dollar
ESFRI	European Strategy Forum on Research Infrastructures
EU	European Union
EUR	Euro
FAIR	Findable, Accessible, Interoperable, Reusable
FO-BO model	Front Office/Back Office model
GBP	Pound Sterling
GDP	Gross Domestic Product
HPC	High-Performance Computing
ICT	Information and Communication Technology
IOF	Infrastructure Operating Fund (Canada)
IT	Information Technology
NCRIS	National Collaborative Research Infrastructure Strategy (Australia)
NFDI	National Research Data Infrastructure (Germany)
NREN	National Research and Education Network
R&D	Research & Development
RDM	Research Data Management
UK	United Kingdom of Great Britain and Northern Ireland
USD	United States Dollar

GLOSSARY OF INTERNATIONAL STAKEHOLDERS

4TU.Centre for Research Data (infrastructure facility / NL)

<http://researchdata.4tu.nl/en>

AARNet – Australia’s Academic and Research Network (infrastructure facility / AU)

<https://www.aarnet.edu.au>

Alan Turing Institute (research facility / UK)

<https://www.turing.ac.uk/about-us>

AMMRF – Australian Microscopy and Microanalysis Research Facility (research facility / AU)

<http://ammrf.org.au/about-us>

ANDS – Australian National Data Service (cooperation platform / AU)

<http://www.ands.org.au>

ARC – Australian Research Council (research funder / AU)

<http://www.arc.gov.au>

ARCHER – Advanced Research Computing High End Resource (infrastructure facility / AU)

<http://www.archer.ac.uk/about-archer>

Australian Government. Department of Education and Training

<https://www.education.gov.au>

Australian Government. Department of Industry, Innovation, Science, Research and Tertiary Education <https://industry.gov.au>

Canadian Government. ISED – Department of Innovation, Science and Economic Development (formerly Industry Canada – IC)

<http://www.ic.gc.ca>

CANARIE – Canadian Network for the Advancement of Research, Industry and Education (infrastructure facility / CAN)

<http://www.canarie.ca>

CARL – Canadian Association of Research Libraries

<http://www.carl-abrc.ca>

Catapult Centres (research and innovation network / UK)

<https://catapult.org.uk>

CCPs – Collaborative Computational Projects (research and infrastructure facility / UK)

<http://www.ccp.ac.uk>

CFI – Canada Foundation for Innovation (research funder / CAN)

<https://www.innovation.ca>

CODATA – The Committee on Data for Science and Technology (international organisation)

<http://www.codata.org>

Compute Canada (infrastructure facility / CAN)
<https://www.computecanada.ca/about>

CSIRO – Commonwealth Scientific and Industrial Research Organisation (research organisation/
funder / AU)
<https://www.csiro.au>

CUCCIO – Canadian University Council of Chief Information Officers (association / CAN)
<http://www.cuccio.net/en>

DANS – Data Archiving and Networked Services (infrastructure facility / NL)
<http://www.dans.knaw.nl/en>

DCC – Digital Curation Centre (infrastructure facility / UK)
<http://www.dcc.ac.uk>

ELC – e-Infrastructure Leadership Council (coalition of stakeholders with an advisory function / UK)
<https://www.gov.uk/government/groups/e-infrastructure-leadership-council>

ELIXIR – A distributed (European) infrastructure for life-science information (European infrastruc-
ture facility)
<https://www.elixir-europe.org>

EMBL – European Molecular Biology Laboratory (European infrastructure facility)
<http://www.embl.org>

EPSRC – Engineering and Physical Sciences Research Council (research funder / UK)
<https://www.epsrc.ac.uk>

ESRC – Economic and Social Research Council (research funder / UK)
<http://www.esrc.ac.uk/about-us>

GÉANT – Pan-European Backbone Network (European infrastructure network)
<https://www.geant.org>

GEOSS – Global Earth Observation System of Systems (European infrastructure network)
<http://www.earthobservations.org/geoss.php>

GO-FAIR – International initiative for the practical implementation of the European Open Science
Cloud (EOSC) using a federated approach
<https://www.dtls.nl/go-fair>

Hartree Centre (research and infrastructure facility / UK)
<https://www.hartree.stfc.ac.uk>

HEFCE – Higher Education Funding Council (research funder / UK)
<http://www.hefce.ac.uk>, <http://www.sfc.ac.uk>, <https://www.hefcw.ac.uk>

IBM – International Business Machines (private company / USA)
<https://www.ibm.com>

Innovate UK (formerly TSB – Technology Strategy Board; research and innovation funder / UK)
<https://www.gov.uk/government/organisations/innovate-uk>

Janet – Research and education network (infrastructure facility / UK)
<https://www.jisc.ac.uk/janet>

Jisc – Joint Information Systems Committee (infrastructure facility / UK)
<http://www.jisc.ac.uk>

KNAW – Royal Netherlands Academy of Arts and Sciences (research organisation/funder / NL)
<https://www.knaw.nl/en/about-us>

KPMG – Global network of auditing and consulting companies
<https://home.kpmg.com/xx/en/home/about.html>

LCDI – Leadership Council for Digital Infrastructure (coalition of stakeholders with an advisory function / CAN)
<http://digitalleadership.ca>

LCRDM – National Coordination Point Research Data Management (coordination point / NL)
<https://www.surf.nl/en/lcrdm>

MRC – Medical Research Council (research funder / UK)
<https://www.mrc.ac.uk/about>

National College for Digital Skills (educational institution / UK)
<https://www.adacollege.org.uk>

NeCTAR – National eResearch Collaboration Tools and Resources (infrastructure facility / AU)
<https://nectar.org.au/about>

Netherlands Government. EZ – Ministerie van Economische Zaken (Ministry of Economic Affairs / NL)
<https://www.government.nl/ministries/ministry-of-economic-affairs>

Netherlands Government. OCW – Ministerie van Onderwijs, Cultuur en Wetenschap (Ministry of Education, Culture and Science / NL)
<https://www.government.nl/ministries/ministry-of-education-culture-and-science>

NHMRC – National Health and Medical Research Council (research funder / AU)
<https://www.nhmrc.gov.au/about>

NLeSC – Netherlands eScience Center (infrastructure facility / NL)
<https://www.esciencecenter.nl>

NWO – Nederlandse Organisatie voor Wetenschappelijk Onderzoek (research organisation / funder / NL)
<https://www.nwo.nl/en>

OCF – Private company for “high performance computing, storage and data analytics” (UK)
<http://www.ocf.co.uk>

ODI – UK Open Data Institute (research and innovation network / UK)
<https://theodi.org>

ODX – Open Data Exchange (research and innovation network / CAN)
<https://codx.ca/about-us>

OECD – Organisation for Economic Co-operation and Development (international organisation)
<http://www.oecd.org>

Pawsey High Performance Computing Centre (infrastructure facility / AU)
<https://www.pawsey.org.au>

PORTAGE – National service network for research data management (CAN)
<https://portagenetwork.ca>

RCUK – Research Councils UK (coalition / UK)
<http://www.rcuk.ac.uk>

RDA – Research Data Alliance (international non-governmental organisation)
<https://www.rd-alliance.org/about-rda>

RDC – Research Data Canada (stakeholder network / CAN)
<http://www.rdc-drc.ca>

RDF – UK Research Data Facility (infrastructure facility / UK)
<http://www.rdf.ac.uk>

RDNL – Research Data Netherlands (alliance of data archives / NL)
<http://www.researchdata.nl/en>

RDS – Research Data Services (infrastructure facility / AU)
<https://www.rds.edu.au>

Royal Society (research organisation / UK)
<https://royalsociety.org>

STFC – Science and Technology Facilities Council (research funder / UK)
<http://www.stfc.ac.uk/about-us>

SURF – Collaborative organisation for ICT in Dutch education and research (infrastructure facility / NL)
<https://www.surf.nl/en>

TARGET Holding (infrastructure facility / NL)
<https://www.target-holding.nl>

TEIN – Trans-Eurasia Information Network (trans-Eurasian infrastructure network)
<http://www.tein.asia>

UK Data Archive (infrastructure facility / UK)
<http://www.data-archive.ac.uk/about/archive>

UK Data Service (infrastructure facility / UK)

<https://www.ukdataservice.ac.uk>

UK Government. BEIS – Department for Business, Energy & Industrial Strategy (UK, since July 2016)

<https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy>

UK Government. BIS – Department for Business, Innovation and Skills (UK, until July 2016)

<https://www.gov.uk/government/organisations/department-for-business-innovation-skills>

Wellcome Trust (research funder / UK)

<https://wellcome.ac.uk>

COUNCIL, MEMBERS, AND GUESTS

The German Council for Scientific Information Infrastructures has 24 members and is composed as follows to ensure equal participation:

- 8 representatives of scientific users from a wide range of scientific disciplines;
- 8 representatives of providers of information infrastructures who cover the entire range of the science system;
- 4 representatives of the German federal and state governments;
- 4 representatives of the public.

The first 16 representatives are appointed in a procedure similar to that for members of the German Council of Science and Humanities. The other 8 representatives are nominated by the Federal and State Government representatives in the Joint Science Conference. All members are appointed by the Chair of the Joint Science Conference for a term of four years. Guests may be invited to council meetings or parts thereof when there is a corresponding need.

“The composition of the Council reflects our fundamental consideration that the future of scientific information infrastructures is a joint task to be carried out by institutions providing the infrastructures, scientific users, funding bodies, and related national and international stakeholders.”

– Joint Science Conference, November 2013 –

Representatives of the scientific users

Prof. Dr. Lars Bernard

Faculty of Environmental Sciences, Technical University of Dresden

Prof. Dr. Dr. Friederike Fless

German Archaeological Institute (DAI) and Freie Universität Berlin

Prof. Dr. Frank Oliver Glöckner

Max Planck Institute for Marine Microbiology and Jacobs University Bremen

Prof. Dr. Stefan Liebig

Faculty of Sociology, Bielefeld University

Prof. Dr. Wolfgang Marquardt

Forschungszentrum Jülich

Prof. Dr. Otto Rienhoff (Chair)

Department of Medical Informatics, University of Göttingen

Prof. Dr. Joachim Wambsganß

Centre for Astronomy of Heidelberg University (ZAH)

Prof. Dr. Doris Wedlich

Division I – Biology, Chemistry, and Process Engineering, Karlsruhe Institute of Technology (KIT)

Representatives of the federal and state governments

Rüdiger Eichel

Ministry of Science and Culture of Lower Saxony

Dr. Thomas Grünewald

Ministry of Education, Science and Research of North Rhine-Westphalia

Dr. Hans-Josef Linkens

Federal Ministry of Education and Research

Dr. Stefan Luther

Federal Ministry of Education and Research

Representatives of the information facilities

Sabine Brünger-Weilandt

FIZ Karlsruhe – Leibniz Institute for Information Infrastructure GmbH

Prof. Dr. Thomas Bürger

Saxon State and University Library Dresden (SLUB)

Prof. Dr. Petra Gehring (Deputy Chair)

Department of History and Social Sciences, Technical University of Darmstadt

Dr. Gregor Hagedorn

Museum für Naturkunde – Leibniz Institute of Evolution and Biodiversity Science

Prof. Dr. Michael Jäckel

Trier University

Dr. Margit Ksoll-Marcon

Directorate General of the Archives of the Bavarian State

Prof. Dr. Klaus Tochtermann

German National Library of Economics (ZBW) Kiel/Hamburg and
Kiel University

Prof. Dr. Ramin Yahyapour

Göttingen Society for Scientific Data Processing mbH (GWDG) and
University of Göttingen

Representatives of the public

Dr. habil. Reinhard Breuer

Science Journalist

Dr. h. c. Albrecht Hauff

Georg Thieme KG

Dr. Simone Rehm

TRUMPF GmbH and Co. KG (until 12/2015)

Andrea Voßhoff

Federal Commissioner for Data Protection and Freedom of Information (BfDI)

Guests

Dr. Konstantin Hirsch

Federal Ministry of Education and Research

Dr. Dietrich Nelle

German National Library of Medicine (ZB MED)

Dr. Stefan Winkler-Nees

German Research Foundation (DFG)

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⁶² The persons listed above participated in the expert consultations of the Working Group on International Orientation in April 2016 and January 2017.

RFII POSITIONS AND RECOMMENDATIONS



JUNE 2015

Opening Declaration, 16 p.



MAY 2016

Enhancing Research Data Management: Performance through Diversity. Recommendations regarding structures, processes, and financing for research data management in Germany, 90 p.



MARCH 2017

Datenschutz und Forschungsdaten. Aktuelle Empfehlungen, 35 p. (available in German only)



APRIL 2017

Diskussionsimpuls zu Zielstellung und Voraussetzungen für den Einstieg in die Nationale Forschungsdateninfrastruktur (NFDI), 4 p. (available in German only)

Digital versions of the publications are available for download from the RfII-Website (<http://www.rfii.de/de/category/dokumente/>).