

# Danish Roadmap for Research Infrastructure 2020

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# 1. Introduction

In this introduction, we will define research infrastructure, outline the history of working with roadmaps and describe the content of the publication.

This Danish roadmap for research infrastructure 2020 is Denmark's national strategy for the research infrastructure area. It contains a series of strategic objectives and specific milestones that point towards the direction for the upcoming years' development in the area. The roadmap also includes concrete proposals for which new national research infrastructures Denmark should invest in over the upcoming years.

Danish research can contribute to the solution of many central socio-economic challenges. Through research, we can monitor and better understand global climate impacts and we can develop new technological solutions that, both locally and globally, can underpin a green transition in our society. And through research, we can develop medicines and vaccines that can enhance population health and, hopefully, halt the evolution of the current COVID-19 pandemic.

Ground-breaking research results are created in complex ecosystems in which skilled scientists with novel ideas – and wide collaboration networks – are granted good frameworks and funding to pursue their research. One of the essential framework conditions for high-quality research is the access scientists have to high-tech facilities and tools: the so-called research infrastructure.

## What is research infrastructure?

Research infrastructures encompass a wide array of advanced equipment, databases, laboratory facilities and many more elements that are necessary in the research process and which form the basis for scientific evolution and research breakthroughs.

Research infrastructures can be classified into the following three types: 1) Stand-alone physical facilities that may either have a fixed location or be mobile; 2) distributed networks of, for example, collections, labs or measuring stations with a single point of access for users; 3) virtual collections of data, tools etc. that users can access online. Research infrastructures can also consist of combinations of the above three types.

Research infrastructures are used in all primary scientific areas. In this roadmap the primary areas are subdivided as follows:

- Social sciences and humanities
- Energy, climate and environment
- Biotech, health and life sciences
- Materials and Nanotechnologies
- Physics and the universe

This Danish roadmap for research infrastructure is the third Danish roadmap for research infrastructure. It replaces the preceding roadmap from 2015, which previously replaced the roadmap from 2011. The preparation of national roadmaps for research infrastructure has over time become a well-established practice in Denmark. This practice takes place in the majority of other European countries as well as under the auspices of the joint European cooperation forum, the *European Strategy Forum on Research Infrastructures* (ES-FRI), of which Denmark is also a member.

Among other things, the roadmap can be viewed as an instrument for the strategic prioritization of financing decisions for the research infrastructure area and as a basis for international collaboration on research infrastructures.

The structure of the roadmap is as follows:

- Chapter 2 outlines the significance of the research infrastructure area for Danish research, education and innovation.
- Chapter 3 outlines how the Danish Ministry of Higher Education and Science works in the area of research infrastructure.
- Chapter 4 outlines the objectives and milestones.
- Chapter 5 presents a catalogue of proposals for new national research infrastructures which are expected to form the basis for investments in new national research infrastructures in the years 2020–2023.

In relation to the previous roadmap from 2015, the new roadmap has one new element. This is that all proposals for new national research infrastructures have been subjected to international peer review. The intention of this is to ensure that all proposals exhibit the required level of high scientific quality.

It should also be noted that an important and recurring ambition of this roadmap is that both national and international research infrastructures should underpin a green transition and contribute towards solutions for the major societal challenges we face, as far as this is possible and relevant. There is, intersecting with the objectives and milestones, an ambition that research infrastructures should support any green transition (see fact box on page 13).

This roadmap is aligned with several of the ministry's other strategies, including the 2020 green research strategy and the 2020 strategy for the Danish ESS input.

In regard to the proposals listed in the catalogue, those which are chosen will be financed by the *Pulje til Forskningsinfrastruktur* (National Fund for Research Infrastructure, hereinafter NFRI). Initiatives from the strategic objectives will be financed within the framework for research infrastructures in the Finance Act.

## Levels of research infrastructure

### Local/institutional research infrastructure

Research infrastructure that users can access at individual universities and research institutions which are financed, developed and run by these institutions to meet specific institutional needs. Users are usually the university or institution's own researchers and students. Frequently, local/institutional research infrastructures of comparable kinds are found at several of the national universities/research institutions.

### National research infrastructure

Research infrastructure that is developed and operated in collaboration with several universities and/or research institutions, and which is designed to address broad national needs. Often the establishment of this type of research infrastructure cannot be technically and/or financially borne by a single university/research institution alone and this national collaboration results in added value for the research infrastructure. Users are found across the national level and also occasionally in foreign universities/research institutions. One can usually only gain access to this research infrastructure via a single or a few select locations in Denmark. National research infrastructure collaborations are often regulated by national consortia or partnership agreements.

### International research infrastructure

Research infrastructure that is developed and operated cooperatively between several countries, and which is designed to meet international/member countries' needs. Often the establishment of this type of research infrastructure cannot be technically and/or financially borne by a single country alone and this international collaboration results in added value for the research infrastructure. Users are dispersed across several countries and one can usually only gain access to the research infrastructure via a single or a few select locations globally. International research infrastructure collaborations are frequently regulated as international organisations or international consortia agreements like the European ERIC model (European Research Infrastructure Consortium). In many cases, Denmark's membership in international research infrastructures will also link with Danish consortia or partnerships – for example, in the context of national departments connected to the international research infrastructures or as accompanying research centres. The purpose of these is to garner large national benefits from the international research infrastructures.

## 2. The significance of research infrastructures

This chapter will describe the significance of research infrastructures and the need for national coordination.

Modern research infrastructures are an integrated part of the international research and innovation ecosystem and form the basis for research and innovation of high quality with extensive impact.

Research infrastructures can form the basis for solutions to many central societal challenges, including in the area of a green transition.

Research infrastructures are a competitive parameter that makes Denmark and Danish research institutions attractive places to pursue research and education; research infrastructures contribute thereby to attracting and retaining research talent in Denmark.

Research infrastructures also often represent important areas of encounter for new research collaborations; whether this is between Danish and foreign researchers, between researchers from different Danish institutions or between research institutions and businesses.

Research infrastructure is fundamentally designed to meet the needs of the research. However, many research infrastructures create a value beyond the scientific domain. In this way, many research infrastructures can contribute to resolving societal challenges and many can also contribute to innovation and growth.



## WindScanner.dk

*National research infrastructure that provides new insight into wind conditions for use in the wind turbine industry, among others.*

Windscanner.dk is a specialised research infrastructure that facilitates the creation of 3D measurements of turbulent wind fields, for example, surrounding large wind turbines.

Windscanner.dk builds upon advanced laser technology that makes it possible to measure the velocity of small, wind-borne dust particles. This forms the basis for an improved and more precise modulation of wind field turbulence.

Windscanner.dk is a mobile unit that can be set up anywhere. Both onshore and offshore, in wind tunnels and in hilly and mountainous terrain.

The potential uses are wide-ranging and include:

- The generation of unique data sets of gauged wind and turbulence fields that provide a deeper understanding of wind flows through wind turbines and the surrounding environment.
- More precise methods to calculate power output from wind turbine energy production and turbine controls.
- Design, control and optimization of specific wind turbines and wind turbine parks.

Windscanner.dk is a collaboration between DTU and AAU and has been fully operational since 2013. The total investment is approx. DKK 34 million.

## 2.1 The need for national coordination

Research infrastructures can be compared to the infrastructures we know from road and telecommunications networks which constitute a general prerequisite for working and leisure activity. Similar to the planning of transport and telecommunications infrastructure, it makes sense to coordinate and prioritize investment in research infrastructures through broad collaborations that consider the research and innovation system as a whole.

When researchers receive funding from public and private funds toward research projects and when universities finance research, this does not typically include financing the research infrastructure itself. This is because research infrastructure is frequently not dependent on projects or persons but instead is utilized by multiple projects, scientists, students and other relevant users within many different research areas.

At the same time, we are talking about a prolonged investment horizon with a subsequently extended period of utilization of the research infrastructure for its research purpose. Investments in research infrastructure therefore can be made based on strategic and long-term objectives and financed via other channels rather than the usual research financing.

National research infrastructures provide access to experiments, trials and data more efficiently and with fewer costs than that which can be provided by individual research institutions. Among other things, this is due to the possibility to achieve benefits of scale by establishing and offering research infrastructures through national collaborations, in particular where there is extensive demand from diverse institutions for access to the research infrastructure. There is also a great deal of national research infrastructure which would not be possible or reasonable for individual universities or research institutions to establish alone. This could be due to the fact that there are insufficient user numbers at the university or that the investment and/or complexity of establishing research infrastructure would exceed the institution's capacity. A corollary of this is the international research infrastructures whose investment requirements or complexity exceed the capacity of a single country.

## DIGHUMLAB

**National research infrastructure that gives students and researchers access to vast source material.**

DIGHUMLAB is a digital ecosystem that provides access to digital materials, digital analytic tools as well as tutorials and workshops on the use of the materials and tools for students and researchers.

These digital materials include digitized cultural heritage sources such as radio and TV broadcasts and newspaper articles. DIGHUMLAB has over 5,000 users yearly.

In addition to the digital platform, this research infrastructure includes a physical laboratory with equipment to record and edit audio-visual materials.

DIGHUMLAB has broadened the scope of what researchers have been able to study and how quickly they can access the results. This is due to the fact that, among other reasons, the infrastructure allows users to quickly and easily navigate a vast amount of source material that would otherwise have been time consuming and difficult to access.

DIGHUMLAB is a collaboration between AU, CU, SDU and the Royal Danish Library. The total investment is DKK 37 million.

In this context, it should be noted that many research fields that are significant to Denmark do not need national research infrastructure. This is because, for example, a number of these have sufficient local/institutional research infrastructure to cover their needs or because they can access research infrastructure on commercial terms which makes it easier or cheaper than if they were to establish their own research infrastructure. This does not, however, mean that these research fields are unimportant to Denmark. However, this roadmap will focus on those research areas that need national research infrastructure.

To ensure that national research infrastructures benefit researchers across national universities and other research institutions, research infrastructures are typically regulated through being established as national partnerships or consortia with multiple national institutions as members. These partnerships/consortia agreements are based on, among other things, the research infrastructure's finances, design and services. An access policy is also set up for the research infrastructure to ensure that all interested researchers – irrespective of their institutional affiliation – are given the possibility to access the research infrastructure and/or the data on fair terms, which is accumulated and generated through the research infrastructure.

## Research infrastructure effects on innovation and business

The significance of research infrastructure on innovation and business can be divided into so-called “upstream” and “downstream” phases, both with varying effects.

### The upstream phase

In the upstream phase, industry provides hi-tech equipment, instrumentation or other components or services for research infrastructures. These provisions are used in design, construction and instrumentation along with for the operation and/or upgrading of the research infrastructure. Private companies are usually involved via tendering and procurement processes. This has an immediate, albeit temporary economic impact by creating revenue for the companies and contributing to job creation.

Though this phase may also have more long-term economic effects by way of “innovation through tendering”. Research infrastructures often require hi-tech equipment and instruments that only exist on the drawing board and which therefore must be developed, evolved or specially adapted for the research infrastructure in question. When companies, as suppliers, are required to produce these deliverables – often in collaboration with researchers – they are forced to innovate. This can have a consequential effect as the company, through innovation, acquires new knowledge and skills. They can apply this in other and/or related markets. Also, as a provider to the research infrastructure, they can enhance their reputation for delivering new innovative products.

### The downstream phase

In the downstream phase, companies function as users of the established research infrastructure, or receivers and co-producers of the new knowledge generated by the research infrastructures. To benefit, companies often need access to test facilities, research data and similar for trialling and developing their products. For many companies, it is not financially feasible or realistic to build and run such facilities alone and they are thus interested in gaining access to research infrastructures that can offer the desired facilities, services and data.

This is frequently provided via research collaborations, contracted research or commercial PhD and post-doctoral schemes. Through these, companies, via established research environments, can access the required skills in addition to the research infrastructure itself. In this way, research infrastructures can help support commercial enterprises in developing new products and enjoying the resulting financial benefits.

## Research infrastructure and the green transition

It will be crucial for Danish researchers to have the best possible tools in hand when they are called upon to help meet the targets of reducing greenhouse gas emissions by 70% by 2030 and reaching climate neutrality by 2050. Research infrastructure contributes to green transitions and growth in several fields including energy, bio-resources, construction, circular economies and environmental technology along with the climate. The ways in which research infrastructure can underpin the green transition can be roughly defined in two areas:

### Research infrastructure which directly supports the green transition

This type of research infrastructure is aimed toward green transitions and gives scientists access to data, for example. This can take the form of measuring stations for data collection on greenhouse gases in the atmosphere, data about the impacts of climate and environmental change on ecosystems, or facilities that help optimize, for example, the durability of wind turbines. These research infrastructures fall within the field of Energy, Climate and Environment.

### Research infrastructures which provide an opportunity to support green research

This form of research infrastructure includes multiuser facilities that give researchers access to experiments that facilitate the development of, for example, new and efficient batteries or more efficient concrete types. This thereby supports research that addresses green areas more directly. Here we can also include supercomputers that give researchers access to enormous computing power. These types of research infrastructure typically fall within the fields of Biotech, Health and Life Sciences, Physics and Universe as well as Materials and Nanotechnology.

# 3. The Danish Ministry of Higher Education and Science's work with research infrastructures

This chapter will present the Danish Ministry of Higher Education and Science's work with research infrastructures, including national and international financing and analyses.

## 3.1 Financing research infrastructures

Research infrastructure is necessary to maintain Denmark's position as one of the world's best research countries and to ensure that major Danish private and public research investments are fully exploited. That is why the Danish Ministry of Higher Education and Science, Danish universities, other research institutions and a range of private funds, etc., invest in research infrastructure within all the major fields of scientific research.

The Danish Ministry of Higher Education and Science, and this roadmap, focus mainly on research infrastructure at the national and international level since local or institutional infrastructure is normally developed and operated by individual universities and research institutions. Thus, it is primarily at the national

and international level that there is a need for coordination and collaboration among the relevant national players.

Via the Finance Act, the Danish Ministry of Higher Education and Science finances research infrastructure at a cost of approx. DKK 640 million annually. This is comprised of approx. DKK 220 million for national research infrastructure, distributed as approx. DKK 80 million for building new national research infrastructures, approx. DKK 70 million towards digital research infrastructure and approx. 70 million towards other national research infrastructure collaborations. Added to this is approx. DKK 420 million that Denmark contributes to major international research infrastructures, including the Danish co-hosting of the European Spallation Source (ESS).

Since 2007, the Danish Ministry of Higher Education and Science has invested over 1 billion DKK in new national research infrastructures, where the Higher Education and Science Minister has conducted the final selection. An equivalent amount has been invested by Danish universities and research institutions for the same national research infrastructure. In addition, several private foundations have invested multiple millions for national research infrastructure in Denmark.

Over the course of 2017-2019, the Danish Agency for Higher Education and Science conducted a number of analyses of the research infrastructure sphere, including investigating the financing landscape for research infrastructures in Denmark, and the returns that Denmark receives from its national and international research infrastructure investments. An overview of these analyses is presented on page 17.

The table on page 56 presents the Danish Ministry of Higher Education and Science's investments in national research infrastructure in collaboration with Danish universities and research institutions, among others. Combined investment in the 45 national research infrastructures exceeds DKK 2.6 billion.

The table on page 61 also shows Danish membership in international research infrastructures, including major convention-based memberships (e.g. CERN, ESO and ESRF) as well as membership in medium-sized European research infrastructures under the auspices of the European Strategy Forum on Research Infrastructures (ESFRI).

### 3.2 Research infrastructure collaborations

The Danish Ministry of Higher Education and Science cooperates with a variety

of stakeholders in the research infrastructure sphere. One of the primary collaboration forums is the National Committee for Research Infrastructure (NCRI) which consists of appointed representatives from all Danish universities and from the academic council of the Independent Research Fund Denmark. The Danish National Research Foundation is an observer. The NCRI advises the Danish Agency for Higher Education and Science on various topics concerning research infrastructure.

In addition to this committee, the Danish Agency for Higher Education and Science has also convened a number of committees that advise on more specific themes within the research infrastructure area. This is the case with the ESS advisory group, various forums concerning Denmark's membership in major international research infrastructures and other research infrastructures under the auspices of the ESFRI, etc.

#### **DANA - national research vessel**

In the research allocation for 2021, it was agreed to earmark DKK 170 million in total for the years 2021, 2022 and 2023 towards a new research vessel to be named Dana V. A research vessel can be employed for research in oceanography, ocean climate interaction, bio-geo chemistry and marine geology. A research vessel can also perform governmental duties such as monitoring fish stocks and the ocean's environmental status.

In addition, the ministry also finances so-called accompanying research centres, which support Danish researchers' use of international research infrastructures such as CERN, ESO and ESS.

Concerning the upstream phase, see box on page 12, the ministry finances

BigScience.dk, which supports Danish supply companies' interaction with research infrastructures to create increased revenue for these providers as well as strengthen their innovation potential in an attractive global hi-tech market.



## **Analyses in the research infrastructure area**

As a follow-up to the previous Danish roadmap for research infrastructure from 2015 and as preparation for this roadmap, throughout 2017-2019, the Danish Agency for Higher Education and Science completed several analyses regarding research infrastructures. These form a significant part of the knowledge base for this roadmap's objectives and milestones.

### **Analysis of the returns from Danish membership of major international research infrastructures and associated plan of action**

This analysis and its associated action plan investigated the returns from Danish membership of major international research infrastructures: ESO, CERN, ILL, ESRF, ESS, EMBL, XFEL and ITER. The analysis shows that Danish research groups are among the most able to exploit the opportunities membership offers. It makes sense for a small country such as Denmark to be a member of major international research infrastructures since we do not possess the resources or capacity to build or operate alone. However, the analysis also shows that there is a general absence of strategies and action plans to exploit these memberships. Based on the analysis, the Danish Agency for Higher Education and Science has published, therefore, a plan of action and has already pursued several of this plan's targets. There remains, however, a need for further initiatives to support Denmark in garnering even more value from its memberships.

### **Mapping the financing landscape for research infrastructures**

The purpose of this survey is to elucidate the financing of research infrastructures by Danish research-financing players and to provide a snapshot of the financing landscape over the period 2015-2017. This survey shows that, despite the fact that all research financing actors view research infrastructures as being key to the quality of research conducted, there are only a few private and public foundations that separately finance research infrastructure.

### **Analysis of investments from the National Fund for Research Infrastructure**

This analysis focused on national research infrastructures financed through 41 allocations from the National Fund for Research Infrastructure. The analysis reveals, among other things, that investments in national research infrastructures support Danish research for many years to come. The analysis also reveals, however, an untapped potential to increase the capacity utilization of research infrastructures and to expand awareness of them.

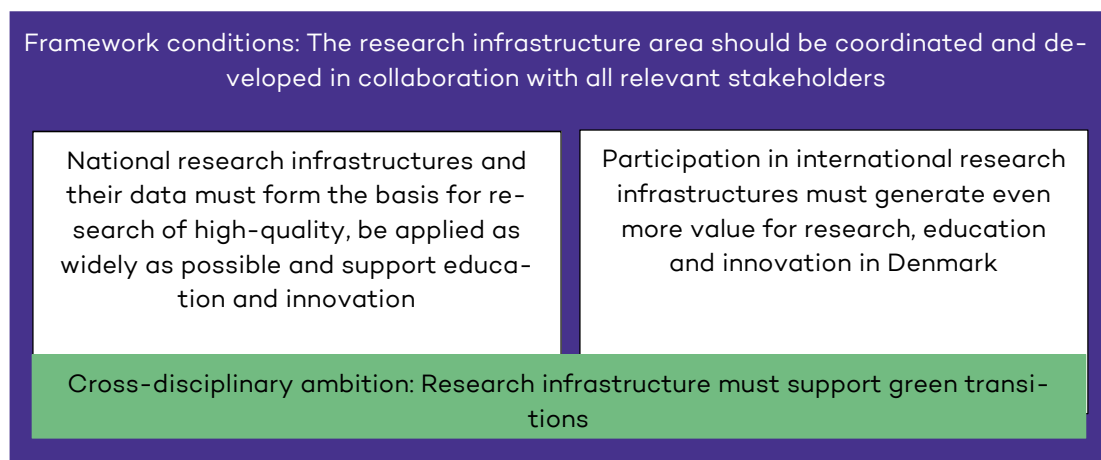
## 4. Objectives and milestones

In this chapter, we present the roadmap's objectives and strategic milestones and, under the rubric of each objective, the specific initiatives that will be implemented in the coming years.

The following strategic objectives and specific milestones show the direction for the future evolution of the work with research infrastructures. The Danish Ministry of Higher Education and Science has been advised on this by the NCRI and by a for-purpose convened working group consisting of representatives from the universities (Copenhagen University and Copenhagen Business School) the GTS (GTS network) and DI.

**Figure 4.1**

Matrix model showing the relationship between objectives in this roadmap:



**Table 4.1**

Overview of objectives and milestones in this roadmap

<b>Objective 1:</b> National research infrastructures and their data must form the basis for research of high-quality, be applied as widely as possible and support education and innovation	<b>Objective 2:</b> Participation in international research infrastructures must generate even more value for research, education and innovation in Denmark
Milestone N1: That proposals from the roadmap catalogue form the basis for new investment in research infrastructure	Milestone I1: That two new national centres for research supporting activities be established (accompanying research centres)
Milestone N2: That research data from national research infrastructures are made even more accessible for re-use	Milestone I2: That targets are set, and a model developed to monitor the returns from membership in major international research infrastructures and to collate international experiences
Milestone N3: That national research infrastructures have a high degree of capacity utilization with many users from many different institutions	Milestone I3: That the commercial returns from international research infrastructures are strengthened
Milestone N4: That a survey is conducted of existing research infrastructures to be used nationally	Milestone I4: That Denmark promotes the increased greening of international research infrastructures
	Milestone I5: That Denmark participates in more European research infrastructures under the auspices of the ESFRI with value for Danish research
<b>Framework for the work: The research infrastructure area should be coordinated and developed in collaboration with all relevant stakeholders</b>	
Milestone R1: That the Danish Agency for Higher Education and Science enter into dialogue with the NCRI on the committee's future role	
Milestone R2: That an expanded dialogue and knowledge sharing be established with other stakeholders	

Note.: Green field for milestones indicates they can contribute to green transitions

## 4.1 Objective 1

### **National research infrastructures and their data must form the basis for research of high-quality, be applied as widely as possible and support education and innovation**

Nationally, work must be done to ensure that national investments in research infrastructure benefit as many and as widely as possible. These investments must first and foremost benefit research in Denmark. It is also important that work is done to garner even greater returns on the effects that research infrastructure can have on education and innovation.

#### **Milestone N1: That proposals from the roadmap catalogue form the basis for new investment in research infrastructure**

This roadmap's catalogue consists of proposals for research infrastructures that have been submitted by Danish universities and research institutions on behalf of wide-ranging Danish partnerships. All proposals have been selected by the Danish Ministry of Higher Education and Science after the proposals were subjected to international peer review. During the international peer review, the proposals were assessed to be academically relevant and important. Thereafter, they were assessed in the NCRI where the proposals were also judged to be of national strategic importance.

The catalogue shall form the basis for the Danish Ministry of Higher Education and Science's investments, from the National Fund for Research Infrastructure, for new national research infrastructures in 2020-2023. This means that the minister will annually select

proposals from those in the catalogue, which will receive financing. NCRI is involved in advising on the prioritisation of the proposals.

Proposals are selected based on their scientific quality, national added value, feasibility and forecasted socio-economic impact. The new research infrastructures shall thus become a foundation for high-quality research. Many of them will also form the basis for solutions to societal challenges. In fact, a large part of them may support the green transition.

Coordinator: The Danish Ministry of Higher Education and Science. The Danish Ministry of Higher Education and Science decides on financing for the proposals from the National Fund for Research Infrastructure. The NCRI is involved in advising on the prioritisation of the catalogue proposals.

Timeframe: 2020-2023.

#### **Milestone N2: That research data from national research infrastructures are made even more accessible for re-use**

Research data that is produced via national research infrastructures must, being publicly financed research, benefit as much research as possible. This is a profitable utilization that ensures optimal exploitation of the public investments in research, so that wider society benefits.

The purpose of this initiative is, therefore, to ensure that newly produced data from research infrastructures is, to an even greater degree, available for reuse by researchers across the whole of Europe. Particularly, that data fulfils the so-called FAIR principles (i.e. Findable, Accessible, Interoperable and Reusable) and is made available through,

among other channels, the EOSC (European Open Science Cloud).

The Danish Ministry of Higher Education and Science and Danish e-Infrastructure Cooperation (DeIC) focus on data compliance with FAIR principles. In this context, DeIC expects to publish a new national strategy for data management based on precisely these FAIR principles in the near future.

Within the EU, more widely, there is also a greater focus on the reusability of data. Along with other measures, a new EU Directive has been adopted regarding open data (formerly the PSI Directive). On the basis of this, the current PSI act shall be reviewed so that it includes rules on how publicly financed research data should be made available for reuse. In addition, the pending EOSC will become a key tool for making research data more accessible at the European level.

The Danish Agency for Higher Education and Science shall specifically, in negotiations on new grants for national research infrastructures, require that research data produced via the new research infrastructures comply with the FAIR principles. The Danish Agency for Higher Education and Science will monitor this compliance. However, Danish universities and research institutions shall remain responsible for the implementation. The Danish Agency for Higher Education and Science will also encourage all existing national research infrastructures comply with the FAIR principles concerning making newly produced data FAIR. It will also encourage all national research infrastructures to make data available for reuse via the EOSC. The initiative will thus apply to all national research infrastructures.

Coordinator: Institutions in the specific grant-aided research infrastructure

partnerships. DeIC shall contribute advice and the like. The Danish Agency for Higher Education and Science shall set requirements and monitor developments.

Timeframe: 2021-2023.

### **Milestone N3: That national research infrastructures have a high degree of capacity utilization with many users from many different institutions**

The analysis of investments from the National Fund for Research Infrastructure see box, page 17, indicates that almost half of existing national research infrastructures do not have full capacity utilisation and that several of the research infrastructures have a low number of users and/or few users outside their host institution.

The Danish Agency for Higher Education and Science expects that this primarily affects research infrastructures that were established early on by the National Fund for Research Infrastructure. The Ministry has, since the launch of the 2015 roadmap, made it a requirement that national research infrastructures be built through national collaborations (consortia, partnerships or similar). Also, the establishment or construction of a large majority of national research infrastructures since 2015 has been financed by several different Danish research institutions collectively. This was intended to ensure that research infrastructures would have the broadest possible usage across the various national research institutions and research fields.

However, there will be a continued focus on optimizing capacity utilization of the newly implemented research infrastructures. This will ensure that they succeed from the start and, that when they transition to full operation, they

will have as many users as possible from the greatest number of research institutions. The initiative will apply to all newly implemented research infrastructures including those research infrastructures that support a green transition.

The Danish Agency for Higher Education and Science will encourage universities to formulate individual and ambitious, albeit realistic targets for capacity utilization and use of the research infrastructure when allocating grants to new research infrastructures. The Danish Agency for Higher Education and Science will also introduce a systematic registration of the number of users and their distribution over institutions and fields. This will allow their development to be monitored so that an assessment can be made about whether there is any need to implement further initiatives for new research infrastructures.

The Danish Agency for Higher Education and Science will also, in cooperation with the wider group of stakeholders, analyse whether special initiatives are required to increase the utilization of, and returns from, existing national research infrastructures, e.g. by engaging new user groups. These initiatives could include, for example, new collaborative models for businesses and researchers.

Coordinator: The Danish Agency for Higher Education and Science in collaboration with partnering institutions for new financed research infrastructures and the wider stakeholder group (universities, GTSS, trade and industry organizations, etc.)

Timeframe: 2021-2024.

#### **Milestone N4: That a survey is conducted of existing research infrastructures to be used nationally**

A survey must be conducted of all research infrastructures in Denmark that are available for use nationally, which will provide a coherent overview of available research infrastructures in Denmark, while contributing to increased utilization.

This work will draw upon experiences in many other European countries as well as the European InRoad project. Many other countries conduct surveys of their national research infrastructure capacities and it is likewise a recommendation of the InRoad project that such surveys be carried out.

The Danish Ministry of Higher Education and Science has already conducted an analysis of the existing national research infrastructures which the Ministry has financed. Based on this analysis, the Minister has drawn up a virtual catalogue in which potential users can find information on how to access these research infrastructures. There remains, however, untapped potential in also mapping the available research infrastructures that can be used nationally and which are not financed by the Ministry. For example, institutional research infrastructures of a certain size.

There will be a special focus on mapping research infrastructures in Denmark that can support a green transition as well as research infrastructures in the field of robot technology (see national robot strategy). As part of this survey, there will also be a focus on surveying the extent of business utilization of research infrastructures and collaborations between universities, GTS institutes, other knowledge institutions and businesses.

The aim is that this more exhaustive survey will be made visible for a greater number of potential users. For example, establishing larger portals or something similar which can provide an overview of access to available research infrastructures. Consideration can be given to different options. The first is whether the portal should present examples of the types of problems which the research infrastructure can be used to assist. It can also be considered whether there should be elements similar to those found on the platform, "Isaaffic - the Arctic gateway" which support new research collaborations through research infrastructures.

This initiative should help to increase utilization of national research infrastructures so that Denmark gains even more benefits in relation to research, education and innovation.

Based on this survey, it may be considered whether to implement further work to identify needs and deficiencies in the Danish research infrastructure landscape. This form of landscape analysis is found in several other European countries' roadmaps.

Coordinator: The survey is carried out by the Danish Ministry of Higher Education and Science in cooperation with Danish research institutions and other relevant players such as GTSS, trade and industry organizations, private foundations and other sectoral ministries.

Timeframe: 2021-2022.

## 4.2 Objective 2

**Participation in international research infrastructures must generate even more value for**

## **research, education and innovation in Denmark**

At the international level, work must be done to ensure that participation in international research infrastructures generates even more value for Denmark both in research, education and innovation.

### **Milestone I1: That two new national centres for research supporting activities be established**

To ensure Danish membership in major international research infrastructures returns large benefits, especially concerning research in Denmark, the Danish Ministry of Higher Education and Science annually finances the operation of three national centres for research-supporting activities (popularly called accompanying research centres). The national accompanying research centres must, in particular, facilitate access to international research infrastructures so that a number of Danish researchers utilize the research infrastructures. An additional task of the centres is to communicate opportunities in research infrastructures, like research-dedicated grant opportunities, and to advise the Danish Agency for Higher Education and Science on the returns and effects of memberships, among other things.

The three existing national accompanying research centres are: DANSCATT re. materials research in connection with memberships of ESRF, ESS, European XFEL and ILL), IDA re. astrophysics in connection with memberships of ESO, NOT and ESA, NICE re. high energy physics and more in connection with membership of CERN (see also overview list of memberships on page 61).

In 2019-2020, the Danish Agency for Higher Education and Science oversaw

the inspection of the Danish model for research-supporting activities. The inspection was performed by an independent international panel of experts who evaluated the Danish model and Danish accompanying research centres along with the potential for new centres. Based on this, the panel submitted recommendations on the model to the Danish Agency for Higher Education and Science.

The evaluation of the expert panel was very positive and pointed out that, for a relatively modest investment in national research centres, Denmark gains large value concerning maximization of the research benefits of its memberships and concerning unifying and strengthening the relevant Danish research environments.

One of the panel's specific recommendations was that the Danish Agency for Higher Education and Science invites discussion on the establishment of two new national accompanying research centres linked with, respectively, EMBL for the Danish molecular biology environment and to FT4/ITER for the fusion environment. The Danish Agency for Higher Education and Science will do this, conditional upon the specific allocation of funds for the establishment in the budgets of 2021-2022, and the later operation of the centres. Both the new centres are expected to support research that can contribute to a green transition.

Coordinator: The establishment will be done with financing from the Danish Ministry of Higher Education and Science and be implemented by the universities.

Timeframe: 2021-2022.

## **Milestone I2: That targets are set, and a model developed for monitoring the returns from membership of major international research infrastructures and collating international experiences**

The analysis of returns from Danish membership in large international research infrastructures and associated action plans (see fact box and the analysis on page 17 and overview of memberships on page 61) indicates that there is a need to set even clearer targets for the returns with a view towards better exploitation and prioritization of resources. The analysis also highlights a need to develop a model for how to continually monitor the returns as well as develop individual plans of action for each membership.

The milestone contains three sub-initiatives:

- Setting targets
- Monitoring plans
- Development of action plans

Thus, the first thing to be done is to set targets for the memberships. These must naturally also include targets for research benefits. There will also be intensified focus on both educational significance and commercial utilization of the research infrastructures for research and innovation.

The targets shall be set by Danish universities in dialogue with the Danish Agency for Higher Education and Science, the national accompanying research centres and BigScience.dk. These targets for utilization of memberships shall be followed up on through continual monitoring. This monitoring of targets will be done to generate an overview of whether there is a need to implement additional initiatives to increase the returns from membership.



Specifically, monitoring the initiative means that the Danish Agency for Higher Education and Science, possibly in cooperation with a series of like-minded countries and taking inspiration from, among others, monitoring proposals from ESFRI and OECD, enters into dialogue with the international research infrastructures about enhanced and more harmonized data accessibility and monitoring. The initiative also encompasses dialogue and reporting from accompanying research centres, information from BigScience.dk, etc.

Based on monitoring, individual action plans for each membership shall also be drafted. The first action plans are expected to be drafted in 2022 by the accompanying research centre for CERN and the new accompanying research centre for EMBL. In the following years, plans for XEFL, ESO, ITER/F4E and ESRF will be prepared (plans for ILL and ESS are part of the Danish ESS strategy from 2020).

As part of this initiative, the Danish Agency for Higher Education and Science will also conduct a desk study to elucidate how other countries work with optimizing returns from their memberships.

Coordinator: Universities in dialogue with the Danish Agency for Higher Education and Science, accompanying research centres and BigScience.dk

Timeframe: Setting targets and desk study in 2021, establishment of monitoring framework in 2022, development of action plans in 2022-2024.

### **Milestone I3: That the commercial returns from international research infrastructures are strengthened**

The analysis of benefits and associated action plans indicate that the large international research infrastructures of which Denmark is a member help to generate innovation and other benefits and can have positive commercial effects. There remains, however, unexploited potential when it comes to Danish trade and industry - this holds true both upstream and downstream (see fact box on page 12).

Upstream, it has been evaluated that Danish business can gain even more orders for provision of services, apparatuses and the like from research infrastructures. The upstream initiative specifically means that work will be done towards securing contracts for Danish companies for DKK 100 million from ESS, DKK 54 million from CERN and DKK 26 million from the remaining international research infrastructures (ESO, ITER/F4E, EMBL, XFEL and ILL) in 2025.

But this also applies downstream (businesses as users/consumers of research infrastructures), where it could be relevant for even more Danish businesses to utilize research infrastructures. Among other things, the returns analysis indicates that there are only a few businesses with their own research and development that have the capacity to directly utilize international research infrastructures.

Specifically, the Danish Agency for Higher Education and Science will initiate a project on the commercial value (downstream) of EMBL and XEFL to clarify the specific opportunities. There will be an eventual rollout to other memberships in the future. For EMBL this will be part of the action plan, while

for XFEL it will be done in collaboration with LINX, which is a collaboration platform to increase companies' utilization of neutron and X-ray research infrastructures.

Coordinator: The Danish Agency for Higher Education and Science, NCRI, Universities, BigScience.dk and LINX (re. XFEL) will also be involved.

Timeframe: 2021-2024.

#### **Milestone I4: That Denmark promotes major international research infrastructures becoming greener.**

In many instances, major international research infrastructures provide opportunities to support research in green transitions. However, at the same time, many cause significant climate impacts (e.g. through the research infrastructures' heavy consumption of power). Thus, they also have negative, indirect climate impacts. The power consumption is used either by servers for storage and processing of data or for the operation of larger standalone research infrastructures such as ESRF, ILL and European XFEL.

With this initiative, the Danish Agency for Higher Education and Science will specifically, as Denmark's representative under the auspices of major international research infrastructures (e.g. CERN, ESRF and ESO), make it a defining Danish issue in its agency work (and ideally together with like-minded countries). The agency will work towards research infrastructures developing a greener profile and assuming an active stance on climate impact, procurement, etc. Promotion of this defining issue will be done in cooperation with BigScience.dk and will support Danish firms that supply the Big Science market.

Coordinator: The Danish Agency for Higher Education and Science and BigScience.dk.

Timeframe: 2021-2023.

#### **Milestone I5: That Denmark participates in more European research infrastructures under the auspices of the ESFRI with value for Danish research**

Denmark already participates in several European research infrastructures under the auspices of the ESFRI. In fact, Denmark is a "node" for several of the distributed ESFRI research infrastructures (see an overview on page 62). Existing European research infrastructures already form the basis for high-quality research as well as, for many, the solution to societal challenges related to health, climate and environment. The expectation is that several new European research infrastructures will do the same. Thus, there will be a continuing need for Danish participation in additional European research infrastructures and, where relevant, becoming a node for these.

With this initiative the Danish Agency for Higher Education and Science will, in cooperation with the NCRI, work toward further Danish participation. Participation in new ESFRI research infrastructures will, in principle, be based on the catalogue in this roadmap, but it may also be possible to participate in new ESFRI research infrastructures that are not mentioned in the catalogue. Concerning the latter, the Danish Agency for Higher Education and Science and NCRI will gauge Danish interest in participating in all ESFRI research infrastructures. A particular point of focus will be to increase Danish participation in research infrastructures that support green transitions.

Coordinator: The Danish Agency for Higher Education and Science is a signatory to the agreements, while decisions on Danish participation will be made in consultation with the NCRI. To a large degree, the universities will also be participants in research infrastructures.

Timeframe: 2021-2023.

### 4.3 Framework for the work

#### **The research infrastructure sphere shall be coordinated and developed in cooperation with all relevant stakeholders**

A fundamental condition for the implementation of this roadmap is that the work must be coordinated and developed in cooperation with all relevant stakeholders.

The Danish Agency for Higher Education and Science already takes part in extensive dialogue and cooperation in the area of research infrastructures. However, this is overwhelmingly and naturally directed towards the university sector as universities are the primary users and financiers concerning research infrastructures. Within this strategy is the key aim that work on research infrastructures will be coordinated and developed in cooperation with all relevant stakeholders, also outside the universities.

The purpose of this is to increase the effectiveness of inputs from all the relevant research-financing players (the Danish Ministry of Higher Education and Science, universities and other research institutions, private foundations, other sector ministries etc.) and various other stakeholders. In terms of utilization of research infrastructures, this also includes commercial users. A better coordination of inputs will also help avoid unnecessary duplication of efforts and facilitate knowledge sharing among all relevant stakeholders.

To underpin this ambition, multiple specific initiatives may be launched.

**Milestone R1: That the Danish Agency for Higher Education and Science enter into dialogue with the NCRI on the committee's future role**

The Danish Agency for Higher Education and Science will enter into dialogue with NCRI on the committee's future role, organization and makeup. This will be done with a particular focus on the organization of work for the preparation of the next roadmap for research infrastructure.

Coordinator: The Danish Agency for Higher Education and Science in cooperation with NCRI.

Schedule: 2021-2023.

**Milestone R2: That expanded dialogue and knowledge sharing be established with other stakeholders**

Work will be done to increase dialogue and knowledge sharing with other stakeholders related to work on research infrastructures. These other stakeholders may not currently be very prominent in the Danish Agency for Higher Education and Science's collaborations on research infrastructure. These include, for example, other sectoral ministries, foundations, trade and industry organizations, GTS institutes and more.

Coordinator: The Danish Agency for Higher Education and Science in cooperation with other relevant stakeholders.

Schedule: 2021-2023.

## 5. Proposal for 16 new national research infrastructures

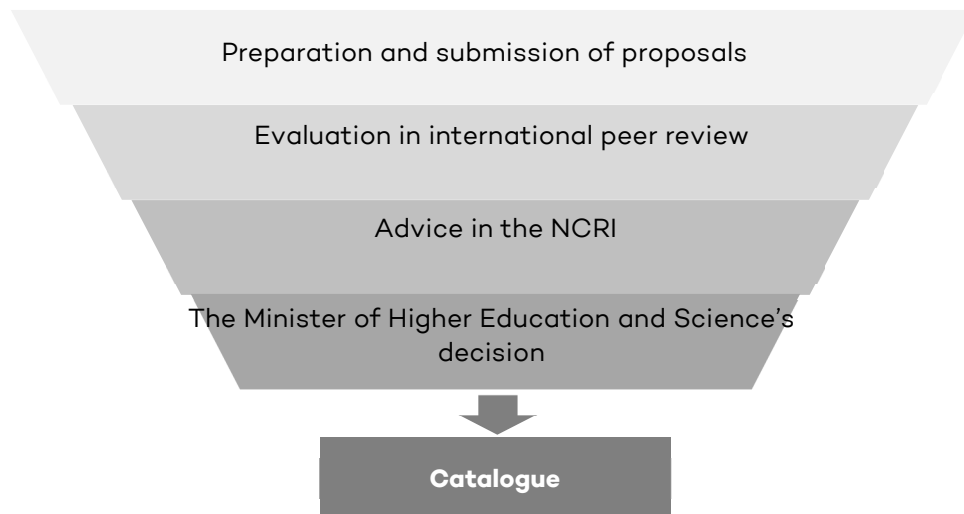
This chapter will present a catalogue with 16 specific proposals for new national research infrastructures. The catalogue thus replaces the catalogue that was part of the Danish Roadmap for research infrastructure 2015.

A key element of the process towards the finished catalogue was to ensure the active inclusion and presence of Danish research institutions and universities to ensure the catalogue supports the institutions' own strategies in the area. Therefore, as with previous roadmaps, the scientific environments have been responsible for drafting proposals for new research infrastructures.

The research environments are thus represented via the universities and the Independent Research Fund Denmark's representatives on the National Committee for Research Infrastructure, who take part in the evaluation process, see figure 5.1 below. Differing from the 2015 roadmap, all incoming proposals have been subjected to international peer review.

**Figure 5.1**

Catalogue proposal and decision process



## 5.1 Formation process

### *Drafting text of invitation*

Based on an evaluation of the national roadmap for 2015, the following amendments were added to the invitational text for this roadmap:

- The time period is shorter (from five to four years).
- Fewer proposals included in the catalogue (from 22 to 16 proposals).
- The proposals must contain a more precise formulation of the research infrastructure's national added value.
- The proposals have been judged by international peer review.

In October 2019, the Danish Agency for Higher Education and Science invited the leaders of Danish universities and national research institutions to submit proposals for specific research infrastructures on behalf of national consortia. Directors were invited to submit proposals for new or significantly upgraded research infrastructures. Pro-

posals could be submitted for all primary areas and all types of research infrastructure.

The purpose of the invitation is to finance research infrastructures that have wide national added value, see text box on page 31

In addition, the research infrastructures must be attainable within a five-year period if they are granted financing in the period 2020-2023. The research infrastructures must endure research relevance.

### *Preparation of proposals at universities and research institutions*

In the autumn of 2019, the Danish Agency for Higher Education and Science held information meetings at Danish universities and two separate meetings for the remaining Danish research institutions to broaden awareness and to help anchor the process and the roadmap.

The universities and research institutions subsequently prepared proposals

for new or significantly upgraded research infrastructure. At the expiry of the proposal deadline on April 22, 2020,

the Danish Agency for Higher Education and Science had received 29 proposals for the roadmap.

## Definition of national added value

In the invitation to submit proposals, each individual proposal was encouraged to fulfil the requirement of added national value based on the following criteria:

- The research infrastructures must have **wide national interest**. This means that the establishment of research infrastructures must be in Denmark's wider interests. This also entails that national strategic considerations may also come into play.
- The research infrastructures must be **nationally, scientifically leading or be part of globally scientifically leading** research infrastructures.
- The research infrastructures must aim to **include all relevant and interested Danish national institutions in the research infrastructure's consortium**.
- After establishment, the research infrastructures must be **accessible for all interested researchers and other relevant users irrespective of their institutional affiliation**. This must include access to physical and virtual laboratories, instruments and equipment as well as access to data from the research infrastructures, depending on the individual research infrastructure's type and purpose.

## 5.2 Evaluation process

### *Evaluation through international peer review*

The proposals received were subjected to international peer review to ensure high quality and transparency in the evaluation process. The process of selecting international panel members began in the winter of 2019 when the Danish Agency for Higher Education and Science selected one panel per field, consisting of 20 international judges in total.

The panel members were thus not invited and selected based on the proposals received, but had to possess the

competencies to evaluate the proposals with the criteria "scientific impact and quality" and "viability". The members of the academic panels were required to have scientific competence within the field, while also having being competent in judging to what extent the research infrastructures could facilitate scientific quality and impact and how they might be constructed. The members should ideally therefore have experience with research infrastructures.

All proposals were evaluated by one or two of the five expert panels. The proposal submitters were given the opportunity to provide an interested party

response to the evaluation that the panel completed.

#### *NCRI's evaluation and advice*

The proposals received were then presented to the NCRI in its advisory capacity. The NCRI thus advised the Danish Agency for Higher Education and Science on the catalogue content and recommended 16 proposals for the roadmap catalogue. The primary proposal submitters were afforded an opportunity to respond to the NCRI's evaluation through an interested party hearing process.

#### *Evaluation and prioritization process in the Danish Ministry of Higher Education and Science.*

Subsequently, the Danish Ministry of Higher Education and Science conducted an independent evaluation and prioritization process. Thereafter, the Danish Ministry of Higher Education and Science chose 16 proposals for the catalogue from the total of 29 submissions. The 16 proposals are the same ones that the NCRI recommended for inclusion. Both the NCRI and the Ministry based their advice on the aforementioned evaluation criteria, including added national value, see text box p. 31, which was published together with proposal submission invitation.

The Ministry and the NCRI also took into consideration that the overall catalogue, across disciplines, should embrace all fields.

## 5.3 Implementation process

One of the fundamental functions of the catalogue, as stated in chapter 3, is to stand as a decision-making basis for future investments in new national research infrastructures.

The Danish Ministry of Higher Education and Science implements the National Fund for Research Infrastructure in the Finance Act annually and the expectation is that the catalogue will function as a prioritization tool for decisions on implementation up to and including 2023. A catalogue-listed proposal is not automatically guaranteed financing from Finance Act funding as the amount earmarked does not currently permit funding of all catalogue proposals.

It is therefore hoped that the catalogue will also serve to inspire other financing parties, for example, private foundations. This is a possibility because the proposal selection was a competitive process, and all are ripe for investment and have achieved a quality stamp of approval through inclusion in this roadmap. They will each lay the groundwork for excellent research and generate new opportunities for innovation and growth.



## 5.4 Introduction to the catalogue

The decision-making process has resulted in the following catalogue with 16 proposals for new research infrastructures and significant upgrades to research infrastructures. There are proposals within all fields and the proposals are supported by, on average, five Danish research institutions.

The catalogue is grouped into the five areas: “Biotech, Health and Life Science”, “Energy, Climate and Environment”, “Physics and Universe”, “Materials and Nanotechnology” and “Social Sciences and Humanities”. The areas do not reflect a prioritization, but are simply a way to categorize the proposals.

Each proposal is presented in the catalogue in a brief single page description

of the research infrastructure and its expected scientific and socio-economic potential. In addition, each proposal lists which research institutions formally support the proposal at the current time. It also includes the primary proposer and co-proposer, as well as other interested parties in the realization of the research infrastructure. This latter category embraces both research institutions, universities, GTS institutes, innovation networks, regions, municipalities and private companies. The type of proposal is also indicated. That is, whether the research infrastructure is standalone, distributed or virtual in nature. Finally, the total estimated investment need is stated, which covers both the requested financing via the National Fund for Research Infrastructure and the expected co-financing contribution from the proposing parties.

# Biotech, Health and Life Science



Biotech, Health and Life Science covers a broad range of disciplines of great relevance for the evolution of the Danish population's general health. This includes the development of new medicines, medical technologies and better and healthier foodstuffs. Research is conducted at universities, hospitals and clinics as well as at sectoral research institutions. These disciplines overlap with and support development and innovation in the private sector, including the pharmaceutical industry, medical and biotech companies and the agri-food industry, all of which are important sources of Danish employment and exports.

Biotechnology covers the development, production, analysis and application of biological systems at micro, cellular and molecular levels. This has significance for developments in health, food production, environmental protection, energy, agriculture and industrial processes, among others.

Health research includes primary research on people, health and illness, and clinical and translational research. It

also includes research on prevention with a broader, population-based health approach as well as health systems research dealing with the organization of healthcare systems.

Life Science includes veterinary medicine, plant and agricultural science, foodstuffs and nutrition. This field links to biotechnology, medicine, pharmaceuticals, biology, population health, environment and chemistry. This research also contributes to the development of agriculture.

This field is widely dependent on research infrastructures such as sampling and testing facilities for clinical research, biobanks, registers and bioinformatic databases as well as supercomputer computing power for statistical analysis of vast data amounts within bioinformatics. Apparatuses for advanced visualizations, including advanced light and electron microscopes, mass spectrometry and particle radiation and large synchrotrons also play a large role. In addition, model organisms, protein production facilities and substance libraries are important research infrastructures in the field.

# CellX

## The Danish Single Cell Examination Platform

### Description

The latest technological developments to detect RNA, DNA and metabolites in single cells has revolutionized the potential to understand the complexity of biological systems. These technologies have made it clear that tissue and organisms are made up of a great number of cell types which in turn are found in many various stages. The understanding of biological systems, including human illness, is utterly dependent on in-depth knowledge of molecular processes in cells. CellX will be a new interdisciplinary platform for the analysis of DNA, RNA, proteins and metabolites in single cells, both in isolation and in their natural tissue context.

### Scientific effect

The significance of being able to study DNA, RNA and proteins in single cells has been recognized in the journal, Science, as the Breakthrough of the Year in 2018 and in the journal, Nature, as Method of the Year in 2019. Being in a position to study single cell DNA, RNA, proteins and metabolites and their development, for example, during illness

can lead to very important scientific progress and better understanding of the development of illnesses. The CellX infrastructure will allow Danish primary research and clinical medicine to take on a leading role in the new research field of single cell analysis.

### Socioeconomic benefits

By studying the development in DNA, RNA, proteins and metabolites in single cells, CellX will be a catalyst for development and improvement of treatment and diagnosis of illness. This can also lead to a leading position for Danish innovation in the field. To facilitate innovation, CellX will collaborate with pharmaceutical companies through an open platform, where both large and small companies can gain access to CellX.

CellX will not only be used for the analysis of human cells but also to analyse animal and plant cells, for example. This can potentially enhance foodstuffs and thereby make food production more efficient.

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**Type:** Distributed

**Primary proposers:** Aarhus University

**Co-proposers:** Copenhagen University, University of Southern Denmark

**Other interested partners:** Aalborg University

**Estimated total investment required:** DKK 102 million

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# DBI

## Danish Bio-Imaging

### Description

Bio-imaging technologies have become important tools for researchers within the bio and health sciences but are in some cases too technically complex and expensive to implement for individual research groups and businesses. Danish BioImaging (DBI) will provide access to ground-breaking instrumentation and expertise in bio-imaging as a network of infrastructure in which each unit has defined expertise within pre-clinical molecular imaging, electron and light microscopy or image analysis. At the time of writing, there are four open access bio-imaging facilities in Denmark, one at Aarhus University, one at the University of Southern Denmark and two at Copenhagen University. DBI will connect these and facilitate the opening of four new facilities at Aalborg University, DTU Technical University of Denmark, Roskilde University and at *Kræftens Bekæmpelse*. In addition, DBI will set up a new national image analysis facility to minimize the bottlenecks that arise when analysing large amounts of complex imaging data generated by bio-imaging facilities.

In 2020, DBI will apply to become a node for ERIC EuroBioimaging and thereby connect Danish researchers to other international infrastructures such as Corbel, ELIXIR, ESS and MAX IV.

### Scientific effect

Bio-imaging instruments allow researchers to visualize and measure biological materials in various dimensions and with hitherto unobtainable precision from centimetres to angstroms. This has, in combination with the discovery of new biomarkers and new genetic tools, made bio-imaging a powerful tool to improve our understanding of biological systems, discover and treat disease and generally improve human health.

### Socioeconomic benefits

DBI will collaborate with a number of companies, hospitals and SSI and help promote innovation in the Life Science industry, thereby raising its competitiveness.

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**Type:** Distributed

**Primary proposers:** Copenhagen University

**Co-proposers:** DTU, *Kræftens Bekæmpelse*, Roskilde University, the University of Southern Denmark, Aalborg University, Aarhus University

**Other interested partners:** AH diagnostics, Aquaporin A/S, Arla, BioNordika, Biopeople, Bispebjerg Hospital, Bitplane, Carl Zeiss, Chemometec, Chr. Hansen, ColoPlast, Evolva A/S and Sejet Plant Breeding, GE Healthcare, Glostrup Hospital, Gubra, Herlev Hospital, Leica, Leo-Pharma, Lundbeck, Molecular devices, Newtec, Novo Nordisk, NovoZymes, Odense University Hospital, Olympus, Perkin Elmer, Ramcon/Nikon, Riemann, Rigshospitalet, Thermo Fisher, Triolab, Statens Serum Institut, Visiopharm, Aarhus University Hospital

**Estimated total investment required:** DKK 111 million

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# PLATO

## Danish National Mass Spectrometry Platform for Proteomics and Biomolecular Imaging

### Description

PLATO will create an entirely new advanced mass spectrometry-based bio-imaging platform for studying tissue and microbial biofilms. At the same time, PLATO will modernize and expand Danish capacity for proteomic analysis in the Life Science field. PLATO will unify and coordinate efforts in six Danish institutions, including very powerful and broad mass spectrometry research environments at the University of Southern Denmark and Copenhagen University and specialized research environments at Aarhus University, Aalborg University, DTU and Odense University Hospital. PLATO will involve all the leading Danish researchers within biological mass spectrometry and proteome analysis and will support more than 400 researchers and their projects at Danish universities, hospitals and businesses.

### Scientific effect

PLATO will support primary research, applied and translational biological, bio-medicinal and biotechnological

research in Denmark. It will support more than 400 researchers and their projects at Danish universities, hospitals and businesses. PLATO will enable precise measurement, profiling and quantification of proteins and other molecules with mass spectrometry combined with computer algorithms and statistical tools. The results will form the basis for the establishment of detailed models for dynamic biological systems, and their organization and regulation. Identification of small changes in proteins and other biomolecules' structure and function is a prerequisite for understanding the processes that maintain life and those that lead to illness.

### Socioeconomic benefits

PLATO will, for example, make it possible to identify the human proteins that interact with pathogenic virus during infection. This can form a basis for the development of vaccines and treatments. Likewise, PLATO can facilitate research into antibiotic resistance in microorganisms and thus contribute to sustainable food production.

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**Type:** Distributed

**Primary proposers:** University of Southern Denmark

**Co-proposers:** DTU, Copenhagen University, Odense University Hospital, Aalborg University, Aarhus University

**Other interested partners:** Alphalyse, ARLA Foods, Chr. Hansen, Denmark's Technological Institute (DTI), Dupont, Evosep, Ferring, FMC, LEO Pharma, Lundbeck, Novo Nordisk, Novozymes, Roskilde University, Statens Serum Institut, Symphogen, Rigshospitalet, Aalborg University Hospital, Aarhus University Hospital, Zealand Pharma

**Estimated total investment required:** DKK 147 million

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# Energy, Climate and Environment



Energy, Climate and Environment covers a broad scientific spectrum that connects to several key societal challenges under intense Danish focus. This includes how we can best mitigate and manage the impacts of climate change, manage our natural resources responsibly and support a green transition of our society and businesses. The area overlaps with and supports development and innovation in the private commercial sector within the fields of wind turbines, bioenergy and environmental tech, in particular.

Energy research is concerned with improving the exploitation of energy resources by, among other measures, developing more energy-efficient technologies, smart electricity grids and developing new energy sources, including sustainable energy sources. For example, improved solid-state batteries support the development of wireless sensors in the IT sector, electric cars and health applications.

Climate research deals with research into climate systems and changes, climate impacts, climate adaptation and measures to reduce greenhouse gasses.

Climate research represents a knowledge base for the development of more climate-friendly technologies and fossil fuel alternatives.

Environmental research includes research into nutrient runoff from agriculture into natural areas, research into biodiversity in different ecosystems and research on the emission of greenhouse gases and their effect on climate systems. In addition, it includes the development of industrial production and limiting the environmental impacts of human activity.

Important research infrastructures within this field include satellite constellations for observation of earth, water and ice-covered surfaces as well as measuring stations on land, in water and the atmosphere. These measure, for example, temperature, precipitation and air quality. In addition, researchers need access to other research infrastructures such as fixed and mobile field stations, research vessels for the Arctic and other regions, test facilities for industrial products and new technologies, for example in the wind turbine sector,

where incubator environments can facilitate new energy system technologies. As part of the goal to reposition the Danish energy supply approaching the year 2050, it is crucial that researchers have access to facilities that

can enable the discovery and development of new energy materials.

# ACTRIS-DK

## Research Infrastructure for Observation of Aerosol, Clouds and Trace gasses

### Description

Climate, air quality and consequent health impacts and effects on the environment are important themes whose progression is necessary to monitor. This requires infrastructure containing measuring stations and lab facilities equipped with complex measuring instruments and models. ACTRIS-DK will upgrade and link four existing platforms for research into air quality and climate: two observation platforms, one in the high Arctic region of Greenland, one in Mid-Zealand and two investigative platforms in Copenhagen and Aarhus, respectively.

ACTRIS is the European infrastructure for the observation of aerosols, clouds and trace gasses. It consists of lab facilities, measuring stations, calibration centres and data centres in Europe. Currently, 22 countries participate in ACTRIS. ACTRIS-DK will apply to become a member and will thereby connect researchers to Danish and international measuring stations and lab facilities.

### Scientific effect

ACTRIS is the program where new research challenges are defined, where instruments and techniques are developed and tested and where measurement quality is assured and standardized. The purpose of ACTRIS-DK is to provide data that enables a better understanding of the correlation between the atmosphere's composition and the observed effects on climate change, air quality, human health and ecosystems in a European context but also beyond Europe.

### Socioeconomic benefits

A new joint infrastructure that collates data from observations and investigative platforms is of crucial importance to elucidate the social and economic consequences that air quality and climate change cause. Another important aspect of ACTRIS-DK is the potential for innovation in the area. This is evident in that two new start-ups have already been established via the existing research environment.

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**Type:** Distributed

**Primary proposers:** Aarhus University

**Co-proposers:** DTU, Copenhagen University

**Other interested partners:**

**Estimated total investment required:** DKK 34 million

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# DaSSCo

## Danish Distributed System of Scientific Collections

### Description

DaSSCo will create a virtual digital unification of Danish national-historical collections with linkage to the European equivalent, DiSSCo, which is in the European roadmap for infrastructure. DiSSCo encompasses 120 institutions (3 of them Danish) in 21 countries and unifies national-historical collections by making 1.5 billion objects accessible for all.

With DaSSCo as a node for DiSSCo, Danish natural historical collections (19 million objects) will be available for use more efficiently and sustainably, both nationally and internationally.

### Scientific effect

As a digital museum, DaSSCo will contain 19 million botanical, geological and zoological objects as well as historical artifacts.

DaSSCo will thus become a crucial element in Danish biodiversity research.

For example, hi-res images of botanical and zoological objects help researchers to better classify species and to suggest correct global biographical hypotheses. By linking collections to known species characteristics, it is possible to predict changes driven by climate change or invasive species.

Collecting physical materials in a virtual database creates new opportunities to store and analyse sample data across populations and regions while simultaneously reducing the costs and scope of research efforts.

### Socioeconomic benefits

By constantly monitoring changes in biodiversity DaSSCo will help fulfil Danish objectives to preserve the balance between protection and exploitation of nature while also preserving a rich and diverse natural world. The data collected will, for example, be able to offer the necessary historical understanding of changes over time.

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**Type:** Distributed

**Primary proposers:** Copenhagen University

**Co-proposers:** Aarhus University, DTU, Natural Historical Museum Aarhus

**Other interested partners:** The Royal Danish Academy of Fine Arts Schools of Architecture, Design and Conservation (KADK), GLOBE Institute (CU), Fisheries and Maritime Museum, the Danish Environmental Protection Agency, Museum Salling, Museum Sønderjylland, Naturama, NaturBornholm, NordGen-Växter, Dept. of Forensic Medicine (CU), Østjyllands Museum

**Estimated total investment required:** DKK 62 million

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# E-MAT

## National Infrastructure Laboratory for Functional Energy Materials

### Description

If Denmark is to reach its ambitious target to be fossil fuel free by 2050, it will be necessary to find alternatives for the future's new energy materials. Functional energy materials for energy conversion and storage are central to innovation across many energy technologies and are thus of key importance for continued economic growth. The E-MAT laboratory will consist of a series of instruments that, under controlled conditions, enable the development and synthesis of new energy materials for use in components.

### Scientific effect

E-MAT will be the most powerful experimental platform of its kind in Scandinavia with a range of complementary storage methods for advanced research and development of surfaces, interfaces and structures for energy materials. The work will be done in a controlled atmosphere using advanced analysis and data simulations. E-MAT will be placed in an environment where skilled experimenters and theoreticians will be at hand. It will also be at a short practical distance to both Max IV and ESS in

Lund for further analytical work. E-MAT will deliver research, development and results at the highest international level and is expected to generate groundbreaking research results in the areas of new batteries (e.g. solid-state batteries), supercapacitors, solar cells and catalysts, among others.

### Socioeconomic benefits

The output and lifespan of batteries, solar cells, fuel cells (electrolysis cells) and other key energy technologies are to a great extent dictated by the quality of the separators between the materials that cells and batteries are made of. The development of green and new efficient energy technologies to solve climate issues demands advanced equipment that can control these separators. E-MAT will contribute to the discovery and development of new functional energy materials through a broad collaboration between universities and industry. Among the expected results are, e.g., improved solid-state batteries that can support the development of wireless sensors for the IT sector, in electrical automobiles and for applications in the health sector.

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**Type:** Standalone

**Primary proposers:** DTU Technical University Denmark

**Co-proposers:** Copenhagen University, Roskilde University, University of Southern Denmark

**Other interested partners:** GN Hearing A/S, Haldor Topsøe A/S, LITHIUM BALANCE A/S, Oticon/Demant, TEGnology A/S, Uppsala University, Aalborg University, Aarhus University

**Estimated total investment required:** DKK 67 million

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# GIOS

## Greenland Integrated Observing System

### Description

Greenland plays a unique and central role in the global climate system. The purpose of the Greenland Integrated Observing System (GIOS) is to measure and understand the governing mechanisms behind environmental changes in Greenland and how they affect the rest of the globe. GIOS will thus be a new coordinated network of sustainable research infrastructures in and around Greenland that will allow observations of changes to the air, ice, land and ocean. GIOS will link all institutions and universities that carry out Arctic research throughout the Danish Realm.

### Scientific effect

The suggested upgrade of existing measuring stations in Greenland will create a unified observation platform that will result in excellent research at a high international level.

The measuring stations can specifically be used to observe climate changes, sea level rises, ocean warming and changed marine ecosystems. It will also be used to monitor changes to the ex-

tent of sea ice, permafrost thaw, altered landscapes, and the importance of space weather.

The scientific quality of the measuring stations is internationally acknowledged and the long-term observation platforms, in particular, are extremely important to fill the knowledge gap as described in the UN's climate panel reports.

### Socioeconomic benefits

GIOS will contribute to increased collaboration within the Danish Realm through a coordinated and visible research infrastructure, which, with the placement of key stations in and around Greenland, covers existing climate gradients in the Arctic.

GIOS will limit its climate impact by implementing renewable energy solutions and limiting fuel consumption by optimizing logistic cooperation and thereby sending a strong signal in support of sustainable development in the Arctic. GIOS will support political decision-making processes concerning climate change and therefore also Danish participation in the international debate.

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**Type:** Distributed

**Primary proposers:** Aarhus University

**Co-proposers:** DTU, Copenhagen University, Aalborg University, Greenland Institute of Natural Resources (GINR), ASIAQ Greenland Survey (ASIAQ), Geological Survey of Denmark and Greenland (GEUS)

**Other interested partners:** Joint Arctic Command (AKO), Danish Meteorological Institute (DMI), Faroe Marine Research Institute (FAMRI), Greenland's National Museum and Archive, Greenland's University, National Museum, SDU

**Estimated total investment required:** DKK 84 million

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# LTER-DK

## Infrastructure for Long Term Ecosystem Research in Denmark

### Description

The purpose of LTER-DK is to increase knowledge about the structure and function of ecosystems and their response to environmental and socio-ecological impacts in order to gain a deeper understanding of how ecosystems and ecosystem services respond and adapt to changes in the global or local environment. This will be used in the green transition.

LTER is a global, European and national network of research infrastructures that conducts long-term observations of ecosystems along with their processes and functions. The observations address the entire ecosystem i.e., the interaction between organisms, biogeochemistry and hydrology and the socio-ecological context. LTER-DK is a network of Danish research platforms linked to the European LTER network. Both at the European and Danish level, the goal is standardized measurements and a central data structure for the collection of extended metrical series in order to address local and global challenges.

### Scientific effect

Danish research platforms include terrestrial, limnological and coastal ecosystems. There is a particular focus on the interaction between biodiversity, biogeochemistry, hydrology and areal utilization. Work is done with standardized methods, data protocols and documentation of existing and new data as important products. The platforms are placed at various locations in Denmark. LTER-DK will supplement the existing research infrastructures, ICOS-DK and AnaEE-DK by adding facilities for long-term observations of biodiversity and geochemical cycles.

### Socioeconomic benefits

With interdisciplinary research and monitoring on local, regional and global scales and focusing on whole ecosystems, LTER will increase understanding of global changes such as extreme climate events, nitrogen deposition and invasive species and ecosystems' responses and adaptation. This data can be utilized by researchers, students and user groups such as decision-makers and area custodians.

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**Type:** Distributed

**Primary proposers:** Copenhagen University

**Co-proposers:** Aarhus University, DTU

**Other interested partners:** Danish EPA, Dansk Miljøteknik, Joint Wadden Sea Secretariat, HedeDanmark A/S, Sorø Academy

**Estimated total investment required:** DKK 36 million

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# NEST

## The National Energy System Transition Facilities

### Description

To reach the target of a fossil-fuel free energy system by 2045 and a 70% reduction in CO<sub>2</sub> by 2030, there is a pressing need to test new technologies, business models and challenge the current framework conditions. This can be done in simulated models, in smaller labs and through large scale demonstrations.

The National Energy System Transition Facilities (NEST Facilities) will link physically separated laboratories across Denmark and allow them to act as one large, interconnected laboratory, where it is possible to mix and utilize the individual facilities as needed to attain the goal of accelerating the required transition to a one hundred percent renewable energy system with a high proportion of wind energy.

### Scientific effect

Five labs from the three participating universities combined with large scale demonstration facilities in Lindø Offshore Renewables Center (LORC),

GreenLab Skive and the national test centres for large wind turbines in Østerild and Høvsøre will cover the whole technology chain, voltage levels and TRL levels. These are important elements for research into a future smart energy system. The linked laboratories in the NEST Facilities together cover all necessary and future technologies for research, development and product maturation from virtual proof-of-concept to full-scale demonstrations.

The interconnection of the distributed energy system on Risø, a hybrid wind power station on Risø, an electro-fuel laboratory in Foulum, a power-to-x lab in Aalborg and a microgrid test laboratory in Aalborg make it possible to use all the facilities' properties in multiple combinations for a future energy system.

### Socioeconomic benefits

The interconnected NEST Facilities will become a powerful and important incubator environment and midwife to provide new energy system technologies with the needed support.

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**Type:** Distributed

**Primary proposers:** DTU Technical University Denmark

**Co-proposers:** Aalborg University, Aarhus University

**Other interested partners:** ABB, Bornholms Energi og Forsyning, Center Denmark, Danish Energy, DEIF, DHI, DMI, EDF energies nouvelles, Energinet, Energy Innovation Cluster, E.ON, European Energy, EuroWind Energy, Everfuel Europe, FORCE Technology, Frontmatec, GreenHydrogen Solutions, GreenLab Vind aps., HOFOR, Hybrid Greentech, IBM, Lithium Balance, Lindø Offshore Renewables Center, NKT, Norlys, Re:Integrate, Siemens, Siemens Gamesa Renewable Energy Vattenfall, Vestas Wind Systems, Visblue, Ørsted

**Estimated total investment required:** DKK 100 million

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# ReWet

## Wetland observatories for rewetting of drained peatlands

### Description

In Denmark, 10% of national GHG emissions come from drained peatlands and without rewetting of these soils, the national target of a 70% reduction cannot be achieved. ReWet will therefore establish four observatories of agricultural land and forestry on drained peatlands that will function as platforms for ecosystem monitoring, experimental research, technology development and demonstration.

The goal of ReWet is to facilitate a climate aware management and change of areal usage in connection with agriculture and forestry on carbon rich soils.

### Scientific effect

The ReWet observatories will focus on measurement of the exchange and emissions of greenhouse gases (GHG) as well as energy, water and substances (including important nutrients and dissolved carbon) in the interface between the upper groundwater, soil, vegetation and atmosphere under various areal usages.

The observatories will create perfect conditions for biodiversity studies concerning vegetation composition and microbial diversity in the soil, for example, both of which are important factors in greenhouse gas and nutrient balance.

### Socioeconomic benefits

Monitoring and research conducted at the observatories will, in combination with nationwide soil databases, enable the development of knowledge-based national and international strategies for rewetting carbon rich peatlands to achieve significantly lower GHG emissions, less nutrient runoff to aquatic ecosystems and increased biodiversity in the landscape.

Rewetting can fulfil other agendas such as mitigation and adaptation of climate changes, water quality, risk management of flooding, preservation of biodiversity and nature conservation in general. This will enable the fulfilment of national and international commitments in the climate area.

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**Type:** Distributed

**Primary proposers:** Aarhus University

**Co-proposers:** Copenhagen University

**Other interested partners:** AnaEE (Analysis and Experimentation on Ecosystems), ICOS (Integrated Carbon Observation System), Region Midtjylland, WETSCAPES (Collaborative research of the Universities of Greifswald and Rostock)

**Estimated total investment required:** DKK 25 million

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# Physics and Universe



Researchers within Physics and Universe concern themselves with seeking answers to the truly large questions. These include quantum technology and its applications, the nature of the universe's dark matter and dark energy, the formation of galaxies in the Big Bang, the quest for new planetary systems, the possibility of life on other planets as well as the explanation of why elementary particles and thus everything in nature has weight.

Physics and Universe encompasses scientific fields like the classic sciences such as physics, astrophysics, geology and mathematics, including particle and nuclear physics, biophysics and more.

Frontline research gives rise to the need for new technology, methods for data processing with supercomputers, electronics and software, design and production in industry, research into materials, data applications, machine learning, AI, instruments for earth-based experiments, telescopes and satellites and the development of quantum computing.

The research contributes toward the solution of a range of societal challenges within climate and environmental monitoring, weather modelling, natural resource management, security, transport, energy and communication. This attracts new hi-tech businesses that create fertile ground for new innovative solutions in even more areas.

This scientific field is to a great degree dependent on access to large national and international research infrastructures. This is due to the fact that research infrastructures are frequently so large and expensive to develop and operate that individual research institutions and even individual countries often do not have sufficient capacity alone. Therefore, they are forced to cooperate nationally or internationally. Important research infrastructures include astronomic observatories and telescopes, collaborations on space exploration and ocean floor drilling, synchrotrons and high energy facilities, plants for fusion energy and advanced laboratories for research into quantum technologies.

# STEP

## STars and ExoPlanets

### Description

STEP is a proposed astronomic satellite mission that will be a key mission for Danish research and industry. STEP is planned to operate for at least 4 years and will collect time-series data related to stars and exoplanets.

STEP will consist of a 20 cm telescope and a sensitive spectrograph that will cover the electromagnetic spectrum from near-UV to infrared.

STEP will be crucial in securing detailed follow-up measurements concerning major ESA and NASA space missions.

### Scientific effect

Denmark plays an active role in several international space missions related to stars and exoplanets. Data from two NASA missions (Kepler and TESS) and ESA's future PLATO and ARIEL missions

supplemented by earth-based facilities such as ESO, NOT and SONG form the basis for a series of research projects at Danish universities. With the types of measurements that STEP can perform, the mission will be a crucial facility in answering key questions related to planets and stars.

### Socioeconomic benefits

The satellite will strengthen collaboration between researchers and Danish industry. Specifically, it is expected that STEP will contribute to creating new technology within, for example, communications between space and the Earth and in data handling. As STEP will help to confirm the existence of new exoplanets, it will also contribute to our understanding of the possibility of life on other planets and thereby assist in evoking the interest of the wider public in space exploration.

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**Type:** Standalone

**Primary proposers:** Aarhus University

**Co-proposers:** DTU, DFM – Denmark's National Meteorology Institute, Copenhagen University, SDU, Aalborg University, Aalborg University

**Other interested and potentially interested parties:** GateHouse Telecom, GomSpace, Space Inventor, SatLab, Terma Space

**Estimated total investment required:** DKK 85 million

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# Materials and Nanotechnologies



Materials and Nanotechnologies both deal with the exploration, characterization and manipulation of materials, including biological materials down to the atomic level. Within recent years, the field has developed into a very dynamic research sphere characterized by a large degree of interdisciplinary research ranging across diverse scientific areas like chemistry and physics to molecular biology, archaeology and medicine. Material properties such as durability, hardness, conductivity and corrosion resistance have, for example, significance for varied tasks like the development and production of materials for construction, aircraft and automobiles to functional materials for medicines, fuel cells and microelectronics. Research on Materials and Nanotechnologies therefore also has large commercial potential in relation to the development of new products and production methods, including within the areas of medicines, wind turbines and the plastics industry. For example, this could be in the production of more robust, durable and environmentally friendly materials.

This research has industrial applications in the design and synthesis of new materials, components and systems with new functional properties that are without parallel on the macroscopic scale.

The research area needs access to a broad array of material characterization facilities where it is possible to analyse materials under conditions that approximate those that the materials will function under in the real world. Examples of these facilities are scanning probe microscopes (SPM), nuclear magnetic resonance spectrometers (NMR) and photon and neutron scattering instrumentation. Several of these characterization techniques can be found at large international facilities. In addition, advanced material production facilities, cleanrooms and supercomputer processing power for material modelling are important research infrastructures in the area. Over the last decades, there has been increased focus on how modelling and simulation of experimental data can provide an increased understanding of material structures and functionality.

# NANOCHEM

## Ultrahigh resolution chemical characterisation

### Description

Recent decades have seen dramatic progress within the field of nanoscale imaging which, in a static and dynamic manner, allows us to image structures within biological and material science (typically nanometres). However, the resolution for elementary and chemical analysis lags significantly behind. Without being able to precisely identify the object investigated, the interpretation of images becomes ambiguous.

NANOCHEM combines optical and non-optical imaging at nanoscale for a unique national nanoscale chemical imaging facility by exploiting the advantages of the synergy between modern facilities for imaging at three faculties at the host institution, as well as national expertise at Aalborg University and Roskilde University.

### Scientific effect

The new national research infrastructure will represent decisive progress for chemical imaging in Denmark and will

provide a unique platform for excellent research.

The use of NANOCHEM will lead to large quantities of scientific data and require advanced image processing methods in parallel with machine learning. It will be possible to use the instruments on samples ranging from technical systems to sub-cellular structures in living tissue.

The areas of application include the transformation and storage of energy, quantum IT and engineering and material science, as well as pharmacology, medicinal diagnostics, biology and biotechnology.

### Socioeconomic benefits

NANOCHEM will have a notable effect on, especially, technological social evolution and its competitiveness in a globalized world. Other particular areas that are expected to benefit from NANOCHEM include health and wellness, climate efforts and clean energy, innovation, national security as well as research and education.

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**Type:** Distributed

**Primary proposers:** University of Southern Denmark

**Co-proposers:** Roskilde University, Aalborg University

**Other interested partners:** Abberior instruments, Arla, Bispebjerg Hospital, Bitzer Electronics, Coherent, Coloplast, Danfoss Drives, Danfoss Industrial Automation, Danfoss Silicon Power, Danfoss Technology Center, Esbjerg Hospital, Hydro Precision Tubing, Leo Pharma, LINAK, Newtec, Odense University Hospital, OJ Electronics, Omnicon A/S, Opvius, Reimann, Siemens Gamesa, Stensborg A/S, Universitätsklinikum Schleswig-Holstein, Aarhus Universitet

**Estimated total investment required:** DKK 60 million

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# SINCRYs

## Single Crystal X-ray Diffraction Side-station at DanMAX

### Description

MAX IV is one of the most intense synchrotron facilities in the world. The DanMax beamline, constructed by Aarhus University, DTU, Copenhagen University and MAX IV focuses on X-Ray diffraction and imaging studies and will open in 2021.

DanMAX has an extra experimental station ("hutch") which can, for a relatively small investment, be developed into a single crystal beamline. Information on 3D atomic structure achieved via single crystal X-Ray diffraction constitutes a cornerstone of modern natural science.

The project is led by Aarhus University, which has expertise in crystallography. The consortium consists of 79 independent research groups from 18 Nordic institutions including 39 groups from Aarhus University, Copenhagen University, the University of Southern Denmark and DTU.

### Scientific effect

Laboratory-based diffraction meters can study crystals that are larger than 100  $\mu\text{m}$ , but in many cases it is impossible to grow crystals of sufficient size. MAX IV allows the study of microcrystals ( $\sim 1 \mu\text{m}$ ), which eliminates this limitation.

The SINCRYs beamline will meet the needs of a wide research field for both researchers and industry, ranging from bioscience and pharmaceutical knowledge to chemistry, materials, geoscience and solid-state physics. It has also been proposed to establish a Scandinavian Crystallography Service (SCS) to thereby create access for researchers within organic chemistry, medicinal chemistry, material science, polymer chemistry and biochemistry. By integrating SINCRYs in MAX IV, access will be created for researchers all over Scandinavia.

### Socioeconomic benefits

Molecular crystallography is used by businesses to develop, for example, medicines, batteries and sustainable materials. SINCRYs will thereby support a broad raft of innovation areas.

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**Type:** Standalone

**Primary proposers:** Aarhus University

**Co-proposers:** DTU, Copenhagen University, SDU

**Other interested partners:** Astra Zeneca, Chalmers University of Technology, KTH Royal Institute of Technology, Luleå University, Lund University, Norwegian University of Science and Technology (NTNU), RISE, Sandvik, SINTEF, Stockholm University, Swedish University of Agricultural Sciences (SLU), Umeå University, Uppsala University

**Estimated total investment required:** DKK 52 million

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# Social Sciences and Humanities



Social Sciences and Humanities is concerned with finding new ways to organize, communicate, learn, motivate and optimize processes, among other things. The field contributes to and is essential for our cultural, social, political and economic life. At the same time, it supports and promotes innovation through a broad range of private commercial enterprises involved in the development of new learning technologies, consulting services, business operation, cultural mediation, language and communication. It is a prerequisite for Danish companies to be able to act in a global market with large linguistic and cultural differences.

Sociology includes research in economics, politics, welfare, social conditions and work life and helps form political and economic initiatives that support our ability to deal with major societal challenges. These concern, for example, securing future welfare with a growing elderly population and increasing employment.

Humanities cover a broad field of disciplines that seek to explain and understand humans and their cultural products. The area includes research in language, history, art, culture, media and pedagogy. Humanities research contributes significantly to social innovation, creative enterprises, cross-cultural understanding and understanding of development processes. This is in addition to the classic functions such as elevating and qualifying our knowledge society.

The field is dependent on research infrastructures such as laboratory facilities for experimental work and highly specialized collections at fixed locations, including libraries and archives as well as various museum collections within culture, art, history and archaeology. In addition, databases play an important role across the research field. These are often part of national or international data networks and include statistical data, like register data for understanding modern voting behaviours and changes in Danes' values, or digitized data, including digitized museum collections.

# DNES

## Danish National Election Study

### Description

The Danish National Election Study (DNES) is a comprehensive high-quality questionnaire survey based on a probability-based sampling of Danish voters taken from the CPR register. Data is linked to Statistics Denmark's register data, which gives access to exhaustive socio-demographic information on the approx. 2 000 respondents. DNES is the most used questionnaire data in Denmark and the longest-running survey. The survey has run uninterrupted since the parliamentary elections of 1971 and the next round will represent the 19th in the series.

### Scientific effect

DNES is the best source for understanding Danish voter behaviour, both contemporary and future behaviour and is the most used data source for both researchers and the wider public such as journalists and students. The surveys have documented and enabled unique analysis of the major societal changes over the last half-century both in relation to single parliamentary elections

and to the general trend of all parliamentary elections since 1971.

The 19th rendition of the survey will result, among other things, in a peer-reviewed book on the upcoming election. There will be a particular focus on election campaign themes, but topics such as populism and climate change will also be addressed. DNES is also part of robust international cooperation, which permits analysis across countries and continents.

### Socioeconomic benefits

Voter surveys aim to provide updated data on Danish values and politics and will provide an in-depth understanding of how modern voting behaviour and democracy has developed over the last 50 years.

DNES collects new data and improves access to existing data from previous elections. It ensures that this data is disseminated to stakeholders in the research world, the private sector, politics and the public.

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**Type:** Distributed

**Primary proposers:** Copenhagen University

**Co-proposers:** The University of Southern Denmark, Aalborg University, Aarhus University

**Other interested partners:** Dansk Selskab for Statskundskab, Dansk Ungdoms Fællesråd, DJØF, Folketinget, Social- og Indenrigsministeriet, VIVE

**Estimated total investment required:** DKK 5 million

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# E-RIHS.DK

## Danish Research Infrastructure for Heritage Science

### Description

The objective of E-RIHS.Dk is to gather nine leading national research initiatives within cultural and natural heritage. For example, historical and archaeological archives, field archaeological programs with links to regional museums, the museum sector, investments in carbon-14 dating, proteomes and genomes, textiles research, conservation research and preservation and conservation of natural and cultural heritage.

Denmark is internationally recognised for its museum sector, archaeological fieldwork and conservation research and is a global leader in the analysis of genomes and proteomes in prehistoric materials. It is crucial for Denmark's international position in the cultural heritage field that E-RIHS.Dk now gathers all research in cultural and natural heritage under a single research infrastructure.

E-RIHS.Dk will be a Danish node in the European research infrastructure E-RIHS. As the Danish hub, E-RIHS.Dk will be a laboratory for biological material analysis with a focus on geochemistry

at GEUS, proteomes, genomes and textiles research at Copenhagen University and related institutions.

### Scientific effect

E-RIHS.Dk will add a biogeochemical laboratory that will expand the multi-omics approach and thereby make CU a unique centre for the analysis of old biomolecules. In addition, E-RIHS.Dk will result in further genomics infrastructure at the Danish National High Throughput Sequencing Center (CU) and make the technology more widely accessible to meet national needs. Finally, E-RIHS.Dk will add new supplementary analytical infrastructure to GEUS when they transition from petroleum to environmental geochemistry.

### Socioeconomic benefits

E-RIHS.Dk will provide access to the newest facilities within the analysis of archaeological materials in addition to offering further education for researchers in cultural and natural heritage. It will thus strengthen relations between disciplines and actively reach out to the entire cultural sector in Denmark to involve it and strengthen the preservation of cultural markers.

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**Type:** Distributed

**Primary proposers:** Copenhagen University

**Co-proposers:** Center for Tekstiltforskning (CTR, CU), De Nationale Geologiske Undersøgelser for Danmark og Grønland (GEUS), GLOBE Institute (KU), Institut for Tværkulturelle og Regionale Studier (CU), Medicinsk Museion (CU), Retsmedicinsk Institut (CU)

**Other interested partners:** Det Kongelige Bibliotek (KB), Det Kongelige Danske Kunstakademis Skoler for Arkitektur, Design og Konservering (KADK), Museum Lolland-Falster, Museum Nordsjælland, Odense By Museer, Statens Museum for Kunst (SMK), Sydvestjyske Museer, Vejle Museerne, Vikingeskibsmuseet, Wadum Art Technological Studies (WATS)

**Estimated total investment required:** DKK 4 million

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# SHARE-DK

## Survey of Health, Ageing and Retirement in Europe

### Description

The proportion of elderly people in relation to the whole population is higher in Europe than on any other continent. SHARE (also called “50+ in Europe”) investigates the various ways in which persons of age 50 and over live their lives. 27 EU states together with Israel participate in the study. The first survey was conducted in 2004, and data is now collected every other year.

SHARE-DK is linked to the ESFRI project SHARE-ERIC where equivalent surveys from 28 European countries are collected to form a unique international data infrastructure. SHARE is a comprehensive interview-based survey among Europeans aged 50 and older and addresses important questions about aging in Denmark and Europe.

The project aims to update the Danish research infrastructure, SHARE-DK, with the addition of surveys 9 and 10 as an extension of the existing surveys 1-7 and survey 8, which is currently being collected.

### Scientific effect

SHARE-DK supports research into aging as well as policies for addressing the challenges of aging such as health, withdrawal from the labour market, finances and institutional issues. Thus, data from SHARE-DK is used in national and international research projects conducted by, for example, the National Working Environment Center, the Danish Center for Health Economy, VIVE and Statens Seruminstitut.

In addition, the current survey 8 and upcoming surveys 9 and 10 will include questions on the experiences of older people during the COVID-19 pandemic.

### Socioeconomic benefits

The collected data can be used to support political decision-making processes and policy development for the aging community. SHARE has a proactive strategy for dissemination and outreach both at national and international levels and frequently holds workshops and participates in mediation events.

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**Type:** Distributed

**Primary proposers:** University of Southern Denmark

**Co-proposers:** Copenhagen Business School, Copenhagen University, Roskilde University, Aalborg University, Aarhus University

**Other interested partners:** Carlsbergfondet, Helsefonden, TrygFonden, Velux Fonden

**Estimated total investment required:** DKK 17 million

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## 6. Appendix

Table 6.1

### National research infrastructures financed by the Danish Ministry of Higher Education and Science in 2007-2019

Name	Year of allocation	Type	Host institution	Total investment in DKK millions (rounded)	Status
<b>Biotech, health and life sciences</b>					
Danish national 7-tesla MR Project	2009	Standalone	Hvidovre Hospital	66.0	Fully operational since 2016
9.4T MRI rodent core	2009	Standalone	Copenhagen University	22.2	Fully operational since 2013
CAB – Center for Advanced Bioimaging Denmark	2009	Standalone	Copenhagen University	41.3	Fully operational since 2011
CACUP – Copenhagen Animal Care and Use Programme	2007	Standalone	Copenhagen University	80.3	Fully operational since 2004
Danish Center for Molecular Biomedicinal Imaging	2009	Distributed	University of Southern Denmark	22.5	Fully operational since 2012
DAGMAR – Danish Genetically Modified Animal Resource	2008	Distributed	Aarhus University	210.5	Fully operational since 2009
The Danish Register of Twins – a national and international resource	2007	Standalone	University of Southern Denmark	24.0	Fully operational since 2013
DK-OPENSOURCE – Danish research infrastructure for chemical biology	2016	Distributed	DTU Technical University Denmark	35.8	Fully operational since 2019
DNB – Denmark's National Biobank	2008	Standalone	Statens Serum Institut	179.0	Fully operational since 2016



Name	Year of allocation	Type	Host institution	Total investment in DKK millions (rounded)	Status
EATRIS – European Advanced Transnational Research Infrastructure for medicine	2011	Standalone	Copenhagen University	49.5	Fully operational since 2012
ELIXIR - The European Bioinformatics Infrastructure - The Danish Node	2009	Distributed	DTU Technical University Denmark	33.6	Fully operational since 2014
Unit for Genomic Medicine – Research infrastructure for Clinical Genomics	2008	Standalone	Rigshospitalet	28.5	Fully operational since 2010
The Interdisciplinary iNANO-Medicine Core Facility	2009	Standalone	Aarhus University	83.6	Fully operational since 2011
Metabolomics infrastructure – an integrated platform for the study of metabolism in microorganism, plants, animals, and man	2008	N/A	Copenhagen University	16.8	Fully operational since 2014
MINDLab – Core Experimental Facility for Cross-disciplinary Cognition and Communication Studies	2007	Standalone	Aarhus University	220.3	Fully operational since 2012
PRO-MS – Danish National Mass Spectrometry Platform for Functional Proteomics	2015	Distributed	University of Southern Denmark	82.4	Fully operational since 2020
A national Tissue Bank and DNA Sequencing Centre	2008	Standalone	Copenhagen University	38.9	Fully operational since 2020
EMBION – CryoEM research infrastructure for biological nanostructures	2018	Distributed	Aarhus University	114.7	Fully operational since 2020
FOODHAY - Open Innovation FOOD and Health Laboratory	2019	Distributed	Aarhus University	103.1	Under construction
<b>Energy, climate and environment</b>					
AnaEE – Infrastructure for experimental ecosystem research in Denmark	2017	Distributed	Copenhagen University	45.6	Fully operational since 2019
DANA	2009	Standalone	DTU Technical University Denmark	13.3	Fully operational since 2011

Name	Year of allocation	Type	Host institution	Total investment in DKK millions (rounded)	Status
UAS-ability – Research infrastructure for use of drones for data collection	2016	Distributed	University of Southern Denmark	64.5	Fully operational since 2019
ICOS/DK – Danish infrastructure for measurement of GHG in the atmosphere and their exchange with ecosystems	2015	Distributed	DTU Technical University Denmark	41.0	Fully operational since 2019
Poul la Cour Tunnel – The Danish Aerodynamic and Acoustic Wind Tunnel	2011	Standalone	DTU Technical University Denmark	85.7	Fully operational since 2019
RV Aurora	2009	Standalone	Aarhus University	47.0	Fully operational since 2014
WINDSCANNER.DK – a new Mobile Facility for Wind Energy and Turbulence Research	2008	Distributed	DTU Technical University Denmark	34.1	Fully operational since 2013
X-Power – Power Electronics Reliability Test Facilities	2019	Distributed	Aalborg University	62.3	Under construction
<b>Physics and Universe</b>					
DanSeis – National Centre for Seismic Instrumentation	2011	Distributed	Copenhagen University	27.3	Fully operational since 2018
Laserlab.dk	2013	Distributed	Aarhus University	41.3	Fully operational since 2017
QUANTECH – Quantum Technology Infrastructure Proposal	2016	Distributed	Copenhagen University	40.0	Fully operational since 2018
CERN-UP – Upgrading of CERN infrastructure for experiments and computing	2019	Standalone	Copenhagen University	22.4	Under construction
<b>Social sciences and humanities</b>					
CLARIN-DK – Centre for Danish Language Resources and Technology infrastructures for the Humanities	2007	Virtual	Copenhagen University	18.0	Fully operational since 2011

Name	Year of allocation	Type	Host institution	Total investment in DKK millions (rounded)	Status
CSSR – Centre for Survey/Register data	2008	Virtual	Formerly The National Research Centre for Welfare - SFI	12.2	Fully operational from 2010-2017
D-DCAF – Danish Data Center for Accounting and Finance	2009	Distributed	Aarhus University	21.5	Fully operational since 2010
DIGDAG – Digital Atlas of the Danish Historical-Administrative Geography	2008	Standalone	Danish State Archives	22.1	Fully operational since 2012
DigHumLab – Digital Humanities Laboratory	2011	Distributed and Virtual	Aarhus University	37.0	Fully operational since 2018
DRDS – Danish Research Data for the Social Sciences	2017	Virtual	Copenhagen Business School	83.5	Under construction
LARM.fm – Radio culture and audio Infrastructure	2009	Virtual	Copenhagen University	25.0	Fully operational since 2012
REGLINK-SHARE - Survey on Health, Ageing and Retirement in Europe	2014	Virtual	University of Southern Denmark	14.8	Fully operational since 2017
Reorganization and strengthening of Danish register research	2013	Virtual	Danish State Archives	15.3	Fully operational since 2014
<b>Materials and Nano-technologies</b>					
ASTRID2 – The Synchrotron radiation source ASTRID2	2008	Standalone	Aarhus University	168.0	Fully operational since 2014
Danchip	2008 and 2009	Standalone	DTU Technical University Denmark	Allocation from Ministry of 42.0	Fully operational since 2013
DANMAX – a Danish beam line for MAX IV	2014	Standalone	DTU Technical University Denmark	96.0	Under construction
Danish Instrument Centre for Ultra-High Field NMR Spectroscopy	2011	Standalone	Aarhus University	44.5	Fully operational since 2014

Name	Year of allocation	Type	Host institution	Total investment in DKK millions (rounded)	Status
DANFIX – The National X-Ray Imaging Facility	2019	Standalone	DTU Technical University Denmark	52.0	Under construction

Table 6.2

### Danish membership of large international research infrastructures

Organisation	Membership contribution in 2020
CERN European Centre for High Energy Physics	Approx. DKK 137 million
ESO – European Southern Observatory (including also the European Extremely Large Telescope – EELT)	Approx. DKK 26.5 million. In addition, three of the Danish universities contribute approx. DKK 4 million annually in connection with construction of the Extremely Large Telescope - EELT
EMBL – The European Molecular Biology Laboratory	Approx. DKK 14.9 million
ESRF – The European Synchrotron Radiation Facility	Approx. DKK 12.45 million
ESS – European Spallation Source	DKK 208.2 million
European XFEL – The European Free Electron X-Ray Laser Facility	Approx. DKK 8.6 million
ILL – Institut Laue-Langevin	DKK 12.3 million
ITER – International Thermonuclear Experimental Reactor	Direct contribution of approx. DKK 0.3 million plus indirect contribution of approx. DKK 90 million through Denmark's EU contribution

Table 6.3

**Denmark's participation in ESFRI research infrastructures**

With delegation agree- ment	ERIC signed but no dele- gation agreement as yet	Participation without membership	Participation at institu- tional level in prepara- tory work
- CLARIN	- EPOS	- ESS Social	- E-RIHS
- DARIAH	- PRACE	- SHARE	- ACTRIS
- CESSDA	- Euro-BioImaging		- DiSSCo
- EU-OPENSOURCE	- AnaEE		- WindScanner
	- ELIXIR		- EMPHASIS
	- INSTRUCT		
	- ICOS		