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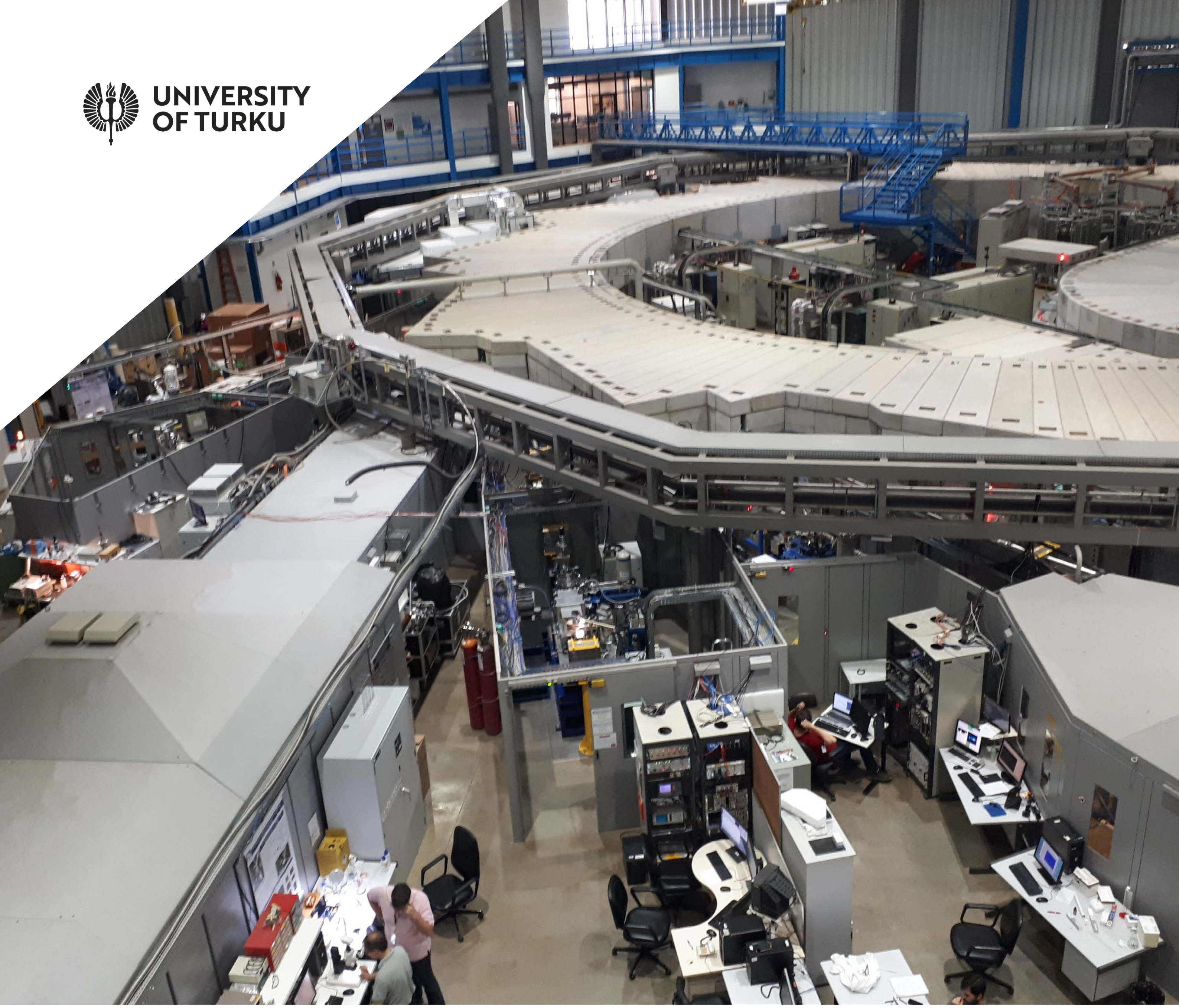

Mikkel Stein Knudsen, Marianna Birmoser Ferreira-Aulu, Elizaveta Shabanova-Danielyan, Weiqing Wang, Jyrki Luukkanen & Jari Kaivo-oja

INTERNATIONAL ENERGY RESEARCH INFRASTRUCTURES: MAPPING THE GLOBAL LANDSCAPE OF ENERGY RIS (RISCAPE)

Based on Finland Futures Research Centre’s contribution to the Horizon 2020 project European Research Infrastructures in the International Landscape (RISCAPE)

FINLAND FUTURES RESEARCH CENTRE
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Mapping the Research Infrastructure Landscape

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the European Union's Horizon 2020 research
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WWW.RISCAPE.EU

Cover photo of the Brazilian electron accelerator at CNPEM (National Center for Research in Energy and Materials) taken by Marianna Birmoser Ferreira-Aulu

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ABSTRACT

This e-book is an expanded version of the Energy Domain Report originally written for the project *European Research Infrastructures in the International Landscape* (RISCAPE), funded by the European Union. The domain report is also available in a shorter version, as well as a single chapter in the consolidated common project report. The full project report by Asmi et al. (2019) is available at https://riscape.eu/riscape-report/

The book is structured into three main parts. First, a preface introduces the report and highlights the field of Research Infrastructures (RIs) in connection with Futures Research. RIs are facilities that provide resources and services for research communities to conduct research and foster innovation. Due to our long history of researching energy futures, Finland Futures Research Centre led the mapping process of energy RIs The second part of this e-book presents an expanded version of the RISCAPE Energy Domain Report with its mapping of international Energy Research Infrastructures. The final list of mapped international energy RIs contains 37 organizations. The third and last part of this e-book consists of a postface and discussion on methodological considerations that can be useful for conducting similar mapping analyses in the future.

PREFACE: Situating the RISCAPE Project in the Research Infrastructure Literature

This e-book contains a modified version of the Energy Domain Report for the project *European Research Infrastructures in the International Landscape* (RISCAPE). The domain report is also available in a shorter version, as well as a single chapter in the consolidated common project report. The full project report is available at the project website: https://riscape.eu/riscape-report/

The RISCAPE project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730974. The stated target of the project was "to conduct an analysis of the Research Infrastructure landscape outside Europe, with a European perspective based on ESFRI infrastructure framework." (Asmi et al., 2019).

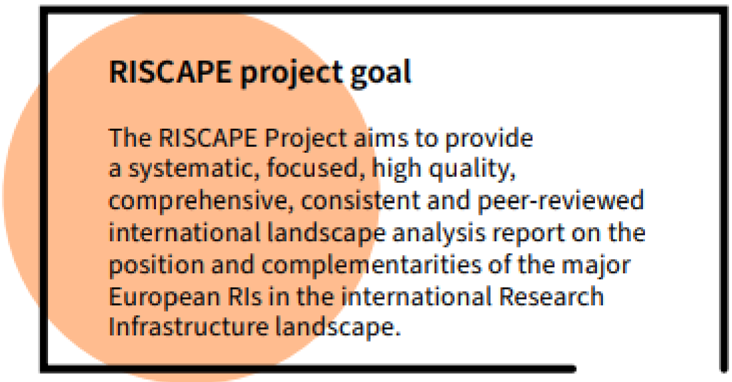

Figure 1. *RISCAPE project goal (Asmi et al., 2019).*

The RISCAPE project contributed to filling important knowledge gaps within the field of studying Research Infrastructures. The project not only systematically mapped existing global Research Infrastructures but also created a methodology that was applied across scientific fields. The reports published by the projects included one consolidated, shared report and eight individual domain reports.

These reports, however, are mostly descriptive, and therefore they do not aim much for critical reflections. In this e-book, we intend to engage with the small, but emerging academic work discussing the importance, functionality, and feasibility of Research Infrastructures and their role and function in science and innovation systems. This preface is therefore a small attempt to connect the RISCAPE project with the community of RI-scholars. We find that the study of Research Infrastructures as an independent research field is only at its earliest stage (Knudsen et al., 2021). Most of the nascent interest can arguably be prescribed to two different groups: One significant part of the published literature on RIs stems from the RI community itself. Members of research organizations involved in RIs serve as authors and co-authors, and the work may take a more empirical approach, putting particular organizations or scientific disciplines under the microscope. It is, in this sense, the story as told by the RI community itself. The other key source of literature derives from a rather small group of Science and Technology Studies scholars dedicated to the RI-field. The chapters in Cramer & Hallonsten (2020) and related works from the same authors (e.g.

Moskovko, Astvaldsson & Hallonsten, 2019; Hallonsten, 2020; Cramer, 2020) provide a good introduction to this literature.

While Finland Futures Research Centre engaged in the RISCAPE project, as elaborated in this report, Research Infrastructures have not received much attention within the field of Futures Research hiherto. However, there are at least five good reasons, cf. *Figure 2*, why futures researchers could engage more with the topic:

Firstly, Research Infrastructures are defined, in part, by their *longevity.* Forming, designing, constructing, and maintaining RIs are therefore examples of long-term decision-making and long-term thinking. It is no coincidence that Roman Krzaric's recent popularized account of *The Good Ancestor: How to Think Long Term in a Short-Term World* (2020) includes the fusion nuclear reactor project, ITER, as an example of '*cathedral thinking'* and '*long-term planning in human history*'. ITER is one of the most prominent Energy Research Infrastructures in the world.

Figure 2. *Why Research Infrastructures should interest futures studies scholars.*

Secondly, necessary long-term thinking underlines the need for *foresight among the RI-community*. Facilities can literally be decades in the making, so considerations are needed to ensure they are not outdated early or even by opening day. One example of this is the *European Spallation Source (ESS)*: the final decision on the location of the facility was made in 2009 after two decades of planning, and it is expected to open only in 2023 (Hallonsten, 2015). Scientific and societal relevance is, almost 15 years hence, not guaranteed without sufficient forward-looking due diligence. Futures researchers and foresight scholars, therefore, have roles to play in assisting the RI-community and policymakers with making informed long-term decisions.

Thirdly, the strategic establishment of long-term research institutions is a way of *mobilizing futures knowledge* (cf. Heino & Hautala, 2021). Groundbreaking long-term-oriented research underpins the ability to make "*sound decisions, plans, and justified policies in turbulent socio-environmental settings*" (ibid.). At the same time, investment decisions preselecting the research questions the research community should be able to tackle a decade+ from now, such as in the case of ESS, contribute to the determination of the future knowledge base of society. Through the process of RI-prioritization, decision-makers are both creating and colonizing the future. If one is interested in how society comes to terms with what "we" should "know" in the future, the topic of Research Infrastructures is therefore an interesting place to start. Indeed, there is ample room for futures researchers to further engage in this process of creation of future(s) knowledge as a general research topic, as well as to delve into the particular processes of RI in providing this knowledge, and the co-creation, transfer, and mobility of this knowledge back into society and decision-making.

Fourthly, this also suggests further attempts to address research into the roles and functions of RIs should for *innovation systems*. STI policy, innovation systems, and innovation ecosystems are historically important topics for the foresight and futures research community, and there is even a journal dedicated to *Foresight and STI Governance*. A recent meta-analysis also shows that articles on innovation systems constitute an important cluster in itself in published studies on regional foresight (Amini et al., 2021). For this research field, the growing amount of literature on the impacts of RIs on regional innovation ecosystems (see e.g. articles in the 2016 vol. 112 special issue of *Technological Forecasting and Social Change*; Castelnovo et al., 2018; D'Ippolito & Rüling, 2019; Li-Ying et al, 2021) is of natural relevance. Research Infrastructures also provide an obvious case story for examinations of whether research, development, and innovation scales with funding (cf. D'Ippolito & Rüling, 2019) or not (cf. Fortin & Currie, 2016), which is an important denominator for designing effective future STI-policies.

Fifthly and finally, RIs are interwoven with the mindset of *tackling grand challenges,* which has come to be ubiquitous in modern science policy discussions (Kaldewey, 2018). In particular, it represents the idea that the grand challenges must be solved *together*: No longer are organizations capable of adequately responding to scientific problems on their own; instead, the pooling of resources in shared RIs is a modern necessity. This has two implications for the futures community: First, in this framing RIs are integral to major global transformations such as the transition to a more sustainable world – they are *necessary for our pursuit of preferable futures*. Second, as RIs mobilize future knowledge and shape our pursuit of preferable futures, they do it through *collaboration and co-creation*. Examinations of RIs contributions to social transformation and co-creation movements should therefore excite certain subfields of the futures research community. However, RIs are not only reflections of scientific or altruistic ideals. Their organizing processes often reflect "*the pursuit of [their] interest by other means*" (Hallonsten, 2014). The original development of "Big Science" facilities in Europe was closely connected to diplomatic engagements in post-war Europe (Papon, 2004). The establishment of CERN was the first major collaborative Western European institution predating the 1957 Treaty of Rome, which established the European Economic Community, by a few years. Our RISCAPE dataset identifies the Solar Energy Research Institute for India and the United States (SERIIUS) as a rather unique case, as it is the only (non-European) joint RI in the dataset. It is also an exemplification of India's embrace of solar energy research as a ticket to global geopolitical influence, which has been highlighted by other researchers (Shidore & Busby, 2019a, 2019b). This shows there are still many sides to international engagements, even in scientific endeavors. Understanding these mechanisms is an important stepping-stone for paving the way for a preferable future.

We hope that our work on this project, and in this e-book, can help inspire other futures researchers to engage more with the RI-field in the future.

1. INTRODUCTION

1.1. European Research Infrastructures in the Global Landscape – the RISCAPE project

This e-book is born out of the Horizon 2020 project European Research Infrastructures in the Global Landscape (RISCAPE). The RISCAPE project ran for 3 years from 1.1.2017 to 31.12.2019. The project consortium included 11 partner organizations, including the consortium coordinators at the University of Helsinki. Finland Futures Research Centre (FFRC) at the University of Turku took part in the consortium with the responsibility for Work Package 6: Energy. The authors of this e-book are the team involved in the work of this work package. Jyrki Luukkanen acted as Project Manager and Jari Kaivo-oja as principal investigator. The research itself was conducted by the project researchers Mikkel Stein Knudsen, Marianna Birmoser Ferreira-Aulu, Elizaveta Shabanova-Danielyan, and intern Weiqing Wang. In total, the RISCAPE project had 11 work packages – three crosscutting work packages (Stakeholder interaction & QA; Common methods and consistency; Management and discussion) and eight work packages providing international landscape analysis of specific scientific fields. The organizational structure mirrors the eight-field division utilized by the European Strategy Forum on Research Infrastructures (ESFRI) roadmaps (e.g. ESFRI, 2018).

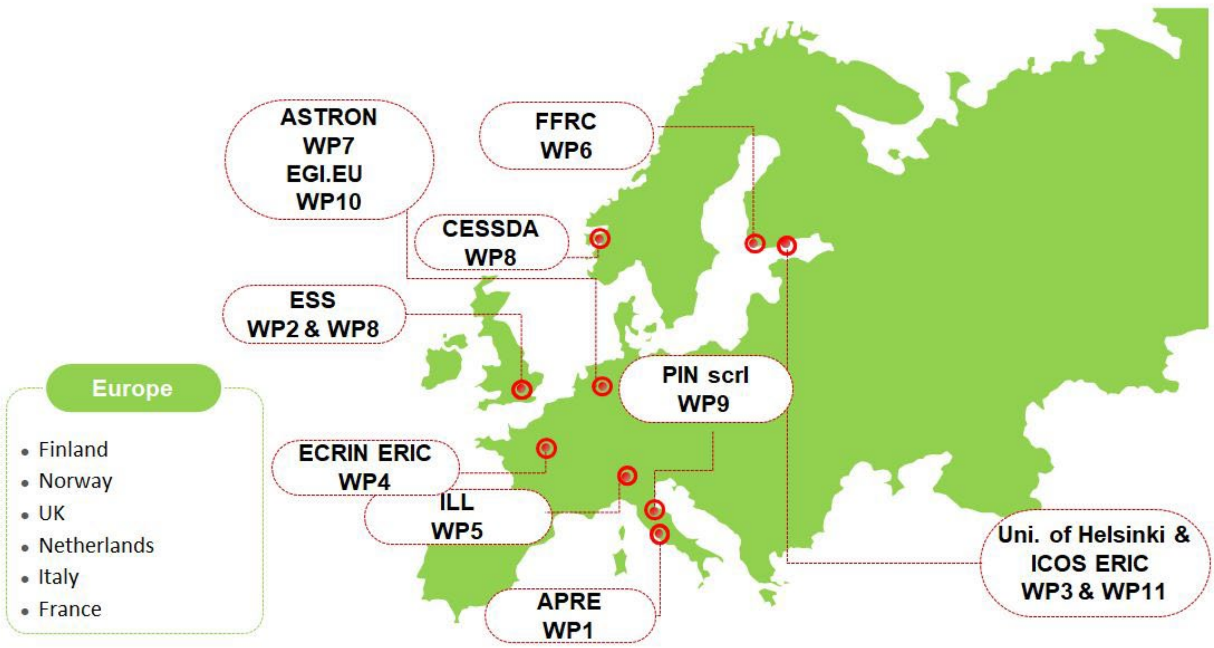

Figure 3. *The RISCAPE consortium.*

From the outset, the main purpose of RISCAPE was to map the international RI-landscape *outside* the European Research Area. RISCAPE is the first such exercise of its kind. It, therefore, attempts to map what has been, more or less, unknown lands. Even as European nations have dedicated a significant amount of funding (€4.2 bn was allocated to RIs from 2007–2020 in FP7 and FP8), there was no systematic account of European RIs' international counterparts. RISCAPE, therefore, provided unique substantial knowledge on the documentation of existing globally relevant research infrastructures. By being a pioneer study, RISCAPE also engaged in methodological developments in terms of defining inclusion criteria, engaging in contacts with international RIs, and providing a systematic account of the results. The consolidated RISCAPE report was presented to policymakers in a workshop in Brussels in December 2019.

Extensive attention was dedicated throughout the project to developing a consistent methodology, which could be applied across all landscape analyses. At the same time, each scientific field has its own independent characteristics, which the project methodology should allow for. At the end of the project, each scientific domain provided a domain report, which was adapted into a common framework for the shared report.

The landscape analyses seek to balance fact-based data collection with narrative overviews of the situation of the given field. On the one hand, providing a well-considered list with names of specific organizations was the main target, including collecting as many descriptive facts about the individual organization as possible. Provided with the right information, the landscape analysis could thus be created based on quantitative analysis and metadata. On the other hand, the insights generated from the study cannot be limited to the numbers obtained, but also comes from the learned experience of the researchers. This qualitative aspect was perhaps particularly underlined given the challenges of obtaining data, which gave a need for researchers to, in some cases, make conclusions based on incomplete data.

1.2. Domain report of the Energy RI landscape

This e-book provides constitutes the consolidated domain report of the international Energy RI landscape as examined through the lens of the RISCAPE project. This has implications for the selected methodology for identifying and contacting the international RIs for the landscape analysis. It also shows up in the areas of investigation for each RI presented in this report, as the prisms of RISCAPE defined the special areas of focus.

The structure similarly seeks to answer the recommendations of the RISCAPE project, although the structure of presenting international RIs differs from the method used for the final RISCAPE report. Primarily, we here structure the international RIs by region and country, while the RISCAPE report presents them by scientific field. This should not have much importance for the substance of the information.

The report here is structured into nine main chapters after this introduction. First, it covers the methodological issues of defining RIs and collecting data. The next chapter addresses boundary issues of what constitutes *energy* research, which is a more challenging definition issue than one might think. Many larger facilities by default seek to address several scientific fields simultaneously. After this, we provide a brief overview of the energy RI landscape in Europe before reaching the main section of this E-book: The overview of the international (non-ERA) energy RI landscape. This section covers a total of four chapters, first introducing the RIs on our final list one by one arranged, as said above, by country, and then analyses of the data focused on areas of particular interest for the RISCAPE-project, before. Finally, the last part of the domain report contains a list of the international Research Infrastructure. A short post-face with some of the methodological insights of the project follows the domain report. As RISCAPE was a pioneer study, we hope these insights might be helpful for future researchers facing the same tasks. Sharing these is therefore one of the main motivations behind this E-book.

The information on international RIs was collected from 2018–2019. Interviews for the reports were finalized in the summer of 2019. This might mean that not all information in the report is entirely up to date. Marianna Birmoser Ferreira-Aulu, Elizaveta Shabanova-Danielyan, Weiqing Wang, and Mikkel Stein Knudsen performed the interviews. Elizaveta Shabanova-Danielyan and Weiqing Wang, in particular, had a large hand in organizing the draft domain report from which this E-book is formed.

1.3. Previous iterations, publications, and activities

Some elements of this domain report, on various iterations, have previously been published through official RISCAPE-deliverables, which can be publicly accessed through the European Commission's CORDIS-database[1]:

- *Draft list of key international Research Infrastructures, selected methodologies and proposed aspects of complementarities to analyse in the energy sector* (Deliverable 6.1, deliverable approved 4 January 2018) (Kaivo-oja & Knudsen, 2017).
- *Draft Landscape analysis report in the energy sector* (Deliverable 6.2, deliverable approved 18 September 2019) (Knudsen et al., 2019).

In addition to the official deliverables, which were set by the original project Grant Agreement, Finland Futures Research Centre has disseminated the RISCAPE project and selected results through various publications and activities:

- Project workshop with European Energy RIs, Brussels, July 2017.
- Presentation at the Biennial International Workshop Advances in Energy Studies (BIWAES), Naples, Italy, September 2017.
- Presentation at the Futures Conference CONSTRUCTING SOCIAL FUTURES – Sustainability, Responsibility and Power, Turku, Finland, June 2019.
- Presentation at the 18th International Conference on European Processes, ICEP2021, Kaunas, Lithuania, April 2021.
- RISCAPE blog: Glances of the landscape: Energy sector's infrastructures are a politically hot topic, April 9th, 2019.
- FFRC blog: University of Turku helps to map global research infrastructures to foster international research collaboration, 19 December 19th, 2019.

Finally, one research article has been published based on the data with particular emphasis on its implications for European integration and studies of European integration:

- *Energy Research Infrastructures in Europe and Beyond: Mapping an Unmapped Landscape* (Knudsen et. al, 2021).

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[1] For RISCAPE-deliverables, see: https://cordis.europa.eu/project/id/730974/results

1.4. Terminology

This report includes a lot of terminologies, which may not be familiar to all readers. The terminology, generally, reflects the use in European Commission policy documents related to the field. A list of the most important acronyms is given below:

- RI: Research Infrastructure
- ERA: European Research Area
  (see: https://ec.europa.eu/info/research-and-innovation/strategy/era_e)
- ESFRI: European Strategy Forum on Research Infrastructures (see: https://www.esfri.eu/)
- ERIC: European Research Infrastructure Consortium (see: https://ec.europa.eu/info/research-and-innovation/strategy/european-research-infrastructures/eric_en)
- GSO: Group of Senior Officials (see: https://www.gsogri.org/)
- Single Site RI: A Research Infrastructure with a geographically localized central facility.
- Distributed RI: A Research Infrastructure with interlinked nodes.

Readers may also consult the glossary at ESFRIs website: https://www.esfri.eu/glossary.

2. METHODOLOGY

The target of RISCAPE was to devise a list of globally relevant international Research Infrastructures. This requires solid definitions to devise transparent and usable inclusion/exclusion criteria, as well as a methodology for screening the field, contacting potential organizations, collecting data, and analyzing the collected information.

Since our research subject is Energy Research Infrastructures, we need to define both what 'Energy Research' and 'Research Infrastructures' mean. The boundary limits of energy research are explained in the following chapter.

2.1. Defining Research Infrastructures

It is not possible to find a single, generally accepted definition of what constitutes a Research Infrastructure. This is perhaps best illustrated by the fact that a total of 60 RIs have appeared on ESFRI roadmaps, and 1042 infrastructures are available in the online MERIL database (Mapping of the European Research Infrastructure Landscape; MERIL, 2021), while Caliari et al. (2020) identify no less than 4857 research infrastructures in Brazil alone.

It has been suggested (Cramer et al., 2020) to distinguish between "research infrastructures" and "Research Infrastructures". Non-capitalized research infrastructures perform functions for *a* scientific community (e.g. a university), while the capitalized Research Infrastructures perform functions for *the* (global) scientific community. Our analysis of the energy landscape is clearly concerned with the capitalized RI-version. Early on in the project (Kaivo-oja & Knudsen, 2017) the modification of the South African RI-roadmap (Department of Science and Technology, 2016) in Figure 4 below was developed to highlight the focus of our attention.

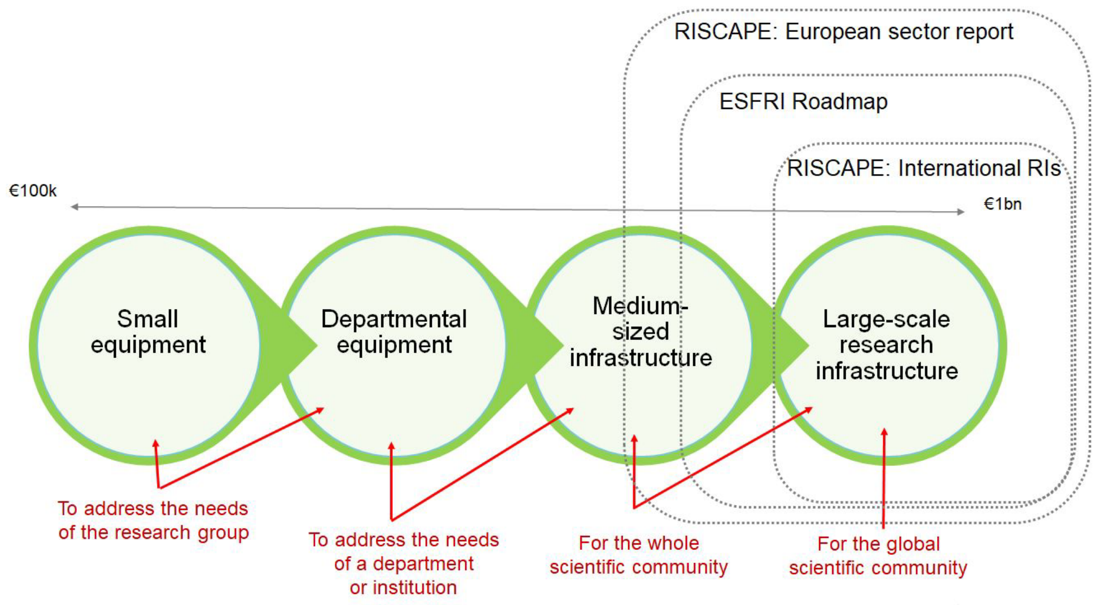

Figure 4. *Zooming in on the right Research Infrastructures.*

For RISCAPE, one WP was tasked to devise guiding principles for what constitutes a RI to decide on inclusion/exclusion on the final project list. These guiding principles were devised through the identification of commonalities between RI-definitions in previous scientific and policy literature (Asmi et al., 2019).

The five guiding principles of RIs are:

1. RIs are meant for research and science purposes.
2. Institutions are single-sited, distributed, or virtual.
3. Institutions are unique and distinguishable from each other.
4. Facilities are accessible to the public in some form or another and serve a diverse range of users beyond those employed by their own organization
5. Facilities are longevity-oriented, activities consider long time horizons

First, RIs are meant for **research and science purposes**. For an organization to fit the criteria of being an RI, it is, therefore, a necessary condition that it is concentrated on supporting science. This may sound self-evident, but it has major implications for mapping the energy RI landscape in the energy sector. It excludes commercial actors for whom research and *supporting science* is only a secondary goal of the organization. This de facto excludes a large part of energy R&D funding as outside the scope of the RI-landscape. It also challenges blurred lines between commercial units and 'real' research entities identified in many energy RIs. As an example, nuclear facilities surveyed in RISCAPE enable the pharmaceutical industry with industrial and medical radioisotopes. These are sold on a commercial basis, which funds important capabilities for research and generates a large, positive societal impact for the RI. Since many organizations have dual scientific/commercial purposes, it requires a balancing act and case-by-case evaluations to determine, when a RI is sufficiently 'concentrated on supporting science'. In the end, for example, one research reactor identified by GSO (2017) was left off the final energy RI map as too commercial. Some RIs, especially nuclear facilities also balance benevolent ideas of supporting the scientific community with more pristine national security needs.

The second guiding principle is that the mapping should not be limited to a universal definition of institutional arrangements. Various RI-definitions use different terms such as institution, organization, facilities, resources, and services. However, the distinction also used for the ESFRI roadmaps between **single-sited, distributed, and virtual RIs** has become commonplace, and these concepts were also used for RISCAPE's mapping. A third guiding principle is the concept of **uniqueness** used by some of the definitions. RIs, at least those of international interest, must be distinguishable from each other, of a particular nature, or of particular interest. This is in the vein of the distinction above, namely that capitalized RIs serve the *global* scientific community. A fourth guiding principle is the suggestion of **access**. RIs do not, per se, need to be public organizations, but they should be accessible for public scientists in some form or another and serve a diverse range of users beyond those employed by their own organizations. Access for outsiders is already an explicit feature of the ERIC-regulations (Moskovko et al., 2019), although our research suggested less focus on this aspect among non-European RIs. For the mapping of the energy research sector, the national security elements inherent in e.g. nuclear research may also complicate this aspect to some extent. A fifth and final guiding principle is **longevity**. Longevity is often overlooked by existing definitions, but long-time horizons are often implicitly assumed in both scientific and policy documents. For mappings such as RISCAPE, identifying organizations would also, quite frankly, be slightly pointless, unless the organization was thought to play a role in the future.

2.2. Data collection methodology

The common RISCAPE methodology is shown in Figure 5 below.

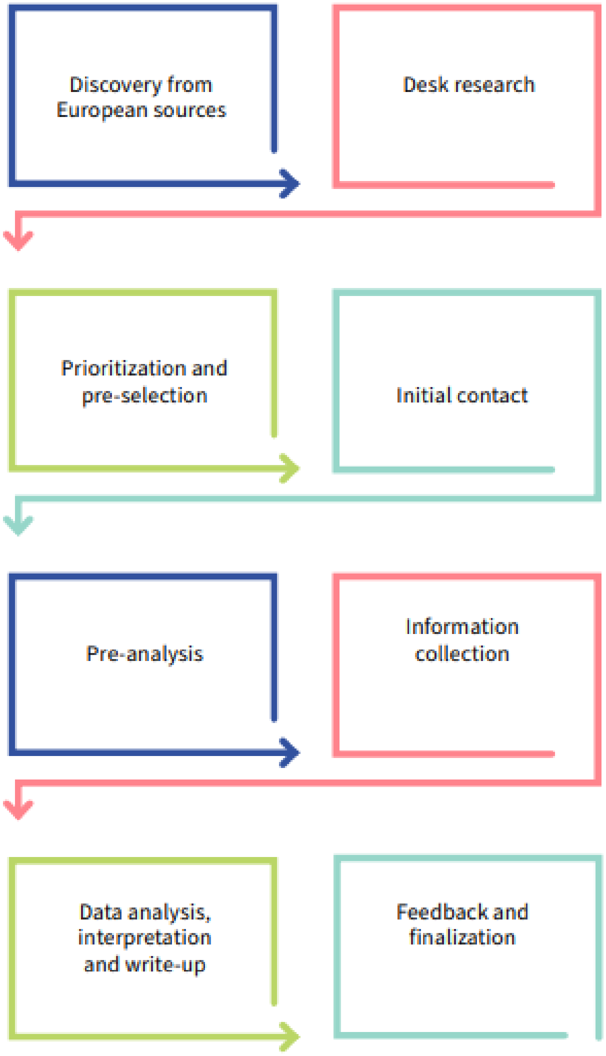

Figure 5. *RISCAPE methodology (Asmi et al., 2019).*

The first phase of the RISCAPE project was concerned with the interaction with the existing European Energy RI landscape. The purpose of this interaction was both to provide an overview of the European landscape, and to use the European organizations as a valuable source of information for the subsequent mapping of the international landscape. The 2016 ESFRI Roadmap was the key indicative reference document during this stage of the project and was used as the starting point of the analysis.

The research phase of the European Energy RIs landscape was conducted with a literature study, desk research, workshop, and interviews (see Figure 6).

Figure 6. *Means of analysis of European Energy RIs (Kaivo-oja & Knudsen, 2017).*

After the initial phase, a draft list of international RIs was presented as a RISCAPE-deliverable (Kaivo-oja & Knudsen, 2017). This list was amended throughout the project, as some organizations were left off after further research, while other organizations came into focus.

The strategy for contacting international RIs is explained in further detail in the Appendix, which also includes the template for contact emails. This contact email was a work package-specific modification of a consortium template contact email, and the English-language version was presented to the consortium coordinator before the first email was sent. Versions of the contact email were also sent in Portuguese, Russian, and Chinese (all of these are available in the appendix).

3. THE ENERGY RESEARCH DOMAIN

The energy sector is key to social and economic development; however, it is also one of the main contributors to global CO_2 emissions. For the EU, the goal of reducing CO_2 emissions in a sustainable framework is a major driver of its energy policy. Thus, the European Commission's Energy Union strategy has formulated the objective of creating a secure, sustainable, competitive, and affordable energy system. Energy Research Infrastructures play a major role in achieving this objective, through driving forward testing and demonstrating technologies and their interplay in the future energy system (ESFRI Roadmap 2018: 49). In this domain report, Energy Research Infrastructures are the research object.

Energy Research Infrastructures perform and support top-level academic and industrial energy research activities. Throughout the successive framework programmes of the EU, such as the current framework programme Horizon 2020, various actions have been developed to support researchers in accessing top-level European Energy Research Infrastructures located outside their own countries, and to improve the coordination and integration of these infrastructures Europe-wide, enabling better research services. Meanwhile, Energy RIs pave the way for the development of scientific and technological advances in energy industries and markets.

In the following, a landscape analysis is made for the RIs in the energy domain, consisting of five sub-domains: **Energy Systems Integration, Renewable Energy**, **Efficient Energy Conversion and Use**, **Nuclear Energy**, and **Cross-sectional Energy RIs**., This division mirrors the ESFRI roadmap (2018).

Some RIs work across several of these sub-domains, and many RIs also have activities related to other scientific fields than energy research. Links with the global physics-community are in many cases unavoidable, but also many linkages with e.g. health research (nuclear medicine), environmental RIs (wind data, Earth-data observations), high-performance computing, and biochemistry are noticeable among the surveyed RIs. Despite our best efforts, in practice it is therefore impossible to define the boundaries of Energy Research Infrastructures in an entirely clear and stringent manner.

3.1. Sub-domains

According to ESFRI Strategy Report and Roadmap (2018), the energy sector is divided in five main areas, which comprise specific fields[2]. *Figure 7* below presents the interlink between the areas:

Energy Systems Integration – including networks, transport, storage, and smart cities/districts. The focus is on the design, operation, and integration of all parts of the energy system of the future safely and securely. It is also important to point out that the socio-economic and human behavior aspects are essential for energy transformation processes.

Renewable Energy – including solar energy, renewable fuels, wind energy, geothermal energy, and ocean energy. The last couple of years have witnessed a considerable drop of levelised cost of energy (LCOE) for renewable energy, and further massive cost reductions can be achieved through the development of new concepts. They require long-term research and state-of-the-art Research Infrastructures.

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2 http://roadmap2018.esfri.eu/landscape-analysis/section-1/energy/

Efficient Energy Conversion and Use – seeking enhanced efficiency in energy production, conversion, and use is an important and viable aim. It is vital for the future system of energy efficiency that it can reliably and securely supply the necessary base-load power at all times and at a reasonable cost.

Nuclear Energy – including fusion and fission. Nuclear power plays an important role to provide stable, base-load electricity. The main strategic objectives are safety aspects and long-term waste disposal. In many countries, the issue of prolonging the life of existing NPPs leads to the development of materials research under nuclear irradiation. In some countries with aging Nuclear Power Plants (NPPs) or considerations of nuclear phase-outs, the issue of the dismantling of NPPs is an important one. Some RIs also take the responsibility of providing governments and the public with technical support in the event of a nuclear or radiological incident.

Cross-sectional Energy RIs – exploiting synergies across different technologies will benefit the energy research community, and in return, the energy research community can further advance the cross-cutting methodological development. Energy technology-oriented roadmaps have prioritized the need for cross-sectional energy RIs in Europe.

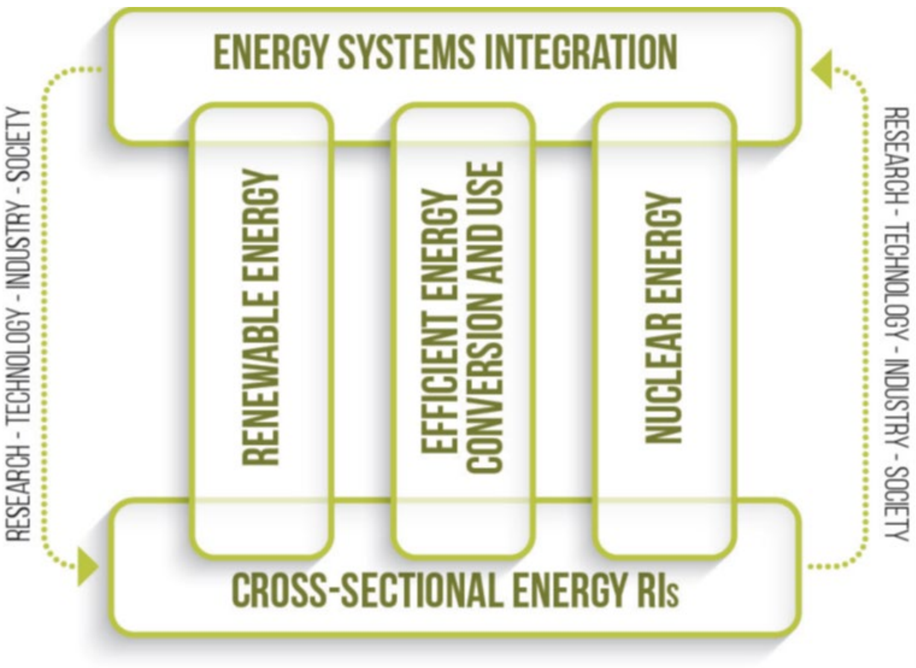

Figure 7. *The interplay of five energy sub-domains (ESFRI Strategy Report and Roadmap 2018: 49)*

4. EUROPEAN ENERGY RIS LANDSCAPE

The ESFRI Roadmap (ESFRI, 2016) contains a landscape analysis of energy RIs in Europe. For this reason, it was not a priority for RISCAPE to conduct an independent analysis of this landscape. However, at the initiation of RISCAPE, we purposefully included a broader contact list than indicated by the 2016 ESFRI Roadmap, for the reason that the 2016 Roadmap only covered some of the energy sub-fields, while consortiums in several other fields have been attempting to build projects for future ESFRI Roadmaps. Table 1 shows the key European RIs, which were identified and contacted.

A dedicated RISCAPE workshop was arranged in Brussels in July 2017 with invitations for main European Energy RI stakeholders. The workshop included participants involved in key research projects of geothermal energy, fuel cell and hydrogen research, biofuels, bioeconomy research, and smart energy and transport solutions.

Note that ITER is a somewhat special case, as it by nature is an international RI. Many identified international RIs therefore already have a formalized working relationship with it. Since it has clear ties to the EU, also its primary location, it was, however, considered a European RI for this analysis.

In 2018, ESFRI released an updated Roadmap based on the 2016 Roadmap, accounting for the results of the end of the ten-year-cycle of those ESFRI Projects that entered in 2008, and the outcomes of the selection of new proposals. Eight new RIs in total were identified as having strategic long-term investments in research capability and capacity, and in the Energy domain, the new one was ***The International Fusion Materials Irradiation Facility-DEMO Oriented NEutron Source (IFMIF-DONES)***. It gained recognition from ESFRI for its strategic role in the implementation of nuclear fusion solutions to the massive production of energy, and for its role as an active actor in the development of nuclear fusion technologies (ESFRI Strategy Report and Roadmap 2018: 14). This nuclear fusion project has not been activated as a participant in the RISCAPE Project, but it serves as an important comparison for the international RIs.

Table 1. *European research infrastructures identified and contacted (2017).*

Short name	Name	Details	Communication
JHR	Jules Horowitz Reactor	ESFRI Landmark (Roadmap 2016) ESFRI Landmark (Roadmap 2018)	E-mail
ECCSEL	European Carbon Dioxide Capture and Storage Laboratory Infrastructure	ESFRI Project (Roadmap 2016) ERIC (status awarded 2017) ESFRI Landmark (Roadmap 2018)	Participant at RISCAPE workshop14
EU-SOLARIS	European SOLAR Research Infrastructure for Concentrated Solar Grid	ESFRI Project (Roadmap 2016) ESFRI Project (Roadmap 2018)	E-mail
MYRHHA	Multi-purpose hybrid Reactor for High-Tech Applications	ESFRI Project (Roadmap 2016) ESFRI Project (Roadmap 2018)	E-mail
WindScanner	European WindScanner Facility	ESFRI Project (Roadmap 2016) ESFRI Project (Roadmap 2018)	E-mail
MARINERG-I	Marine Renewable Energy Research Infrastructure	Funded by Horizon 2020.	Participant at RISCAPE workshop
MaRINET2	Marine Renewables Infrastructure Network	MaRINET (2011–2015) was funded by 7th Framework Programme; MaRINET2 (2017–2021) was funded by Horizon 2020.	Participant at RISCAPE workshop
ITER		ITER-agreement signed by EU, China, India, USA, Russia, South Korea and Japan.	E-mail
JET	Joint European Torus	RI in operation, supported by EU (EURATOM).	E-mail
DEMO	Demonstration Fusion Power Reactor		E-mail
ERIGrid	European Research Infrastructure supporting Smart Grid Systems Technology, Validation and Roll-Out.	Funded by Horizon 2020 as Integrating Activity.	Participant at RISCAPE workshop
BRISK-2	Biofuels Research Infrastructure for Sharing Knowledge	Integrating activity, funded by 7th Framework Programme / Horizon 2020.	Participant at RISCAPE workshop
H2FC		Project funded by Horizon 2020.	E-mail

5. INTERNATIONAL ENERGY RIS LANDSCAPE

5.1. Introduction to International Energy RIs Landscape

The list of non-EU Energy RIs for this domain report was drafted based on desk research and comments from European stakeholders. It was extended and adapted during the more detailed research phase through snowball sampling, with some RIs added and some deleted according to the adopted RI definitions mentioned above. The final contact list includes 36 organizational structures outside European Union which pursue energy studies within at least one energy sub-domain described in previous chapters (see Table 2. International research infrastructures by countries and continents). Some of these organizational structures focus exclusively on energy research, while others are multi-program organizations that have energy research as a part of their research portfolio. Energy-related RIs are spotted on all continents except Africa where the organization is recognized as commercially-oriented and thus is excluded from this domain report. The procedure for contacting the RIs is described in the "Contact Strategy" chapter, which is in the Appendix of this report.

It is important to note that the RIs list includes also two university initiatives (Stanford University's Precourt Institute for Energy and MIT Energy Initiative in the USA), which are organizational structures providing support (organizational, financial, support in communication) for energy research inside the university. These organizations themselves do not own any research facilities for shared use. However, the research facilities and services are available at the university. Such initiatives may serve as contact points for establishing collaborations with energy research teams inside the university.

***Table 2**. International research infrastructures by countries and continents.*

	Number of contacted RIs
Total	**36**
By continent	
Africa	0
Asia	13
Australia	3
Europe (non-EU)	2
North America	15
South America	3
By country	
Australia	3
Brazil	3
Canada	4
China	4
India	3
Japan	5
Russia	2
South Korea	1
USA	11

North America and Asia are almost equally presented on the international landscape map with 15 organizations located in North America and 13 organizations in Asia. However, on the North American continent, the United States of America clearly dominates the energy research landscape: 11 organizations are located in the US versus four organizations in Canada, and none in Mexico. In Asia, energy research organizations are more equally distributed across countries: five of them in Japan, four of them in China, three in India, and one in South Korea.

In South America, only three organizations – all from Brazil – were identified as qualifying to the RI definition of the project. In Australia, three organizations were identified. Among non-EU countries, on the European continent, Russia is a significant actor in nuclear energy research.

The most presented energy research sub-domains internationally are **Renewables** (17 RIs) and **Nuclear Energy** (19 RIs), with a leading role in North America and Asia. Of all the countries listed above, at least one of their RI is a nuclear research organization. RIs focused on **Renewable Energy** studies are less widespread. In the renewables sub-domain the important actors are: USA (six RIs), Japan (five RIs), Canada (three RIs), Brazil (two RIs), India (two RIs), and China (one RI).

11 international RIs conduct studies in materials research that is within **Cross-sectional Energy** sub-domain. The majority of these RIs are located in Asia (six RIs) and North America (four RIs, all in the USA) and one RI is in Australia. Six RIs are active in studies of **Energy Systems Integration** (four RIs is the USA, one RI in Canada, and one RI in Australia). Finally, four RIs pursue studies in the field of **Efficient Energy Conversion and Use** (three RIs in the USA and one RIs in Japan).

As a country, the USA leads all energy research sub-domains by numbers of identified RIs: seven American RIs are in nuclear sector, six RIs are in the renewables sector, four RIs are in cross-sectional energy sub-domain (primarily materials research), four RIs in energy systems integration sub-domain and three RIs in efficient energy conversion and use.

Below in this sub-chapter, there is a short description for each RIs identified in the landscape analysis[3].

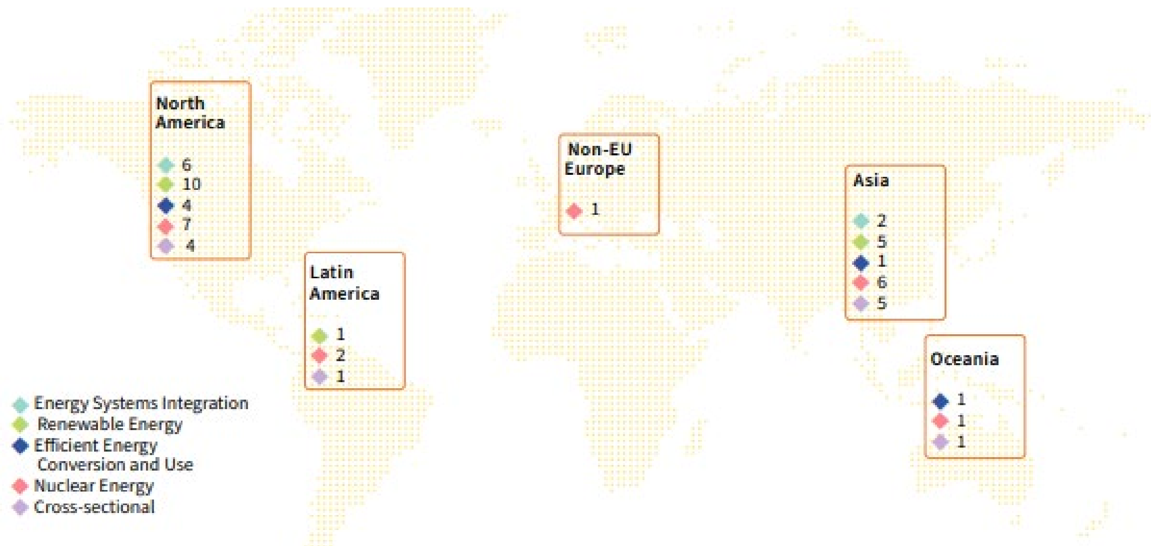

Figure 8. *The geographical location of the final list of non-EU Energy Research Infrastructures (Asmi et al., 2019).*

[3] The only project that was identified as RI but is not present in the description is the Russian-Italian tokamak «IGNITOR» project. The project is on the development stage now and not much information about it has been disclosed publicly.

6. IDENTIFICATION OF INTERNATIONAL ENERGY RIS

Please note that the information provided in this chapter is primarily based on information provided by the RIs, which has not been independently verified.

6.1. Asia

China

Institute of Plasma Physics, Chinese Academy of Science (ASIPP)

Description/Background: ASIPP was founded in September 1978 for the peaceful utilization of fusion energy through the tokamak approach. As one of the most important laboratories in China, ASIPP has been conducting research in high-temperature plasma physics and magnetically confined fusion engineering, and it has built the world’s first non-circle cross-section full superconducting tokamak, namely Experimental Advanced Superconducting Tokamak (EAST). ASIPP is a major contributor in China for ITER, having undertaken up to 73% of China’s ITER Procurement Packages tasks which include superconducting conductors, correction coils, superconducting current leads, etc. It has established close cooperation relationships with more than 30 countries and regions such as the EU, the US, Russia, and Japan.

Infrastructure: ASIPP has built various tokamak fusion experimental facilities including HT-6B, HT-6M, HT-7, and EAST.

Services provided: ASIPP has established nearly 20 companies that create both economic and social benefits. Hainan New Energy Research Centre is one example, forming a complete chain from basic research to industrialization. ASIPP hosts various international seminars and workshops, and actively supports fusion research in developing countries. *Plasma Science and Technology* is the journal founded by ASIPP for reporting novel experimental and theoretical results in the fields related to plasma.

Nuclear Power Institute of China (NPIC)

Description/Background: Founded in 1965, NIPC is the only large-scale comprehensive R&D base in China incorporating reactor engineering research, design, test, operation, and small batch production. It has established a complete research and development system, including nuclear power engineering design, reactor operation, and application research, nuclear fuel and material research, nuclear technology application research and services, etc.

Infrastructure: NIPC has established 90 laboratories, including two national key laboratories and two national energy R&D centers. It has designed seven nuclear facilities on self-reliance such as the first High Flux Engineering Test Reactor in China. There are 18 large-scale test installations for R&D of reactor engineering. It has developed nuclear power plants CP600/CP1000/CPR1000 and undertakes the R&D of the next generation of nuclear power plants ACP100, ACP600, and ACP1000. A new comprehensive R&D base is under construction.

Services provided: NIPC provides a series of specialized technical services for nuclear power plants and research reactors, such as the overhaul and regular maintenance, supply of special tools, qualification of nuclear equipment, and treatment of radioactive wastes. It has also developed a series of primary products.[4]

Institute of Electrical Engineering, Chinese Academy of Science (IEE, CAS)

Description/Background: IEE is a national research institution oriented to the development of electrical science and engineering, and it is also one of the important institutes which engage in energy research in CAS. Its research fields include renewable energy technologies, new electric power technologies, and frontier inter-discipline subjects of electrical science. It has become a strategic backbone of Chinese innovations in related fields.

Infrastructure: IEE has six Laboratories and one Interdisciplinary Research Centre[5].

Services provided: No information.

Shanghai Synchrotron Radiation Facility (SSRF)

Description/Background: SSRF is the largest synchrotron research facility to date in China, and it is one of the advanced third-generation light sources in the world, supporting and pushing cutting-edge scientific research and innovation.

Infrastructure: SSRF is composed of one 150 MeV linear accelerator, one 3.5 GeV booster, one 3.5 GeV storage ring, beamlines, and experimental stations[6].

Services provided: Since 2009 SSRF has provided bright x-ray beams to more than 10000 users from universities, institutes, hospitals, and high-tech companies around China and the world. The facilities have been used in various areas of scientific research and industrial development, including biology, physics, material science, chemistry, environmental science, archeology, biomedical applications, medicine, and drug development, etc. SSRF is also actively involved in the training and education of the next generation of scientists and engineers.

India

Bhabha Atomic Research Centre (BARC)

Description/Background: The establishment of BARC dated back to 1954 as a multidisciplinary research program essential for the ambitious nuclear program of India. It is the parent body of the R&D institutions such as IGCAR, RRCAT, VECC, etc. It carries out pioneering research on nuclear and accelerator technologies and industrial establishments.

Infrastructure: BARC has active groups for R&D in reactor technologies, fuel reprocessing and waste management, isotope applications, radiation technologies, and so on. There are multiple research reactors constructed by BARC such as APSARA, ZERLINA, and CIRUS Reactor[7].

Services provided: No information.

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4 Ability and Service http://en.npic.ac.cn/service/capability/power/
5 See details in the Organization Chart. http://english.iee.cas.cn/an/
6 Detailed introduction of the facilities. http://e-ssrf.sinap.cas.cn/about/overview/
7 Research Reactors in BARC. http://www.barc.gov.in/about/index.html#

Solar Energy Research Centre for India and the United States (SERIIUS)

Description/Background: SERIIUS facilitates joint R&D and related activities on clean energy by teams from India and the United States. Through an environment of cooperation and innovation “without borders”, it aims to develop emerging and revolutionary solar electricity technologies. It will achieve this goal by lowering the cost per watt of photovoltaics (PV) and concentrated solar power (CSP).

Infrastructure and Services Provided: SERIIUS has three research thrusts, including Sustainable Photovoltaics, Multiscale Concentrated Solar Power, and Solar Energy Integration, to ensure high-impact research and development to address key technical barriers in solar electricity generation. Under each research thrust, there are respective infrastructures and services provided[8].

DBT-ICGEB Centre for Advanced Bioenergy (DBT-ICGEB)

Description/Background: Thriving upon ICGEB, DBT-ICGEB was established for strengthening the existing capacity in synthetic biology and to promote cutting-edge research in the biofuel area. It mainly performs research in molecular biology and biotechnology, using advanced genetic tools, metabolic engineering, and system biology approaches, and will serve as a platform for synthetic biologists to work in diverse bioenergy areas such as microbial engineering, biochemical engineering, algal engineering, and systems biology.

Infrastructure: There are 41 facilities in DBT-ICGEB. The detailed list of facilities can be found here http://icgeb-bioenergy.org/facilities/

Services provided: DBT-ICGEB involves in skill development programs and organizes various workshops and training programs. It coordinates the activities of Mission Innovation initiatives of India with other partnering countries, and it will sync with the main/apex Mission Innovation Secretariat worldwide. The Unit will encourage liaising between public/private partnerships in India and other partner countries for various collaboration activities, share information and coordinate with interested potential business investors.

Japan

Global Research Centre for Environment and Energy Based on Nanomaterials Science (GREEN)

Description/Background: GREEN was established in October 2009 with NIMS as the host institution. Building upon the strength of Japan in the field of nanotechnology and materials science, GREEN engages in the fundamental research of environmental technology, contributing to the creation of new materials for solving environmental and energy problems.

Infrastructure: NanoGREEN Building was opened in 2012. It is an eco-friendly laboratory featuring solar panels, LED lighting, photocatalyst glass watering systems, etc. It consists of research facilities such as a super dry room (DP of SA <-90℃), a Femtosecond Laser System, and a Photocatalysis Reaction System.

Services provided: GREEN invites researchers from universities and research institutes in Japan to work on topics well linked to GREEN's mission through a public recruiting process. GREEN open-lab guest researchers have the opportunity to communicate with NIMS researchers from various fields, and jointly analyze the experimental results obtained by using the cutting-edge facilities at NIMS. Green is also the

[8] More information of research thrusts. https://www.seriius.org/thrusts.html

host of the Green Symposium, NBCI-NIMS Joint Seminar, Battery Research Platform, and Analysis Forum for Battery Materials[9].

The National Institute of Advanced Industrial Science and Technology (AIST)

Description/Background: AIST is one of the largest public research organizations in Japan. It focuses on the creation and practical realization of technologies useful to Japanese industry and society, and on bridging the gap between innovative technological seeds and commercialization.

Infrastructure: AIST consists of five departments and two centers which are the Department of Energy and Environment, Department of Life Science and Biotechnology, Department of Information Technology and Human Factors, Department of Materials and Chemistry, Department of Electronics and Manufacturing, Geological Survey of Japan, and National Metrology Institute of Japan. AIST has eight research bases throughout Japan for improving regional innovation. Fukushima Renewable Energy Institute, AIST (FREA) is established in Fukushima, promoting R&D in renewable energy and open to the world.

Services provided: AIST promotes collaborative work with leading companies, research institutions, and universities worldwide. It strives to build an international cooperative relationship between academia and industry through its global research network. It is one of the major research and innovation hubs where there is a high potential for creating new business opportunities[10].

Research Institute for Energy Conservation, AIST (iECO)

Description/Background: Description/Background: iECO is one of the research institutes of the Department of Energy and Environment, AIST[11]. It conducts R&D on energy technologies to improve the efficiency of utilization and conversion.

Infrastructure: iECO has eight research groups: Thermofluid System Group, Thermal Energy Applications Group, Thermoelectric Energy Conversion Group, Energy Interface Technology Group, Energy Conversion Technology Group, Energy Storage Technology Group, Turbomachinery Group, and Engine Combustion and Emission Control Group. It has three laboratories: Collaborative Engine Research Laboratory for Next Generation Vehicles, Energy NanoEngineering Research Laboratory, and Advanced Technology Laboratory for Solid State Energy Conversion (ALSEC)[12].

Services provided: No information.

Japan Atomic Energy Agency (JAEA)

Description/Background: As Japan's sole comprehensive nuclear research and development institution, JAEA aims to contribute to the welfare and prosperity of human society through nuclear science and technology. Its priorities are the research into improving nuclear power safety, basic and fundamental research of nuclear power, and R&D on the nuclear fuel cycle. In response to the accident at Fukushima Daiichi

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9 See details on the 3rd page of the 2017 pamphlet. https://www.nims.go.jp/GREEN/en/about/pamphlet.html

10 Collaboration Inquiry Form can be found via https://www.aist.go.jp/aist_e/form/col_inquiry_form.html

11 Other energy research institutes of the Department of Energy and Environment are: Research Institute of Energy Frontier, Research Institute of Electrochemical Energy, Research Centre for Photovoltaics, Renewable Energy Research Centre, and Advanced Power Electronics Research Centre. In this landscape analysis we highlight the Research Institute for Energy Conservation as it provided more information by answering our questionnaire. For more information of other sub-research institutes of the Department, please see https://www.aist.go.jp/aist_e/dept/en_denvene.html

12 More information https://unit.aist.go.jp/ieco/en/groups/index.html#tfs

Nuclear Power Plant, it has been conducting R&D for decommissioning and environmental restoration. It also strives for the promotion of international cooperation and has developed cooperation with countries in Europe, North America, Asia, etc[13].

Infrastructure: "Fugen", "Monju" and Tokai Reprocessing Plant.

Services provided: In an event of a nuclear or radiological incident, Nuclear Emergency Assistance and Training Centre, launched by JAEA, provides support to central and local governments in various technical ways including the prompt dispatch of experts for emergency radiation monitoring and provision of technical advice to the governments and the public[14].

The New Energy and Industrial Technology Development Organisation (NEDO)

Description/Background: As one of the largest public research and development management organizations in Japan, NEDO has two missions, namely addressing energy and global environmental problems, and enhancing industrial technology. NEDO coordinates and integrates the technological capabilities and research abilities of industry, academia, and government instead of employing its own researchers. NEDO aims to introduce advanced Japanese technologies to countries and regions around the world having diverse needs and infrastructures[15].

Infrastructure: Barge-type floating offshore wind turbine system demonstrator, Real-grid operation of high-temperature superconducting cables, Demonstration facilities for oxygen-blown IGCC, Environmentally-friendly waste oil recycling system demonstration plant, High-efficiency wind lens turbines, etc.

Services provided: NEDO provides small and medium-sized enterprises and venture businesses with support at various phases, ranging from support for technology seeds to practical application by businesses. NEDO has been offering support for practical applications in renewable energy and welfare equipment fields. It has also built systems that allow experts to provide advice on topics such as venture capital financing, legal issues, accounting, and intellectual property as they relate to commercialization.

South Korea

National Fusion Energy Institute (NFRI)

Description/Background: NFRI is the national institute dedicated to conducting research and development of fusion energy. It has constructed the world's highest-ranking fusion research device named Korea Superconducting Tokamak Advanced Research (KSTAR) and has been actively involved in ITER. It collaborates with other RIs in countries such as the US, Russia, China, Japan, and India as well as European countries including the UK, Netherlands, France, Germany, Italy, and Hungary.

Infrastructure: NFRI has constructed KSTAR, the high-efficiency tokamak. The research for the Korean Fusion Demonstration Plant (K-DEMO) is carried out.

Services provided: No information.

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13 More information of Strategy of International Cooperation. https://www.jaea.go.jp/english/about/international_strategy/strategy.pdf

14 More information of Nuclear Emergency Assistance and Training Centre. https://www.jaea.go.jp/04/shien/en/index.html

15 For more information of NEDO's overseas activities, see page 18 of "Profile of NEDO 2019". https://www.nedo.go.jp/library/pamphlets/ZZ_pamphlets_00023.html

Australia

Australian Nuclear Science and Technology Organization (ANSTO)

Description/Background: ANSTO is the home of Australia's most significant landmark and national infrastructure for research. It partners with scientists and engineers and applies new technologies to provide real-world benefits. ANSTO's areas of activities involve health research, environmental protection, and promoting the emergence of new businesses and industries.

Infrastructure: ANSTO operates much of Australia's landmark infrastructure including one of the world's most modern nuclear research reactors, OPAL; a comprehensive suite of neutron beam instruments; the Australian Synchrotron; the National Imaging Facility Research Cyclotron, and the Centre for Accelerator Science.

Services provided: Health products, mineral consultancy, radiation services, Silicon irradiation, Gamma irradiation, Neutron Activation Analysis and Neutron Irradiation, measurement, and ANSTO Synroc-Waste Treatment Technology[16].

Centre of Excellence in Exciton Science, Australian Research Council (ACEX)

Description/background: The Centre is funded by the Australian Research Council, working with researchers and industry, to research better ways to manipulate the way light energy is absorbed, transported, and transformed in advanced molecular materials. It finds innovative solutions for renewable energy in solar energy conversion, energy-efficient lighting and displays, ad security labeling, and optical sensor platform for defense.

Infrastructure: The Centre is a collaboration of researchers at the University of Melbourne, Monash University, RMIT, University of NSW, and the University of Sydney. It works with Industry Partners such as the Reserve Bank of Australia, CSIRO, and the Department of Defence: Defence Science & Technology Group. The Centre has extensive infrastructure for device fabrication including complete solar cell characterization systems, a wide range of printing and deposition technologies, clean room access, a wide range of deposition methods, and roll-to-roll printing and slot die coating facilities at CSIRO.

Services provided: One of the Centre's highlighted priorities is to translate research into commercially viable products and services.

Australian National Fabrication Facility (ANFF)

Description/Background: ANFF links eight university-based nodes to provide researchers and industrial partners with access to state-of-the-art fabrication facilities. The nodes, located across Australia, draw on existing infrastructure and expertise. Each offers a specific area of expertise including advanced materials, nanoelectronics & photonics, and bio-nano applications.

Infrastructure: ANFF has a network of eight nodes including 21 institutions throughout Australia[17]. Its facility portfolio consists of over 500 instruments.[18]

Services provided: ANFF provides services for both academic researchers and industrial companies. It enables users to process hard materials (metals, composites, and ceramics) and soft materials (polymers

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[16] More information of Products and Services. https://www.ansto.gov.au/business/products-and-services

[17] See detailed information of the network. http://www.anff.org.au/australian-national-fabrication-facility-network.html

[18] See detailed information of the facilities. http://www.anff.org.au/capabilities.html

and polymer-biological moieties) and transform these into structures that have applications in sensor medical devices, nanophotonics, and nanoelectronics. Researchers can either gain direct access to facilities under expert guidance, contract for specialized products to be made, or undertake contract research projects.

6.2. Europe (non-EU)

Russia

Joint Stock Company "State Scientific Research Center of Atomic Reactors" (JSC "SSC RIAR")
Description/Background: JSC "SSC RIAR" is a research and development center located in Dmitrovgrad (Ulyanovsk region, Russian Federation). Founded in 1956 as a nuclear testing center, granted the status of State Scientific Center in 1994. In 2008 it also became a joint stock company.

Infrastructure: Six test reactors; post-irradiation examination facilities; radiochemical facility to perform NFC-related research activities, SNF, RW, and minor-actinides handling; radionuclides production area; fuel development and manufacturing area; full-cycle infrastructure, incl. nuclear fuel production, spent nuclear fuel and radioactive waste management, treatment of minor actinides; R&D-related lab-scale, research, and design infrastructure. Currently, the new multipurpose fast reactor MBIR is under construction.

Services provided: Access to local research facilities, databases, research methods, and guidelines; production of radioisotopes; practical training of scientific and technical personnel, conferences, seminars, and meetings on research and production activities of JSC "SSC RIAR".

6.3. North America

Canada

National Research Council Canada Energy, Mining and Environment Research Centre (NRC EME)
Description/Background: EME is one of 14 research centers within the National Research Council (NRC) Canada, uniting R&D capabilities and facilities in energy, mining, and environmental research. In energy research, EME focuses on bioenergy systems, energy storage, and novel material for clean energy and aims to support Canadian industry in bringing the latest science and technological achievements to the market. According to expert estimation, the largest part (about 75%) of funding for EME comes from a Parliamentary grant through the Department for Innovation, Science and Economic Development with investment plans done for five years and program plans for eight years. EME also receives funding from "other government funding programs and revenue from industry" with a shorter time horizon of one to three years.

Infrastructure: EME has facilities to conduct bioenergy research and energy storage research. A new facility related to energy materials development is under construction.

Services provided: EME provides physical and virtual access to local research facilities, datasets, specialized research tools or services, computing, and field implementation for projects. According to the interviewed expert's estimation, about 25% of services are available to external parties through temporary employment at EME or collaborative projects, which are conducted by EME's researchers for external clients.

Wind Engineering, Energy and Environment Research Institute (WIndEEE)

Description/Background: WindEEE Research Institute was established in 2011 at Western University in Canada. The Research Institute includes a WindEEE Dome facility, which was commissioned in October 2014[19]. According to the interviewed expert, "the main objective of the WindEEE RI is to advance the development of wind energy, wind engineering, and wind environment through research, education, innovation, and collaboration". Since 2015 Wind EEE has been recognized by the Group of Senior Officials as part of Global Research Infrastructures[20].

Infrastructure: The major infrastructure is WindEEE Dome – a 3D wind chamber, located in Ontario, Canada. WindEEE Dome can accommodate multi-scale, three-dimensional, and time-dependent wind testing[21].

Services provided: WindEEE provides physical access to local research facilities and virtual access to datasets either through collaboration on projects or a commercial basis (fee for use). According to expert estimation, from 95 to 100% of facilities are provided to external parties and actually used.

Fundy Ocean Research Centre for Energy (FORCE)

Description/Background: FORCE is a private, non-profit institute, supported by the Governments of Canada and Nova Scotia and participating developers. It is Canada's leading demonstration facility for tidal in-stream energy conversion (TISEC) technology[22].

Infrastructure: The natural test site is located in the Bay of Fundy with the world's highest tides. The site is used for testing TISEC devices.

Services provided: FORCE acts as a host to TISEC developers, providing a shared observation facility, subsea power cables, and grid connection at its test site. FORCE also provides environmental studies, environmental monitoring, and applied research acting as a steward of the test site[23].

Canadian Nuclear Laboratories (CNL)

Description/Background: Established in the middle of the 20th century, Canadian Nuclear Laboratories has been a primary national nuclear research laboratory in Canada. In the past years, CNL recognized the need to formulate a new vision. The strategy for 2016-2026 has a special focus on the revitalization of the Chalk River Laboratories site. For the coming years, CNL sets the following priorities in energy R&D: (1) life extension and long-term reliability of existing reactors, (2) development of new methods for next-generation fuels fabrication, (3) small modular reactors, and (4) decarbonization of transport sector through demonstration of hydrogen-based bulk transport.

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19 Annual Report 2016-2017, page 5. https://www.eng.uwo.ca/windeee/research_publications.html

20 Annual Report 2016-2017, page 5. https://www.eng.uwo.ca/windeee/research_publications.html

21 Annual Report 2016-2017, page 13. https://www.eng.uwo.ca/windeee/research_publications.html

22 Annual report 2016, page 3. http://fundyforce.ca/wp-content/uploads/2012/05/FORCE-Annual-Report-2016final.pdf

23 Annual report 2016, page 3. http://fundyforce.ca/wp-content/uploads/2012/05/FORCE-Annual-Report-2016final.pdf

Infrastructure: For decades until the shutdown in 2018, the National Research Universal reactor was one of the world's most versatile high-flux research reactors. Currently, CNL has a ZED-2 research reactor and several research facilities for materials research, fuel testing, etc.

Services provided: CNL offers collaboration opportunities to universities, small and medium-sized enterprises, and other interested third parties.

USA

Pacific Northwest National Laboratory (PNNL)

Description/Background: PNNL is included in the list of national laboratories under the USA Department of Energy. It receives funding mostly from US federal agencies and its projects that typically last for one to five years. The scientific domains that PNNL mostly focuses on are catalysis, earth sciences, data analytics, cybersecurity, the electric power system, and nuclear science and technology. In energy research, the core problem that PNNL aims to address is the creation of energy resilient systems.

Infrastructure: PNNL holds several user facilities which are open for access by a broader scientific community. *Services provided*: Facilities provide physical, remote, and virtual access to users which is mainly determined by a peer review process.

National Renewable Energy Laboratory (NREL)

Description/background: Many of the most prominent identified RIs are organized as parts of the National Renewable Energy Laboratory under the USA Department of Energy. NREL includes several laboratories, research centers, and research programs:

- National Bioenergy Centre conducts research in bioenergy, -fuels, and -products. The research areas comprise analysis and characterization, bioenergetics, and biochemical and thermochemical processes.
- National Centre for Photovoltaics focuses on increasing solar cell conversion efficiency, cost reduction of solar cells, modules, and systems, and improving the reliability of PV components and systems.
- Concentrating Solar Power Research focuses on developing materials for use in CSP, materials characterization, field characterization, engineering, and techno/economic analysis.
- National Wind Technology Centre conducts research in wind energy, waterpower, and grid interaction.
- The geothermal Program aims to conduct the full spectrum of research on geothermal energy including geothermal impact analysis, evaluation of hybrid systems (geothermal systems combined with renewable and fossil energy technologies), geothermal exploration and resource assessment, and sedimentary and enhanced geothermal systems.

Infrastructure: NREL includes multiple research facilities:

- For bioenergy studies: Integrated Biorefinery research facility, Thermal, and Catalytic Process Development Units.
- For photovoltaics studies: Solar Energy Research Facility, Science and Technology Facility, Outdoor Test Facility and Related Facilities, Regional Test Centres.
- For concentrating solar power research: Thin-Film Deposition Laboratory, Advanced Thermal Storage Materials Laboratory, Receiver Test Laboratory, Optical Characterization Laboratory, Large-Payload Solar Tracker, High-Flux Solar Furnace.

- For wind energy studies: Field research validation sites for wind energy studies (including six wind research turbines, and four meteorological towers), Dynamometer research facilities, Structural research facilities, and Controllable grid interface.
- For geothermal energy studies: Energy Systems Integration Facility, High-Performance Computing Data Center, Solar Radiation Research Laboratory, Thermal Test Facility.

Services provided: NREL offers opportunities for partnerships and collaborations with industrial and governmental organizations, as well as research and non-profit organizations. NREL provides opportunities to use facilities, develop technology partnerships, and license technology.

Oak Ridge National Laboratory (ORNL)

Description/Background: ORNL is a multi-program national laboratory under the USA Department of Energy. The scientific portfolio in energy research includes nuclear energy technologies, fusion science and technologies, energy efficiency, and renewable energy. ORNL is a member of the ITER project.

Infrastructure: ORNL provides several user facilities which are open to researchers outside the laboratory. Facilities that can be related to energy research are High Flux Isotope Reactor, Building Technologies Research, Integrated Center, Carbon Fiber Technology facilities, and National Transportation Research Center. *Services provided*: No information.

Sandia National Laboratory (SNL)

Description/Background: SNL came into existence in 1945 as a single-mission organization to engineer non-nuclear components of nuclear weapons within the Manhattan Project. In 1948 SNL became a Laboratory and in 1979 a US Department of Energy National Laboratory. Energy studies are a part of SNL's research portfolio and include multiple research areas, namely: energy storage, hydrogen power, electrical grid, solar power, and nuclear energy.

Infrastructure: SNL includes several Technology Deployment Centres assessable not only to US industry, governmental organizations, universities, and academic institutions but by the general scientific community. Some of these user facilities[24] are relevant for energy research, namely: National Solar Thermal Test Facility (solar power), Nuclear Energy and Fuel Cycle Programs (nuclear energy), Advanced Power Source Engineering Facility (energy storage), Combustion Research Facility (hydrogen power), Distributed Energy Technology Laboratory (electrical grid), Nuclear Facilities Resource Center (nuclear energy), Photovoltaic Laboratories (photovoltaics).

Services provided: No information.

Lawrence Berkeley National Laboratory (LBNL)

Description/Background: LBNL was founded in 1931 by Ernest O. Lawrence, a Nobel Prize winner in Physics. Now LBNL positions itself as a leading basic sciences national laboratory. It is also a US Department of Energy National Laboratory. The Energy Sciences area in LBNL encompasses multiple scientific disciplines with major activities concentrated in Materials Sciences Division and Chemical Sciences Division. In addition to these divisions, Basic Energy Sciences programs funded by the US Department of Energy

[24] The full catalogue of Technology Deployement Centers is presented on the web-site: https://www.sandia.gov/research/facilities/technology_deployment_centers/index.html

are also conducted within Joint Centre for Energy Storage Research (JCESR), led by the Energy Technologies Area), the Centre for Advanced Mathematics for Energy Research Applications (CAMERA, led by the Computational Research Division), and the Centre for Nanoscale Controls on Geologic CO2 (an Energy Frontier Research Centre led by the Earth and Environmental Sciences Area). Implications of Basic Energy Studies relate to multiple energy areas: photovoltaics, photosynthesis, biofuels, energy storage, combustion, catalysis, and carbon capture/sequestration.

Infrastructure: National user facilities within the Energy Sciences area at LBNL include Advanced Light Source, Molecular Foundry, Energy Sciences Network, and National Energy Research Scientific Computing Centre.

Services provided: Provides external access to its national user facilities.

DIII-D National Fusion Facility (DIII-D NFF)

Description/Background: DIII-D National Fusion Facility is a laboratory operated by General Atomics for the U.S. Department of Energy. The laboratory investigates a broad range of fusion energy research topics from fundamental plasma science to the work of fusion power plants.

Infrastructure: DIII-D tokamak operated since mid-1980s.

Services provided: To provide access to the research facility General Atomics organizes a DIII-D Research Program that is open to research proposals from all countries having a cooperative agreement with the US Department of Energy.

Idaho National Laboratory (INL)

Description/Background: INL is one of the US Department of Energy National Laboratories focused on nuclear energy studies.

Infrastructure: INL offers numerous user facilities for researchers, such as beamline, ion irradiation, post-irradiation examination, and gamma-irradiation facilities. The laboratory also offers access to 10 nuclear reactors; each of those offers different capabilities for nuclear research.

Services provided: For researchers, INL offers access to user facilities, computing resources, access to libraries, and publications as well as access to the nuclear infrastructure database.

Savannah River National Laboratory (SRNL)

Description/Background: Established in 1951, Savannah River National Laboratory belongs to the US Department of Energy National Laboratories. It is a multi-program applied research and development laboratory working to achieve goals in environmental management, national and homeland security, as well as energy security. SRNL regards as its core capabilities: Environmental remediation and risk reduction, nuclear materials processing and disposition, nuclear detection, characterization and assessments, gas processing, storage, and transfer systems. In addition, SRNL has research programs and facilities related to hydrogen, bioenergy, and energy materials.

Infrastructure: In addition to the main campus (which concentrates the nuclear-related research facilities), SRNL comprises Aiken County Research Laboratory (research portfolio includes bioenergy research), Hydrogen Technology Research Laboratory, and Energy Materials Research Laboratory.

Services provided: SRNL provides opportunities for cooperation with industry, government, and academic institutions.

National Energy Technology Laboratory (NETL)

Description/Background: NETL is owned and operated by the US Department of Energy and supports its mission. NETL is the only laboratory in the US Department of Energy National Laboratory that specializes in fossil energy studies. Due to its fossil fuel research focus, this laboratory is perhaps a less interesting partner for European RIs, although there might be opportunities in the future regarding e.g. energy conversion efficiency or carbon, capture, and storage.

Stanford University's Precourt Institute for Energy (Stanford Energy)

Description/Background: Stanford University Precourt Institute for Energy is a focal point for Energy Research across various academic departments, labs, and research programs of Stanford University. It focuses on supporting energy research projects in the following areas: renewables (bioenergy, geothermal, photovoltaics, renewable fuels, solar thermal, wind), energy storage and grid modernization, policy and economics, energy end use and efficiency, fossil and nuclear energy, environmental impacts.

Infrastructure: Stanford University Precourt Institute for Energy does not by itself operate any user research facilities. However, there are research facilities available at Stanford University.

Services provided: Funding allocation through a seed grant program, organization of educational programs, and dissemination of research results.

MIT Energy Initiative (MITEI)

Description/Background: MIT Energy Initiative is an institute-wide initiative that brings together energy researchers within MIT and promotes collaborations with industry and governmental partners. MITEI focuses on energy solutions that mitigate greenhouse gas emissions and address climate change issues. The Initiative prioritizes eight areas for energy research (advanced nuclear energy systems, carbon capture, utilization and storage, electric power systems, energy storage, energy bioscience, materials in energy and extreme environments, mobility systems, and solar energy) and organizes them into corresponding Low-Carbon Energy Centres.

Infrastructure: No information about any specific infrastructure/facilities for energy research.

Services provided: MITEI provides funding for research and development projects at MIT, promotes collaborations with industry and government, organizes educational programs, and disseminates results.

6.4. South America

Brazil

Centro de Desenvolvimento da Tecnologia Nuclear (CDTN)

Description/Background: CDTN is a nuclear institute that researches radiochemistry, radioprotection, radiological metrology and dosimetry, nuclear/radiological safety, radioactive waste management, and nuclear technology (thermodynamics and neutronics). In addition to research activities, this is also an educational organization that holds the Graduate programme (Ph.D. & M.Sc.) of Science and Technology of Radiations, Minerals, and Materials.

Infrastructure: The main nuclear/radioactive facilities of CDTN are the Nuclear Research Reactor TRIGA IPR-R1, Unit for Research and Production of Radiopharmaceuticals –UPPR, and Laboratory of Gamma Irradiation.

Services provided: CDTN plays a significant role in the technological development and the provision of specialized services for the mineral and metallurgical sectors. For example, CDTN offers radiopharmaceuticals production for applications in positron emission tomography, calibration of radiation dosimeters, and individual monitoring to the community for the health area.

Brazilian Centre for Research in Energy and Materials (CNPEM)

Description/Background: CNPEM is a private non-profit Social Organization supervised by the Ministry of Science, Technology, Innovation, and Communications (MCTIC). Located in Campinas, São Paulo State, it consists of four National Laboratories open to the scientific and technological communities, with competencies in biosciences, materials, renewable energies, and advanced instrumentation.

Infrastructure: Four laboratories: The Brazilian Synchrotron Light Laboratory (LNLS), The Brazilian Biosciences National Laboratory (LNBio), The Brazilian Bioethanol Science and Technology Laboratory (CTBE), and The Brazilian Nanotechnology National Laboratory (LNNano).

Services provided: CNPEM implements, maintains, and operates open-access facilities to ensure the access of researchers from all over the country and abroad, including UVX, Sirius, microscopy characterization, Electron Microscopy, and Cryomicroscopy facilities, Atomic Force Microscopy, microfabrication, functional systems and devices, the nanostructured soft materials facilities, proteomics (MAS), spectroscopy and calorimetry (LEC), nuclear magnetic resonance (RMN), protein crystallization (RoboLab), and the Pilot Plan for Process Development (PPDP).

Instituto de Pesquisas Energéticas e Nucleares (IPEN)

Description/Background: Nuclear and Energy Research Institute is an autarchy of the São Paulo State, associated with the University of São Paulo for educational purposes, supported and operated technically and administratively by the National Nuclear Energy Commission (CNEN). It is recognized as a national leader in research, development, and applications in the areas of radiopharmacy, radiation technology, nuclear physics, materials, lasers, biotechnology, environment, and clean energy, and also in the design and operation of nuclear reactors and radioactive facilities.

Infrastructure: There are 11 Research and Development Centres on the campus of the University of São Paulo. Other facilities include nuclear electric power plants and petrochemical facilities. The new facility in the plan is the Brazilian Multipurpose Reactor (RMB).[25]

Services provided: Analysis of radionuclides in environmental and food samples; environmental radiological impact evaluation; external and internal individual monitoring and dose calculation; clinical and high-dose dosimetry; production of dosimetry materials; calibration of radiation detectors; radiation protection services; treatment of radioactive waste, and responses to radiological emergencies.

[25] More information of RMB. https://www.ipen.br/portal_por/portal/interna.php?secao_id=2520&campo=10370

7. OVERVIEW OF RESPONSES

Of the 36 international RIs contacted, 11 completed survey questionnaires (the detailed information is provided in section 5 “Lists of RIs”). For the rest of RIs information was collected from the websites of those organizations.

The analysis presented in this chapter is based on responses to the RISCAPE survey and covers the following themes:

- Type of organization, financial aspects, and time-horizon
- Mission statement, focus goals, and challenges
- Plans to develop facilities
- Services and access
- Data Policies
- Scientific and socioeconomic impact
- International collaboration and partnerships with European RIs
- Complementarities with European research infrastructures

7.1. Type of organization, financial aspects, and time-horizon

According to Table 3, the RI with the lowest construction costs (30 million euros) is the **Wind Engineering, Energy and Environment Research Institute (WindEEE)**, which operates a WindEEE Dome – a 3D wind chamber, located in Ontario, Canada.

Centro de Desenvolvimento da Tecnologia Nuclear (CDTN) in Brazil and OPAL reactor at Australian Nuclear Science and Technology Organization (OPAL), both related to the nuclear sub-domain, have a similar order of magnitude in terms of construction costs (300-350 million euro).

According to expert estimation, **Japan Atomic Energy Agency (JAEA)** has the highest both construction and operation costs among interviewed RIs.

The majority of interviewed RIs (nine RIs) receive funding (total or major part) from the national/federal government. Some of them have mixed funding schemes, where governments (usually there are several government agencies or funding programs) provide the major part of funding supplemented by the revenue from commercial contracts, industry, user fees, or other foundations. The two RIs that stand out from this model are **JSC RIAR** and **Stanford Precourt Institute for Energy**. Though **RIAR** is a state-owned company, it does not receive funding from governmental agencies but finances its activities by getting revenue from commercial contracts for Russian and international clients (contracts on scientific research and development as well as production of radionuclides). At the same time, RIAR conducts its own research and acts as a scientific organization (publishes its scientific articles, participates in and organizes conferences, etc.). The **Stanford Precourt Institute for Energy** receives funding for its activities mainly through donations and sponsorship.

Table 3. *Basic information on interviewed RIs: sub-domain, type, construction, and operation costs.*

Sub-domain	Full name	Short name	Type of organization	Construction costs	Operation costs (per annum)	Operation costs stand-alone or based on a larger organization
nuclear energy	Joint Stock Company "State Scientific Center Research Institute of Atomic Reactors"	Russia, RIAR	single-sited	10 billion euro	120 million euro	stand alone
renewables, energy systems integration	National Research Council Canada Energy, Mining and Environment Research Centre	Canada, EME	distributed	13–14 billion euro	17 million euro	stand alone
renewables	Wind Engineering, Energy and Environment Research Institute	Canada, WindEEE	single-sited	30 million euro	NA	NA
energy systems integration	Pacific Northwest National Laboratory	USA, PNNL	distributed	NA	NA	NA
renewables, nuclear energy, energy systems integration, efficient energy conversion, and use	Stanford Precourt Institute for Energy	USA, Stanford Energy	single-sited	NA	13-18 million euro	NA
nuclear energy	Centro de Desenvolvimento da Tecnologia Nuclear	Brazil, CDTN	single-sited	300 million euro	3 million euro	other
renewables	Brazilian Centre for Research in Energy and Materials	Brazil, CNPEM	single-sited	800 million euros (considering Sirius, synchrotron light source)	25 million euro (w/o Sirius and w/o individual research grants), 70 million euros (including Sirius and w/o individual research grants)	larger organization
nuclear energy, renewable energy	Instituto de Pesquisas Energéticas e Nucleares	Brazil, IPEN	single-sited	4–5 billion euro	59 million euro	larger organization
nuclear energy	Japan Atomic Energy Agency	Japan, JAEA	distributed	100 billion euro	1.2 billion euro	stand alone
efficient energy conversion and use, renewables, cross-sectional	National Institute of Advanced Industrial Science and Technology	Japan, AIST	distributed	NA	820 million euro	stand alone
nuclear energy	OPAL reactor at Australian Nuclear Science and Technology Organization	Australia, OPAL (ANSTO)	single-sited	300-350 million euro	20 million euro	stand alone

All RIs representatives (except **Stanford Precourt Institute for Energy**) mentioned that their organization has either statutes or a business plan. The operational time horizon goes beyond a typical science project for most of RIs, except for **IPEN**, Brazil (the operational planning is done annually while typical projects last for 3–5 years) and **JAEA** (Japan).

Only four RIs (**EME, PNNL, CNPM, OPAL ANSTO**) stated clearly that they receive multi-annual funding for their activities, though the period varies depending on the organization. **RIAR** also receives multi-annual funding (commercial contracts can run for a period of up to 10 years), but it does not have secured state funding. However, according to RIAR's expert "*The functioning of JSC "SSC RIAR" as the main industry centre of ROSATOM for conducting scientific research is guaranteed*".

OPAL reactor at the Australian Nuclear Science and Technology Organization seems to be the most stable research infrastructure in terms of funding. As stated by the expert from OPAL (ANSTO): "*At the time of building the Australian government committed to funding the RI during the entire lifetime of the research reactor*".

Surprisingly, some nationally important RIs do not receive multi-annual funding. For example, for **CDTN** and **IPEN** (both from Brazil), although these are strategic infrastructures, there is no existing long-term financial commitment from the government. Funding decisions are negotiated yearly and depend on government approval. Similarly, the expert from **Japan Atomic Energy Agency** answered that **JAEA** does not receive multi-annual funding. However, as mentioned above, JAEA has the highest operational costs among interviewed RIs.

7.2. Mission statement, focus goals, and challenges

Experts from all organizations within the nuclear energy sub-domain mentioned that their organizations exist on the national or international roadmap. **JSC State Scientific Center Research Institute of Atomic Reactors (RIAR, Russia)** belongs to ROSATOM state corporation, therefore RIAR should follow all strategic goals identified by a mother organization[26]. In Brazil, all three organizations contacted are included in Federal Government Plan[27]. **Japan Atomic Energy Agency (JAEA)** is incorporated into the Strategic Energy Plan of Japan and also in a Mid-and-Long-Term Roadmap toward the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4[28]. **Australian Nuclear Science and Technology Organization (ANSTO),** with its major facility – OPAL reactor, is mentioned in Australian National Research Infrastructure Roadmap 2016[29]. On this roadmap, OPAL is given a Landmark Infrastructure status.

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[26] ROSATOM "Strategic goals 2030. Corporation of knowledge. Corporation of the future" (in Russian) http://niiar.ru/sites/default/files/rosatom_strategy_17-08-17_1.pdf

[27] CNEN "PROGRAMA POLÍTICA NUCLEAR PPA 2016–2019 E LOA 2016" www.cnen.gov.br/images/cnen/documentos/planejamento/ProgramaPoliticaNuclear-PPA-2016-2019.pdf

[28] Ministry of Economy, Trade and Industry "Cabinet Decision on the New Strategic Energy Plan" http://www.meti.go.jp/english/press/2018/0703_002.html; Ministry of Economy, Trade and Industry "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1–4" http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/index.html

[29] Australian Government "2016 National Research Infrastructure Roadmap" https://docs.education.gov.au/system/files/doc/other/ed16-0269_national_research_infrastructure_roadmap_report_internals_acc.pdf

Contrary to this, organizations related to renewables, energy systems integration, and efficient energy conversion and use sub-domains, according to experts' responses, were not mentioned in any national or international roadmap.

The majority of organizations' representatives were able to provide mission statements for their organizations (except for the **Research Institute for Energy Conservation, The National Institute of Advanced Industrial Science and Technology** in Japan).

7.3. Plans to develop facilities

Among RIs within the *nuclear sub-domain* the following projects for the development of facilities were mentioned by interviewed experts:

At **RIAR, Russia** several projects for upgrading research facilities are undergoing. (1) The first project aims to refurbish the fast test reactor BOR-60 which was commissioned in 1969. The lifetime of the test reactor is scheduled to extend until 2025. Plans also include improving safety and expansion of experimental capabilities, "*to ensure the experimental substantiation of the main parameters of the IV Generation reactors*". (2) The second project, planned for the years 2017–2020, aims to modernize the high-flux research reactor SM-3 and extend its lifetime until 2030 and beyond. As a project outcome, the reactor should improve its operational reliability and expand its experimental characteristics (particularly, increase the number of high-flux cells for irradiation). (3) Finally, the third project is related to the construction of the new multipurpose fast test reactor MBIR and polyfunctional radiochemical research complex.

At **IPEN, Brazil** the undergoing project is the construction of the Brazilian Multipurpose Reactor. As mentioned in the progress report published on IPEN's website: "*The Nuclear Reactor RMB will be an open pool type reactor with maximum power of 30 MW having the OPAL nuclear reactor of 20 MW, built in Australia, as a reference*"[30].

As explained by the representative of the **Australian Nuclear Science and Technology Organization** operating the **OPAL** research reactor, is currently in the "scoping stage" of planning upgrades to the facility. The planning stage is expected to last two years more and will be followed by eight years of building up to the final commissioning in 2029.

According to the expert from **CNPEM, Brazil,** the project of Sirius, a synchrotron light source, is planned to be completed in 2020. Also, cryomicroscopy facilities were launched in 2018 at CNPEM.

A new facility related to energy material development is under construction at **EME, Canada**, according to the expert interview. An expert from **PNNL, USA** has also mentioned that the laboratory plans to add new facilities, geographically extend facilities, or do major upgrades in the organization, but did not give any specific information on which developments are planned.

[30] IPEN "Brazilian Multipurpose Reactor. Progress report" , p.373 https://www.ipen.br/portal_por/portal/interna.php?secao_id=2520&campo=10370

7.4. Service Catalog

Most interviewed RIs mentioned that they have some kind of service catalog for their research services available on their websites. At the same time, the analysis of "service catalogs" provided by RIs representatives shows that the content and structures of those catalogs vary significantly between organizations. Thus, most of RIs provide descriptions of their *research facilities* (available for outside users), while fewer clearly describe exactly which *services* they provide or how to get *access* to these facilities.

The availability of facilities, and access to outside users, is one of the key characteristics of research infrastructures according to the RISCAPE framework. For this type of facility different wordings are used by RIs, such as User facilities, shared facilities, and research base. Some RIs offer multiple research facilities that can be accessed by outside users (**EME** in Canada, **PNNL** in the USA, **RIAR** in Russia). Others have only one major research facility (**Wind EEE** in Canada and **OPAL** research reactor in Australia). In their "service catalogs" published online, some organizations just provide a list of available facilities, while others give detailed descriptions of all technical capabilities and ways to use them.

Some RIs clearly describe *possibilities for cooperation or partnerships* with users outside the organization. For example, the website of **PNNL** (https://www.pnnl.gov/) has a separate section devoted to partnerships ("Partners with PNNL").

There are RIs that give a clear scheme for *getting access* to research facilities. A good example is **JAEA, Japan** which presents a detailed explanation of the procedure for getting access to shared facilities (https://tenkai.jaea.go.jp/facility/3-facility/05-support/jaea-facilities-eng.html).

Though most websites of RIs contain comprehensive information, the information is often scattered across the website. Perhaps, the most structured way of presenting its service catalog is provided by **EME, Canada** RI at the webpage: https://nrc.canada.ca/en/research-development/research-collaboration/research-centres/energy-mining-environment-research-centre. The page gives the list of research facilities for each area of research the RI specialized at. The page also mentions research programs (with a clear description of possibilities for collaboration), technical and advisory services, industrial R&D groups, and technology licensing.

7.5. Research services and resources provided for researchers

As *Figure 9* shows, most RIs provide access to local research facilities (such as lab spaces, research reactors, equipment for research, etc.). Fewer organizations provide access to mobile research instruments and remote sensing instruments (only **PNNL** and **Stanford Energy**[31] mentioned that). "Other" types of services and resources include, for example, the production of radioisotopes (**RIAR**), practical training for scientific and technical personnel (**RIAR**), conferences, seminars, and meetings (**RIAR**), and field implementation for projects (**EME**).

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[31] It should be noted that Stanford Precourt Institute for Energy does not have it's own research facilities or services provided for researchers, however, there are facilities and services available at Stanford University.

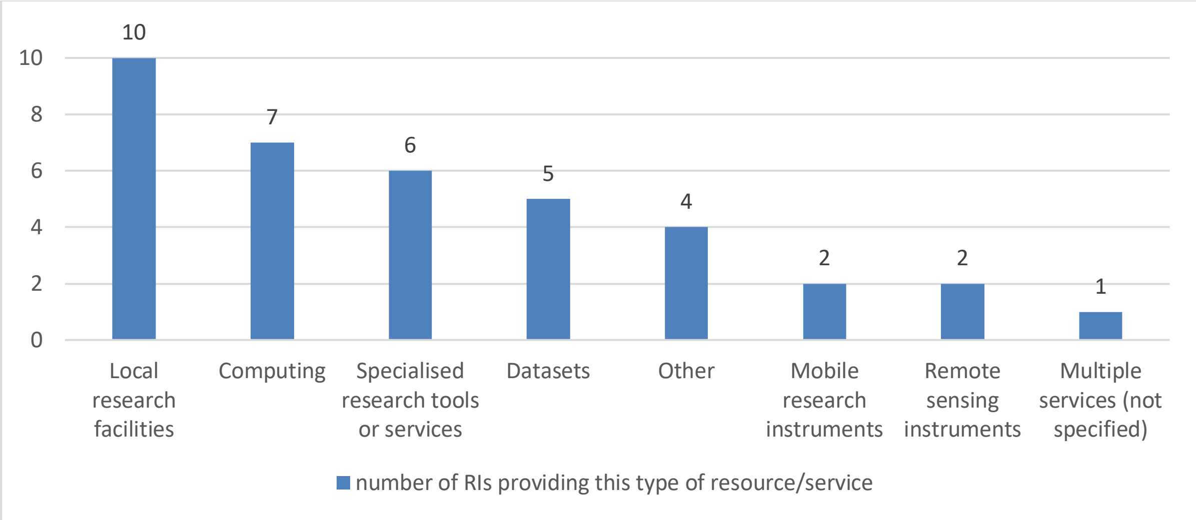

Figure 9. *Services and resources provided by research infrastructures for research or researchers (number of RIs responded to Q25 = 11).*

7.6. Access

As *Figure 10* shows, all responding RIs offer some *physical access* to their services and resources. In many cases, physical access is combined with *virtual access* (for example, virtual access to databases) or *remote access*. **PNNL**, USA is the only RIs providing all these three kinds of access. At the same time, **JAEA** in Japan offers only physical access.

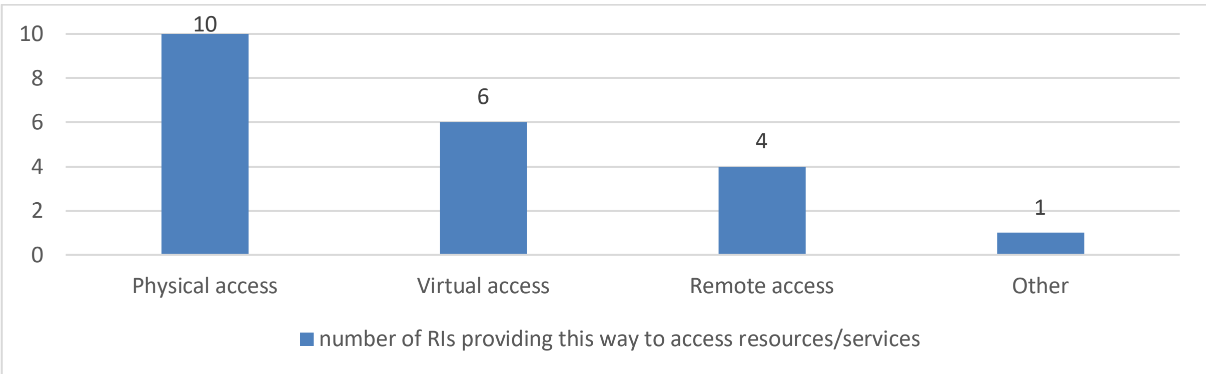

Figure 10. *Types of access to services and resources available at RIs (number of RIs responded to Q26 = 10).*

The expert from **CDTN** has mentioned that virtual access is currently not provided due to a lack of infrastructure, however, it is under development.

For **RIAR,** the main type of access seems to be remote access ("Research and development work, as well as experiments in the framework of services provision using reactor facilities and laboratory equipment of JSC "SSC RIAR" in the interests of external organizations, are performed by the personnel of JSC "SSC RIAR".). Though in some cases the organization may also offer physical access to its research facilities

("Customer's representatives can potentially visit experimental facilities or participate in experiments when the following conditions are met: – availability of medical admission to work with the use of ionizing radiation sources; – admission to secured areas of JSC "SSC RIAR"; – passing the necessary instructions (radiation and electrical safety, safety labour protection instructions, etc.)".

Figure 11 presents the proportions of RI's services available to external parties and actually used by them. **RIAR**, **Wind EEE,** and **OPAL (ANSTO)** mentioned that 95–100% of their services are available to external parties and the actual usage is also very high (about 100%).

According to experts from **AIST**, **EME,** and **PNNL** less than 25% of services are available to external parties. The expert from EME also claims that the actual usage is very low, "*but collaborative arrangements are under development*".

For half of RIs, it is hard to define, what is the current level of usage of their services, because it may vary from service to service and depend on the laboratory. As an expert from **CDTN** says: "*In general, about all resources that are available to external parties are used. The use would be higher if demand was also higher*".

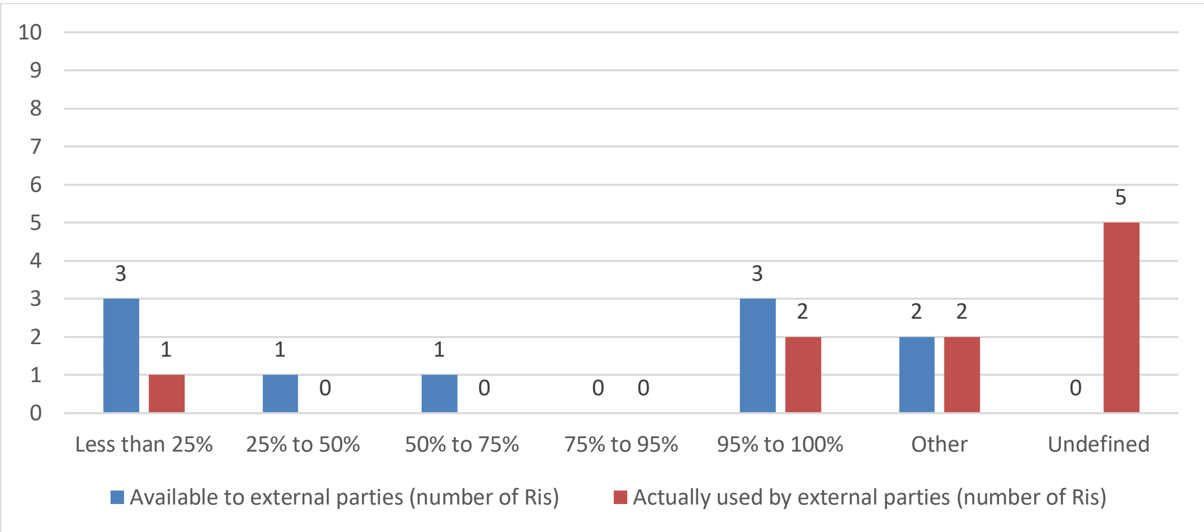

Figure 11*. Proportions of research infrastructure services available to external parties vs. actual usage by external parties (number of RIs responded to Q29 and Q30 = 10).*

Figure 12 illustrates that access to services can be granted on both peer-reviewed and commercial basis.

Thus, experts from **PNNL**, **CNPEM**, **JAEA,** and **OPAL** RIs claimed that access to their services and facilities is determined by a *peer review process*:

- "Each CNPEM open access facility has a platform for submitting proposals and committees with external and internal members to review the proposals" (expert from **CNPEM**).
- "The Technical Committee of the Shared Use Facility Council will review, from a scientific and technical viewpoint, the scientific relevance of the project, the need for using the JAEA facility and equipment, its feasibility, safety, and past achievements of the applicant and the project members accomplished by using the JAEA facility and equipment." (expert from **JAEA**)
- "Access is determined by a merit-based scheme. There are 2 calls a year for proposals, and researchers must prepare a project proposal, and after submission, this is assessed by an

independent panel. The independent panel awards the access on the order of merit, with the access matched up by the availability of access." (expert from **OPAL**)

The expert from **OPAL** mentioned that in his organization access on a commercial basis is also possible. That requires a fee for access and also has a different procedure for granting access, compared to the peer-reviewed process used when for scientific purposes.

Examples of RIs which provide access mainly on a *commercial basis* are **RIAR** and **IPEN**. "*SAC is a public channel where you can request access and we send the budget, see if you need permission, etc*." (expert from **IPEN**). The expert from RIAR highlights that there is a kind of peer review process existing for situations when the client requests physical access to RIAR's facilities (by default the access to facilities is remote): "*Physical access for Customer's representatives to the experimental facilities is stipulated at the stage of negotiation/conclusion of a commercial contract for the performance of work (taking into account regulatory requirements, regulations and restrictions provided for by the internal rules of JSC "SSC RIAR")*" (expert from **RIAR**).

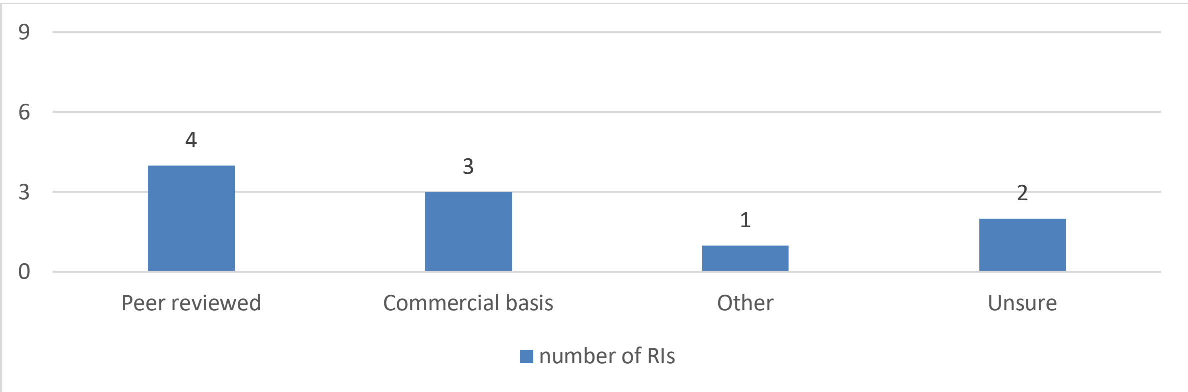

Figure 12. *The basis for granting access (number of RIs responded to Q27 = 9).*

Experts from interviewed RIs did not mention special quotas or limitations set for access to their services. However, some of RIs' representatives note that situational limitations for access are possible:

- "Depending on the scenery, external users may overload the capacity of the organization. The limit is our capacity." (expert from **CDTN**)
- "Depends on the project's demand." (expert from **IPEN**)
- "In principle, we have no limitations. However, depending on the usage system, external users are obligated to publish results." (expert from **JAEA**)

7.7. Data Policies

The number of RIs claiming that they have an existing data policy is almost equal to the number of those claiming the absence of a data policy (Figure 13).

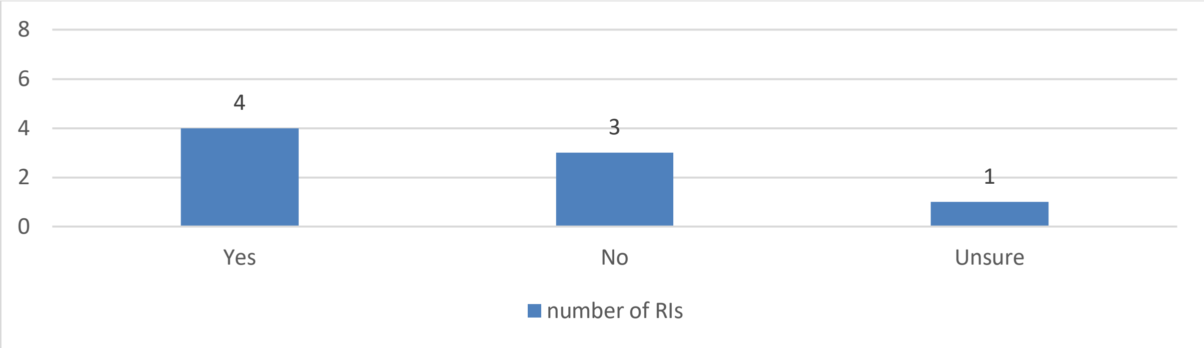

Figure 13. *Do you have an existing data policy publicly available (number of RIs responded to Q32 = 8).*

In some RIs data regulations may differ from project to project:

- “Data is usually not open source. Data policy often varies from project to project and the funder.” (**CDTN**, Brazil)
- “Each database has its own guideline” (AIST, Japan)

Open licenses are most often not provided (especially not when access to user facilities is determined on a commercial basis), however, it may depend on the projects and special agreements. Some RIs (for example, OPAL) have different approaches to data licensing for external and internal researchers: “*It is part of the merit-based access agreement that researchers own the data they have produced. It, therefore, depends on the policy of the visiting researcher whether this data is open. For the data produced for the organizations' own researchers open licenses for data are usually applied.*” (**OPAL**, Australia).

7.8. Scientific impact

As Figure 14 shows, the majority of RIs claim that their scientific impact is followed either by the research infrastructure itself or by third parties. Many RIs also publish annual reports on their scientific achievements online. The scientific impact can be evaluated by various stakeholders, such as:

- Funding agencies
- Governmental agencies and commissions
- Scientific advisory panels and committees

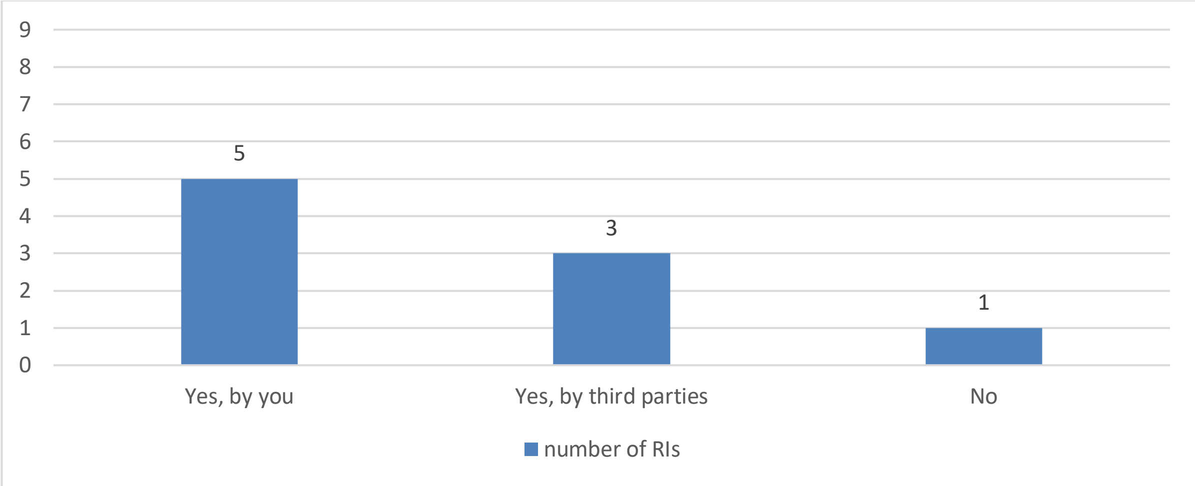

Figure 14. *Is the scientific impact of research done in your facility followed in some way (number of RIs responded to Q35 = 9)*

The impact is often presented as quantitative metrics (the number of publications, participation in conferences, impact factor, citation index, number of trained students, and number of patents). However, qualitative evaluations are also possible (for example, case stories).

In the nuclear energy research sub-domain, International Atomic Energy Agency (IAEA) provides audit and certification and gives the status of International Centres based on Research Reactors (ICERRs) to certain research reactor facilities. Currently, the list of ICERRs[32] includes two European facilities (French Alternative Energies and Atomic Energy Commission (CEA) and Belgian Nuclear Research Centre (SCK•CEN). Apart from those, three international research infrastructures are included in the list: the Russian **Research Institute of Atomic Reactors State Scientific Centre (RIAR)**, *Idaho National Laboratory (INL),* and *Oak Ridge National Laboratory (ORNL)* both from the USA.

7.9. Socio-economic impact

Though the scientific impact is usually followed regularly, generally RIs provide very little information on how they follow the socio-economic impact.

The experience of **RIAR**, Russia showcases an example of how a research infrastructure may see its socio-economic impact. The expert from **RIAR** explains that the organization attaches high importance to the development of Dimitrovgrad city and Ulianovsk region (the city and the region where an RI is located). For RIAR, the city's ability to attract talented scientists is important. Being the city's largest employer, RIAR strives to take part in improving urban livelihood. Indicators of this are, for example, the health of citizens, average salary, etc. The institute implements programmes to support social initiatives, sporting events, etc. There is work underway on this with the city's authorities and regional professional associations. However, RIAR does not conduct systematic work to develop and monitor socio-economic impact indicators.

[32] IAEA "International Centres based on Research Reactors (ICERRs)" https://www.iaea.org/about/partnerships/international-centres-based-on-research-reactors-icerrs

Another interesting example is **EME**, Canada which claims that some of its programs have certain targeted parameters set on the planning state of the program. Apart from scientific impact (such as the number of publications), those targets may be related to socio-economic impact (for example, possible reduction of GHG emissions).

7.10. International collaboration and partnerships with European organizations

Some experts mentioned international organizations, such as EUREKA and International Atomic Energy Agency (IAEA), as important for developing international partnerships.

According to the expert from **OPAL**, there is a well-established international research community in nuclear energy research. That allows researchers to find and access easier necessary user facilities for their research purposes. "*The international neutron community is seen by OPAL as a well-functioning global network. Previously, when OPAL had a longer period of downtime, researchers temporarily relocated from Australia to ISIS in the UK. As Paul Scherrer Institut in Switzerland experiences a planned downtime in 2019, several researchers will relocate to OPAL in Australia for that time period.*" (expert from **OPAL**, Australia).

International RIs collaborate actively with European organizations. Currently, access to services for European organizations is provided in various ways:

- on a commercial basis (**RIAR**, Russia; **WindEEE**, Canada; **CDTN**, Brazil; **IPEN**, Brazil, **OPAL**, Australia);
- research collaboration (**EME**, Canada; **PNNL**, USA);
- strategic partnerships (**PNNL**, USA);
- submitting proposals to user facilities and going through a peer-reviewed process (**PNNL**, USA; **CNPEM**, Brazil; **JAEA**, Japan; **OPAL**, Australia).

Some international RIs have already established connections with organizations from Europe:

- "At present, JSC "SSC RIAR" is conducting research in the interests of individual European companies, scientific organizations, and laboratories (based on commercial contracts)." (expert from **RIAR**, Russia)
- "NRC[33] has collaborative agreements with the UK and Germany… and is developing relationships with European research organizations." (expert from **EME**, Canada)
- "In 2017, 89 international institutions used CNPEM´s open access facilities, out of which 36 were European organizations." (expert from **CNPEM**, Brazil)
- "About 40% of total users are international, and Europeans are tentatively assumed to constitute about 50% of that number. In total, about 20% of current users are therefore assumed to come from European organizations." (expert from **OPAL**, Australia)

[33] NRC is a Canadian federal agency National Research Council. EME belongs to NRC.

7.11. Complementarities with European research infrastructures

Nuclear sub-domain

The following RIs relate to the nuclear sub-domain on the European landscape:

- Jules Horowitz Reactor (JHR) and Multi-purpose hybrid Reactor for High-Tech Applications (MYRHHA) in *fission energy*
- ITER, Demonstration Fusion Power Reactor (DEMO) and Joint European Torus (JET) in *fusion energy*

On the international landscape, some research infrastructures provide nuclear research reactors as user facilities open for access. Among interviewed RIs these are **RIAR** (Russia), **OPAL** (Australia), **IPEN** (Brazil), and **JAEA** (Japan).

RIAR currently has 6 research reactors (and a new MBIR research reactor is in the building stage to substitute the reactor BOR-60). According to the expert from RIAR, European research reactors MYRRHA and Jules Hurwitz Reactor (JHR) compared to BOR-60 and the upcoming MBIR reactor are completely different reactors, aimed to perform different tasks, there is no overlap in parameters. Therefore, these reactors may be complementary to MYRHHA and JHR depending on the research purpose.

Experts from **OPAL** (Australia) and **JAEA** (Japan) also mentioned that facilities from their organizations may be complementary to similar facilities in Europe:

- "There are the same types of facilities in Europe, especially, France and the United Kingdom. However, our facilities and these facilities may play complementary roles." **JAEA** (Japan);
- "OPAL may not at the moment have any globally unique equipment, but some of the neutron scattering instruments are more specialized or includes particular features than anything else available globally (and therefore also in Europe). This can for example be detectors with higher resolutions. In addition, a lot of attention is put on the unique capabilities of the staff operating the equipment. For OPAL, investing in Research Infrastructures means not just to invest in physical facilities, but also to invest in highly trained and skilled persons to occupy these facilities. RIs are not just steel, it's also people. The combination of the two elements do provide OPAL with certain capabilities beyond its global collaborators and competitors." **OPAL** (Australia).

Renewables sub-domain

In the renewables sub-domain the following European RIs were identified:

- *Wind energy*: European WindScanner Facility (WindScanner)
- *Solar energy*: European SOLAR Research Infrastructure for Concentrated Solar Grid (EU-Solaris)
- *Marine energy*: Marine Renewable Energy Research Infrastructure (MARINERG-I), Marine Renewables Infrastructure Network (MaRINET2)
- *Bioenergy*: Biofuels Research Infrastructure for Sharing Knowledge (BRISK-2)

According to an expert from **WindEEE** (Canada), the major research facility WindEEE Dome is a unique user facility in the world. Due to its technical capabilities, it can:

- "create any type of wind system, including tornadoes, hurricanes, monsoons, downbursts
- customize testing to specific regions for managing the risk of severe weather

- measure the wind energy potential of a structure, town, or city
- validate wind farm design with realistic atmospheric turbulence and sheer conditions
- become the world's most sophisticated weather machine to mimic rain, dust, and ice storms, as well as testing patterns of airborne pollutants."

Mixed scientific portfolio

Some international RIs have a mixed research portfolio; therefore they may conduct research in various areas of energy research simultaneously. It is therefore difficult to make individual analyses for the subdomains of Energy Systems Integration and Efficient Energy Conversion and Use. It also makes it difficult to make comparisons between International RIs and European RIs, which have more focused on a single sub-domain.

For example, experts from **PNNL** (USA) and **CDTN** (Brazil) had difficulties describing how their organization differs from European RIs, due to the diversity of research programs:

- "The diversity of our programs makes this question impossible to answer." (expert from **PNNL**, USA)
- "Very diversified, multifaceted and interdisciplinary facilities, even in small laboratories. Applied sciences force us to be interdisciplinary." (expert from **CDTN**, Brazil)

The expert from **EME** (Canada) compared the organization with similar European organizations having various research topics: "NRC[34] is similar to institutes like Fraunhofer, VTT, and others and EME is similar to the clean energy programs within those organizations and there is significant overlap in capabilities. The main difference is that EME is focused on problems that are particular to Canada".

[34] NRC is National Research Council, a Canadian federal agency National Research Council. EME belongs to NRC.

8. SPECIFIC FINDINGS

In this chapter, in addition to the RIs which have filled in the survey (marked in **bold** font), RIs with information collected from their websites are also included in the analysis (marked in *italics*).

8.1. Historical Contextualization of the establishment of international Nuclear RIs

As mentioned in Section 2.3 International Energy RIs Landscape, research was conducted on non-EU RIs across five continents including North America, South America, Asia, Australia, and Europe.

Within the dataset, it appears that USA and Canada were pioneers in establishing international energy RIs still lasting to this day. Many identified RIs from this region were established during the 1930s and 1950s, with *Lawrence Berkeley National Laboratory* in the USA founded as the earliest, in 1931. Nuclear research in particular also gained momentum in the period up to and during World War II. *Oak Ridge National Laboratory*, established in 1943, was involved in The Manhattan Project aimed at developing nuclear weapons[35]. *Chalk River Laboratories*, now part of *Canadian Nuclear Laboratories*, was one of the Canadian sites established for The Manhattan Project. In the post-war era, the utilization of nuclear power for energy generation became a priority, while other nations sought to develop (peaceful and sometimes also military) nuclear capabilities on their own.

In Russia, **JSC “SSC RIAR”** was founded in 1956 as a nuclear testing center, with facilities commissioned during the 1960s and 1980s. Currently, following the Strategy for Scientific Development and Technological Development adopted by the Russian Federation, **JSC “SSC RIAR”** has a long-term horizon of planning, at least until 2035. It conducts nuclear research for the peaceful utilization of atomic energy and the nuclear fuel cycle.

Like in the USA, Canada, and Russia, the investment in nuclear energy in South America also coincides with a historical moment of high militarization. In Brazil, the RIs **Centro de Desenvolvimento da Tecnologia Nuclear (CDTN),** and **Instituto de Pesquisas Energéticas e Nucleares (IPEN)**, as well as the Angra Nuclear Power Plant were all built during the years of military dictatorship (1964–1985). This is a period of Brazilian history marked by high political instability and declining economic growth. This was also a period in which the country faced truculent investments in urban development, transport, and energy infrastructures. CDTN and IPEN are hitherto Ris highly reliant on the national state and momentary needs of the national government. As discussed earlier, it became clear during the face-to-face interviews, that these Ris do not have multi-year funding guaranteed, and must re-negotiate their budget with the Ministry of Energy on yearly basis. This instability might contribute to a lack of freedom of research, as activities must be adapted yearly according to the needs and interests of the national state.

Besides the general militarized environments of the era, the 1950s is also considered a landmark period for ‘Big Science’ (Papon, 2004). Large-scale modern scientific facilities required major investments

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35 “Seventy-Five Years of Great Science”. https://www.ornl.gov/content/seventy-five-years-great-science#historical_overviews

and national prioritization. At the same time, RIs were seen as important for establishing modern, national industrial systems, boosting economic development, and for improving nations' status on the international stage. This is visible also for the Asian countries included in the landscape analysis. For example, the *Nuclear Power Institute of China* gains the reputation of "The Cradle of Nuclear Engineering in China" for making a great contribution to the national economy, and similarly, *Bhabha Atomic Research Centre* in India was planned as an effort to exploit nuclear energy for the benefit of the nation.

8.2. The Cooperation and Complementarity with the EU Energy RIs

It was clear from interviews that many countries, and RIs, take pride in self-developed facilities capable of competing with or complementing EU facilities. However, some of the same non-EU facilities attached great importance to the cooperation with EU RIs, e.g. eagerly highlighting their cooperative relationship with ITER.

As an example of the self-reliant, but cooperative mindset, China boasts of having become largely self-sufficient in reactor design and construction, and relative to the rest of the world, one of its major strengths is the nuclear supply chain[36]. Experimental Advanced Superconducting Tokamak (EAST), mainly designed and constructed by the *Institute of Plasma Physics, Chinese Academy of Science (IPP, CAS)*, is similar to ITER in shape and equilibrium, yet more flexible, and will be one of the few international devices that can serve as the experimental test bench for the related plasma science and technology research of ITER[37]. Therefore, *IPP* expects it will be followed closely by European researchers during the next decade.

In South Korea, *National Fusion Research Institute (NFRL)* has constructed a world-class fusion research device named Korea Superconducting Tokamak Advanced Research (KSTAR) with domestic technology. It also gets involved in the ITER Korea Project which has a long timeline until 2042 and beyond.

JSC "SSC RIAR" in Russia sees itself as outstanding due to its unique research and production facilities which have contributed to scientific studies in various fields, such as reactor tests, radiochemistry, fuel cycle closure, and minor actinide treatment, and the development of new nuclear fuels and materials. **JSC "SSC RIAR"** cooperates with the EU by carrying out research for individual enterprises and scientific organizations in Europe based on commercial contracts. It claims to be interested in further developing cooperation with European scientific institutions, for example for bilateral commercial contracts for research, the implementation of joint research projects (under the auspices of the IAEA, OECD NEA, and other organizations), as well as the organization of radioisotope products supply.

Open Pool Australian Lightwater (OPAL) reactor, the centerpiece of the *Australian Nuclear Science and Technology Organization (ANSTO)*, is a state-of-the-art 20-megawatt multi-purpose reactor that uses low-enriched uranium (LEU) fuel. OPAL is one of the small number of reactors around the world with the capacity to produce commercial quantities of radioisotopes. Other similar production facilities are the Safari-1 reactor in South Africa and the HFR reactor at Petten in the Netherlands. These reactors play a vital role in producing radioisotopes for cancer detection and treatment, and neutron beams for fundamental materials research[38].

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36 https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx
37 http://english.ipp.cas.cn/rh/east/
38 https://www.ansto.gov.au/research/facilities/opal-multi-purpose-reactor

Another energy domain in which EU RIs can seek cooperation opportunities and complementarity is renewable energy, or to be specific, bioenergy. ESFRI Strategy Report and Roadmap 2018 points out the need for EU RIs to make advancements in the production of biofuels (ESFRI Strategy Report and Roadmap 2018: 55). The non-EU RIs included in this report which conducts research in bioenergy are **NRC EME** (Canada), *NBC, NREL* (the USA), *SRNL* (the USA), **CNPEM** (Brazil), as well as *DTB-ICGEB* (India).

8.3. Nuclear Energy vs. Renewable Energy

Both nuclear energy and renewable energy are seen as essential for the replacement of fossil fuels and the reduction of global energy-related CO_2 emissions. While renewable energy may be seen as the more preferable choice (faster to market, more flexibility, fewer safety concerns, no nuclear waste disposal concerns, etc.), the analysis shows a lot stronger RI presence for nuclear energy. This can probably be explained by specific technology characteristics – nuclear energy requiring very high up-front investments, long timeframes, national prioritizations, etc. – it also provides an interesting potential contrast between stated energy policy preferences and energy *RI* policy and investments.

It is also noteworthy that several international collaborations exist for nuclear energy technologies. Among the RIs included in this domain report, *Solar Energy Research Centre for India and the United States* (SERIIUS) is on the other hand the only transnational organization for renewable energy research. SERIIUS has joint funding from both India and the USA, under the endorsement of India's Jawaharlal Nehru National Solar Energy Mission and the USA Department of Energy's SunShot Initiative. Through cooperation and innovation "without borders", *SERIIUS* has a promising prospect in developing revolutionary solar electricity technologies.

8.4. Different ways of organization

Most of the RIs in this domain report primarily employ their own researchers and conduct self-developed research. However, some RIs, instead of employing their own researchers, conduct research by coordinating and integrating the technological capabilities and research abilities of other academia, government, and industry. **Stanford Precourt Institute for Energy** (the USA), *MIT Energy Initiative* (the USA), *The New Energy and Industrial Technology Development Organisation* (Japan), and *Australian National Fabrication Facility* (Australia) are such kinds of RIs. The advantages of this organizational approach are various: one RI can pool resources and know-how from numerous partners; RIs can promote collaborations with industry and government, and they enable their users' access to a larger scale of services. However, this kind of network-based organizational structure can make it difficult to decide whether or not they fit the 'label' of being RIs.

8.5. Converting Scientific Research into Social Benefits

Research Infrastructure, as its name and definition imply, has science or research as its core. In addition, many RIs attach great importance to the application of their research to practice, benefiting the public through product updates, training programmes, and industrial upgrading. Among them, Hainan New Energy Research Centre, as part *of the Institute of Plasma Physics, Chinese Academy of Science (ASIPP)*, is one example that forms a complete chain from basic research to industrialization. *NEDO* in Japan has been offering support for practical applications in renewable energy and welfare equipment fields. *DBT-ICGEB* in India organizes various workshops and training programmes. *Centre of Excellence in Exciton Science, Australian Research Council* recognizes translating research into commercially viable products and services as one of its proclaimed core drivers.

8.6. Other Specific Services Provided by the RIs

In addition to the regular services provided by most of the RIs, such as access to facilities and technological applications, some RIs provide the government and the public with specific services in accordance with their missions and organizational structures.

The **Japan Atomic Energy Agency** (**JAEA**), with the operation of its Nuclear Emergency Assistance and Training Centre (NEAT), offers the government and the public technical advice and support in the emergence of a nuclear or radiological incident. In response to requests from the national and local governments, NEAT takes the responsibility for dispatching experts, providing equipment, and supporting emergency monitoring in case of nuclear incidents. To make emergency measures and preparation more effective, NEAT conducts training for the protection of people who will be involved in the nuclear emergency response from radioactive exposures and contamination. The training center also contributes to improving the nuclear disaster prevention system by participating in the nuclear disaster prevention drills implemented by the national and local governments. Considering the shortcomings of nuclear energy mentioned above, NEAT provides a valuable practice that could be used as an example for other RIs in terms of nuclear disaster countermeasures.

9. LISTS OF THE RIS

Table 4. *The list of RIs and contact information.*

Country	Sub-domain	Long name	Short name	How information was collected	Web-page	Further contact information
Russia	nuclear energy	Joint Stock Company “State Scientific Center Research Institute of Atomic Reactors”	JSC "SSC RIAR"	interview, online survey	http://niiar.ru/eng	Fedor GRIGORYEV, Deputy Director for Development and International Activities. Email: adm@niiar.ru
Russia	nuclear energy	Russian-Italian Project of Tokamak IGNITOR	IGNITOR	website	http://eng.nrcki.ru/pages/eng/international_megaprojects/ignitor/index.shtml	no data
Canada	renewables, energy systems integration	National Research Council Canada Energy, Mining and Environment Research Centre	NRC EME	online survey	https://nrc.canada.ca/en/research-development/research-collaboration/research-centres/energy-mining-environment-research-centre	James McKinnell; Strategy Advisor for NRC EME, james.mckinnell@nrc-cnrc.gc.ca
Canada	renewables	Wind Engineering, Energy and Environment Research Institute	WindEEE	online survey	http://www.windeee.ca	Horia Hangan, Director, hmhangan@uwo.ca
Canada	renewables	Fundy Ocean Research Centre for Energy	FORCE	website	http://fundyforce.ca/	no data
Canada	nuclear energy	Canadian Nuclear Laboratories	CNL	website	http://www.cnl.ca/en/home/default.aspx	no data
USA	nuclear energy, renewables, cross-sectional	Oak Ridge National Laboratory	ORNL	website	https://www.ornl.gov/	no data
USA	nuclear energy, renewables, energy systems integration	Sandia National Laboratories	SNL	website	https://energy.sandia.gov/energy/	no data
USA	renewables	National Renewable Energy Laboratory	NREL	website	https://www.nrel.gov/	no data
USA	energy systems integration	Pacific Northwest National Laboratory	PNNL	online survey	www.pnnl.gov	Malin Young, Deputy Lab Director for Science and Technology, malin.young@pnnl.gov
USA	cross-sectional	Lawrence Berkeley National Laboratory	LBNL	website	https://www.lbl.gov/	no data
USA	nuclear energy	DIII-D National Fusion Facility	DIII-D NFF	website	http://www.ga.com/diii-d	no data
USA		National Energy Technology Laboratory	NETL	website	https://www.netl.doe.gov/	no data
USA	nuclear energy	Idaho National Laboratory	INL	website	https://inl.gov/	no data
USA	nuclear energy, renewables, cross-sectional, efficient energy conversion, and use	Savannah River National Laboratory	SRNL	website	https://srnl.doe.gov/	no data

USA	efficient energy conversion and use, energy systems integration, renewables, nuclear energy, cross-sectional	MIT Energy Initiative	MITEI	website	http://energy.mit.edu/	no data
USA	renewables, nuclear energy, energy systems integration, efficient energy conversion, and use	Stanford Precourt Institute for Energy	Stanford Energy	online survey	https://energy.stanford.edu/	Maxine Lym, Senior Manager - Outreach and Communications, maxlym@stanford.edu
Brazil	nuclear energy	Centro de Desenvolvimento da Tecnologia Nuclear	CDTN	Face-to-face interview, online survey	http://www.cdtn.br/en	Daniel de Almeida Magalhães Campolina; Luiz Claudio Andrade Souza
Brazil	renewables	Brazilian Centre for Research in Energy and Materials	CNPEM	Face-to-face interview, online survey	http://cnpem.br/	Patricia Toledo - patricia.toledo@cnpem.br
Brazil	nuclear energy, renewables	Instituto de Pesquisas Energéticas e Nucleares	IPEN	Face-to-face interview, online survey	https://www.ipen.br/portal_por/portal/interna.php?secao_id=723	Responsible person for Internationalization: Dr. Isolda Costa <icosta@ipen.br>
China	nuclear energy, cross-sectional	Institute of Plasma Physics, Chinese Academy of Science	ASIPP	website	http://english.ipp.cas.cn/	no data
China	nuclear energy, cross-sectional	Nuclear Power Institute of China	NPIC	website	http://en.npic.ac.cn/	no data
China	nuclear energy, cross-sectional	Shanghai Synchroton Radiation Facility	SSRF	website	http://e-ssrf.sinap.cas.cn/	no data
China	renewables	Institute of Electrical Engineering, Chinese Academy of Science	IEE, CAS	website	http://english.iee.cas.cn/intro/	no data
Japan	nuclear energy	Japan Atomic Energy Agency	JAEA	online survey	https://www.jaea.go.jp/english/	Kazumasa HIOKI, hioki.kazumasa@jaea.go.jp
Japan	cross-sectional	Global Research Centre for Environment and Energy Based on Nanomaterials Science	GREEN	website	https://www.nims.go.jp/GREEN/en/index.html	no data
Japan	renewables, efficient energy conversion and use, cross-sectional	Research Institute for Energy Conservation, The National Institute of Advanced Industrial Science and Technology	iECO, AIST	online survey	https://unit.aist.go.jp/ieco/en/	Fumio TAKEMURA, Dr. takemura.f@aist.go.jp
Japan	renewables	The New Energy and Industrial Technology Development Organisation	NEDO	website	https://www.nedo.go.jp/english/index.html	no data
Japan	renewables	Advanced Low Carbon Technology Research and Development Programme	ALCA	website	http://www.jst.go.jp/alca/en/	no data
India	nuclear energy, cross-sectional	Bhabha Atomic Research Centre	BARC	website	http://www.barc.gov.in/index.html	no data

India	renewables	Solar Energy Research Cente for India and the United States	SERIIUS	website	https://www.seriius.org/	no data
India	renewables	DTB-ICGEB Centre for Advanced Bioenergy	DTB-ICGEB	website	http://icgeb-bio-energy.org/	no data
South Korea	nuclear energy	National Fusion Energy Institute	NFRI	website	https://www.nfri.re.kr/eng/index	no data
Australia	nuclear energy	OPAL at Australian Nuclear Science and Technology Organization	OPAL (ANSTO)	Phone interview, online survey	https://www.ansto.gov.au/	Miles Apperley, milesa@ansto.gov.au
Australia	energy systems integration	Centre of Excellence in Exciton Science, Australian Research Council	no short name	website	https://excitonscience.com/	no data
Australia	cross-sectional	Australian National Fabrication Facility	ANFF	website	http://www.anff.org.au/	no data

Table 5. *Basic information about RIs.*

Country	Sub-domain	Long name	Short name	When it was commissioned/operations started	Construction costs	Operation costs (per annum)	Type)
Russia	nuclear energy	Joint Stock Company “State Scientific Center Research Institute of Atomic Reactors”	JSC "SSC RIAR"	RIAR was established in 1954, and testing facilities were mainly commissioned in the 60s-80s	10 billion euro	120 million euro	single-sited
Russia	nuclear energy	Russian-Italian Project of Tokamak IGNITOR	IGNITOR	no data	no data	no data	no data
Canada	renewables, energy systems integration	National Research Council Canada Energy, Mining and Environment Research Centre	NRC EME	EME was established in 2012	13–14 billion euro	17 million euro	distributed
Canada	renewables	Wind Engineering, Energy and Environment Research Institute	WindEEE	WindEEE established in 2011, WindEEE Dome commissioned in 2014	30 million euro	no data	single-sited
Canada	renewables	Fundy Ocean Research Centre for Energy	FORCE	no data	the cost of the site selection: roughly 800–900 000 euros in research	no data	single-sited
Canada	nuclear energy	Canadian Nuclear Laboratories	CNL	CNL established in the 1940s	no data	no data	no data
USA	nuclear energy, renewables, cross-sectional	Oak Ridge National Laboratory	ORNL	Established in 1943	no data	no data	single-sited
USA	nuclear energy, renewables, energy systems integration	Sandia National Laboratories	SNL	Established in 1945	no data	no data	single-sited
USA	renewables	National Renewable Energy Laboratory	NREL	no data	no data	no data	single-sited
USA	energy systems integration	Pacific Northwest National Laboratory	PNNL	Established in 1965	no data	no data	distributed

USA	cross-sectional	Lawrence Berkeley National Laboratory	LBNL	Founded in 1931	no data	The sum of annual operational budgets of basic energy research-related divisions + user facilities is: 160–170 mln euro	single-sited
USA	nuclear energy	DIII-D National Fusion Facility	DIII-D NFF	the mid 1980s	no data	no data	single-sited
USA		National Energy Technology Laboratory	NETL	no data	no data	no data	single-sited
USA	nuclear energy	Idaho National Laboratory	INL	since 1949			single-sited
USA	nuclear energy, renewables, cross-sectional, efficient energy conversion, and use	Savannah River National Laboratory	SRNL	established in 1951			single-sited
USA	efficient energy conversion and use, energy systems integration, renewables, nuclear energy, cross-sectional	MIT Energy Initiative	MITEI	since 2006	no data	no data	single-sited
USA	renewables, nuclear energy, energy systems integration, efficient energy conversion, and use	Stanford Precourt Institute for Energy	Stanford Energy	no data	no data	13–18 million euro	single-sited
Brazil	nuclear energy	Centro de Desenvolvimento da Tecnologia Nuclear	CDTN	established in 1974	300 million euro	3 million euro	single-sited
Brazil	renewables	Brazilian Centre for Research in Energy and Materials	CNPEM	established in 1997	800 million euros (considering Sirius, synchrotron light source)	25 million euros (w/o Sirius and w/o individual research grants), 70 million euros (including Sirius and w/o individual research grants)	single-sited
Brazil	nuclear energy, renewables	Instituto de Pesquisas Energéticas e Nucleares	IPEN	established in 1982	4–5 billion euro	59 million euro	single-sited
China	nuclear energy, cross-sectional	Institute of Plasma Physics, Chinese Academy of Science	ASIPP	established in 1978	no data	no data	single-sited
China	nuclear energy, cross-sectional	Nuclear Power Institute of China	NPIC	established in 1965	no data	no data	single-sited
China	nuclear energy, cross-sectional	Shanghai Synchroton Radiation Facility	SSRF	established in 2009	no data	no data	single-sited
China	renewables	Institute of Electrical Engineering, Chinese Academy of Science	IEE, CAS	established in 1963	no data	no data	single-sited
Japan	nuclear energy	Japan Atomic Energy Agency	JAEA	established in June 1956	100 billion euro	1.2 billion euro	distributed

Japan	cross-sectional	Global Research Centre for Environment and Energy Based on Nanomaterials Science	GREEN	established in October 2009	no data	no data	distributed
Japan	renewables, efficient energy conversion and use, cross-sectional	Research Institute for Energy Conservation, The National Institute of Advanced Industrial Science and Technology	iECO, AIST	established on 1 April 2015	no data	820 million euro	single-sited
Japan	renewables	The New Energy and Industrial Technology Development Organisation	NEDO	established in October 1980	no data	1.2–1.3 billion euro/ FY2019 Budget	distributed
Japan	renewables	Advanced Low Carbon Technology Research and Development Programme	ALCA	launched in 2010	no data	no data	distributed
India	nuclear energy, cross-sectional	Bhabha Atomic Research Centre	BARC	established in 1954 with the name of Atomic Energy Establishment, Trombay (AEET); Renamed BARC in 1966	no data	no data	single-sited
India	renewables	Solar Energy Research Cente for India and the United States	SERIIUS	no data	no data	22–23 mln euro for 5 years (50% India side+50% US side); 22–23 mln euro matching funds	distributed
India	renewables	DTB-ICGEB Centre for Advanced Bioenergy	DTB-ICGEB	established in March 2012	no data	no data	single-sited
South Korea	nuclear energy	National Fusion Energy Institute	NFRI	established in September 2002	no data	no data	distributed
Australia	nuclear energy	OPAL at Australian Nuclear Science and Technology Organization	OPAL (ANSTO)	established based on the Australian Atomic Energy Commission (AAEC) in 1987	300–350 million euro	20 million euro	The OPAL research reactor facility is single-sited. ANSTO is distributed.
Australia	energy systems integration	Centre of Excellence in Exciton Science, Australian Research Council	no short name	no data	no data	no data	single-sited
Australia	cross-sectional	Australian National Fabrication Facility	ANFF	established in 2007	no data	no data	single-sited

10. POSTFACE: Methodological Considerations

By *Mikkel Stein Knudsen & Marianna Birmoser Ferreira-Aulu*

RISCAPE was a pioneer study, and as it happens when one pursues brand new endeavors, there were some things that we, in retrospect, might have done differently compared to the expectations when the study was originally designed. We adapted and modified many of these elements already during the project period, although our flexibility was somewhat limited by still having to adhere to the original structure and funding of the project.

For RISCAPE, the European scientific community was the first stepping stone toward gathering international information. The project, therefore, relied on collecting *known* information from European colleagues. However, as RISCAPE set out to map the *unknown* landscapes, we also had an explicit target of uncovering information in parts of the world with which the European research community is less familiar. This required us to limit actively known biases. We knew we had a major risk of finding RIs only where we were specifically looking for them, and from the beginning of the project, we wanted to take efforts to minimize this risk of overlooking relevant information.

This quickly proved challenging. For example, for desk research and information gathering, a simple, but major methodological challenge was to look beyond only organizations with regularly updated English-language websites. This was a bigger issue than we had probably anticipated. Many organizations, even large-scale ones, do not seem to put much effort into general communication outreach to English-speaking audiences. We assume that these organizations find other avenues of reaching their global scientific audiences, but without updated websites, simple desk research yielded almost no valid information.

Even when we did have solid information and contacts in order, linguistic and cultural challenges proved more notable than assumed at the outset of the project. For the energy domain mapping, we, therefore, added researchers with various local cultural and language skills to the team. Native-tongue interviews were eventually conducted in English, Russian, Chinese, and Brazilian-Portuguese. There was a clear tendency among the answers that more detailed answers were given in the respondent's mother tongue compared to when respondents were forced to respond in English. Some interviews were also conducted face-to-face with visits to the international facilities, which provided the interviewer with a much richer understanding of the reality and environment of the surveyed RI.

We were the only work package involved in the RISCAPE project to actively engage in non-English information search. However, other work packages also struggled to various degrees with collecting sufficient data on e.g. Russian RIs, so we were not the only work package with the need for linguistic skills.

For similar international landscape analyses in the future, we, therefore, suggest putting more emphasis on cultural and linguistic skills, and on the ability to reach respondents within their own environment. This would most likely be at a cost of more simplified and systematic cross-field data collection, however, with the benefit of getting richer and more informative results.

Another recommendation we make for similar studies is to instead of having a predefined questionnaire with a terminology set by European policy documents, researchers should be open to listening to a wider narrative of experiences told from the point of view of the international RIs. Similarly, to enhance international RI collaboration, European organizations could also be advised to be open to meeting different organizational, legal, linguistic, and budgetary frameworks even within the same 'global research scientific community' of their given fields. It was very clear from our research that international organizations do not see the world through European eyes. Finally, and for the same reasons, it could be also considered to organize work packages of a landscape analysis project not by scientific fields, but by geographical location, perhaps with the aid of local experts in the region, rather than domain experts.

Having said this, we want to remind the reader that we experienced a lot of interest in our study among international RIs. For all the challenges we faced in speaking the same language – both literally and as a metaphor for using very different terminology – as our surveyed RIs, we did find a general enthusiasm for increasing international RI cooperation.

So the basis for further international cooperation between European and International RIs very much exists today, and we do believe a landscape analysis like RISCAPE provides a good introduction to new potential international partnerships.

REFERENCES

Amini, H., Jabalameli, M.S. & Ramesht, M. H. (2021). Development of regional foresight studies between 2000 and 2019: An overview and co-citation analysis. *European Journal of Futures Research*, 9(1).

Asmi, A. Ryan, L., Salmon, E., Kubiak, C., Battaglia, S., Förster, M., Dupré, J., Walter, H., Stirling, W. G., Clausen, K., Knudsen, M., Ferreira-Aulu, M., Shabanova-Danielyan, E., Wang, W., Luukkanen, J., Kaivo-oja, J., Baldovin, C., Timmer, M., van der Meer, R., Vermeulen, R., Versic, I., Niccolucci, F., Sipos, G., Piscitelli, R. & Sundet, J. (2019). *International Research Infrastructure Landscape 2019*. Available at www.riscape.eu, https://10.5281/zenodo.3539254.

Caliari, T., Rapini, M. S. & Chiarini, T. (2020). Research infrastructures in less developed countries: the Brazilian case. *Scientometrics*, 122: 451–475.

Castelnovo, P., Florio, M., Forte, S., Rossi, L. & Sirtori, E. (2018). The economic impact of technological procurement for large-scale research infrastructures: Evidence from the Large Hadron Collider at CERN. *Research Policy*, 47(9): 1853–1867.

Cramer, K.C. (2020). *A Political History of Big Science*: *The Other Europe*. Cham: Palgrave Macmillan.

Cramer, K.C. & Hallonsten, O. (2020). *Big Science and Research Infrastructures in Europe*. Cheltenham: Edward Elgar Publishing Limited.

Cramer, K.C., Hallonsten, O., Bolliger, I. K. & Griffiths, A. (2020). Big Science and Research Infrastructures: History and Current Trends. In Cramer, K.C. & Hallonsten, O. (eds.) *Big Science and Research Infrastructures in Europe*. Cheltenham: Edward Elgar Publishing Limited.

Department of Science and Technology (2016). *South African Research Infrastructure Roadmap. First Edition.* Available at http://www.hsrc.ac.za/uploads/pageContent/7451/SARIR_2016.pdf

D'Ippolito, B. & Rüling, C.-C. (2019). Research collaboration in Large Scale Research Infrastructures: Collaboration types and policy implications. *Research Policy,* 48(5): 1282–1296.

European Strategy Forum on Research Infrastructures (ESFRI) (2016). *Roadmap 2016. Strategy Report on Research Infrastructurues.* Available at https://www.esfri.eu/sites/default/files/20160308_ROADMAP_single_page_LIGHT.pdf

European Strategy Forum on Research Infrastructures (ESFRI) (2018). *Roadmap 2018. Strategy Report on Research Infrastructurues.* Available at http://roadmap2018.esfri.eu/media/1066/esfri-roadmap-2018.pdf

Fortin, J.M. & Currie, D.J. (2013). Big Science vs. Little Science: How Scientific Impact Scales with Funding. *PLOS One,* 8(6).

Group of Senior Officials on Global Research Infrastructures (GSO) (2017). *Progress Report 2017*. Available at http://www.gsogri.org/wp-content/uploads/2019/12/gso_progress_report_2017.pdf

Hallonsten, O. (2014). The Politics of European Collaboration in Big Science. In Mayer, M., Carpes, M. & Knoblich, R. (eds.): *The Global Politics of Science and Technology – Vol. 2.* Berlin: Springer.

Hallonsten, O. (2015). Unpreparedness and risk in Big Science policy: Sweden and the European Spallation Source. *Science and Public Policy*, 42: 415–426.

Heino, H. & Hautala, J. (2021). Mobile futures knowledge: From research policy to research and public policy? *Geoforum,* 118: 83–92. https://doi.org/10.1016/j.geoforum.2020.12.007

Kaivo-oja, J. & Knudsen, M. S. (2017). Draft list of key international Research infrastructures, selected methodologies and proposed aspects of complementarities to analyse in the energy sector. Deliverable 6.1. Available from https://cordis.europa.eu/project/id/730974/results

Kaldewey, D. (2018). The Grand Challenges Discourse: Transforming Identity Work in Science and Science Policy. *Minerva,* 56: 161–182.

Knudsen, M. S., Ferreira-Aulu, M. B., Shabanova-Danielyan, E., Wang, W., Luukkanen, J. & Kaivo-oja, J. (2019). *Draft Landscape analysis report in the energy sector. RISCAPE Deliverable D6.2.* Available from https://cordis.europa.eu/project/id/730974/results

Knudsen, M. S., Ferreira-Aulu, M. B., Kaivo-oja, J. & Luukkanen, J. (2021). Energy Research Infrastructures in Europe and Beyond: Mapping an Unmapped Landscape. *European Integration Studies*, 15. https://doi.org/10.5755/j01.eis.1.15.28840.

Krznaric, R. (2020). *The Good Ancestor*. London: W.H. Allen.

Li-Ying, J., Forneris, J., Korsholm, S. B., Jensen, A. & Zangenberg, N. (2021). How European Big Science Organizations and Suppliers Innovate through Public Procurement. *Research-Technology Management*, 64(2): 46–56.

Mapping of the European Infrastructure Landscape (MERIL) (2021). Database availalble at https://portal.meril.eu/meril/

Moskovko. M., Astvaldsson, A., & Hallonsten, O. (2019). Who is ERIC? The Politics and Jurisprudence of a Governance Tool for Collaborative European Research Infrastructures. *Journal of Contemporary European Research*, 15(3).

Papon, P. (2004). European Scientific Cooperation and Research Infrastructures: Past Tendencies and Future Prospects. *Minerva*, 42: 61–76.

Shidore, S., & Busby, J. W. (2019a). One more try: The International Solar Alliance and India's search for geopolitical influence. *Energy Strategy Reviews*, 26: 100385.

Shidore, S., & Busby, J. W. (2019b). What explains India’s embrace of solar? State-led energy transition in a developmental polity. *Energy Policy*, 129: 1179–1189. https://doi.org/10.1016/j.enpol.2019.02.032

APPENDIX: Contact Strategy

1. *Strategy for Engagement*

In contacting the identified non-EU Research Infrastructures for Work Package 6 of the RISCAPE project, firstly e-mails were sent out to invite the RIs to collaborate through answering the questionnaire/taking an interview. The need is underlined for a continuous effort in engaging RIs in case there is no immediate response, and thus max four contact attempts for each RI are made following the strategy below:

The first attempted contact: E-mail with official invitation letter based on the RISCAPE cover letter-template attached.

The second attempted contact: If the first contact does not lead to response, a follow-up e-mail will be sent 14 days later.

The third attempted contact: If there is still no response, we will try to follow up with a phone call seven days later than the second attempted contact.

The fourth attempted contact: If there is still no response, a fourth and final follow-up e-mail will be sent seven days later. This e-mail will contain a seven-day deadline for contributing to the project.

All contact attempts are recorded in a database.

Prioritizing RIs

In order to maximize the value gathered from the questionnaire/the interview, and to optimise the possibility of learning from the engagements, contacts were first carried out with the RIs from English-speaking countries. In order to begin gathering information from places assumed to be 'easy' and then undertaking tasks with more challenges later, contacts with the RIs in the United States of America were postponed. Thus, the first RIs contacted were from Canada and Australia.

Revision of Contact Strategy

In the initial stage of contact, invitation e-mails were all sent in English. However, as experience gained from contacting the Brazilian RIs in Portuguese by Marianna Birmoser Ferreira-Aulu has shown, the RIs from non-English speaking countries tended to be more willing to respond if the invitation was sent in their native language. Therefore, the need was recognized to recruit Elizaveta Shabanova-Danielyan and Weiqing Wang into the research team as they are respectively the native speaker of Russian and Chinese. The invitation e-mail for the first contact attempt was also translated into Russian and Chinese.

Interviews

After the RIs fill in the questionnaire, in case of unclear answers from the respondents, they were invited for an interview so that the research team could make clarification of the questions and thus obtain better answers.

Interviews have been carried out by Marianna Birmoser Ferreira-Aulu, Mikkel Stein Knudsen, Elizaveta Shabanova-Danielyan and Weiqing Wang.

Interviews were organized with two interviewers presenting each time during the first round of interviews. This was also necessitated due to language or logistical reasons. These preliminary interviews turned out to be successful, and thus single-person interviews became possible as the project advanced.

Templates of the Invitation E-mail for the First Contact in English, Portuguese, Russian and Chinese

A template of the invitation e-mail was firstly drafted in English, and then the team members translated them into Portuguese, Russian and Chinese. These templates are attached in the following:

Contact e-mail in English

Dear [title, name, organization],

My name is [**name], and I work for Finland Futures Research Center, in the University of Turku-Finland.

On behalf of my research team and Research Director Dr. Jari Kaivo-oja, I am writing to invite [**name of institution] to collaborate with the project RISCAPE (European Research Infrastructures in the International Landscape) funded by European Union's Horizon2020. The project aims at mapping the world's major Research Infrastructures (RIs) across eight fields of science, and assessing how European research infrastructures fit the international landscape. You can read more about the RISCAPE project here: http://riscape.eu/

In the RISCAPE, my team is responsible for the work package on Energy Research Infrastructures. We recognize that [**name of institution] is one important RI in energy research field, and we plan to include information about it in our report. In order to make sure that the information is accurate, we would like to collect it directly from an expert of your organization. We kindly ask for your collaboration by answering an on-line questionnaire which can be found in the link: [link]

Please share the link with colleagues to fill in specific information, if necessary, and you may refuse to answer any questions without explaining the reason. Please note that the deadline to answer the questionnaire is [**date]. The results from this questionnaire will be incorporated into our report for the European Commission in 2019. You will also have access to the report once it is published. The report will serve as an important guideline for international research and innovation collaborations, especially the upcoming EU framework programs.

After you fill out the questionnaire, if it is possible, we would also ask you for a Skype meeting or phone call as followed-up conversation in [**language]. In the conversation we can go through questions which need further clarification. We estimate that this will take no longer than one hour. In the end, you will have the opportunity to check that all the information is correct.

Please find attached a formal invitation letter from the consortium leader, Dr. Ari Asmi, and Energy RI work package leader, Research Director, Dr. Jari Kaivo-oja.

We hope you have an interest, time and opportunity to contribute. If you have any questions, please do not hesitate to contact us.

Thank you in advance, and I look forward to hearing from you soon.

[**name]

[**title]

Finland Futures Research Centre, University of Turku

[**Tel]

Contact e-mail in Portuguese

Caro ...(título, nome)...

Meu nome é [**name], e sou pesquisadora brasileira no Centro de Pesquisa de Futuros da Finlândia (Finland Futures Research Centre), departamento da Universidade de Turku.

Em nome do Diretor de Pesquisa Dr. Jari Kaivo-oja, e do projeto de pesquisa RISCAPE (European Research Infrastructures in the International Landscape), escrevo-lhe para convidar a ...(nome da organizacão)... para uma entrevista, a qual o resultado será incluído no nosso mapeamento internacional de infraestruturas de pesquisa.

O projeto RISCAPE é financiado pelo H2020 da União Européia, e tem como objetivo mapear as principais infraestruturas de pesquisa (Research Infrastructures -RIs) do mundo em oito campos da ciência, e avaliar como as infraestruturas de pesquisa européias se encaixam no panorama internacional. O trabalho final será apresentado em forma de um relatório à ser apresentado à União Européia, e será uma importante diretriz para colaborações internacionais de pesquisa e inovação.

O RISCAPE é um consórcio no qual diversas universidades européias colaboram. Nós, da Universidade de Turku-Finlândia, somos responsáveis pelo pacote de trabalho sobre Infraestruturas de Pesquisa Energética. Com base em nossa pesquisa inicial, pré-selecionamos uma série de instituições RIs importantes e relevantes para nossos propósitos.

Reconhecemos que a sua organização é uma delas, e esperamos poder incluí-los em nosso mapa. Para isso, precisamos coletar algumas informações sobre a sua instituição, e convidamos o senhor para uma entrevista. O método de pesquisa é uma entrevista estruturada, ou seja, as perguntas serão fornecidas de antemão para que possam se preparar, e então, a entrevista em si será uma conversa na qual percorremos pergunta por pergunta, possibilitando-nos um esclarecimento do contexto, e quando necessário, permitindo-nos um aprofundamento em diferentes assuntos. Estimamos que as entrevistas levem aproximadamente uma hora e, ao final, o senhor terá a oportunidade de verificar se todas as informações estão corretas.

As informações serão armazenadas com segurança e o senhor pode se recusar a responder a quaisquer perguntas sem precisar explicar o motivo. As respostas serão analisadas pelo projeto RISCAPE e serão publicadas em um relatório em 2019, ao qual, naturalmente, os senhores terão acesso. Esperamos que os senhores tenham interesse, tempo e oportunidade para contribuir.

Estarei no Brasil por conta do projeto RISCAPE nos meses de dezembro/2018 e janeiro/2019. Espero poder marcar a entrevista durante esse tempo, e quem sabe, fazer uma visita à sua instituição. Caso os meses de dezembro e janeiro não lhes sejam adequados, podemos fazer a entrevista por telefone ou Skype conforme as suas preferências e possibilidades, podendo ser agendada com de acordo com o seu calendário (neste caso, por favor, leve em consideração a diferença de fuso-horário com a Finlândia).

Caso o senhor considere que outra pessoa dentro de sua organização seja melhor qualificado para participar desta entrevista, por favor informe-nos e /ou encaminhe este e-mail à seu/sua colega.

Em anexo se encontra uma carta convite formal (em inglês) do líder do consórcio, Dr. Ari Asmi, e do líder do pacote de trabalho sobre Instraestruturas de pesquisa de energia, Dr. Jari Kaivo-oja.

Leia mais sobre o projeto RISCAPE neste link: http://riscape.eu/

Aguardo seu contato em breve. Se tiver alguma pergunta, por favor, não hesite em nos escrever.

Obrigada desde já,

[**name], [**title]

Finland Futures Research Centre, University of Turku

[**Tel]

Contact e-mail in Russian

Уважаемый [title, name, organization]

Меня зовут [**name], я работаю в Центре Исследований Будущего Университета Турку (Финляндия).

От имени моей рабочей группы и директора по исследованиям д-ра Яри Кайво-оя, я приглашаю [**name of institution] принять участие в исследовательском проекте RISCAPE (European Research Infrastructures in the International Landscape - Европейские научно-исследовательские инфраструктуры на международном ландшафте). Проект финансируется в рамках программы Европейского Союза по развитию исследований и инноваций Horizon 2020. Целью проекта является описание наиболее значимых в мире научно-исследовательских инфраструктур по 8 научным направлениям и оценка того, какое место занимают европейские научно-исследовательские инфраструктуры в мире. Более подробную информацию о проекте Вы можете получить на сайте: http://riscape.eu/

Рабочая группа, которую я представляю, в рамках проекта RISCAPE ответственна за изучение научно-исследовательских инфраструктур в области энергетики. Мы рассматриваем [**name of institution] в качестве научной организации, обладающей мировой значимостью в этой области. Мы планируем включить информацию о Вашей организации в отчет. Частично данная информация доступна на Вашем сайте в Интернет, однако, мы должны убедиться, что используем самые актуальные и достоверные данные. Поэтому мы хотели бы провести интервью с Вами (или другим представителем [**института, центра – вставить нужное], который обладает экспертными знаниями об организации). Интервью предполагает заполнение электронной анкеты (на английском языке), которая находится по ссылке: [link].

Вы можете поделиться данной ссылкой с коллегами для заполнения отдельных секций анкеты, если в этом есть необходимость. Вы также можете отказаться отвечать на вопросы на любом этапе заполнения анкеты и данные о Ваших ответах будут удалены. Мы просим Вас завершить заполнение анкеты до 31 мая 2019 года включительно.

После того как Вы заполните электронную анкету, мы хотели бы дополнительно провести интервью в устной форме на русском языке (с помощью программы Skype), если у Вас будет для этого возможность. Проведение устного интервью позволило бы нам уточнить детали Ваших ответов, при необходимости углубиться в отдельные темы. По нашим оценкам, интервью в устной форме займет около 1 часа. По итогам интервью Вы сможете лично проверить, что все Ваши ответы достоверно записаны.

Результаты, полученные в рамках данного интервью, будут включены в отчет для Европейской Комиссии, работу над которым планируется завершить к концу 2019 года. Вы сможете ознакомиться с данным отчетом, когда он будет опубликован. Отчет будет использоваться в дальнейшем для принятия решений о международном сотрудничестве в области исследований и инноваций в будущих программах Европейского Союза.

В приложении Вы найдете официальное пригласительное письмо (на английском языке) от лидера исследовательского консорциума проекта RISCAPE д-ра Ари Асми и лидера рабочей группы по исследованиям научно-исследовательских инфраструктур в области энергетики, директора по исследованиям д-ра Яри Кайво-оя.

Мы надеемся на вашу заинтересованность и возможность поучаствовать в проекте. В случае возникновения любых вопросов, пожалуйста, свяжитесь с нами.

[**name], [**title]

Finland Futures Research Centre, University of Turku, [**Tel]

Contact e-mail in Chinese

尊敬的（职位，姓名，机构名称）：

您好！我叫 [姓名] 是芬**兰图尔库大学的芬兰未来研究中心的一名工作人员。

我谨代表我的研究团队和主任亚利先生，邀请贵单位 **[**院、所] 参与到我**们名为 RISCAPE **的研究**项目中来 （**即** European Research Infrastructures in the International Landscape, **"国**际环境中的欧洲研究设施"）。RISCAPE 项目是在欧盟的**"地平**线 2020" （**即** EU's Horizon2020）计划支持下进行的，旨在了解全球的主要科研基础设施，并对国际环境中欧洲的科研基础设施做进一步评估。您可在此了解更多关于 RISCAPE 项目的信息：http://riscape.eu/

在此项目中，我的团队主要负责关于全球能源研究基础设施的调查。经筛选，**我**们认为贵单位 **[**院、所] 与我**们的项目密切相关，并且计划在我们的研究报告中写入对贵单位 **[**院、所] 的**调查信息。为确保信息的准确性，我们希望可以直接从贵单位 **[**院、所] 收集相关信息。因此，我**们诚切地邀请贵单位 **[**院、所] 参与其中，并填写我**们的一个调查问卷：（问卷链接）

谨提醒您，问卷填写的截止日期是 **[**截止日期] 日。如有必要**，请您将问卷链接分享给相关同事以便填写某些专业信息。您有权拒绝回答某些问题，且无需提供理由。我们会将您的回答涵括在 2019 **年提交**给欧盟委员会的报告中，并在报告发表后给您发送一份副本。这份报告会对我们未来的国际研究，创新与合作具有重要的指导意义。

如果方便的话，我也希望可以有机会以中文为工作语言，就问卷中的问题对贵单位 **[**院、所]** 进行远程采访以作进一步了解。在采访中我们可以向您逐一阐析不明确的问题。预计远程采访会进行不超过一个小时的时间，最后您还可以复查所填信息是否正确。

另外在此附上了我们研究集团领导艾力先生以及 RISCAPE **能源方向研究主任**亚利先生的正式邀请信，请您查收。

我们诚切地希望贵单位 **[**院、所] 加入到我**们的研究中来。如对问卷有任何问题，欢迎您来信咨询。我们期待您的回复。

[**姓名]
RISCAPE **能源研究工作**组成员
2019 **年五月**

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