

Danish Roadmap for Research Infrastructures 2015



Ministry of Higher Education
and Science

—
Danish Agency for Science,
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Bredgade 40
1260 Copenhagen K
Denmark
Phone: +45 3544 6200
Email: fi@fi.dk
www.ufm.dk/en

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Introduction

1. Introduction

Research infrastructure is the collective term for a wide variety of equipment, measuring instruments, test facilities, databases, laboratory facilities, test plants, supercomputers and other tools and resources employed in research processes and in generating new knowledge. Research infrastructure may be in the form of a single-sited physical facility (a single resource at a single location, whether static or mobile); a distributed network (comprising collections, laboratories or measuring stations); or a virtual facility (offering online access).

Research infrastructure is utilised within all of the main scientific disciplines, but takes different forms from one discipline to the next. One common denominator, however, of all types and forms of contemporary and advanced research infrastructures is that they constitute an essential 'tool box' for developing and supporting Danish research, education and innovation at an internationally competitive level. This gives them a key role in boosting Danish knowledge and growth.

Danish researchers need access to state-of-the-art facilities in order to sustain their ranking among the global elite in the future. Equally, access to up-to-date research infrastructure is a competitive parameter in the retention and recruitment of top students and researchers, while research infrastructures also serve as hubs for knowledge, innovation and technology transfer between research and industry.

The present Roadmap was developed by the Danish Ministry of Higher Education and Science as a strategic delineation of future research infrastructure initiatives.

A national strategy is important in addressing some of the structural challenges currently shaping research infrastructure policy, and which are causing key decisions on research infrastructure to tend in favour of national-level coordination. The present publication, "Danish Roadmap for Research Infrastructure 2015", consequently presents the Danish Ministry of Higher Education and Science's vision and strategic objectives for this policy area over the coming five years. At the same time, it presents a catalogue of specific proposals for national infrastructures, which in the short term are recommended as investment prospects.

Chapter 2 elaborates on the potential and significance of research infrastructure for research, education, innovation and growth. This chapter also sets out a number of challenges that lead into the presentation of the Ministry's vision and eight strategic objectives towards 2020 in Chapter 3. These will pave the way for the Ministry's research infrastructure initiatives in the coming years. Chapter 4 contains a catalogue of 22 specific proposals for research infrastructures of national significance; see Text Box 1.1 below.

The Roadmap and its catalogue were compiled on the basis of active involvement by and dialogue with Danish universities and other national research institutions, and replace the previous Danish Roadmap for Research Infrastructure from 2011.

TEXT BOX 1.1: CATALOGUE PROPOSALS BY PRIMARY SCIENTIFIC FIELD

Biotech, Health and Life Sciences

- COLLECT – Centre for Cell Analysis and Cell-Based Therapy
- DaBiS – Danish Biological Sample Preparation Facility
- DBN – Danish Bioimaging Network
- DK-OPENSREEN – Danish research infrastructure for chemical biology
- EMBION – CryoEM research infrastructure for biological nanostructures
- FOODHAY – Open Innovation FOOD and Health laboratory
- INSPECT – Danish Instrument Centre for Interdisciplinary NMR Spectroscopy
- MedBio-BigData – Medical bioinformatics platform
- PRO-MS – Danish National Mass Spectrometry Platform for Functional Proteomics

Energy, Climate and Environmental Sciences

- AnaEE Denmark – Infrastructure for experimental ecosystems research in Denmark
- HydroObs – Agro-hydrological and hydro-biogeochemical observatories
- ICOS/DK – Danish infrastructure for measuring atmospheric greenhouse gas emissions and ecosystem exchange processes
- UAS-ability – Research infrastructure for the use of unmanned aerial systems (drones) for data collection
- WindScanner.eu – The European WindScanner Facility
- X-Power – Power Electronics Reliability Test Facilities

Physical Sciences

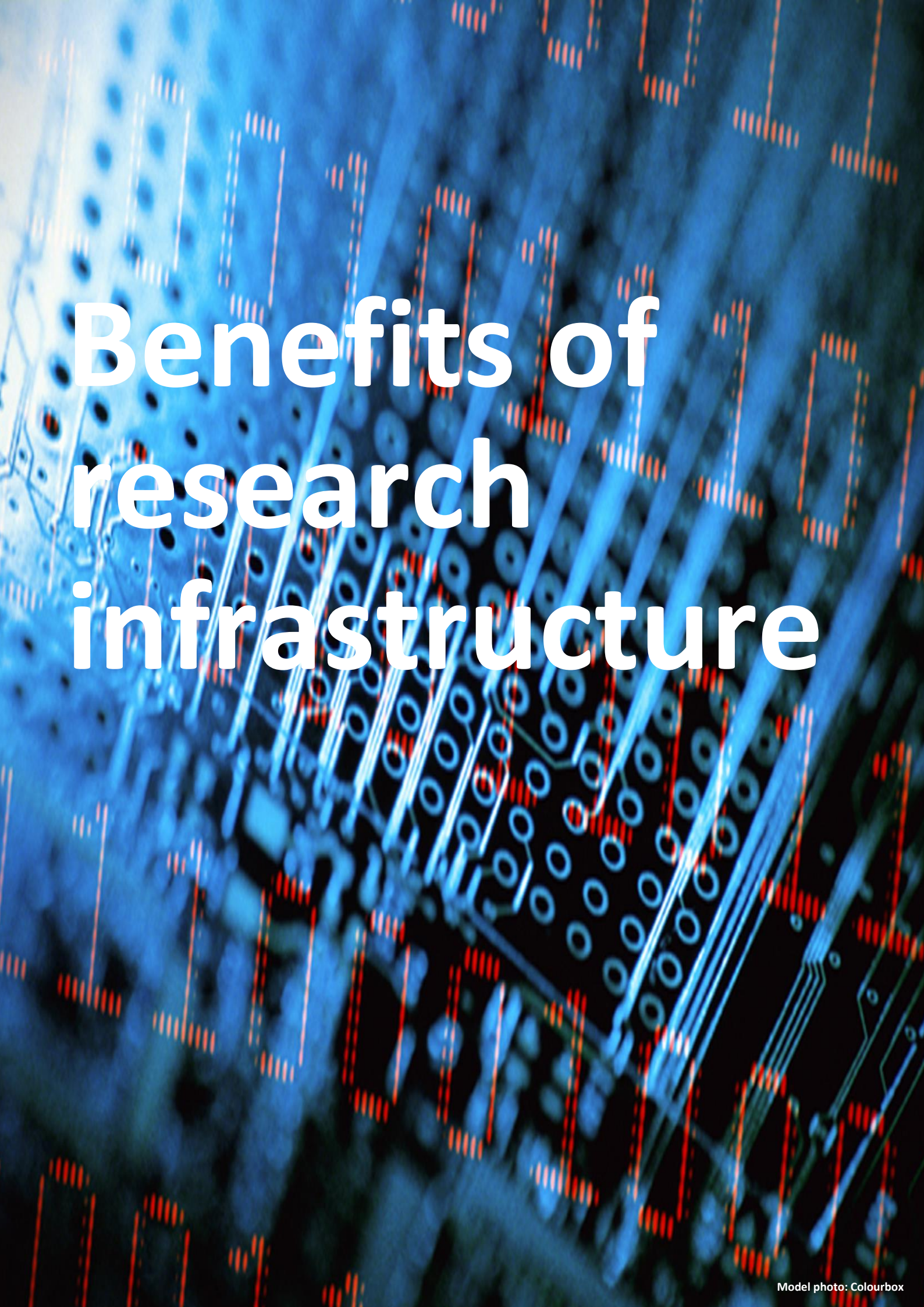
- CERN-UP – Upgrading infrastructure for CERN experiments and computing
- QUANTECH – Quantum Technology Infrastructure Proposal

Humanities and Social Sciences

- BICLabs – Behaviour, Interaction and Cognition Labs
- DigHumLab 2.0 – Digital Humanities Lab Denmark
- DRDS – Danish Research Data for the Social Sciences

Materials Technology and Nanotechnology

- DANFIX – Danish National X-Ray Imaging Facility
 - FiberLab – New Fibre Composites Laboratory
-



Benefits of research infrastructure

2. Benefits of research infrastructure

The scientific and socioeconomic value of research infrastructure has been analysed and proven many times over. Studies of the positive impacts of research infrastructure appear, however, to be devoted primarily to large and isolated big science facilities with European or global significance and scope. Conversely, to our knowledge, there have been no studies of the value of medium-sized national research infrastructures or of research infrastructures that are distributed or virtual in nature.

It must be assumed that the value demonstrated by the big science facilities is also present in other types of research infrastructure, albeit on a smaller scale. The scale of the actual benefit, not least the financial benefit, naturally depends on the particular research infrastructure, the disciplines it serves and its characteristics. A distributed research infrastructure for instance is intrinsically expected to have less financial impact locally and regionally than a single-sited facility. It is naturally also a given that the scale of socioeconomic returns is likely to be proportional to the scale of investment.

This chapter discusses a number of commonly recognised and generalised benefits that may be anticipated as derivable from Danish investments in advanced research infrastructure. The focus here is on the positive socioeconomic impacts. This chapter rounds off with a number of issues and trends in the area, all of which challenge realisation of the full national benefit from research infrastructure.

2.1 Scientific benefits

New research findings and breakthroughs within all the main scientific fields are contingent on researchers having access to state-of-the-art research infrastructures. Cases in point would be the significance of databanks for genomics research, the importance of measuring stations for environmental science, or the indispensability of radiation facilities and clean-room facilities for the development of new materials and advances in nanotechnology. The new distributed and online facilities within the humanities and the social sciences have yielded an exponential increase in data, the linkage and integration of which hold unprecedented opportunities for comparative research in time and space within these research areas.

There are many such examples within the different research areas. Today, outstanding research is not possible without access to high quality research infrastructure. Aside from extending scientific borders and boosting research areas, research infrastructure also has a crucial positive influence on the organisation, processes and effectiveness of the research itself and hence on research results.

Research infrastructure helps to stimulate networking between researchers within and across research disciplines and in so doing is a positive factor for critical mass. This is often the case in the development and utilisation of large single-sited facilities. But it can also be achieved by distributed and virtual research infrastructures, in which research groups cluster around access to shared data across institutions and national borders.

Attractive physical settings for research are crucial for researcher mobility, and access to the very latest research infrastructure is a key component of such settings. The best researchers naturally gravitate towards the locations that offer the best research settings. It follows that within a given scientific field being able to offer access to crucial research infrastructures is now increasingly a competitive parameter on the global knowledge market.

This is also what grants researchers, whether undergraduate or postgraduate, access to the latest methods, data and knowledge within their field – competencies which make them competitive on both the academic and industrial labour market. State-of-the-art research infrastructure is thus also a key factor in Denmark's competitiveness in terms of educational quality and capacity building.

In this way, research infrastructure serves both to retain national, and attract international, PhD students and fully qualified researchers. Experience indicates that this effect is notable at large physical single-sited and unique facilities.

Finally, national research infrastructures can be expected to enhance the potentials for engaging in international research collaboration and the Danish share of international research grants.

2.2 Socioeconomic benefits

While research infrastructure fundamentally is and should be designed to cater to the needs and curiosity of research, the positive impacts and added value of the facilities extend beyond the scientific domain. This is because the majority of facilities can contribute to solving major prevailing societal challenges, while at the same time stimulating innovation and growth in society.

The need for advanced and up-to-date research infrastructure reflects society's need for research to contribute to solving major societal challenges. For this reason, a number of research infrastructures address major global challenges directly, and are crucial in overcoming them. A couple of examples are presented here:

One of the global societal challenges is to stem anthropogenic climate change. Research infrastructure serving the climate, energy and environmental area is geared both to development and testing of technologies for renewable energy, and to the collection and analysis of data on climate and environmental change in order thereby to help to extend knowledge of climate change impacts on the terrestrial and marine environments. With increased knowledge on climate impacts and the development of new technologies designed to limit future adverse impacts on the climate, research infrastructure is thus a key factor in the efforts to solve this major societal challenge.

Another of the major societal challenges both nationally in Denmark and globally is to improve public health and disease prevention. Research infrastructure within the field of health sciences is crucial for fundamental pathology and for fostering innovations for new and improved therapies and pharmaceutical drugs.

If we turn to the more economic impacts, investments in research infrastructure share many of the characteristics and positive impacts on economic growth of investments in "ordinary" infrastructure in society such as roads, bridges and buildings. But unlike "ordinary" infrastructure, in many cases, research infrastructure has more wide-ranging positive impacts on innovation.

The significance of research infrastructure for innovation as well as trade and industry is often classed in what is known as upstream and downstream phases, each of which has different impacts. The common element in the two phases is that research infrastructures come to serve as privileged forums for a diversity of stakeholders engaged and expert in research, develop-

ment, technology and innovation, and this spurs knowledge transfer between stakeholders, which in turn stimulates innovation and economic growth.

TEXT BOX 2.1: THE POSITIVE IMPACTS OF RESEARCH INFRASTRUCTURE ON INNOVATION AND GROWTH

A number of studies have been conducted into the economic added value created by large, single-sited facilities. Conversely, to our knowledge, no studies have been devoted specifically to the value of small and medium-sized national research infrastructures or to the distributed or virtual variants. However, as the background to a report, Technopolis conducted a web survey of 41 Dutch infrastructures composed of a mix of single-sited, distributed and virtual facilities. The study reveals that:

- 22 per cent of construction, instrumentation, services and purchasing suppliers were based in the research infrastructure's immediate vicinity, while another 42 per cent were from elsewhere in the Netherlands. 36 per cent of the suppliers were international.
- 25 per cent of the research infrastructures created spin-offs based on knowledge accumulated from provision of technical support, while 47 per cent of the research infrastructures created spin-offs based on scientific knowledge and know-how. The first of these categories comprised an average of 2.1 "technical" spin-offs per research infrastructure and the second 5.7.
- Almost two thirds of the research infrastructure facilities cooperate with the commercial sector, and 16 per cent of the research time at the facilities is used by industry. The average number of businesses utilising each research infrastructure facility is 69.
- Almost 75 per cent of respondents state that research infrastructures are important for public-private research and development partnerships, and the same percentage state that research infrastructures are very important for innovation.

Source: Technopolis, 2011: "The role and added value of large-scale research facilities"

In the upstream phase, industry assumes the role of supplier, and contributes to the design, construction and instrumentation of the research infrastructure. This role is typically exercised via public procurements and purchasing. The investment has the immediate, yet transient, economic impact of generating revenue for the businesses and boosting job creation. However, research infrastructures also have to be operated and maintained and ultimately also upgraded. This yields a more long-term economic benefit in that businesses typically also contribute to this phase, and a dedicated workforce may be recruited to serve the research infrastructure itself.

This phase may also positively impact what is commonly referred to as "innovation through tendering"; research infrastructures often consist of high-tech equipment and instrumentation which initially exist only on the drawing board and therefore have to be developed, enhanced or customised for a given research infrastructure.

A good many research infrastructures require newbuild premises or the acquisition of new and advanced instrument sets. Their construction and start-up phases commonly involve industrial contracts, which yield a direct industrial benefit in the form of orders and job creation. Some infrastructures are so pioneering and cutting edge that the suppliers involved benefit from the spillover effect of successfully developing new products with added market potential.

When unique components are required for research infrastructures, industry – in many cases in partnership with researchers – is then contracted to develop, design and test products, and in so doing becomes innovation-intensive. One knock-on benefit in this process may occur when a business develops expertise and know-how which increases its competitiveness in related or other markets, while the company may also improve its reputation credentials by supplying cutting-edge high-tech equipment.

TEXT BOX 2.2: EXAMPLES OF DANISH BIG SCIENCE SUPPLIERS

A number of Danish businesses have won contracts to build, operate and maintain, or upgrade, big science facilities, often in partnership with Danish research institutes or advanced Technology Groups (GTS Institutes).

A unique partnership between the Danish high-tech company Polyteknik AS and the Danish Technological Institute, for example, resulted in a series of contracts, initially to analyse faults and then subsequently to upgrade the sputtering equipment that coats the mirrors on one of the European Southern Observatory (ESO) telescopes. JJ X-ray, a small high-tech niche company just outside Copenhagen, which previously supplied products for the free-electron laser at Stanford University in the USA, is now, in partnership with DTU - Technical University of Denmark, supplying beam lines for The European X-Ray Free-Electron Laser Facility (European XFEL) in Hamburg, Germany.

However, aside from niche services, such facilities also procure a wide range of more conventional products, solutions and services. Within electronics, the Danish firms of CB Svendsen and Necas have thus won several contracts to manufacture power supplies and PCBs, respectively, for the European Organization for Nuclear Research (CERN). CERN has also built up close relations with some 15 Danish machining workshops which supply mechanical workpieces on a regular basis to the largest single machine in the world, the Large Hadron Collider (LHC).

Source: BigScience.dk

In the downstream phase, businesses are the users of the established research infrastructure or the recipients and (co-)producers of new knowledge. Here, the research infrastructure stimulates innovation, and potentially, spillover benefits in the form of job creation and economic growth.

In many contexts, the businesses benefit from or need access to state-of-the-art facilities and the like in order, for example, to test and develop their products. For the vast majority of such enterprises, independently establishing and operating their own research infrastructure and test facilities is in no way financially viable or realistic. A number of such enterprises will not even have any need to have their own facilities on hand. For that reason, continual demand exists among Danish enterprises to utilise the instruments and facilities offered by research infra-

structures in order to test, develop or validate new products and services or in order to gain access to research-generated data.

At the same time, many such businesses do not possess the expertise to utilise highly specialised research infrastructures, which is why the commercial sector often finds it valuable to engage in research partnerships, contract research or in Industrial PhD/postdoctoral programmes which give them access to the expertise they lack through collaboration with established research centres.

In every case, the downstream phase results in crucial science and technology transfer to such businesses, with all the commercial potential this holds. The development of a new research infrastructure may thus ultimately result in new products, patents and high-tech spin-off enterprises around the research infrastructure.

In the wake of a newly established research infrastructure, there is the potential to engender a favourable innovation and industry climate emanating from clustered enterprises. Such clusters typically arise around large physical research facilities and may in some cases attain the critical mass that results in spillover to the regional research and innovation system, creating positive synergies between innovation-intensive research and industry and a robust labour market, which attracts international companies.

2.3 Trends and challenges

The scientific and socioeconomic gain of investment in state-of-the-art research infrastructure is thus indisputable. This is a worthwhile investment.

Traditionally in Denmark, the universities and research institutions have assumed independent responsibility for the development of and investment in research infrastructure and research facilities. This will continue to be the case. However, a number of factors and ongoing trends mean that some of the responsibility for research infrastructure is tending towards the national level, and this necessarily entails an active national coordinatory commitment given that the aim is to invest in internationally leading research infrastructures, and realise the full return on the investment required. These factors and trends are discussed below.

Firstly, the research infrastructure domain has undergone a significant development on account of the new opportunities afforded by information and communication technology. In this field, new and costly supercomputers, advanced computer networks and digitisation and the collection of vast data volumes have presented research with unprecedented opportunities for processing large quantities of data and performing highly complex computations.

Another prevailing characteristic is that today's research infrastructures call for far larger investment than formerly. This is due partly to the fact that new research tools often need to be custom-designed for a given research specification or environment. In addition, research infrastructures are often so complex and advanced that, as stated, it is often necessary to develop brand new technological solutions in order for the facilities to function as intended. The consequence of this may be that establishing new research infrastructures will in many cases be beyond the means of individual institutions, and instead require a national commitment.

At the same time, research generally is increasingly transnational and internationalised. Breakthrough research, many of the major societal challenges and many research topics and fields require large international, unique facilities, which cannot be managed or utilised efficiently by a single country, or which require the collection and processing of data across national borders. This might be the case, for instance, in the development of international research infrastructures entailing the construction of research facilities at a single, fixed physical location, which can scarcely be undertaken by a single nation. It may also, however, be in the shape of binding networked partnerships, which support the coordination of and access to national dis-

tributed data and facilities. This steps up the need and demand for international facilities, and infrastructure alliances.

As international collaboration increases, so does the need for national collaboration. The formation of national consortia with relevant research institutions and universities around research infrastructures thus offers a robust gateway to Europe and European research infrastructures. Moreover, many large, international research facilities are financed by funds from national affiliates.

Finally, at the national level, there is a keen interest in reaping the full rewards of investments in research infrastructure. Only research infrastructures that operate and thrive within open and inclusive interinstitutional alliances are to be regarded as expedient national investments. A national infrastructure programme will serve to prevent inexpedient duplication of local and institutionally confined efforts or of undertakings locked with individuals or single projects. A national programme entails coordinated and more efficient investment, and the granting of access for researchers regardless of their institutional affiliation.

The value-adding effect of research infrastructure for innovation and economic growth is not necessarily achieved automatically. Studies of a number of existing research infrastructures have, among other things, indicated that cultural, scientific, organisational and financial barriers are inhibiting for friction-free and efficient transferability. A targeted national programme has to address these challenges and enable research infrastructure to assume its rightful role in the research and innovation system so that the transfer of knowledge and technology benefits business and society at large.

Thus, from a general perspective, a number of factors and trends are shifting research infrastructure governance in favour of the national level, which calls for an active Danish national commitment in this domain.



Vision and strategic objectives

3. Vision and strategic objectives

The Danish Ministry of Higher Education and Science's commitment and focus embrace research infrastructures and related activities of national significance and origin, and in which Danish researchers across institutions have interests and collaborative projects. Over the years, these activities have comprised much of the Danish 'ecosystem' for research infrastructure, and their share is now increasing. The Ministry will thus be continuing to intensify its commitment.

TEXT BOX 3.1: VISION AND STRATEGIC OBJECTIVES

Vision

The Danish Ministry of Higher Education and Science's vision is to create the best conditions for conducting research and pursuing studies and innovation in Europe. This is why Denmark is to be an international front-runner in research infrastructure by 2020.

Strategic objectives

The Ministry will therefore:

1. act as a catalyst for new national research infrastructures
2. advocate increased funding for new national research infrastructures
3. help to ensure that investments in new national research infrastructures are value adding
4. step up Danish participation in and access to more European research infrastructures
5. facilitate global alliances on research infrastructures with growth countries
6. focus on the benefits of international memberships
7. assist in securing the full benefit of investment in the European Spallation Source (ESS)
8. spot opportunities for attracting research infrastructures to Denmark

This vision embraces both the national (objectives 1-3) and international (objectives 4-8) levels and embodies an ambition to consolidate the returns both from previously made investments and from new investments.

Based on the vision, the Danish Ministry of Higher Education and Science's commitment over the next five years will be based on the eight strategic objectives elaborated on in Sections 3.1-3.8. Section 3.9 summarises the objectives and their milestones for the Ministry's commitment.

3.1 Catalyst for new national research infrastructures

For several years, the Danish Ministry of Higher Education and Science has funded national research infrastructures that create value for researchers across institutions. This comprises a series of earmarked funding allocations for, for instance, registry research under the Coordinating Body for Register Research (KOR) and e-infrastructure alliances under Danish e-infrastructure Cooperation (DeIC); see Text Box 3.2 below.

TEXT BOX 3.2: DANISH E-INFRASTRUCTURE COOPERATION (DEIC)

The object of DeIC is to support Denmark as an e-science nation through the provision of e-infrastructure (computing, data storage and networks) for research and research-based teaching. DeIC is a virtual organisation organised under the Danish Agency for Science, Technology and Innovation.

DeIC's strategic objectives include support for the national advancement of e-infrastructure or international standards; helping to create relationships between stakeholders and e-infrastructures for international cooperation and knowledge sharing; e-science outreach; and coordination of solutions for data management and Big Data.

DeIC, in association with universities and other national research institutions, has established three large High Performance Computing (HPC) facilities: National HPC Center at the University of Southern Denmark; National LifeScience Supercomputer (also known as Computerome) at Technical University of Denmark; and the DeIC National Cultural Heritage Cluster at the Danish State and University Library. Cooperation is also in progress with other Nordic countries on a common e-infrastructure.

In 2007, a National Fund for Research Infrastructure was established in the National Budget, from which funds have since been allocated in excess of approx. EUR 134 million. Allocations from the Fund have followed a series of phases (see Text Box 3.3 below), but a common aspect of all phases has been that the Fund has enabled the Ministry to catalyse the development of new national research infrastructures. For the purposes of the present Roadmap, the Ministry has also orchestrated a process resulting in the catalogue component of this Roadmap comprising a number of specific proposals for new research infrastructures.

TEXT BOX 3.3: DANISH FUNDING ALLOCATION MODELS

The National Fund for Research Infrastructure was originally established in 2006 by allocation of funds from the Danish Globalisation Fund to a special programme designed to finance investments in large-scale research infrastructures. The Minister for Higher Education and Science has since then served as the funding allocation authority, and the purpose of the Fund has been to support the establishment of promising national strategic research infrastructures.

The allocations model has since been developed and finalised, and can be divided into three phrases:

-
1. In a first phase in 2007-2009, allocations from the Fund were made along the lines of a research council model whereby the then minister annually allocated funds to projects based on applications. Allocation was made on the basis of advice from the Danish Research Coordination Committee and a specially appointed international panel of experts.
 2. In 2010, the Ministry decided, in line with trends in other European countries, to switch to a roadmap model, which constituted the second allocations phase, and was active from 2010 to 2014. Based on proposals from the Danish research communities, which were considered by six expert panels, a roadmap was created in 2011, which constituted the factual basis for priority-setting and decision-support that informed the then minister's allocations.
 3. The third phase commences with the present Danish Roadmap for Research Infrastructure 2015. The Roadmap's catalogue of proposals for specific research infrastructures is intended to serve as a strategic, factual basis for priority-setting and decision-support for future public-sector investments in research infrastructure. As of 2015 and some years ahead, allocation of the National Fund for Research Infrastructure is expected to be based on the proposals in the present Roadmap.
-

The catalogue is the outcome of a proposal and dialogue process in which the Ministry invited proposals from the central management of Danish universities and research institutions. The proposals were selected by a national procedure based on advice from the National Committee for Research Infrastructure (NUFI).

The proposals in the catalogue represent the main investment foci in a new national research infrastructure for the coming years; see also Text Box 3.3 above. The proposed infrastructure investments were submitted in open competition, are investment-ready and have all been quality approved by inclusion on the present Roadmap. Each of them will pave the way for excellent research and represent substantial scientific value for the stakeholders involved. In addition, the proposals support the research institutions' own strategies for research infrastructure. In this way, fulfilment of the proposals will also entail substantial co-financing – as a point of departure 50 per cent – from parties including the proposing universities and research institutions.

TEXT BOX 3.4: NATIONAL COMMITTEE FOR RESEARCH INFRASTRUCTURE

In the interests of promoting expansion of Danish national research infrastructure and increasing Danish participation in international research infrastructures, in spring 2013, the Danish Agency for Science, Technology and Innovation appointed a permanent National Committee for Research Infrastructure.

The Committee is mandated to act as a forum for preparing decision-support documents and agreements on prioritisation, establishment, continuation and financing of national and international research infrastructures, and research-support activities to facilitate optimal national utilisation of the research infrastructures.

The Committee is composed of representatives from the Danish universities and the Danish Council for Independent Research, with the Danish National Research Foundation as an observer.

The proposals are also open and based on non-exclusive consortia. They seek to involve all relevant and interested parties and to ensure that all interested researchers, regardless of their institutional affiliation, have the opportunity to gain access to the research infrastructure or its data, depending on the type of research infrastructure. This open-access policy aims to ensure that research infrastructures benefit the Danish research and innovation landscape to its widest extent. The underlying aim is to ensure maximum use of the investments.

The resources for investment in new national research infrastructures are limited, which means that Denmark has to prioritise and abide by an informed investment strategy. For this reason, the catalogue aims to serve as a strategic, factual basis for priority-setting and decision-support for future public-sector investments. From 2015 onwards, allocation of the National Fund for Research Infrastructure is expected to be based on the proposals in the present Roadmap.

Table 3.1
Grants under the Danish Roadmap for Research Infrastructure 2011

Title	Amount granted (approx. in EUR)
DANMAX – Danish beam line for MAX IV	4,695,000
DanSeis – National Centre for Seismic Instrumentation	3,353,000
Danish e-science restructuring and advancement	6,707,000
Danish Center for Ultrahigh-Field NMR Spectroscopy	4,426,000
DigHumLab – Digital Humanities Lab	4,024,000
EATRIS – European Advanced Translational Research Infrastructure in Medicine	3,622,000
ELIXIR – European Life Science Infrastructure for Biological Information	3,353,000
Laserlab.dk - Danish National Laser Centre	2,723,000
Reorganisation and strengthening of Danish register research*	3,005,000
Large-Scale National Wind Tunnel Facility	5,365,000
Total	41,274,000

* Of which approx. EUR 952,000 was earmarked for SHARE – Survey on Health, Ageing and Retirement in Europe.

The financing, however, need not necessarily be exclusively from public-sector sources. The hope is that the Roadmap's catalogue of proposals will serve as an inspirational directory for other funding sources such as research-financing foundations and regional investors.

Milestone for 2020:

- *The catalogue has provided a basis for new investments in Danish national research infrastructures.*

3.2 Funding must keep pace

Danish investments in research infrastructure are already substantial. The Ministry's direct investments totalled around EUR 106 million in 2015.

Table 3.2

Danish Ministry of Higher Education and Science total investments in research infrastructure 2015

Category	Purpose	National Budget 2015 (approx. in EUR)
Convention-based international memberships	The European Organization for Nuclear Research – CERN	16,660,000
Convention-based international memberships	The European Organisation for Astronomical Research in the Southern Hemisphere – European Southern Observatory (ESO)	2,938,000
Convention-based international memberships	The European Space Agency – ESA (mandatory participation)	14,835,000
Convention-based international memberships	The European Molecular Biology Laboratory – EMBL	2,079,000
Convention-based international memberships	The European Synchrotron Radiation Facility – ESRF	1,435,000
Convention-based international memberships	The European X-Ray Free Electron Laser Facility – European XFEL	2,227,000
Convention-based international memberships	Joint European experiments at the Norwegian reactor in Halden (OECD Halden Reactor Project)	322,000
Other international memberships	The European Space Agency – ESA (optional)*	15,452,000
Other international memberships	The International Thermonuclear Experimental Reactor project – ITER	54,000
Other international memberships	European Spallation Source – ESS	28,370,000
Other international memberships	European Extremely Large Telescope – E-ELT **	510,000
Special Danish research infrastructures	Register research	1,315,000
Special Danish research infrastructures	Danish Data Archive – DDA Health	456,000
Special Danish research infrastructures	Computing and e-science	1,985,000
Special Danish research infrastructures	High-speed networks	6,908,000
Special Danish research infrastructures	The Zackenberg Research Station	469,000
Open funds for new research infrastructures	National Fund for Research Infrastructure	9,510,000
Total		105,706,000

Source: 2015 National Budget

Note: The table does not include the indirect contribution paid by Denmark to ITER via the Euratom budget. It also does not include a number of minor items in the National Budget earmarked for administrative overheads and dissemination/outreach activities.

* equivalent to the 2015 expenditure level.

** by virtue of Denmark's convention-based membership of ESO

The trend over time indicates that the Danish Ministry of Higher Education and Science's direct investments in research infrastructure have risen by just over approx. EUR 20 million in real terms since 2007. This positive trend generally reflects a significant increase in Danish participation and investment in international research infrastructures. Notable examples are the European Spallation Source (ESS); the European X-Ray Free-Electron Laser Facility (European XFEL) and the European Extremely Large Telescope (E-ELT), all of which are currently under construction.

At the same time, the balance between funds earmarked for specific purposes, and funds made available for co-funding of new proposals from the Danish universities and research insti-

tutions for new research infrastructures has shifted. Figures 3.1 and 3.2 below, which are based on the categories in Table 3.2 above, indicate that open funds in 2007 accounted for 32 per cent of the Ministry's investments, but in 2015 for 9 per cent. The financial scope for investing in new national research infrastructures has thus been reduced.

Figure 3.1

Breakdown of investments in the Danish Ministry of Higher Education and Science's annual appropriations in National Budget 2007

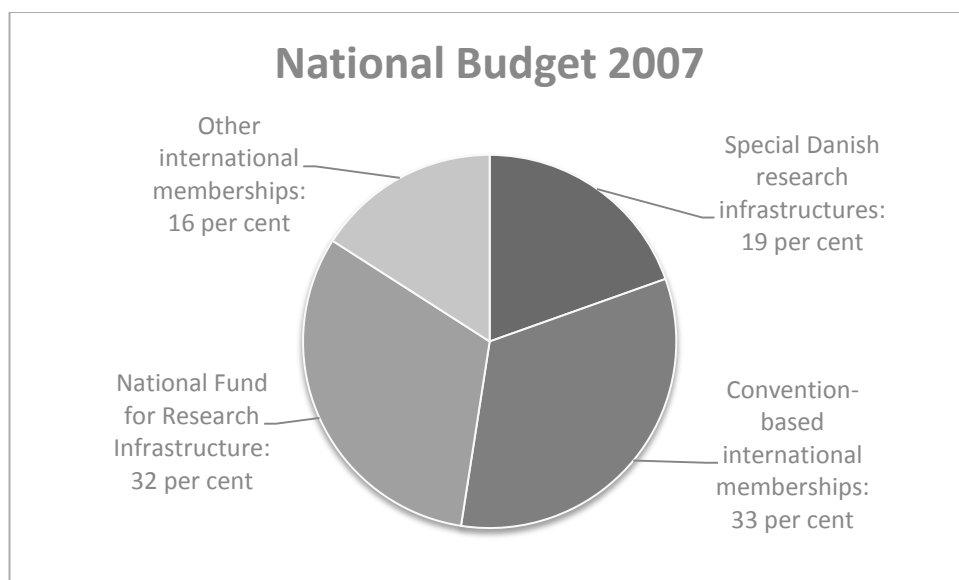
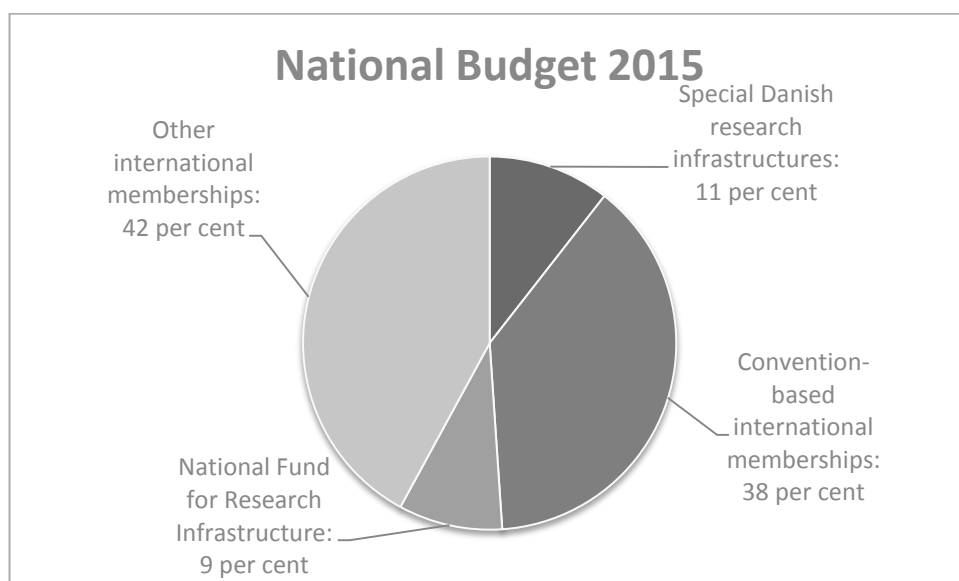


Figure 3.2

Breakdown of investments in the Danish Ministry of Higher Education and Science's annual appropriations in National Budget 2015



TEXT BOX 3.5: THE NEED FOR INVESTMENT IN NATIONAL RESEARCH INFRASTRUCTURE

While no precise projection of Denmark's research infrastructure investment needs exists, the proposals received by the Danish Ministry of Higher Education and Science as part of the Roadmap process (see also Chapter 4) effectively represent the minimum investment required. These 42 proposals were prioritised across the Danish universities and research institutions and submitted in a national procedure. The proposals represent a total investment requirement of just under approx. EUR 376.2 million. To this must be added proposals that have not been accorded sufficiently high priority by the universities and research institutions for them to be presented as national proposals.

The Roadmap's prioritised catalogue containing 22 proposals will require a total investment of approx. EUR 214.6 million in order to be fully realised.

It is difficult to compare investments in research infrastructure across European countries. However, the production and funding of national roadmaps are commonplace in Europe, and not only under the auspices of the European Strategy Forum on Research Infrastructures (ES-FRI), see Section 3.4 below, but also at the respective national level, which thus makes a rough comparison possible.

To that end, the Danish Ministry of Higher Education and Science conducted a survey of a number of the countries Denmark typically compares itself with, and which have all in recent years produced national roadmaps for research infrastructure. The survey solely concerned investments in proposed new research infrastructures on the national roadmaps.

The information from Finland, the Netherlands, Norway and Sweden offers a general impression of Danish investments relative to the investment levels of a number of other countries. It reveals that, among these, Denmark ranks at the lowest investment level. To a varying degree, part of the explanation for this is the difference in national policy on investment in new research infrastructures on the respective roadmaps. This means that, in Sweden for example, the creation and implementation plus a share of the operating costs of new national research infrastructures are financed by centralised national funds via the Swedish Research Council. To some extent, this accounts for why the Swedish centralised funds for financing of Swedish roadmap proposals are substantially larger than the Danish funds, which are allocated solely for the establishment and implementation of the research infrastructures.

In all the surveyed countries, a certain amount of co-funding from universities and other research institutions helps to finance the new national research infrastructures on the respective roadmap. However, the rate of co-funding varies from one country to the next, and is for example estimated to amount to 25 per cent in the Netherlands and Norway and 30 per cent in Finland. In Denmark, the co-funding rate is expected to be approx. 50 per cent for establishment and implementation of new research infrastructures, meaning that 50 per cent of the financing is typically covered by the universities and other research institutions. The expectation is that universities and research institutions carry the entirety of the ensuing costs of operating research infrastructures in Denmark. The co-funding rate is a key factor when seeking to form an impression of total investments in research infrastructures on a national roadmap, and the Danish investment policy aims to achieve a higher rate of co-funding than many of the other countries. The rationale for this is that co-funding and responsibility for operating the research

infrastructures help to instil a sense of ownership in and embed the research infrastructures institutionally at the research institutions that use them.

The current Danish governmental funds for financing of the present Roadmap's catalogue of proposals are not sufficient to finance all proposals, which is why the Ministry is focused on procuring funding for this purpose. However, direct governmental financing cannot and should not stand alone. It is important to the Ministry that investments are conditional on substantial co-funding and with a formal agreement to assume responsibility for the operating expenses once the research infrastructures have been established, with a view to instilling ownership and embed them institutionally. The Ministry will also be engaging in dialogue with foundations mandated to fund research on (co)financing of proposals in the catalogue.

Milestone for 2020:

- *Investments have been made in at least 15 of the catalogue's proposals for new research infrastructures from public-sector and/or private-sector sources.*

3.3 The investments must be value adding

It is imperative for the Danish Ministry of Higher Education and Science to help to ensure that public-sector investments in research infrastructure also benefit Danish industry in order to realise the full socioeconomic benefit. This means that the Ministry will direct focus at public-private partnerships and on the transferability and utilisation of research infrastructure for innovation and growth.

The Danish Ministry of Higher Education and Science will seek to extend both upstream and downstream potentials for innovation and growth.

Upstream, the Ministry will seek to sustain and advance the current Danish industry programme to promote investment in international big science research infrastructures. A proportion of the membership contributions to the international big science research infrastructures is channelled into public procurements for international industrial contracts, which companies in the member states are eligible to bid for. In this way, the member states can recoup their membership 'dues' in the shape of industrial contracts, also known as "industrial returns". The procurements involve both highly scientific and high-tech deliverables, but also many more conventional deliverables. There are consequently substantial returns in play for Danish stakeholders to claim.

TEXT BOX 3.8: BIGSCIENCE.DK

In 2010, Denmark set up BigScience.dk as a Danish node for the promotion of Danish downstream returns from large international research infrastructures. BigScience.dk is run by the Big Science Secretariat (BSS).

BigScience.dk acts as Industrial Liaison Officer (ILO) for the research infrastructures and in this way supports Danish industry with information, business services, matchmaking and network activities. More than 150 Danish businesses have registered with the BigScience.dk network.

BigScience.dk is a joint initiative run by the Danish Technological Institute and the Technical University of Denmark and is funded by the Ministry of Higher Education and Science with additional support from the Capital Region of Denmark's Growth Forum and the European Regional Development Fund.

The Ministry's ambition is to continue to develop BigScience.dk and the Big Science Secretariat (BSS) as the Danish anchor for promoting Danish downstream returns.

BigScience.dk estimates that the international big science market is worth an annual approx. EUR 37.2 billion, of which the Danish market share is currently estimated as approx. EUR 40.2 million. The size of this figure should be viewed in relation to the direct investments in Danish memberships worth approx. EUR 84.4 million in 2015. BigScience.dk further estimates that a targeted and concentrated drive could potentially push Danish industry revenues up to approx. EUR 134.1 million by 2020.

The Ministry will also be pursuing closer dialogue with BigScience.dk on realising further synergistic potentials between the Ministry's representation and supervision of Danish memberships and Danish downstream returns.

As regards the downstream phase, the Ministry will be concentrating on the new public investments in national research infrastructures in the Roadmap's catalogue and supporting such investments in driving Danish innovation and growth.

This means that every new research infrastructure realised from the catalogue by means of funds from the National Fund for Research Infrastructure will be required to submit a concept for industrial partnering with specific benchmarks. This will include setting out an explicit plan for engagement and involvement of enterprises, other external stakeholders and approved technological institutions (GTS) and innovation networks in the proposal's project organisation and consortium where applicable. Well-defined policies must be laid down for industrial access to the research infrastructure or the data it generates. This must naturally take account of the applicable State Aid rules which stipulate that if more than 20 per cent of the capacity of a research infrastructure is intended to be put out to tender to private-sector enterprises (for example by means of contract research, supply of research services or leasing to businesses), then creation of the research infrastructure in the first place must be at least 50 per cent co-financed by private-sector enterprises. Finally, plans must be presented for user support and knowledge transfer, and estimates must be made of the research infrastructure's potential contribution to economic growth, for example, in the shape of new technology, partnership projects, contract research and spinoffs.

The Ministry will also be taking the initiative for a conference on "research infrastructures as value-adding investments" for attendance by Danish research infrastructure owners, users and stakeholders. For that initiative, the Danish and international experiences of best practices in innovation and growth promotion will be discussed.

Milestones for 2020:

- *The Danish market share of the big science market share has increased, and the returns have doubled in value.*
- *The new Danish research infrastructures now realised each have a tailored policy in place for partnering with approved technological institutions (GTS) and industry.*
- *A conference has been held on the contribution of research infrastructures to innovation and growth.*

3.4 Strengthened European efforts

The need to strengthen research infrastructure governance applies not least at the European level where the Danish Ministry of Higher Education and Science will continue to seek to facilitate Danish participation in European research infrastructures with relevance, potential and interest for Danish stakeholders.

Denmark is consequently an active party to the European Strategy Forum for Research Infrastructures (ESFRI), which is composed of representatives of the 28 EU Member States, the Associated States and the European Commission. ESFRI's mission is to promote the establishment of large pan-European research infrastructures and to act as a European catalyst. Since its establishment in 2001, ESFRI has achieved broad consensus on the need for and value added of establishing a number of selected joint European research infrastructures.

ESFRI's main instrument is the development of pan-European roadmaps for research infrastructures, which identify especially promising collaborative projects of pan-European relevance and interest. Since 2006, ESFRI has published three roadmaps, and the latest of these, Strategy Report and Roadmap Update 2010, comprises 38 proposals representing all main scientific fields and 10 projects under implementation. At present, 25-30 projects are regarded as being under implementation. In the first half of 2016, ESFRI is expecting to launch an updated roadmap for European research infrastructures.

Table 3.3
ESFRI projects with Danish participation

Projects in which the establishment of Danish nodes and membership are funded by the National Fund for Research Infrastructure.
CESSDA – Council of European Social Science Data Archives (funded by Danish Data Archive)
CLARIN – Common LAnguage Resources and technology INitiative
DARIAH – DigitAI Research Infrastructure for the Arts and Humanities
EATRIS – The European Advanced Translational Research Infrastructure in Medicine (until 31 December 2016)
ELIXIR – European Life-Science Infrastructure for Biological Information
EPOS – European Plate Observing System
INSTRUCT – An integrated Structural Biology Infrastructure for Europe
PRACE – Partnership for Advanced Computing in Europe
Projects in which Danish participation is funded by Danish international memberships
ESS – European Spallation Source
ESRF Upgrade – European Synchrotron Radiation Facility Upgrade
European XFEL – European X-Ray Free-Electron Laser
ILL 20/20 Upgrade – Upgrade of the ILL neutron source
As-yet non-funded Roadmap 2015 projects
AnaEE – Infrastructure for Analysis and Experimentation on Ecosystems
EU-OPENSREEN – European Infrastructure of Open Screening Platforms for Chemical Biology
ICOS – Integrated Carbon Observation System
WindScanner.eu – European WindScanner Facility

Note: This list could be extended by a number of proposals in which Danish researchers and institutions are involved to a greater or lesser extent. A case in point would be the participation by Danish institutions in preparatory undertakings (EU preparatory phase) for 19 projects, of which a number are, however, included in the lists above.

However, ESFRI does not have own funds at its disposal for investment in the actual implementation of priority projects. It is thus up to the individual participant country to decide the extent to which it wishes to invest in the realisation of individual research infrastructure projects. Participation normally requires that the member country establishes a national node for the project, which in many cases requires the creation of a wholly new research infrastructure and in any event entails the payment of a membership contribution to the European research infrastructure project. Danish funding may stem from many different sources, but in every case, Danish participation requires that the Ministry of Higher Education and Science signs a binding agreement – often in the form of a European Research Infrastructure Consortium (ERIC) – pledging Denmark's commitment. The signing of ERIC agreements and the ensuing distribution of tasks, burdens, obligations and rights is often both a lengthy and complex process typically taking 3-5 years.

Danish participation in the start-up of a number of projects is, however, supported financially via the National Fund for Research Infrastructure, as allocated on the basis of the Roadmap 2011, while in the catalogue in the present Roadmap, a number of proposals concern ESFRI projects such as Danish nodes; see Text Box 3.3 above. In this way, the Danish Roadmap supports Danish participation in alliances on European research infrastructures.

In addition, there are opportunities for investment via the EU programmes for research and innovation and technological development, for which funding has been granted for the preparation of ESFRI research infrastructures. Under the ongoing Horizon 2020 (H2020), funding has likewise been granted for implementation of some of the highest priority projects on the ESFRI Roadmap.

H2020's total budget for research infrastructure in the period 2014-2020 is just under EUR 2.5 billion and also comprises opportunities for funding non-ESFRI European projects. However, experience indicates that these do not benefit Danish research environments to an adequate extent. The provisional status report in November 2015 found that Danish participation in the initial calls under the H2020's work programme for research infrastructure amounted to 1.02 per cent, which is substantially less than Denmark's overall H2020 share of 2.57 per cent.

A decision has thus been made to intensify efforts to improve the Danish success rate and participation. To that end, in 2015, the Ministry strengthened the Danish National Contact Point (NCP) for research infrastructure under H2020, which advises Danish research environments on research infrastructure funding opportunities. This was undertaken above all with a view to identifying the reasons for the low Danish success rate, and ascertaining Danish interest in the programme, and ultimately in the interests of increasing the Danish share of signed grant agreements in order to boost overall returns for Denmark.

Milestones for 2020:

- *Denmark has signed three new agreements on Danish participation in new European research infrastructures.*
- *Denmark's share of signed grant agreements under the Horizon 2020 programme for research infrastructure is at the same level as the Danish share of signed grant agreements of the total funding offered.*

3.5 Collaboration with growth countries

International collaboration on research infrastructure is not limited to the European arena, and Denmark has secured access to a number of research infrastructures such as the European Or-

ganization for Nuclear Research (CERN), the Global Biodiversity Information Facility (GBIF) (see Text Box 3.2), and the International Thermonuclear Experimental Reactor (ITER), in which collaboration is global. The latter is the world's largest research collaboration, which in addition to Europe, allies Canada, Japan, India, China, South Korea and the USA, and thereby represents more than 80 per cent of the world's population in the project to produce energy from fusion.

Although Denmark is thus already participating in a number of global collaborative projects, there may be a need to engage in further global initiatives focusing on bilateral agreements. This is because the scientific geography is in the process of changing, and a number of strong new research nations making massive investments in research and development with derived impacts on research scope and quality are now on the rise.

This trend also comprises investments in research infrastructure, which holds collaboration potential for Danish researchers and research infrastructures. Examples of large-scale research infrastructures include the Shanghai Synchrotron Radiation Facility (SSRF) and Sirius in São Paulo, which are China's largest and Brazil's forthcoming large synchrotron facilities, respectively. Other examples of potential collaboration partners of interest to Danish researchers, institutions and research infrastructures include Korea Polar Research Institute (KOPRI), which owns the ARAON research vessel, and the Indian Space Research Organisation (ISRO), which is responsible for India's national space research programme.

Denmark is also a pioneer country by virtue of having established innovation centres in a number of these countries, such as in Brazil, India, China and South Korea. So far, however, none of these have worked systematically on research infrastructures.

TEXT BOX 3.6: THE DANISH INNOVATION CENTRES

The Danish innovation centres were co-established by the Danish Ministry of Higher Education and Science and the Ministry of Foreign Affairs of Denmark, and are located in Shanghai, Silicon Valley, Munich, São Paulo, New Delhi and Seoul, respectively.

Their principal objects are to liaise between Danish and international research, innovation and educational environments together with private-sector enterprises and investors for the purpose of bridge-building between Denmark and some of the leading nations in research, higher education and business development as well as some of the world's leading innovation centres and growth markets. Their mandates consist locally of facilitating access to international knowledge, technology, capital and markets for Danish business and research institutions.

As a new initiative, the Danish Ministry of Higher Education and Science wishes to facilitate access to and collaboration with new promising research infrastructures in these growth countries and will therefore be engaging in dialogue with the Danish innovation centres and the Danish universities and research institutions regarding opportunities and interest. The aim is to assist in establishing bilateral agreements and platforms for cooperation on and access to research infrastructures in order thereby to foster new opportunities for global alliances based on research infrastructure.

Milestone for 2020:

- *Three cooperation agreements have been concluded between the owners of the research infrastructures in Denmark and the growth countries.*

3.6 Benefits of international memberships

For a number of years, the Ministry has facilitated the funding of Danish and typically convention-based memberships of a number of large international research infrastructures – the big science facilities – such as the European Organization for Nuclear Research (CERN) – of which Denmark has been a member since 1954. Since then, further international, convention-based memberships of research infrastructures have followed, including the European Molecular Biology Laboratory (EMBL) in 1973 and the European Synchrotron Radiation Facility (ESRF) in 1988. The most recent memberships of this type is of the European X-Ray Free-Electron Laser Facility (European XFEL), which was obtained in 2012 (the facility is scheduled to come on line in 2017), and of the European Spallation Source (ESS), which is currently under construction, see also section 3.7. Funding of the so-called research-supporting activities has also been lodged under the national programme.

Total Danish investment in the big science facilities amounts to around EUR 85 million per annum (see Table 3.2), and it is in the Ministry's interest that Denmark derives maximum benefit from this commitment. The membership fees solely cover the cost of Danish memberships, and in this way cover the facilities' main and basic construction and operation. Danish research based on the membership access is typically funded at the national level by grants from the research institutions or via the research council system.

Research-supporting activities usually denotes the activities undertaken between operation of the research infrastructure and the actual research. This would include salaries for staff on secondment to a facility (for example, technicians or postdoctoral researchers), the calibration and testing of instruments and equipment, the development of hardware and software, testing and validation and travel activity in connection with access.

In recent years, research-supporting activity funding and organisation has undergone realignment. In 2012, a working party commissioned for the purpose compiled a report on research-supporting activities and researcher access to and utilisation of large international research infrastructures. Since then, many of the recommendations have been implemented. These include a more clear-cut delineation of responsibilities between the Danish Council for Independent Research and the National Fund for Research Infrastructure, whereby National Budget 2013 enacted the transfer of funding responsibility from the Council to the National Fund.

Based on the recommendations, the Danish Ministry of Higher Education and Science has funded three centres mandated to boost and maximise Danish research potential tied up in the memberships. Moreover, the instrument centres are nationally anchored in order to ensure that the totality of Danish interests within their respective fields of research are advanced in the context of the international memberships.

TEXT BOX 3.7: THE THREE NATIONAL CENTRES FOR RESEARCH-SUPPORTING ACTIVITIES

DANSCATT (instrument centre for Danish users of synchrotron and neutron sources and free-electron X-ray lasers)

DANSCATT's principal objective is to facilitate Danish user access to international neutron and X-ray scattering facilities such as the European Synchrotron Radiation Facility (ESRF), the European X-Ray Free-Electron Laser Facility (European XFEL), the Institut Laue-Langevin (ILL) and the Paul Scherrer Institute (PSI). Going forward, DANSCATT will also have a key role to play in relation to the European Spalla-

tion Source (ESS) and MAX IV. The centre is managed by Technical University of Denmark on behalf of a Danish consortium, whose board is composed of representatives of Aarhus University, University of Copenhagen, Roskilde University, University of Southern Denmark and the firm Haldor Topsøe. DANSCATT has a membership of some 350 researchers and students and e.g. funds trips to foreign facilities, postings abroad and education and training.

IDA (Instrument Centre for Danish Astrophysics)

The principal objective of IDA is to support and facilitate Danish astrophysics research in relation to utilisation of the Danish membership of European Southern Observatory (ESO), the European Space Agency (ESA) and Nordic Optic Telescope (NOT). The centre is managed by Aarhus University on behalf of a Danish consortium, whose board is composed of representatives of Technical University of Denmark, University of Copenhagen and University of Southern Denmark. IDA has a membership of some 80 Danish researchers and students and funds activities such as observation schools, performance of observations, access to specific facilities and development and design of new and up-to-date instrumentation.

NICE (National Instrument Centre for CERN Experiments)

The principal objective of NICE is to facilitate Danish access to the European Organization for Nuclear Research (CERN). The centre is managed by University of Copenhagen on behalf of a Danish consortium, whose board is composed of representatives of Aarhus University, Technical University of Denmark, and University of Southern Denmark. NICE has a membership of some 70 researchers and students and funds activities such as foreign postings and trips to CERN along with the operation, development and construction of new instruments.

Given that the Ministry has funded the centres since 2014, a review of the centres and Denmark's benefit from its memberships from an international perspective would be timely. This will also include an appraisal process in dialogue with the stakeholders with a view to identifying how the research-supporting activities would best be managed and funded as part of the efforts to identify a more resilient and sustainable funding scheme. To that end, the centres' performance and commitment to Danish industrial interests will also be examined.

Milestone for 2020:

- *Danish research-supporting activities are funded under a new scheme and by an alliance of relevant stakeholders.*

3.7 Reaping the full benefits of ESS

Denmark and Sweden will jointly host the European Spallation Source (ESS), one of the largest research infrastructure projects currently under construction in Europe. ESS is a neutron scattering facility used for investigating materials and materials processes from pharmaceutical science to construction materials and from the preservation of cultural heritage to the development of new superconductors.

The ESS facility is under construction in Lund, Sweden, while the ESS Data Management and Software Centre will be located in Copenhagen. Construction started in September 2014 and the ESS facility is expected to supply the first neutrons for research use in 2019. The cost of con-

struction is approx. EUR 1.88 billion, around half of which will be covered by the host countries: Sweden and Denmark. In the period 2014-2022, Denmark for its part will be investing approx. EUR 268 million in ESS.

Between 2,000 and 4,000 visiting researchers from universities, institutions and industry are expected to visit ESS annually to use the facility's neutron source to answer their scientific questions. The return on ESS, however, will not be realised of their own accord. In 2014, Copenhagen Economics¹ estimated that the potential gross return on ESS and MAX IV for the Capital Region of Denmark amounts to around EUR 268 million, depending on how well the efforts are optimised. This estimate, however, is predicated on the best possible framework conditions. In the presence of less favourable conditions, the gain is expected to be halved.

It is therefore vital that Denmark even now has a clear plan for how the full benefit of its co-hosting is to be realised. This concerns factors such as the means by which Danish businesses will benefit from ESS and how Denmark can attract international companies. It also relates to how Danish researchers will derive maximum benefit from the investment, and how ESS staff can take up residence in Denmark and contribute to the Danish economy.

TEXT BOX 3.9: ESS STRATEGY OBJECTIVES

The principal aims for development by 2025 under the ESS strategy are thus:

- capacity building: capacity building has ensured that there are three times more neutron users than at present.
- beacon environments: Denmark has established 3-5 internationally recognised beacon environments in areas of strategic significance for Danish research and industry.
- bridge-building via ESS: Denmark has achieved a close interaction between ESS and Danish centres of research excellence.
- involvement of Danish business and industry: businesses have flexible and efficient access to ESS and beacon environments.
- high-tech supplier firms are serving ESS: Denmark has established a Danish cluster of companies specialising in supplying research facilities.
- anchoring of ESS in Denmark: ESS staff take up residence in Denmark, moving flexibly within the region, and Denmark is succeeding in attracting leading innovation enterprises and researchers through ESS and MAX IV.

Source: Ministry of Higher Education and Science, 2015: "ESS som drivkraft for fremtidens vækst - Strategi for den danske ESS-indsats" (ESS as a driver for future growth - Strategy for Denmark's ESS commitment)

Milestone for 2020:

- *The Ministry has fulfilled its obligations vis-à-vis the ESS strategy.*

¹ Copenhagen Economics, 2014: "Samfundsøkonomiske effekter af ESS/MAX IV for Hovedstadsregionen" (The positive socioeconomic impacts of the ESS/MAX IV facilities in Lund, Sweden, on the Capital Region of Denmark)

3.8 Denmark as a host country

The majority of international research infrastructures have been or are in the process of being established outside Denmark, with a couple of significant exceptions. Denmark has hosted the Global Biodiversity Information Facility (GBIF) since 2001, and, as detailed above, will be co-hosting European Spallation Source (ESS) with Sweden.

GBIF and ESS are widely differing research infrastructures. Whereas GBIF is basically distributed and virtual within a field with no immediate industrial interest, ESS, on the other hand, is characterised as being a single-sited physical facility with immense industrial promise and potential.

TEXT BOX 3.10: GLOBAL BIODIVERSITY INFORMATION FACILITY (GBIF)

GBIF – Global Biodiversity Information Facility is a global research infrastructure, the purpose of which is to make the world's data on biodiversity (plants, animals and other organisms) freely available for online search and analysis. GBIF's data portal is the largest in the world for biodiversity data, and GBIF thus facilitates research that was formerly impossible. GBIF's portal currently contains 15,000 data sets made available by more than 750 institutions around the world.

38 countries are affiliates of GBIF and 15 countries are associates. Each affiliate is required to establish and operate a member node in order to make their biodiversity data available for searching via the GBIF portal.

GBIF was established in 2001, and Denmark was selected in an international competition to host the GBIF secretariat, currently with a staff of more than 20 located at the Natural History Museum of Denmark, University of Copenhagen. The Danish node, Danish Biodiversity Information Facility (DanBIF), manages Denmark's membership of GBIF and is funded by the relevant Danish universities (currently, Aarhus University, University of Copenhagen and University of Southern Denmark).

The implications of Denmark hosting the two research infrastructures thus differ markedly, yet there is a strong case for a country of Denmark's size having much to gain from hosting international research infrastructures for the benefit of Danish research, education, innovation and growth. The ESS case is unique in this context. It is expected that within materials research, ESS will serve as a magnet for Denmark and the Øresund Region by attracting talent and giving rise to research beacons, innovative business clusters and so forth.

For a given country to succeed in becoming the host of a European research infrastructure is a difficult process requiring both political backing and efforts, but also the ability to raise funds for the so-called "host premium".

The opportunities for future Danish hosting might, for instance, involve one or more of the projects on the ESFRI European Roadmap, several of which, notably the distributed research infrastructures, have not yet established the European node. Preparation of the Danish Roadmap for Research Infrastructure included an appraisal of the options for Denmark to host one or more international research infrastructures or nodes.

While large international research infrastructures on Danish soil would also entail considerable establishment costs for Denmark, the Ministry of Higher Education and Science will con-

tinue to bear in mind opportunities for attracting international research infrastructures in the form of single facilities within areas in which Denmark ranks among the international elite.

Milestone for 2020:

- *A European research infrastructure node – such as on the ESFRI Roadmap – has been attracted to Denmark.*

3.9 Overview of programme objectives and milestones

The strategic objectives will be translated into specific and binding milestones for the Danish Ministry of Higher Education and Science's research infrastructure commitment over the next five years. These will contribute to realisation of the vision.

TEXT BOX 3.11: OBJECTIVES AND MILESTONES

Objectives: "The Ministry will...":	Milestones: "Achievements by 2020...":
1. act as a catalyst for new national research infrastructures.	the catalogue has provided a basis for new investments in Danish national research infrastructures.
2. advocate increased funding for new national research infrastructures.	investments have been made in at least 15 of the catalogue's proposals for new research infrastructures from public-sector and/or private-sector sources.
3. help to ensure that investments in new national research infrastructures are value adding.	<p>the Danish market share of the big science market has increased, and the returns have doubled in value.</p> <p>the new Danish research infrastructures now realised each have a tailored policy in place for partnering with approved technological institutions (GTS) and industry.</p> <p>a conference has been held on the contribution of research infrastructures to innovation and growth.</p>
4. step up Danish participation in and access to more international research infrastructures.	<p>Denmark has signed three new agreements on Danish participation in new European research infrastructures.</p> <p>Denmark's share of signed grant agreements under the Horizon 2020 programme for research infrastructure is at the same level as the Danish share of signed grant agreements of the total funding.</p>
5. facilitate global alliances on research infrastructures with growth countries.	three cooperation agreements have been concluded between the owners of the research infrastructures in Denmark and the growth countries.
6. focus on the benefits of the international memberships.	Danish research-supporting activities are funded under a new scheme and jointly between relevant stakeholders.
7. assist in securing the full benefit of investment in ESS.	the Ministry has fulfilled its obligations vis-à-vis the ESS strategy.
8. be aware of opportunities for attracting research infrastructures to Denmark.	A European research infrastructure node – such as on the ESFRI Roadmap – has been attracted to Denmark.

Proposals for new research infrastruc- tures

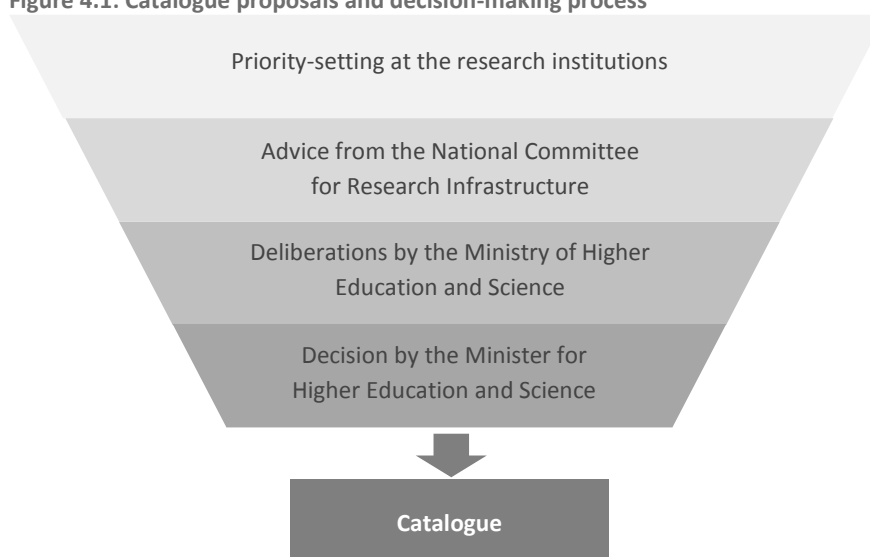


4. Proposals for new research infrastructures

This chapter presents a consolidated and prioritised catalogue of the 22 research infrastructures assessed as having the greatest national significance for the competitiveness of Danish research and innovation over the coming five years. As such, this catalogue replaces the version presented by Danish Roadmap for Research Infrastructure 2011.

A key element in the process of producing the final catalogue was to facilitate the active involvement and engagement of the Danish research institutions and universities in order to enable the catalogue to underpin the institutions' own strategies in this domain. For this reason, the research communities were involved in both the proposals process and the first part of the decision-making process; see Figure 4.1 below.

Figure 4.1: Catalogue proposals and decision-making process



4.1 Creation process

The process of compiling the catalogue commenced in November 2014 when the Danish Agency for Science, Technology and Innovation invited central management of Danish universities and national research institutions to submit proposals for national research infrastructures on behalf of national consortia. The central managements were invited to submit proposals for new or substantially upgraded research infrastructures. Proposals could be made within all main research fields and for all types of research infrastructures.

The wording of the invitation attached great importance to the embedding of the proposed research infrastructures nationally, as well as the maturity and feasibility of the proposed research infrastructures, and each proposal was therefore expected to comply with certain criteria; see Text Box 4.1 below.

TEXT BOX 4.1: PROPOSAL CRITERIA

In the invitation to submit proposals, each proposal was requested to comply with the following specific criteria:

- To be of national strategic interest and significance. The proposals are required to support, at national level, the research institutions' strategies for the research infrastructure domain and to have great scientific significance for the relevant Danish research communities.
- To be permanent or long-term and be sufficiently mature for the research infrastructures to be realisable scientifically, technologically and financially within a period of a few years (up to five years).
- To be open. Ideally, they should be based on non-exclusive consortia or the like and should seek to involve all relevant and interested parties and ensure that all interested researchers, regardless of their institutional affiliation, have the opportunity to gain access to the research infrastructures.
- Must be realisable with substantial co-funding from the research institutions – with at a point of departure 50 per cent co-financing to be pledged – and the research institutions involved are expected to assume responsibility for operation of the infrastructures once established and for any decommissioning.
- Where relevant to be linked to international research infrastructures, such as those on the existing or planned ESFRI Roadmap.

In the description of the proposals, which forms the basis for their evaluation, the proposers were asked to set out both their scientific, societal and industrial prospects.

In November and December 2014, the Danish Agency for Science, Technology and Innovation held briefings at the Danish universities and a separate meeting for other Danish research institutions in order to raise awareness of and gain backing for the process and the Roadmap.

At submissions deadline on 30 April 2015, the Agency had received 42 proposals for the Roadmap; see Text Box 3.5.

4.2 Evaluation process

The proposals received were presented to the National Committee for Research Infrastructure, which is composed of representatives of the Danish universities and the Danish Council for Independent Research with the Danish National Research Foundation as an observer (see Text Box 3.4) with reference to the Committee's advice. NUFÍ advised the Danish Agency for Science, Technology and Innovation on the contents of the catalogue, recommending 27 proposals for the Roadmap's catalogue. Subsequently, the Ministry carried out an independent evaluation and prioritisation process, as part of which, supplementary materials were obtained concerning the proposals' industrial and innovation potentials. This resulted in the Ministry of Higher Education and Science deciding on a catalogue of 22 proposals selected from among the 27. Both NUFÍ and the Ministry based their evaluation on the foregoing criteria, as listed in Text Box 4.1, which were published together with the invitation to submit proposals.

Across the proposals, the Ministry also wanted the final catalogue to embrace all research areas, and for the proposals to be endorsed by an average of four research institutions with wide institutional and geographical outreach.

4.3 Allocation procedure

One of the main purposes of the catalogue (see Chapter 3) is to provide decision-support for future investments in new national research infrastructures.

The Minister for Higher Education and Science allocates the National Fund for Research Infrastructure on annual appropriations in the National Budget, and the expectation is that the catalogue will serve as a priority-setting tool for decisions on funding allocations until 2020. This means that a proposal published in the catalogue is not automatically guaranteed a grant from the fund, as the size of the fund does not currently permit the financing of all of the catalogue's proposals.

The hope is therefore that the catalogue will also serve as an inspirational directory for other funding parties such as private foundations and Denmark's regions. This is due not least to the fact that the proposals were selected in open competition, are investment-ready and have all been quality approved by inclusion on the present Roadmap. Each of them will pave the way for excellent research and hold new opportunities for innovation and growth.

4.4 Introduction to the catalogue

The decision-making process resulted in the following catalogue of 22 proposals for new or substantially upgraded research infrastructures. There are proposals within all research areas, and each proposal is on average endorsed by five Danish research institutions and universities.

The catalogue is grouped according to the five research areas that formed the basis for the entire process. Several of the catalogue's proposals have a substantial or quasi e-science infrastructure, but none were made as a purely e-science proposal. The proposals with e-science content are consequently presented under the descriptions of the five research areas.

In addition, a number of the proposals are interdisciplinary, comprising disciplines from two or more research areas. This is notably the case between the research areas of "Biotech, Health and Life Science", "Energy, Climate and Environment" and "Materials Science and Nanotechnology". The interdisciplinary proposals are listed under the research area that predominates in each individual proposal.

Each proposal is presented in the catalogue on a single page with a brief description of the research infrastructure and its anticipated scientific and value-adding potential. In addition, for each proposal, indication is provided of which research institutions and universities have formally endorsed the proposal at the time of submission as principal proposers and co-proposers, and which other parties are interested in realising the research infrastructure. This last category comprises research institutions, universities, approved technological institutions (GTS), innovation networks, regions, local authorities and the private sector. The type of proposal is also stated, meaning whether the research infrastructure is single-sited, distributed or virtual in nature. Finally, each entry states the total estimated investment requirement, including both the requested funding via the National Fund for Research Infrastructure and the co-funding expected to be pledged by other sources.

Biotech, Health and Life Sciences

The research area of "Biotech, Health and Life Sciences" spans a wide range of disciplines of great relevance for improvements in the health of the Danish nation, including the development of new pharmaceutical drugs and medical technologies together with higher-quality and healthier foods. The research is conducted at e.g. universities, hospitals and clinics, and at sectoral research institutions. The research areas are closely aligned with, and support, development and innovation in trade and industry, including the pharmaceutical industry, medical devices and biotech companies as well as the food industry, all of which are important sources of Danish employment and exports.

Biotech (biotechnology) covers the development, production, analysis and utilisation of biological systems at the micro level, cellular level and molecular level. It is important in, for example, the development of healthcare, food production, environmental protection, energy, agriculture and industrial processes.

Health science research comprises basic research in human health and disease, clinical and translational research, disease prevention research by a broad, population-based health approach, and health service research concerning the organisation of the health service.

Life Sciences (bioscience) includes disciplines such as veterinary medicine, plant and agricultural sciences, food and nutrition science, and the area ties in with biotechnology, medicine, pharmaceutical drugs, biology, public health, the environment and chemistry. The research also contributes to advances in agriculture.



Model photo: Colourbox

This research area is to a great extent reliant on research infrastructure such as experimental and test facilities for clinical research, biobanks, registries and bioinformatics databases together with supercomputer capability for statistical analysis of Big Data, within bioinformatics especially. Instruments for advanced imaging, including Positron Emissions Tomography (PET), advanced light and electron microscopy, multimodal scanning and X-radiation and particle radiation together with large synchrotrons play a major role in the research. In addition, model organisms, protein production facilities and chemical libraries are vital research infrastructures in this field.

TEXT BOX 4.2: PROPOSALS WITHIN BIOTECH, HEALTH AND LIFE SCIENCES

- COLLECT – Centre for Cell Analysis and Cell-Based Therapy
 - DaBiS – Danish Biological Sample Preparation Facility
 - DBN – Danish Bioimaging Network
 - DK-OPENSOURCE – Danish research infrastructure for chemical biology
 - EMBION – CryoEM research infrastructure for biological nanostructures
 - FOODHAY – Open Innovation FOOD and Health Laboratory
 - INSPECT – Danish Instrument Centre for Interdisciplinary NMR Spectroscopy
 - MedBio-BigData – Medical bioinformatics platform
 - PRO-MS – Danish National Mass Spectrometry Platform for Functional Proteomics
-

COLLECT

Centre for Cell Analysis and Cell-Based Therapy

The proposal is for a centre for cell analysis and cell-based therapy. The centre will contain cell biology laboratory facilities and cell analysis instruments and expertise on cell culture, isolation, analysis and therapy. It will be suitable for use by researchers within the biological and medical fields. The centre will be established with two branches; one at the University of Copenhagen and one at Aarhus University.

The research infrastructure will be able to form the basis for new pure and applied science and will also form the basis for developing new pharmaceutical drugs using single- cell techniques. The prediction is that these pharmaceutical drug types will in future be used to treat a large number of pathological conditions such as communicable, regenerative and oncological diseases. The research infrastructure is expected to be able to further consolidate Denmark's existing strong position in the field of medicine and biology.

The pharmaceutical industry will benefit from using the centre to develop new drugs, and private-sector businesses will be involved in developing the technology for the centre's instrumentation. The centre will hold user courses, annual workshops and issue newsletters in the interests of knowledge transfer. In addition, the centre will maintain contact with industry through the participating universities' technology transfer and business partnerships. The research infrastructure aims to make Denmark a leading nation within cell-based therapy and contribute to economic growth by providing a platform for clinical and commercial drug discovery.

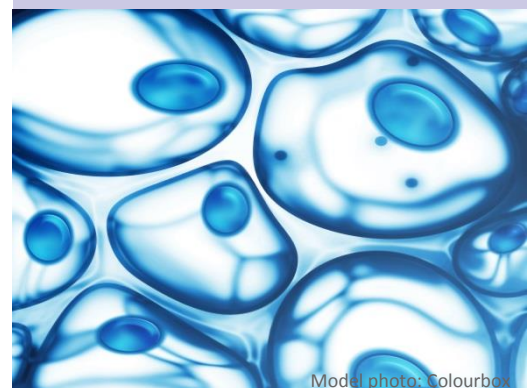
Type
Distributed

Principal proposer
Aarhus University
Contact: Professor Søren Riis Paludan, Department of Biomedicine

Co-proposers
University of Copenhagen, Rigshospitalet (University Hospital of Copenhagen), Statens Serum Institut, Aalborg University Hospital and Aarhus University Hospital

Other interested and potentially interested parties
Bioneer, FOSS, ImmuDex, Lundbeck, SKAU Vaccines and Symphogen

Estimated total investment requirement
Approx. EUR 12-13 million



Model photo: Colourbox

DaBiS

Danish Biological Sample Preparation Facility

The proposal is to establish a research infrastructure for the preparation of biological samples for use at characterisation facilities such as synchrotrons, cryo-electron microscopes or NMR spectrometers. The research infrastructure will be established as a walk-in facility, located at the University of Copenhagen, and with special focus on the production of deuterated biological macromolecules.

The samples will be suitable for use at the European Spallation Source (ESS), MAX IV in Lund, Sweden and at the European X-Ray Free-Electron Laser Facility (European XFEL) in Hamburg, Germany. The facility will facilitate the production and preparation of biological samples for the above-mentioned international facilities for Danish researchers, and in this way optimise the Danish outcome. DaBiS, together with the characterisation facilities, is expected to strengthen the basis for the development of new medical therapies using both protein-based drugs and conventional small molecular drugs.

The pharmaceutical and biotech industries will benefit from access to the facility, either independently or in collaboration with academic research groups, for the preparation of samples for the characterisation facilities. DaBiS will in this way also optimise Danish industrial utilisation of the facilities. Knowledge transfer will be maintained through an advisory body including representatives from industry and also through openings for Industrial PhDs and Industrial Postdocs. It is expected that new technologies developed in DaBiS will be patentable.

Type
Single-sited

Principal proposer
University of Copenhagen
Contact: Professor Michael Gajhede,
Department of Drug Design and
Pharmacology

Co-proposers
Technical University of Denmark
and Aarhus University

Other interested and potentially interested parties
Bioneer, Biopeople (Denmark's life
science cluster), Lundbeck, Novo
Nordisk and Novozymes

Estimated total investment requirement
Approx. EUR 3-4 million



Model photo: Colourbox

DBN

Danish Bioimaging Network

The proposal is to establish a research infrastructure for advanced bioimaging and bioimage processing. The research infrastructure will consist of two entities: an entity for image acquisition, offering facilities for live, super-resolution and single molecule microscopy as well as an entity for image processing and analysis, offering the requisite hardware, software and expertise. These entities will be established with nodes at the participating universities and research institutions. Aside from its own imaging facilities, the research infrastructure will also link in with imaging capability at MAX IV and European Spallation Source (ESS) in Lund, Sweden.

Image acquisition and image processing are essential elements in biomedical research. Expertise in both fields is mutually complementary in that it strengthens the entire workflow from the imaging of biological components to the processing and analysis of images. The research infrastructure will boost Danish imaging and image processing capability and catalyse knowledge exchange and competence spread between researchers within and across the two fields. In addition, the research infrastructure is expected to allow the Danish scientific community to benefit from imaging beamlines at MAX IV and ESS.

The pharmaceutical and biotech industries will gain from making use of or collaborating with the imaging and image processing facilities offered by the research infrastructure, which is expected to improve the basis for industrial breakthroughs. For the purposes of knowledge transfer, the proposal includes training courses, meetings and symposia, and offers Industrial MSc and PhD programmes.

Type

Distributed and virtual

Principal proposer

University of Copenhagen
Contact: Professor Dr Alexander Schulz, Department of Plant and Environmental Sciences

Co-proposers

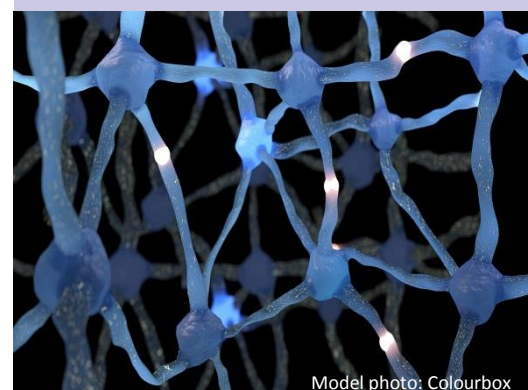
Technical University of Denmark, Danish Cancer Society, Roskilde University, University of Southern Denmark and Aarhus University

Other interested and potentially interested parties

AgroTech – Department of Agricultural and Food Innovation, Aquaporin, Arla Foods, Aalborg University, Bioneer, Chr. Hansen, Dansk Biotek, Biopeople (Denmark's life science cluster), Evolva, INBIOM – Innovation Network for Biomass, Medicon Valley Alliance, Medtech Innovation (innovation network for medical technology), Novo Nordisk, Novozymes, Sejet Plant Breeding, Danish Technological Institute, Visiopharm and Zealand Pharma

Estimated total investment requirement

Approx. EUR 12-13 million



Model photo: Colourbox

DK-OPENSREEN

Danish research infrastructure for chemical biology

The proposal is to establish a Danish node for EU-OPENSREEN, an ESFRI joint European research infrastructure for chemical biology, which unites leading laboratories in the field across a large number of European countries, and which will give Danish researchers access to European data. The Danish node for the European research infrastructure will be established with three regional nodes: one at the Technical University of Denmark specialising in a national chemicals library service; one at the University of Copenhagen specialising in high-throughput screening; and one at Aalborg University specialising in diagnostics.

The Danish node will serve as a platform for open access to screening of chemical compounds and biological activity. It will also include the curating of a national chemicals library to support the identification of compounds with potentials for early drug discovery, diagnostics and medical research geared to communicable diseases, multiresistant bacteria and chronic diseases. The research infrastructure will strengthen Danish researcher access to chemicals and testing facilities within the biological and chemical field and is expected to stimulate collaboration in this area.

The expectation is that new nodes for the research infrastructure will ultimately be based at accredited technological service institutes and private-sector enterprises, and that the research infrastructure will hold potential for spinoff ventures. The plan is to facilitate knowledge transfer through training courses, digital communication, newsletters and information events. Small and medium-sized enterprises within the pharmaceutical and biotech industries engaging in independent or contract research will stand to benefit especially from use of the library of compounds for screening; facilities that are otherwise the preserve of large pharmaceutical firms.

Type
Distributed

Principal proposer

Technical University of Denmark
Contact: Professor Mads H. Clausen, DTU Chemistry - Department of Chemistry

Co-proposers

University of Copenhagen, Aalborg University and Aarhus University

Other interested and potentially interested parties

Alexandra Institute, Bioneer, Dansk Biotek, Biopeople (Denmark's life science cluster), LEO Pharma, Medicon Valley Alliance, Medtech Innovation (innovation network for medical technology), Novo Nordisk and Danish Technological Institute

Estimated total investment requirement

Approx. EUR 4-5 million



Model photo: Colourbox

EMBION

CryoEM research infrastructure for biological nanostructures

The proposal is to establish a research infrastructure for cryoelectron microscopy of biological specimens. It will be established at two facilities; one at the University of Copenhagen and one at Aarhus University, to offer cryoelectron microscopy. The research infrastructure will also be linked with other advanced X and neutron radiation facilities including MAX IV, European Spallation Source (ESS) and the European X-Ray Free-Electron Laser Facility (European XFEL) together with ESFRI's INSTRUMENT programme.

Cryoelectron microscopy is used within structural biology for research in molecular cell biology and in both medicine and biotechnology. The technology enables structural determination of large biological molecules such as proteins, RNA and DNA and facilitates research in molecular models of intracellular and intercellular interaction networks. Equally, it paves the way for the discovery of protein-based drugs and advances in the production of foods, green chemistry, industrial enzymes and new protein-based materials. The research infrastructure is expected to boost Danish protein and enzymatic research.

The pharmaceutical and biotech industries stand to gain independently or collaboratively from utilising the facility, and the research infrastructure is expected to promote economic growth by creating enhanced opportunities for the development of new drugs, biotechnology and protein-based materials and holds potentials for spinoff enterprises. Useful raw data, protocols and checklists for designing and preparing optimised experiments from the facility will be released on open-access databases with a view to knowledge transfer. Other knowledge transfer activities will include courses, open symposia, Industrial PhD and Industrial Postdoc opportunities, and training courses in cryoEM techniques and facilities.

Type
Distributed

Principal proposer

Aarhus University
Contact: Professor Poul Nissen,
Department of Molecular Biology
and Genetics

Co-proposers

Technical University of Denmark,
University of Copenhagen, Statens
Serum Institut and University of
Southern Denmark

Other interested and potentially interested parties

ALK-Abello, Aqua, Arla, AstraZeneca, Biopeople (Denmark's life science cluster), Carlsberg, Chr. Hansen, Dupont, Ferring, Genmab, GlaxoSmithKline, INBIOM – Innovation Network for Biomass, LEO Pharma, Lundbeck, Novo Nordisk, Novozymes, Pcovery, Pfizer, Roche and Symphogen

Estimated total investment requirement

Approx. EUR 17 million



Model photo: Colourbox

FOODHAY

Open Innovation FOOD and Health Laboratory

The proposal is to establish a research infrastructure for food research with a view to extending innovation science and implementation for the benefit of the Danish food industry. The research infrastructure will consist of a primary laboratory linked to Aarhus University at Agro Food Park and a distributed platform for infrastructure and knowledge sharing.

The research infrastructure will be made up of five components: 1) a biomarker and screening platform for in vitro screening of biological responses from food components combined with specialised analysis facilities; 2) a proteomics and metabolomics research platform for analysis of foods and biofluids; 3) a food biophysics platform equipped with a range of scanners, spectrometers, microscopes and more for analysing structural changes in food proteins and food lipids and their interactions; 4) a sensory and consumer platform for experimental and experiential human food perception analysis, with facilities for activities such as product development and behavioural spaces including video and eye-tracking instruments; 5) a platform for nutrition and health information, which will make data available to food industry and health sector stakeholders. The research infrastructure is expected to underpin Danish food research, food education and food innovation.

As an open-access innovation lab, a minor use of the infrastructure activities will consist of facility-leasing by industrial operators, whereas the primary industrial interest will be through research partnerships, demonstration projects and the translation of experimental science into directly industrially implementable know-how. Knowledge transfer will be core to the research infrastructure, which will also offer Industrial PhD and Industrial Postdoc opportunities. The infrastructure is expected to stimulate increased innovation in the Danish food industry.

Type
Distributed

Principal proposer

Aarhus University
Contact: Michelle Williams, Head of Department of Food Science

Co-proposers

Technical University of Denmark, University of Copenhagen, University of Southern Denmark and Aalborg University

Other interested and potentially interested parties

Agro Business Park, Agro Food Park, AgroTech, Arla, Carlsberg, Central Denmark Region, Chr. Hansen, Danish Crown, Danish Food Cluster, Dupont, FOODBEST KIC Nordic Secretariat, FoodNetwork DK, Future Food Innovation, ISI Food Protection, ISIS, KMC, Lantmännen Schulstad/Unibake, Rynkeby, SEGES, Danish Technological Institute, Trade in Denmark and others.

Estimated total investment requirement

Approx. EUR 14-15 million



Model photo: Colourbox

INSPECT

Danish Instrument Centre for Interdisciplinary NMR Spectroscopy

The proposal is an elaboration on an implemented proposal from the 2011 Roadmap concerning a Danish GHz solid state nuclear magnetic resonance (NMR) instrument centre of 950 MHz. The proposal is to establish a Danish instrument centre for interdisciplinary NMR spectroscopy and procure a 1.2 GHz NMR spectrometer to be located at the University of Copenhagen.

The spectrometer will be capable of generating images of the structure of biomolecules at atomic level in an environment equivalent to that in which the molecules naturally exist. In comparison to currently existing spectrometers, both in Denmark and worldwide, it will have the highest sensitivity and resolution available, which will make it suitable to study larger molecules, lower concentrations and more complex biological and chemical samples such as proteins in membranes and large enzyme systems. The spectrometer will enable new applications within molecular and cell biology and serve to advance the development of more efficient food production, research in pharmaceuticals, health and disease, and the development of green chemistry and many other areas.

Industry will be involved via the steering committee for the consortium for Danish NMR Spectroscopy, DAN-SPEC, and will have access to the facility through DAN-SPEC's industry portal either via independent use or commissioned research and research partnerships. DAN-SPEC will serve as an umbrella organisation for the three national NMR centres. Training and courses will be offered in use of the facility, a database of guidelines and experiences will be created, and presentations will be made at scientific and discipline-specific conferences in the interests of knowledge sharing. The facility is expected to enable advances in the food manufacturing, biotech and pharmaceutical industries and contribute to solutions to environmental and climate challenges.

Type
Single-sited

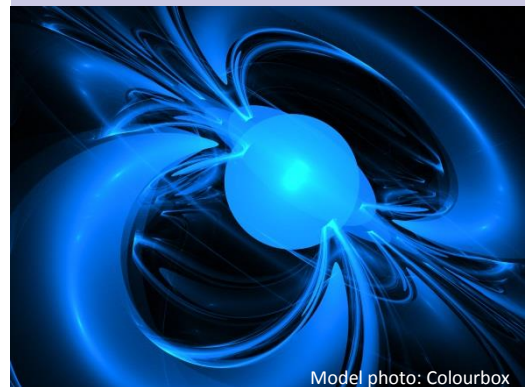
Principal proposer
University of Copenhagen
Contact: Professor Birthe Brandt Kragelund, Department of Biology

Co-proposers
Technical University of Denmark, Roskilde University and Aarhus University

Other interested and potentially interested parties

Albeda Research, Aquaporin, Bi-oneer, Biopeople (Denmark's life science cluster), Biopro, CP Kelco, Dansk Biotek, Dupont, FMC Corporation, GEHealthcare, Haldor Topsøe, LEO Pharma, Lundbeck, Medicon Valley Alliance, Novo Nordisk, Novozymes, Red Glead Discovery and Aalborg Portland

Estimated total investment requirement
Approx. EUR 16-17 million



Model photo: Colourbox

MedBio-BigData

Medical bioinformatics platform

The proposal is to establish a research infrastructure for medical bioinformatics. The research infrastructure consists of an extension and pooling of the three supercomputer installations GenomeDenmark at Aarhus University, Computerome at Technical University of Denmark-University of Copenhagen and DeIC National HPC Centre at University of Southern Denmark such that these will be extended by facilities geared to medical bioinformatics.

The research infrastructure is dedicated to the management, storage and integrated analysis of large data volumes (Big Data) for optimised and individualised treatment and prevention of disease, and is expected to strengthen Danish research in this area. The proposal also envisages the development and distribution of national data analysis protocols and distributed software for the research. The research infrastructure will place particular focus on protection of personal data, including genomic, registry and other health-related data.

Industrial players will be able to gain access to the facility via GenomeDenmark, DeIC National HPC Centre and Computerome under their commercial arrangements. The research infrastructure is expected to facilitate advances in personalised medicine and thereby make a positive contribution to economic growth. Relevant stakeholders will be invited to serve on an innovation committee and in decentralised user groups. The plan is furthermore to host supplementary training for both research and industrial players in the interests of knowledge transfer.

Type

Distributed and virtual

Principal proposer

Aarhus University

Contact: Professor Anders Børghlum, Department of Biomedicine, Head of Centre

Co-proposers

Technical University of Denmark, University of Copenhagen and University of Southern Denmark

Other interested and potentially interested parties

Include: Alexandra Institute, ALK-Abello, AROS Applied Biotechnology, BGI-Europe, Bioneer, Biopeople (Denmark's life science cluster), CLCbio, Danish Technological Institute, DLF Trifolium, ELIXIR-Denmark, Danoffice IT, Intomics, LEO Pharma, Lundbeck, Nordic Seed, Novo Nordisk, Novozymes, Pfizer, TeraData, the university hospitals in Denmark

Estimated total investment requirement

Approx. EUR 13-14 million



Model photo: Colourbox

PRO-MS

Danish National Mass Spectrometry Platform for Functional Proteomics

The proposal is to establish a national platform based on mass spectrometry for functional protein research and proteomics. The platform will be established as an open-access virtual platform, which will formalise, coordinate and integrate collaboration between Danish proteomics and mass spectrometry laboratories located at University of Southern Denmark, University of Copenhagen, Aarhus University, Aalborg University and Technical University of Denmark. All of the partner laboratories will be upgraded with new tandem mass spectrometers and associated chromatography systems and software.

Proteomics and mass spectrometry techniques are used in bioscience and health science. The research infrastructure will facilitate the determination and characterisation of the structure and function of proteins within cell biology, plant biology and microbiology, food science, biotechnology as well as in veterinary, biomedical and clinical protein research. The technologies are of relevance for research in, for instance, the mechanisms underlying antibiotics resistance in livestock and humans.

Industrial partners will be represented in the research infrastructure's steering committee and will have access to the facility via research partnerships. For the purposes of knowledge transfer, the plan is to organize workshops and symposia, training sessions, courses and to offer Industrial PhD and Industrial Postdoc opportunities. In principle, the data are expected to be open-access. The research infrastructure has the potential to contribute to economic growth by strengthening the foundation for technological advances in the biotech, pharma and food sectors, and it holds potential for spinoff enterprises.

Type

Distributed and virtual

Principal proposer

University of Southern Denmark
Contact: Professor Ole Nørregaard Jensen, Head of Department, Department of Biochemistry and Molecular Biology

Co-proposers

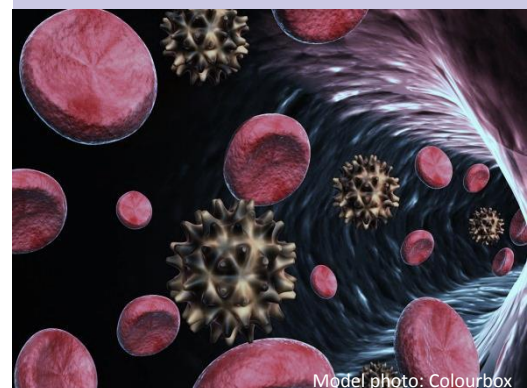
Technical University of Denmark, University of Copenhagen, Odense University Hospital, Aalborg University and Aarhus University

Other interested and potentially interested parties

Agro Food Park, ALK-Abello, Alpha-lyse, Biomar (under SEGES), Bruker, Chr. Hansen, Danish Crown, Danish Pig Research Centre, Danish Technological Institute, Dupont, Dupont Finland, EpiTherapeutics/Gilead Sciences, Ferring, FORCE Technology, Genmab, GenoScan, KMC Brande, LEO Pharma, NEWTEC, NOFIMA, Nordic Bioscience, Novo Nordisk, Novozymes, Sanofi Aventis, Sanovo Foods, Sciex, Symphogen, ThermoFisher and Waters

Estimated total investment requirement

Approx. EUR 11-12 million



Model photo: Colourbox

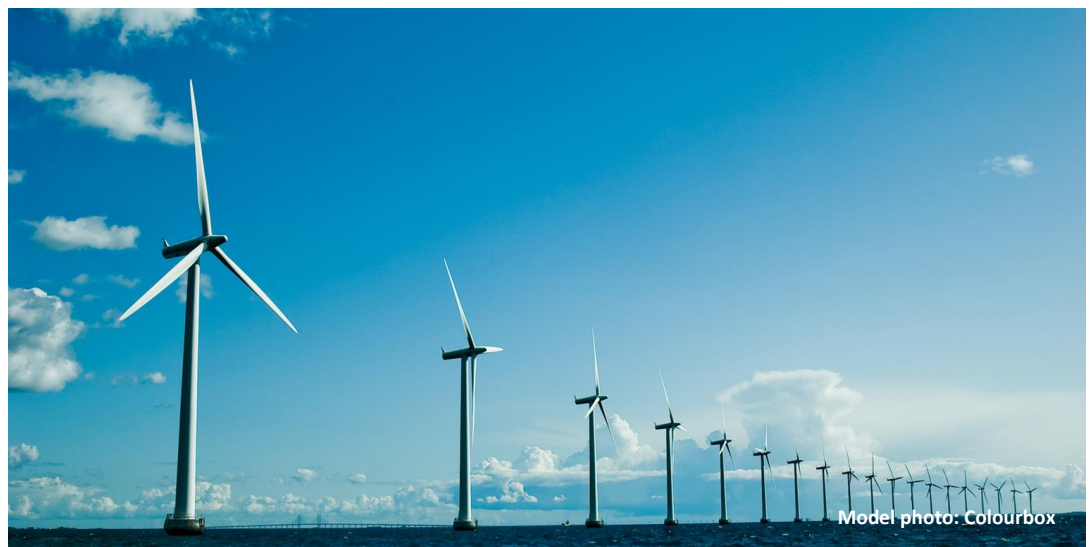
Energy, Climate and Environmental Sciences

The research area of "Energy, Climate and Environmental Sciences" spans a wide range of disciplines which link into a number of key societal challenges with keen Danish focus. This includes how best to minimise and mitigate climate change impacts, prudently manage Denmark's natural resources and support energy conversion of Danish society and industry. The area is closely aligned with and supports development and innovation in private-sector business and industry, particularly within wind turbine, bioenergy and environmental technologies.

Energy research addresses objectives such as enhanced utilisation of energy resources through the development of more energy-efficient technologies, smart grid systems and develops new energy sources, including renewable energy sources.

Climate research involves research in areas such as climate systems and climate change, climate impacts and vulnerability, climate adaptation and measures to reduce greenhouse gases. Among its other outputs, climate research creates a scientific basis for developing more climate-friendly technologies and alternatives to fossil fuels.

Environmental research is traditionally branched into investigations of the atmosphere, hydrosphere, biosphere and geosphere, and comprises research into nutrient flows from cities and agriculture into the natural environment, research in the biodiversity of different ecosystems and research in greenhouse gas emissions and their impacts on climate systems. It also comprises the advancement of industrial production and mitigation of adverse environmental impacts on humans.



Within this field of research, satellite constellations for observation of terrestrial, marine and ice-covered surface structures and measuring stations on land, at sea and in the atmosphere, which perform measurements of factors such as temperature, precipitation and air quality, are key research infrastructures. In addition, the researchers need access to other research infrastructures such as fixed and mobile field stations, research vessels for investigation of Arctic regions and test facilities for industrial products and new technologies such as within the wind turbine sector.

TEXT BOX 4.3: PROPOSALS WITHIN ENERGY, CLIMATE AND ENVIRONMENTAL SCIENCES

- AnaEE Denmark – Infrastructure for experimental ecosystems research in Denmark
 - HydroObs – Agro-hydrological and hydro-biogeochemical observatories
 - ICOS/DK – Danish infrastructure for measuring atmospheric greenhouse gas emissions and ecosystem exchange processes
 - UAS-ability – Research infrastructure for the use of unmanned aerial systems (drones) for data collection
 - WindScanner.eu – The European WindScanner Facility
 - X-Power – Power Electronics Reliability Test Facilities
-

AnaEE Denmark

Infrastructure for experimental ecosystems research in Denmark

The proposal is to establish a Danish node for the ESFRI project AnaEE, a pan-European research infrastructure for experimental ecosystems research under an alliance of a number of European nations, which will give Danish researchers access to European data. The Danish node will be established by setting up 12 research platforms, some of which will be located within different ecosystem types, including forest and grassland, while others will be mobile or in-vitro platforms. In addition, the node will establish a coordinated investigator network for the purpose of disseminating knowledge and methods in this research area.

The research platforms will have applications in climate and environmental manipulation designed to demonstrate changes in ecosystems as a result of climate and environmental changes, including changes affecting agriculture. The research infrastructure will be instrumental in substantiating predictions of how future climatic and environmental changes might impact food safety, drinking water, biodiversity and bioenergy. It is expected to boost Danish ecosystems research and advance the adoption of long-term sustainable exploitation and management of Danish ecosystems.

Industrial stakeholders will participate in the research structure's advisory body and in user groups, and will have access to conducting experiments at research platforms and benefit from open access. For purposes of knowledge transfer the plan is for open access projects, dissemination via a dedicated website, meetings, workshops and conferences.

The research infrastructure is envisaged to strengthen the basis for development ventures within the agricultural sector, to have spinoff potential in relation to the producers of wood and bioenergy and to be of relevance for consulting engineering firms and companies engaged in the development of innovative technologies for environmental surveys.

Type Distributed

Principal proposer

University of Copenhagen
Contact: Svend Christensen, Head of Department, Department of Plant and Environmental Sciences

Co-proposers

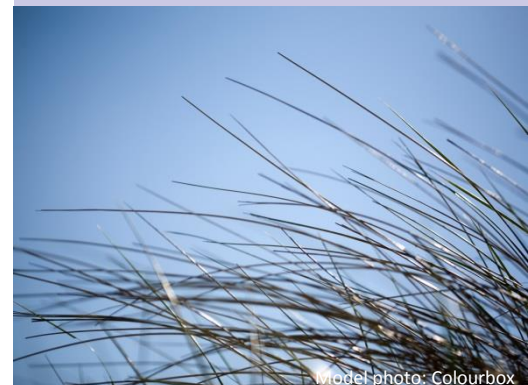
Technical University of Denmark, Roskilde University and Aarhus University

Other interested and potentially interested parties

AgroTech – Department of Agricultural and Food Innovation, ALECTIA, Bolding og Bruggeman, Carlsberg, COWI, Crop Innovation Denmark, Danish Christmas Tree Growers' Association, Danish Forestry Association, Danish Technological Institute, DELTA – Danish Electronics, Light & Acoustics, DHI, FORCE Technology, INBIOM – Innovation Network for Biomass, Inno-MT – Innovation Network for Environmental Technologies, Novozymes, Orbicon, Prenart Equipment RoboCluster and SEGES

Estimated total investment requirement

Approx. EUR 7 million



Model photo: Colourbox

HydroObs

Agro-hydrological and hydro-biogeochemical observatories

The proposal is to establish a number of instrumented agrohydrological and hydro-biogeochemical observatories for monitoring fluxes of energy, water and matter from agricultural zones. The observatories will be further developed in three different hydrological catchments representing three discrete sets of hydro-geological conditions, and will be located in West Jutland, East Jutland and South Zealand.

The research infrastructure will facilitate integrated process studies of water flows within and across hydrological domains on different scales together with studies of compound transport and conversion. The observatories will serve concurrently as independent research platforms. The research infrastructure is expected to boost Danish agrohydrological and hydro-biogeochemical research and to be of relevance in the development of new environmental regulation and sustainable food production.

Private-sector enterprises can gain association with and access to the research infrastructure as associated partners and through research partnerships for which expertise will duly be made available for interpretation of data. Data can also be available for test purposes and the like. The prediction is that the research infrastructure will be able to contribute to economic growth by improving the basis for developing more cost-effective food production and generating growth in downstream industries such as machinery and manure makers/suppliers, information and communication technology, processing and consulting enterprises and companies pursuing the development of sensor, monitoring and environmental technologies.

Type
Distributed

Principal proposer

Aarhus University
Contact: Charlotte Kjærgaard, Senior Researcher, Department of Agroecology

Co-proposers

GEUS - Geological Survey of Denmark and Greenland and University of Copenhagen

Other interested and potentially interested parties

Include: Agrohydrologerne, ALEC-TIA, Danish AgriFish Agency, Danish Nature Agency, Danish Soil Partnership, Danish Water Test Centre, DANVA, DHI, DLMØ, Ejlskov, Fagerberg, Hach Lange, HydroInform, the Innovation Partnership Future Cropping, Farming & Foods, Odder Municipality, Op-landsrådet Norsminde Fjord (fjord catchment council), Orbicon, Rambøll, Ringkøbing-Skjern Municipality, SEGES, Spectrofly, Sorbisense, UN GEF and Vandkvalitetsprojekt i Vivede Mølleå (water quality project)

Estimated total investment requirement

Approx. EUR 3 million



Model photo: Colourbox

ICOS/DK

Danish infrastructure for measuring atmospheric greenhouse gas concentrations and ecosystem exchange processes

The proposal is to establish a Danish node for the ESFRI ICOS ERIC project, which consists of a network of measuring stations in a number of European countries for data collection on atmospheric greenhouse gases. The infrastructure will comprise a number of different measuring stations: atmospheric stations, ecosystem stations and marine stations, all of which will collect data on greenhouse gases. By establishing the Danish node, a number of new measuring stations will be set up in Denmark and Greenland.

The research infrastructure will collect and grant Danish researchers access to data from Denmark and Greenland, and via the European network will grant access to European data. Data will be standardised and quality-assured via the European network to make them fully comparable across measurements. The research infrastructure is expected to form the basis for greater understanding of the factors implicated in climate change by increasing the basis of knowledge concerning the development in greenhouse gas concentration in the atmosphere and exchanges with land and sea surfaces.

Industrial and innovation players will be invited to participate in the research infrastructure's user group, but there is no plan to grant access to direct use of the facility. Instead, stakeholders will be able to influence the type of data collected. Data will be available via the European ICOS platform with opportunities for contract research, and are expected to be applicable to a diverse range of industrial products (customised maps, models, simulations, consulting services) with potential for positive economic growth and spinoffs. The plan is to publish information materials in industry journals and popular science articles in association with industrial players and to offer training sessions in the interests of knowledge transfer.

Type

Distributed and virtual

Principal proposer

Technical University of Denmark
Contact: Professor Kim Pilegaard,
DTU Environment - Department of
Environmental Engineering

Co-proposers

University of Copenhagen, Roskilde
University and Aarhus University

Other interested and potentially interested parties

AgroTech – Department of Agricultural and Food Innovation, Air Liquide Denmark, Ammongas, Aquavitec, BBK bio airclean, COWI, Daniit, Danish Technological Institute, DHI, EnviDan, Explicit, FORCE Technology, HOFOR, Innovation network for climate adaptation, Inno-MT – Innovation Network for Environmental Technologies, Leapcraft, NIRAS, Nordvand, and Rambøll.

Estimated total investment requirement

Approx. EUR 5-6 million



Model photo: Colourbox

UAS-ability

Research infrastructure for the use of unmanned aerial systems (drones) for data collection

The proposal is to establish a research infrastructure for the development of drone technology, integration and use of drones in research, especially for data collection within the field of climate and environment. The research infrastructure will be sited at three specialised centres in Denmark: one for the development of drone technology at University of Southern Denmark; one for the integration of drone technology at Aalborg University and one for drones- based research at Aarhus University.

The research infrastructure will form the basis for boosting Danish research in drone technology enhancements and will facilitate increased and more efficient use of drones for research. The expectation is that drone technology will ultimately enhance and ease data collection – especially in scarcely accessible regions – notably for use in climate, energy and environmental research. Drones may, for instance, be employed in studies of climate change impacts on the Arctic, environmental monitoring of Denmark's coasts, or thermographic analyses of energy loss in buildings. At the same time, in connection with the research infrastructure, there will be a focus on drone operator training.

Industrial and innovation sector players will participate in working parties under the research infrastructure with a view to preparing requirements specifications and a directory of services offered by the facilities. Industry will benefit from using the facilities independently or via partnerships and will engage in technology development. For the purposes of knowledge transfer, the expectation is that the facilities will host conferences and offer drone operator training. The potential for economic growth is expected to arise out of technology development and drone production together with opportunities for spinoff enterprises and the ability to attract foreign companies to Denmark.

Type
Distributed

Principal proposer

University of Southern Denmark
Contact: Kasper Hallenborg, Head of Institute, Maersk Mc-Kinney Moller Institute

Co-proposers

Technical University of Denmark, Danish Meteorological Institute (DMI), DELTA – Danish Electronics, Light & Acoustics, University of Copenhagen, Aalborg University and Aarhus University

Other interested and potentially interested parties

Airbus, Danish Emergency Management Agency, fire and emergency services, Boeing, CenSec, Danish Aviation Systems, Danish Institute of Fire and Security Technology (DBI), Explicit, FORCE Technology, Danish Geodata Agency, HCA Airport, MyDefense Communication, Danish AgriFish Agency, Danish Nature Agency, Naviair, Odense Municipality, Danish Security and Intelligence Service, Reseiwe, RoboCluster, SCION UAS, Sky-Watch, Danish Technological Institute, TERMA, Danish Transport and Construction Agency, UAS Denmark, UAS Test Center Denmark, Danish Road Directorate, ViaCopter and Weibel

Estimated total investment requirement

Approx. EUR 12-13 million



Model photo: Colourbox

WindScanner.eu

The European WindScanner Facility

The proposal is to host a Danish node serving the ESFRI joint European research infrastructure, WindScanner.eu as well as hosting the hub in the distributed facility. WindScanner.eu is a mobile and distributed research infrastructure for 3D remote sensing based scanning of wind and turbulence in the atmosphere. Under a proposal from the Danish Roadmap for Research Infrastructure 2011, a Danish WindScanner facility has already been established, and the proposal is to upgrade the capacity of this facility to perform more far-reaching measurements in connection with future large wind turbines and wind farms as a Danish node serving WindScanner.eu. Its potential applications will in addition to wind energy research also be aiming at applications in connection with buildings, bridges, aviation and the urban environment.

The mobile WindScanner facility will permit 3D scanning of wind and turbulence fields in the atmospheric boundary layer and is used in connection with wind turbine development and testing. The scanning capability is relevant for wind turbine development in respect to wind loads and optimised siting for wind turbines and wind farms. Membership of WindScanner.eu also gives Danish researchers access to European WindScanner data. The research infrastructure is expected to boost Denmark's existing strengths in wind energy research.

Industrial players will be connected by means of user groups and will have access to the facility independently or via partnership projects. Data will be made available via a WindScanner e-Science and open access platform for the national, European and global users alike, and via workshops for user groups created for that purpose. The research infrastructure is predicted to boost the Danish wind energy industry and to result in the development of saleable WindScanner technology and, potentially, spinoff businesses.

Type

Distributed and mobile

Principal proposer

Technical University of Denmark
Contact: Søren Knudsen, Senior Executive Officer, DTU Wind Energy - Department of Wind Energy

Co-proposers

DMI – Danish Meteorological Institute, Aalborg University and Aarhus University

Other interested and potentially interested parties

DHI, Dong Energy, EDF energies nouvelles, FORCE Technology, Offshoreenergy.dk – Offshore Knowledge and Innovation Centre, Siemens Wind Power and Vestas Wind Systems

Estimated total investment requirement

Approx. EUR 6-7 million



Model photo: Colourbox

X-Power

Power Electronics Reliability Test Facilities

The proposal is to establish a national centre for reliability testing of power electronics. The centre will be located at Aalborg University with nodes at University of Southern Denmark in Odense and Sønderborg. Each of the centre's departments will be equipped with various instruments for reliability test analysis and modelling.

The centre will provide a setting for a national programme to enhance power electronics and boost Danish research in this field, including in relation to optimising the design of apparatus for a given service life. The centre will also provide access to facilities for testing and analysing fault mechanisms in power electronics systems and components. It will, for instance, permit reliability testing of power electronics in relation to a range of stress factors such as temperature, moisture, vibrations and power grid interfaces. The research infrastructure is expected to be relevant for the continually increasing global utilisation of power electronics due partly to the transition of energy production to renewable energy, a keener focus on energy efficiency and the electrification of transport.

Industrial players will be invited to participate in an advisory body/steering committee and will benefit from access to the facility for reliability testing of new components. This might, for instance, be in relation to new materials that need to be able to withstand demanding weather conditions, be compatible with extended operational times, particular safety conditions, designs featuring complex electronic systems and for a specific service life is desirable. With its industrial relevance, the research infrastructure is predicted to hold significant potential for economic growth.

Type
Distributed

Principal proposer

Aalborg University
Contact: Professor Frede Blaabjerg,
Department of Energy Technology

Co-proposers

Technical University of Denmark,
DELTA – Danish Electronics, Light
& Acoustics, University of Southern
Denmark and Aarhus University.

Other interested and potentially interested parties

Include: Danfoss Power Electronics,
Danfoss Silicon Power, Dantherm,
European Center Power Electronics,
Grundfos Holding, KK-Wind Solutions,
PowerCon, Siemens Wind
Power and Vestas Wind Systems

Estimated total investment requirement

Approx. EUR 8-9 million



Model photo: Colourbox

Physical Sciences

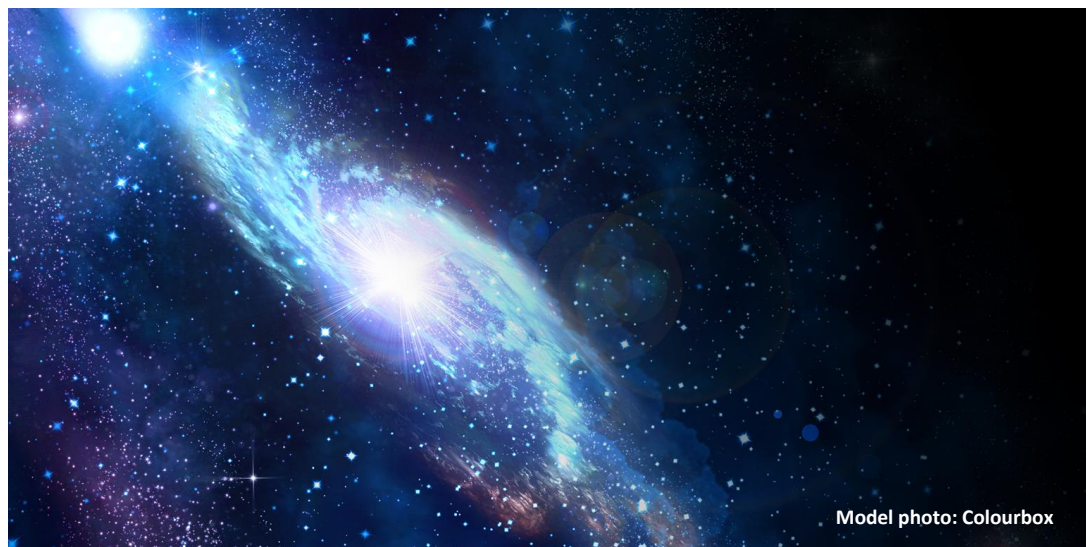
Within the research area of "Physical Sciences", researchers seek to confirm hypotheses about some of the greatest unknowns such as the nature of cosmic dark matter and dark energy, to identify new planetary systems and the potential for life on other planets, to investigate Earth's magnetic field, how stars and galaxies were formed by the Big Bang, and to solve the mystery of why elementary particles and hence all things in nature have mass.

Physical Sciences span the classical sciences of physics, astrophysics, geology and mathematics, including particle and nuclear physics, biophysics and so forth.

In pursuing frontline research, the need arises to develop novel technologies, methods for data processing on supercomputers, for employing data, and for electronics and software together with instruments for telescopes and satellites.

Satellites contribute to the solution of a number of societal challenges within climate and environmental monitoring, natural resource management, security, transport and communication. This attracts new high-tech companies, which pave the way for new, innovative solutions in yet more areas. The need for enhanced navigational and environmental safety in Danish waters and in the North Atlantic, surveillance and enforcement of sovereignty together with the need for climate monitoring of the Arctic are examples of this.

This research area is heavily reliant on having access to large national and international research infrastructures because their facilities tend to be so large-scale and costly to develop and operate that single research institutions and even individual countries, may not have sufficient capacity on their own and may need to collaborate nationally or internationally. Important research infrastructures include astronomical observatories and telescopes, partnerships on space research and seabed drilling, synchrotrons and high-energy facilities.



TEXT BOX 4.4: PROPOSALS WITHIN PHYSICAL SCIENCES

- CERN-UP – Upgrading infrastructure for CERN experiments and computing
 - QUANTECH – Quantum Technology Infrastructure Proposal
-

CERN-UP

Upgrading infrastructure for CERN experiments and computing

The proposal is for an upgrade to CERN experimental facilities with important Danish participation, including the Large Hadron Collider (LHC) experiments ALICE and ATLAS, and the fixed-target ISOLDE and ALPHA/ELENA experiments. An upgrade of High Performance Computing and GRID capacity for distributed data storage and processing is also proposed. The proposal strengthens the Danish membership of CERN and NICE, the National Danish Infrastructure Center for CERN related research, significantly.

Danish membership of CERN provides Danish researchers with access to unique facilities, leading at the world scale, for fundamental physics research. The upgrades are expected to boost returns from the Danish membership. The LHC experiments investigate high-energy collisions between protons and between heavy lead nuclei aiming at understanding the Standard Model and beyond and the properties of the Quark Gluon Plasma. The two fixed-target programmes study phenomena of significance for astrophysics (ISOLDE) and for antimatter using antiprotons to synthesize antihydrogen (ALPHA/ELENA).

CERN generates significant industrial returns, and supports basic science, advanced technology (for example, NMR, cryotechnology, image processing, data processing and radiation-hard electronics), advanced computing, accelerator technology (for medical applications, for example) etc. For the specific upgrades proposed, the expectation is that Denmark will participate in the development, construction and delivery of individual elements and system assembly. In addition, efforts are in progress to establish a Scandinavian production cluster with the goal of being able to supply more components to CERN in future. BigScience.dk is responsible for CERN knowledge transfer in Denmark and organises, for example, matchmaking and other events including visits to CERN.

Type
Single-sited

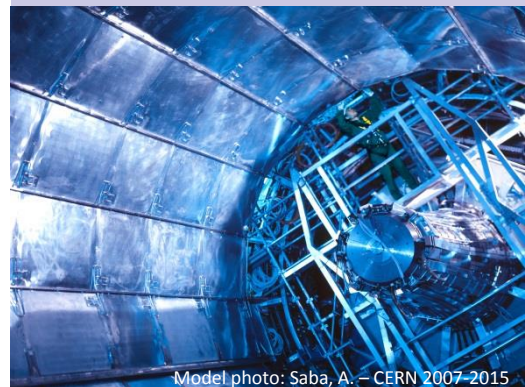
Principal proposer
University of Copenhagen
Contact: Professor Jens Jørgen Gaardhøje, Niels Bohr Institute

Co-proposers
Technical University of Denmark,
University of Southern Denmark
and Aarhus University

Other interested and potentially interested parties

AM Værktøj, ASA-TOR, Axcon, CB Svendsen, Danfysik, Danish Technological Institute, Dyrmark Systems, East Metal, Ipm, Jobindex, Kirkholm, Necas, ODU, PolyMacs, Polyteknik, Prodan, Røttgers Værktøj, TransElectro and Weissenborn

Estimated total investment requirement
Approx. EUR 7 million



Model photo: Saba, A. — CERN 2007-2015

QUANTECH

Quantum Technology Infrastructure Proposal

The proposal is for the establishment of a research infrastructure for quantum technology which will consist of a national facility located at University of Copenhagen and Technical University of Denmark with a number of instruments for the production and characterisation of photonic and electronic quantum components. The instrumentation will include an electron-beam writer dedicated to ultrahigh-resolution production of quantum nanostructures.

The proposed research infrastructure is expected to boost Danish capability for quantum technology research as regards both the pure science and technological applications, including research in scalable quantum networks, quantum simulations, quantum metrology, quantum electronics and materials for quantum technology. Quantum technology is an area undergoing intensive international development and the expectation is that the research infrastructure will improve the efficiency of development, production and testing of new quantum materials and components with potential applications for the synthesis of novel materials or advancing information and communication technology.

Industrial stakeholders will benefit from using the facilities via collaborative projects. In the interests of knowledge transfer, the plan is to host annual quantum technology symposia for researchers and industry. The expectation is that technology developed for the project will also have potential applications in industry, including for sensing, energy-efficiency technologies and green IT. In addition, quantum technology generally holds industrial and innovation potentials, and the research infrastructure is expected to assist in unlocking these potentials, including creating patents and spin-out companies.

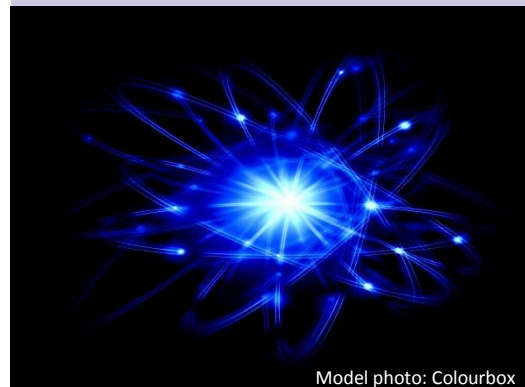
Type
Distributed

Principal proposer
University of Copenhagen
Contact: Professor Peter Lodahl,
Niels Bohr Institute

Co-proposers
Technical University of Denmark,
University of Southern Denmark
and Aarhus University

Other interested and potentially interested parties
Danish Technological Institute/Danfysik, DFM – Danish National Metrology Institute, Cryptomathic, QuantumWise, Accelink Denmark, NKT Photonics, NIL Technology, FOSS, M Squared Lasers, Attocube Systems, Toptica Photonics AG, Montana Instruments, Scontel, Elionix and ID Quantique

Estimated total investment requirement
Approx. EUR 7 million



Model photo: Colourbox

Humanities and Social Sciences

The research area of "Humanities and Social Sciences" addresses topics such as identifying new modes of social organisation, communication, learning, motivating and optimising processes. The research area contributes to and is essential for our cultural, social, political and economic life. Equally, it enables and promotes innovation across a wide front within the segments of business and industry engaged in, for example, the development of new learning technologies, consulting services, corporate management, cultural outreach, language and communication, and is a success criterion for Danish businesses operating in a global market characterised by cultural and linguistic diversity.

The humanities span a wide range of disciplines which seek to explain and understand human existence and cultural products. The area includes research in languages, history, art, culture, media and educational theory. Humanities research makes a significant contribution to social innovation, creative endeavours, intercultural understanding and understanding of developmental processes beyond the conventional functions of knowledge society enlightenment and competence-building.

The social sciences comprise research in economics, politics, welfare, societal conditions and working life, and are instrumental in designing political and economic policy measures underpinning the capacity to overcome major societal challenges such as future-proofing welfare for an increasingly ageing population and raising the rate of employment.



The research area is reliant on research infrastructures such as laboratory facilities for experimental projects and highly specialised collections at static locations, including libraries and archives together with diverse museum collections devoted to domains such as culture, art, history and archaeology. In addition, databases play a key role across this research area. These are often implemented in national or international data networks and comprise material that includes statistical data such as registry data or digitised data; e.g. linguistic and media data and digitised museum collections.

TEXT BOX 4.5: PROPOSALS WITHIN HUMANITIES AND SOCIAL SCIENCES

- BICLabs – Behaviour, Interaction and Cognition Labs
 - DigHumLab 2.0 – Digital Humanities Lab Denmark
 - DRDS – Danish Research Data for the Social Sciences
-

BICLabs

Behaviour, Interaction and Cognition Labs

The proposal is to establish a research infrastructure with- in experimental behavioural research entailing an upgrade of existing laboratory facilities at a number of universities with new equipment. The laboratories will be specialised in a range of fields and methods within behavioural re- search and diversification will be implemented across the laboratories. The laboratories will also be linked in a net- work, and Danish researchers will have open access to all laboratories in the network regardless of their institutional affiliation.

The purpose of the research infrastructure is to boost Danish research in human behaviour, interaction and cognition by upgrading and integrating existing facilities in the interests of giving researchers access to expertise and overview of the diverse laboratory facilities. Together, the facilities will cover the research area's principal foci, including creativity and play, decision-making and collec- tive behaviour, design, objective measurement of subjec- tive experience, behavioural interventions, health and wellbeing. The research infrastructure is expected both to boost Denmark's existing strengths within the above- stated areas and also facilitate new interactions between them. In addition, the participating institutions will share experimental technology, including software.

On commencement, a call will be issued for expres- sions of interest from industrial and innovation stakehold- ers via Universities Denmark and the Confederation of Danish Industry. Industrial stakeholders will have access to using the research infrastructure and its associated expertise, and the participating innovation networks will engage in outreach to small and medium-sized and start- up enterprises seeking to develop new services and tech- nologies. The research infrastructure is expected to strengthen the basis for developing new, innovative design products (such as learning products for children) and to generate new consumer and market research.

Type
Distributed

Principal proposer

Aarhus University
Contact: Per Baltzer Overgaard,
Vice-Dean for Research and Talent
Development, Aarhus BSS

Co-proposers

Copenhagen Business School, Tech-
nical University of Denmark, Uni-
versity of Copenhagen and
University of Southern Denmark

**Other interested and potential-
ly interested parties**

Alexandra Institute, CLEAN cluster,
Design2Innovate (EU project), Dan-
ish Broadcasting Corporation,
FORCE Technology, Innovation
Network for Finance IT, Inno-SE –
Innovation network for Smart Ener-
gy, Danish Competition and Con-
sumer Authority, Lego Foundation,
Play User Lab (Capital of Children
project in cooperation with Billund
Municipality and with 30 associated
companies) and Danish Technologi-
cal Institute

**Estimated total investment
requirement**

Approx. EUR 9-10 million



Model photo: Colourbox

DigHumLab 2.0

Digital Humanities Lab Denmark

The proposal is to significantly enlarge DigHumLab, the existing digital research infrastructure spanning the humanities disciplines, which was one of the realised proposals from the 2011 Roadmap. This research infrastructure links into the ESFRI DARIAH ERIC and CLARIN ERIC projects, which give Danish researchers access to European digitised research data.

This research infrastructure consists of the addition of three new research fields to DigHumLab: 1) materials and text-based cultural heritage research; 2) research in technology-supported learning; 3) research in social and mobile media. This upgrade comprises the development of a large number of new digital research resources (software) and a database for the new research fields together with research training in the use of digital resources and standards. The research infrastructure is expected to be valuable in the development of digital teaching modes, research in Denmark's cultural heritage, and fact-finding on and advances in the use of digital and mobile media.

The accredited technological service institutes and innovation networks will participate in the research infrastructure's technology development, commercialisation, development of a sustainable business model and match-making with commercial partners. Test and user cases are planned as well as partnerships with industry and innovation players for the purposes of knowledge transfer. The research infrastructure's three principal foci are expected to tie in with a number of commercial segments and to contribute to economic growth through these: cultural heritage with the architectural, consulting engineering and IT segments; mobile and social media with sectors comprising the language technology and text analysis market; digital technologies and online learning with public administration, publishing and learning design segments.

Type
Virtual

Principal proposer

Aarhus University
Contact: Johnny Laursen, Dean,
Faculty of Arts

Co-proposers

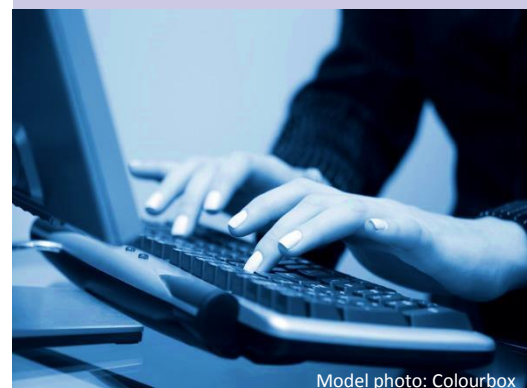
Alexandra Institute, the Royal Library, University of Copenhagen, Roskilde University, State and University Library, University of Southern Denmark and Aalborg University

Other interested and potentially interested parties

Ankiro, Google, Danish ICT Innovation Network - Infinit, Infomedia, Brandbase innovation network, InViO – Innovation Network for Knowledge-Based Experience Economy, Service Cluster Denmark (innovation network), local, regional and central government administration, LEGO, Meltwater, Microsoft, Mindjumpers, Post & Tele Museum (national museum of post and telecommunications), Society for Danish Language and Literature, Tekker group, Trustpilot and Vico

Estimated total investment requirement

Approx. EUR 13 million



Model photo: Colourbox

DRDS

Danish Research Data for the Social Sciences

The proposal is to establish a research infrastructure with a twofold purpose: one, to give Danish researchers access to a number of international databases and two, to curate and develop new longitudinal registry data. A Danish Registry Board will be formed to support the selection of relevant registry data. The longitudinal registry data will be curated through systematisation, purging and pooling of already collected, but not systematised, small data sets, and the new registry data will be compiled at Statistics Denmark.

In recent years, access to international social science databases has become an indispensable resource for research at the international level, especially within economics and financial research. The development of new longitudinal registry data at the micro level will facilitate wide access among Danish researchers to data on financial decisions in households, social policy data, election data, consumption data, economic and employment data for all Danish companies. The research infrastructure is expected to boost Danish social science research notably within the economic fields in a broad sense.

Registry data generated via the research infrastructure will be made available to industrial and innovation stakeholders through Statistics Denmark's researcher programme, including a proposed business statistics data warehouse. Industrial players will be able to gain access to data from the international databases via research partnerships. The plan is for analyses from Statistics Denmark, reports for contracting authorities, a communication plan and courses/seminars in the interests of knowledge transfer. The research infrastructure is expected to boost commercially-oriented research within a wide field, including the financial and pension sectors, to enhance political decision-support with the aim of driving economic growth and welfare, and via geodata to permit more accurate property valuations and enhanced models for localisation of retail businesses.

Type
Virtual

Principal proposer
Copenhagen Business School
Contact: Professor Peter Ove Christensen, Department of Finance

Co-proposers
Statistics Denmark, KORA - Danish Institute for Local and Regional Government Research, University of Copenhagen, Roskilde University, SFI – Danish National Centre for Social Research, University of Southern Denmark, Aalborg University and Aarhus University

Other interested and potentially interested parties
Include: ATP, Confederation of Danish Enterprise, Confederation of Danish Industry, Copenhagen Economics, DAMVAD Analytics, Danish Ministry of Business and Growth, Danish Technological Institute and Danmarks Nationalbank

Estimated total investment requirement
Approx. EUR 12-13 million



Model photo: Colourbox

Materials Technology and Nanotechnology

Materials Technology and Nanotechnology both concern the study, characterisation and manipulation of materials, including biological materials. In recent years, this field has evolved into a highly dynamic and interdisciplinary research area spanning right from chemistry, physics and the materials manufacturing industry to subjects such as biology, molecular biology and medicine. Materials properties such as resilience, hardness, conductivity, corrosion resistance thus have implications in as diverse undertakings as the development and manufacture of high-grade construction materials for buildings, aircraft and cars to functional materials for drugs, fuel cells and microelectronics. Research in materials science and nanotechnology consequently also holds immense industrial potential in relation to the development of new products and production methods within the pharma, wind turbine and plastics industries, for instance, in the production of more robust, resilient and eco-friendly materials.

Materials technology and nanotechnology deal with analysis, modelling and production of materials and the manipulation of processes at atomic level, that is, down to one millionth of a millimetre. The research has industrial applications in design and synthesis of materials, components and systems with new functional properties, which are unparalleled at the macroscopic scale.



This research area needs access to research infrastructures such as materials characterisation facilities at nanolevel, for example, including facilities for characterising materials under conditions resembling those the materials operate under in the real world. Examples of such facilities are scanning probe microscopes (SPM), nuclear magnetic resonance (NMR) spectrometers and photon and neutron scattering instruments. These are commonly in the shape of large international facilities. In addition, advanced materials production facilities, cleanrooms and super-computer power for materials modelling are important research infrastructures in this area.

TEXT BOX 4.6: PROPOSALS WITHIN MATERIALS TECHNOLOGY AND NANOTECHNOLOGY

- DANFIX – Danish National X-Ray Imaging Facility
 - FiberLab – New Fibre Composites Laboratory
-

DANFIX

Danish National X-Ray Imaging Facility

The proposal is for the establishment of a Danish facility for X-ray imaging. The facility will be located at the Technical University of Denmark and will consist of eight complementary instruments for visualisation of a diverse range of materials. The research infrastructure will also be linked with MAX IV, including the Danish DANMAX beam line, and European Spallation Source (ESS). The research infrastructure is expected to hold relevance for a wide range of industrial interests in Denmark.

The research infrastructure must be able to visualise materials and biotechnological components in 3D, and facilitate the study of their development by means of process studies. It must also enable the digitisation of museum collections. The research infrastructure will have applications across a wide range of research areas, including food science, pharmacy, manufacturing research, environmental research, archaeology et cetera.

An imaging industry portal will be linked to the facility for the purpose of solving specific problems for industry either via research partnerships or on a commercial basis. In addition, industry will serve on the DANFIX board. The plan is for collaboration with the Confederation of Danish Industry, the Danish Regions, innovation networks and industry organisations in the materials domain and for annual meetings, themed meetings, trade fairs, newsletters, folders of cases (industrial sector-specific), a website, a series of meetings for business and demonstration projects (especially for new start-ups). In addition, industrial contacts will be exchanged between the university partners, and there is the prospect of Industrial PhD and Industrial Postdoc opportunities as well as supplementary training courses. The prediction is that the research infrastructure will boost advances in production technology, energy components, pharmaceutical drugs, foods and building materials.

Type

Single-sited

Principal proposer

Technical University of Denmark
Contact: Professor Henning Friis Poulsen, DTU Physics

Co-proposers

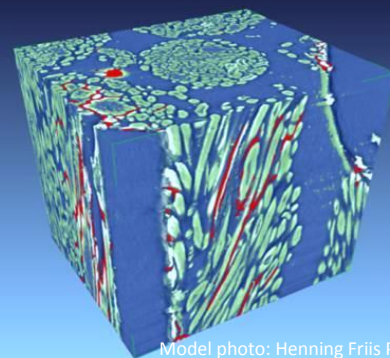
University of Copenhagen, Roskilde University, Aalborg University and Aarhus University

Other interested and potentially interested parties

Include: Alexandra Institute, COWI, CPH Inventures, CO-RO, Danpo, DBI - Danish Institute of Fire and Security Technology, Danish Technological Institute, DMN (Danish materials innovation network), DELTA – Danish Electronics, Light & Acoustics, FORCE Technology, Grundfos, Haldor Topsøe, Hempel, INBIOM – Innovation Network for Biomass, Inno-MT – Innovation Network for Environmental Technologies, Inno-Pro – Innovation Cluster for Production, Offshoreenergy.dk – Offshore Knowledge and Innovation Centre, JJ X-ray, LEGO, LM Wind Power, Medtech Innovation (innovation network for medical technology), Midgaard, Mærsk, NIRAS, Novo Nordisk, Novozymes, Rockwool International, Siemens, and Siemens Wind Power

Estimated total investment requirement

Approx. EUR 8-9 million



Model photo: Henning Friis Poulsen

FiberLab

New Fibre Composites Laboratory

The proposal is for the establishment of two laboratories for research in the production of fibre-reinforced polymer-based composites. One laboratory will be established at the Technical University of Denmark in extension of the existing Fiberlab dedicated to production of composites based on long fibres, while the other laboratory will be established at Aalborg University and dedicated to production of short fibre composites.

The research infrastructure will consist of equipment for documented processing of advanced fibre composites and test specimens, materials characterisation and facilities for working and producing test pieces. This, combined with materials modelling and mechanical testing, will form the basis for research and development of advanced composites. The research infrastructure is relevant for the development of lightweight materials, which are particularly essential within the transport and wind energy sectors.

Innovation networks, accredited technological service institutes and other representatives of industry will participate in the research infrastructure's consortium. The consortium will direct focus on the design and specification of the facilities, user contracts, supervision of establishment processes and subsequently focus on commissioning activities. Danish industry will gain access to the facilities via research alliances, and the research infrastructure will serve as a centralised contact point for industrial players requiring conceptualisation, design, dimensioning, prototyping and proof-of-concept. The research infrastructure is expected to boost advances in drone, satellite, space and telecommunications technology besides the general development of new composite materials.

Type
Distributed

Principal proposer

Technical University of Denmark
Contact: Professor Bent F. Sørensen, Head of Section, DTU Wind Energy - Department of Wind Energy

Co-proposers

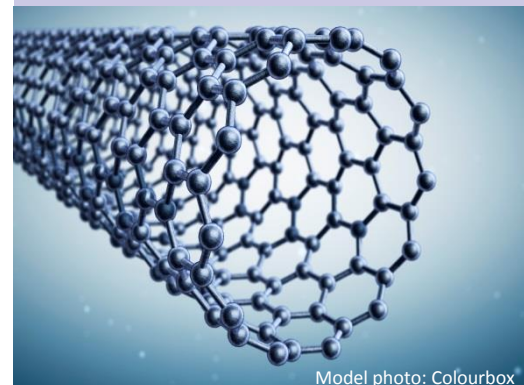
University of Southern Denmark, Aalborg University and Aarhus University

Other interested and potentially interested parties

Danish Technological Institute, FORCE Technology, Fiberline Composites, DMN (Danish materials innovation network), Inno-Pro – Innovation Cluster for Production, INBIOM – Innovation Network for Biomass, LM Wind Power, Medtech Innovation (innovation network for medical technology), Danish Plastics Federation, Siemens Wind Power, and Vestas Wind Systems

Estimated total investment requirement

Approx. EUR 9-10 million



Model photo: Colourbox