DANISH ROADMAP FOR RESEARCH INFRASTRUCTURES 2011

Danish Agency for Science
Technology and Innovation

Ministry of Science
Technology and Innovation

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September 2011

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Published by:
Danish Agency for Science, Technology and Innovation
Bredgade 40
1260 København K
Email: fi@fi.dk
Tel: +45 3544 6200

This publication can be downloaded from the Danish Agency for Science, Technology and Innovation website at: fi.dk

Printed by: Rosendahls Schultz Grafisk a/s
Layout: ToolboxDesign
Photo: Søren M. Osgood

ISBN: 978-87-92776-19-8
ISBN (internet):978-87-92776-20-4

September 2011

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Foreword >

The establishment and development of new research infrastructures is a mission to future-proof Danish research.

If Denmark and Danish researchers are to play a part in creating scientific breakthroughs, this requires a focus on both human resources and physical facilities. We need to focus on improving the framework conditions that are essential for conducting research.

The establishment and development of research infrastructures is a matter of making the most of technological advances such as enhanced microscopes, larger telescopes, faster accelerators and computers to ask other scientific questions – and find even better answers than in the past. It is therefore also a matter of ensuring that research serves to find solutions to some of the many – and often interdisciplinary and cross-frontier – issues faced by our society such as in energy, climate and health.

Investments in research infrastructures must be based on a solid foundation of both scientific and political considerations. We need to ensure that public-sector funding is used where the need and potential to create knowledge, progress and growth are greatest.

In response to this challenge, national roadmaps are currently being drawn up both in Denmark and in almost all other European countries, which identify the key needs for research infrastructures and chart a strategic direction for national initiatives.

In Denmark, the government and co-signatories to the Agreement on Future Prosperity, Welfare and Investments in the Future have since 2007 allocated in excess of DKK 800m for investments in large-scale research infrastructures of national importance.

In March 2010, in the interests of building up a solid basis of knowledge concerning the needs of research for national and international research infrastructures, I appointed six academic panels. The panels were tasked with mapping and prioritising needs over the coming years for research infrastructures within their respective fields. This project, following discussions with university leaders and other key stakeholders, has resulted in a Danish Roadmap for Research Infrastructures, in which a total of 19 promising proposals for concrete projects or initiatives have been identified.

On the recommendation of the Danish Agency for Science, Technology and Innovation, for the some DKK 200m available for 2011, I have selected six new projects which it is intended to realise over the course of the year. Common to all the projects is that they are of broad national interest and that they will serve to fulfil the objective of bringing Danish research to the very fore.

Charlotte Sahl-Madsen
Minister for Science, Technology and Innovation

1.

STRATEGIC FOCUS ON RESEARCH INFRASTRUCTURES OF NATIONAL IMPORTANCE

Research infrastructures are currently employed within all the main fields of science, and comprise a very wide array of advanced tools and facilities that are essential for conducting research.

Technological progress within the last few decades has had great impact on the development of research infrastructures and continually pushes the boundaries of scientific potentials. This requires that the frameworks and the research infrastructures available to research are attractive and contemporary. Access to state-of the-art research infrastructures is therefore an international competitive parameter and is a crucial determinant for the capacity of Danish research institutions both to produce pioneering research results and to educate, retain and attract the best students and the greatest research talents on a global and increasingly competitive knowledge market.

Research infrastructures are not only crucially important for the quality of the research that can be accomplished; the establishment of major research infrastructures will often foster an industrial climate so favourable that it has wide-ranging and direct positive impact on society at large in the shape of spin-off companies, market opportunities for equipment suppliers etc., the development and testing of new, innovative products and services and new forms of treatment in the health sector.

The establishment and development of research infrastructures should consequently be regarded as a key element in the efforts to future-proof Danish research and contribute to the general development and growth of Danish society.

The Danish Roadmap for Research Infrastructures 2011 presents a complete and prioritised catalogue of the national needs for research infrastructures in the short term and charts a strategic direction for national initiatives in this field.

Strategic focus on research infrastructures of national importance

In the year 2007-2009, the Danish government and the signatory parties to the 2006 Agreement on Future Prosperity, Welfare and Investments in the Future (the Welfare Agreement) allocated a total of DKK 600m from the Danish Globalisation Fund to a special programme designed to finance investments in large-scale research infrastructures of national importance. The three allocations to the National Programme for Research Infrastructures made so far have secured the establishment of a large number of promising research infrastructures.

During 2009, the government and the signatory parties resolved to continue the national measures for research infrastructures in the year 2010 and 2011 and allocated DKK 240m for that purpose.

In the *Ministry of Science, Technology and Innovation's Action Plan for Research Infrastructures* of 2010, the first three allocations and experiences from the National Programme for Research Infrastructures were analysed with a view to assessing the need for any changes and adjustments to the national measures.

The action plan points out the need to strengthen inter-institutional cooperation and organisational frameworks in establishing national research infrastructures, including the need for a more explicit division of tasks between the various parties involved. The action plan also identifies the need to support more long-term prioritisation of national needs for research infrastructures both in Denmark and abroad.

The Ministry of Science, Technology and Innovation's Action Plan for Research Infrastructures is available (in Danish only) on the Danish Agency for Science, Technology and Innovation's website; www.fi.dk/viden-og-politik/strategier-og-handlingsplaner/infrastruktur

The investments required to secure attractive frameworks for Danish research tend to be substantial, among other things because many research infrastructures, in line with the advances made in technology and research, have become significantly more complex and resource-intensive. This requires the building of sufficient critical mass and raises the costs of establishment and operation. This means that even major research institutions often find it difficult to provide their researchers with sufficient access to the necessary facilities.

Decisions regarding the establishment of new research infrastructures should therefore be informed by both scientific and political considerations in order to ensure that funds are put to best use and where they are most needed.

To that end, in both Denmark and in virtually all European States, national roadmaps are currently being drawn up to identify principal research infrastructures over an extended period of years. Danish Roadmap for Research Infrastructures will now enable Denmark, on a much better basis than in the past, to engage in the ongoing discussions as to which European research infrastructures are to be realised.

In the process of preparing the Danish Roadmap, the focus has been on research infrastructures of decisive national importance and interest, that is, research infrastructures of interest to a wide circle of researchers and research institutions in Denmark, and where a research infrastructure would make a crucial difference to Danish research, irrespective of whether the research activity takes place in Denmark or abroad.

The aim has been to identify national research infrastructures where, in terms of research quality, critical mass among the users, access and utilisation etc. it is of the essence, in terms of both research and resources, to involve all relevant research environments across research institutions.

Explicit division of labour between stakeholders in the field of research infrastructures

Initiatives in the field of research infrastructures are currently supervised by a large number of different stakeholders from the Danish Ministry of Science, Technology and Innovation, other appropriate ministries, research councils and institutions, the EU, the Nordic Council of Ministers and various foreign research-funding bodies, enterprises, private foundations etc.

The stakeholders' initiatives are instituted at several levels – from funding for individual items of equipment or instruments, through accompanying research grants (covering research related to the utilisation of research infrastructures) and instrumentation centres to actual membership of the large-scale international research infrastructures.

The Danish Roadmap for Research Infrastructures seeks to clarify the division of tasks between the various stakeholders. It does so by indicating above all those projects and initiatives that embody a distinct national quality, and in which Danish researchers across research institutions and national borders are in need of access to state-of-the-art research infrastructures. At the same time, the Danish Roadmap is based on the premise that national investments for the establishment of research infrastructures will be matched by a commitment to operation, education and research activities by the institutions involved.

In order to ensure a well-defined and operational division of tasks between the various stakeholders in the field of research infrastructures, the roadmap and the allocation of funds from the National Programme for Research Infrastructures are geared towards research infrastructures of national importance. More institution- and project-specific research infrastructures and accompanying research activities are expected to be funded by, for example, the Danish research council system or the research institutions' basic grants.

The utilisation of large-scale research infrastructures via accompanying research activities in relation to the Danish memberships etc. of international research infrastructures will be addressed at greater length by the Danish Agency for Science, Technology and Innovation in extension of a forthcoming strategy for Danish access to X-ray laser, synchrotron and neutron radiation facilities abroad.

International cooperation on research infrastructures

Denmark is currently a member of, or involved in, a number of partnerships on large-scale international research infrastructures within various disciplines and research areas. Financial contributions to these binding partnerships amount to around DKK 250m per annum.

In connection with the Danish roadmap process, both the scientific panels and relevant Danish research environments and research institutions have expressed their support for a Danish commitment to both existing large-scale international research infrastructures such as the European Molecular Biology Laboratory (EMBL), the European Organization for Nuclear Research (CERN), the European Southern Observatory (ESO) and the European Space Agency and others as well as new international research infrastructures currently being planned or established such as European Spallation Source (ESS) and the European X-Ray Free-Electron Laser Facility

Danish involvement in and memberships of large-scale international research infrastructures

Research infrastructures	Disciplinary field
The European Molecular Biology Laboratory - EMBL	Biotech, Health and Life Sciences
European Spallation Source - ESS	Materials Technology and Nanotechnology
The European X-ray Free-Electron Laser Facility – European XFEL	Materials Technology and Nanotechnology
The European Synchrotron Radiation Facility - ESRF	Materials Technology and Nanotechnology
Institut Laue-Langevin - ILL	Materials Technology and Nanotechnology
European Organization for Nuclear Research - CERN	Physical Sciences
European Southern Observatory - ESO	Physical Sciences
The European Space Agency (ESA)	Physical Sciences

(European XFEL), (see table below). State-of-the-art national research infrastructures are of crucial importance for Danish researchers' opportunities to participate in international collaboration and for our utilisation of existing international research infrastructures. A research environment with advanced research infrastructures at its disposal will, all things being equal, be more attractive as a research partner to international research environments.

A prevailing trend is increased interdisciplinary and cross-border collaboration among researchers. Data that was formerly dispersed among many different sources is now being collected and distributed in virtual networks. Such networks and their use of computers for simulation, modelling and remote access to research infrastructures are creating new scientific and cost-efficient potentials.

Experiences from research infrastructure partnerships formed to date clearly demonstrate that pan-European research infrastructures strengthen European research and create added value in the form of enhanced collaboration and utilisation of resources. However, it is not currently possible for the EU to support the actual establishment or operation of international research infrastructures, including projects that have arisen in connection with the ongoing ESFRI process.

Denmark to co-host the establishment of the world's largest neutron microscope

The Danish government has decided that Denmark, in collaboration with Sweden, is to host European Spallation Source (ESS), a research infrastructure to be established in the Dano-Swedish Øresund Region.

The siting of ESS in the Øresund Region will give Scandinavia its first large-scale pan-European research infrastructure, and will employ around 400 permanent researchers and also receive throughput of 2,000-5,000 visiting researchers annually.

The Dano-Swedish joint hosting will entail the siting of ESS activities on both sides of the Øresund. The ESS facility itself will be built in Lund, Sweden, while ESS Data Management and Software Centre (ESS-DMSC) will be located in Copenhagen. Once fully developed, ESS-DMSC will employ around 70 researchers and technicians, and will be responsible for all data activities in connection with monitoring of instruments at ESS, data collection, data processing and visualisation of data, access to data analysis equipment and simulation of the instruments.

The total cost of establishing ESS is expected to be in the region of DKK 11.1bn (2008 prices) of which the Danish share of the construction costs is expected to amount to 12.5%, or approx. DKK 1.3bn.

ESS will offer a wide array of potential applications in that it will not only be of importance for traditional basic research in physics, chemistry and so forth, but companies and applied research and development will also stand to benefit from the research infrastructure.

From a Danish perspective, dimensions such as the neutron scattering technology capability for analysing hydrogen and carbon molecules will make the facility attractive to industry. ESS will for example facilitate the study of biological materials and molecules in their natural environments and will offer precise impressions of the processes involved in both biological and chemical reactions. This will, for example, hold unprecedented opportunities for research in enzymes and proteins

which is a key research field for branches of the Danish pharmaceutical industry for example.

The establishment of ESS in the Øresund Region is expected to strengthen both scientific and industrial development in that Danish research environments and businesses will have more immediate access to the latest research infrastructure.

ESFRI and the EU framework programmes for research

The international focus on research infrastructures and the creation of national roadmaps in almost all European States has arisen and been spurred not least by the work in progress within the European Strategy Forum for Research Infrastructures (ESFRI). With its roadmaps in 2006, 2008 and now in 2011, the ESFRI has played a key role in the identification and development of the some 50 proposals for especially promising European research infrastructures which have now been inscribed on the European roadmap.

A number of the prioritised initiatives on the Danish Roadmap entail Danish membership of new European research infrastructures. At the EU level, ERIC (European Research Infrastructure Consortium) has been adopted as a legal instrument for establishing future research infrastructures. The intention is to make it easier for EU Member States and associated countries to set up and operate research infrastructures of European interest.

ESFRI however has neither the financial means nor a political mandate to institute the actual implementation of the roadmapped projects. Under its 7th Framework Programme (FP7), the EU has now been in a position to grant financial support for the preparation of projects on the ESFRI roadmap. FP7 does not however permit funding for the actual construction and operation of new research infrastructures. It is thus up to the individual countries to assess the extent to which they wish to participate in the realisation of the individual research infrastructure projects.

The Danish Roadmap for Research Infrastructures should be seen in the context of the mounting European focus on the importance of the research infrastructures in realising the European Research Area (ERA), as it was recently underpinned by ESFRI's efforts and the European Commission's *Innovation Union* Communication, which is part of the so-called flagship initiative within the EU's overarching growth strategy, *Europe 2020*.

In this context, the preparation of the Danish Roadmap is a key resource in enabling us to engage actively in European cooperation in this area and in the activities likely to ensue from the EU and forthcoming 8th Framework Programme's (Horizon2020) prioritisation of research infrastructures.

In connection with the drafting of the forthcoming Horizon2020, Denmark will be advocating an increase in the financial frameworks for research infrastructures. In recognition of the singular importance of research infrastructures for the EU's competitiveness, the development of ERA and increased European cohesion, it is crucial that the financial frameworks for the research infrastructures programme are increased.

Denmark for its part aspires for Horizon2020 to go further than in the past in supporting the utilisation and development of research infrastructures, and that efforts should be made on the basis of an overarching requirement for scientific excellence to achieve greater cohesion between Horizon2020 and other sources of financing such as the EU's Structural Funds and Cohesion Fund. In that context it will be useful to look at the possibilities for developing distributed research infrastructures, organised with nodes in different countries and facilitated by increased use of IT-based remote access.

Equally, the Danish position is that European researchers throughout the Member States should continue to be granted access to the best research infrastructures available through an ambitious access programme under the forthcoming Horizon2020.

Furthermore, under Horizon2020, efforts should be made to achieve increased and stable financing of excellent European research infrastructures through grants to cover construction and operational costs. Selection of new research infrastructures should be informed by the ESFRI roadmap, supported by the national roadmaps for research infrastructures.

2.

THE DANISH ROADMAP FOR RESEARCH INFRASTRUCTURES – NEEDS, TRENDS AND PRIORITIES

TE-Buf
pH=8
5 mM
Tris-HCl
pH=7.6
EtOH
96%
10%
Glycerol

The Danish Roadmap for Research Infrastructures presents a complete and prioritised catalogue of the national needs for research infrastructures in the short term and charts a strategic direction for national initiatives in this area.

The roadmap identifies a total of 19 proposals for projects or initiatives, which are given highest priority overall by the Danish research environments and institutions. The 19 proposals will all serve to significantly improve the framework conditions for Danish research and constitute a solid foundation for further advances in Danish research.

Broad-based disciplinary and strategic premise for the roadmap process

A key element in the process leading up to the present roadmap has been to ensure broad-based disciplinary and institutional involvement in assessment and prioritisation of national needs for research infrastructures. Pivotal for the process have been the six academic panels, which in late 2010, on the basis of more than 150 concrete proposals and other input from Danish research environments and institutions, presented a number of survey and prioritisation reports indicating the main needs for research infrastructures in the relevant fields of research.
The six academic panels covered the following fields:

- Humanities and Social Sciences
- Energy, Climate and Environmental Sciences
- Biotech, Health and Life Sciences
- Materials Technology and Nanotechnology
- Physical Sciences
- e-Science

Based on the survey and prioritisation reports of the academic panels and a special discussion paper containing comments on the priorities and recommendations of the six reports, the Danish Agency for Science, Technology and Innovation has conducted a comprehensive dialogue process with a wide circle of stakeholders in the Danish research community, university leaderships and other key stakeholders. The object of the dialogue process has been to collect additional points of view and opinions as to which research infrastructures Denmark should devote special focus to realising in the short term (within three to five years), including the willingness of the research institutions to assume financial and operational responsibility for the prioritised research infrastructures in line with their own strategic priorities.

The survey and prioritisation reports of the six academic panels and other materials relating to the Danish Roadmap for Research Infrastructures are available on the website of the Danish Agency for Science, Technology and Innovation; /www.fi.dk/viden-og-politik/strategier-og-handlingsplaner/infrastruktur

Realisation of prioritised research infrastructures in 2011

Based on the Danish Roadmap and the total of 19 prioritised proposals for projects or initiatives in the field, the Minister for Science, Technology and Innovation has indicated six specific research infrastructures for Denmark to seek to realise in 2011 with funding from the National Programme for Research Infrastructures.

The projects are as follows: Danish Digital Humanities Lab (DigHumLab); Large-Scale National Wind Tunnel Facility; EATRIS - European Advanced Translational Research InfraStructure in Medicine; Danish GHz Solid State NMR Instrumentation Centre; DanSeis – National Centre for Seismic Instrumentation; and Reorganisation and Strengthening of Danish e-Science.

The purpose of the National Programme for Research Infrastructures is to support projects of wide-ranging national importance with a solid national base of support. It is therefore crucial to seek to involve all relevant and interested parties in the various consortia and for this to be reflected in the research infrastructure's organisation and in the long-term models for financing the operation of the research infrastructures, and where applicable, embedding and continued development with the parties involved. In order to ensure maximisation of investments in the designated research infrastructures, it is also of great importance that all interested researchers, irrespective of institutional affiliation, are granted access to the facilities.

The research institutions behind the six designated research infrastructures will on that basis be

invited in 2011 to draw up concrete proposals for realisation of the projects. For each of the projects, the Danish Agency for Science, Technology and Innovation will be appointing a single institution which will be assigned responsibility for setting up national consortia of relevant stakeholders and supervising progress on the preparation of the project proposals.

Concrete proposals for realisation of the six designated projects are expected to be available by August 2011.

On the basis of the concrete proposals for realisation of the six designated projects, the Danish Agency for Science, Technology and Innovation will initiate evaluation of the proposals and, where necessary, will engage in further dialogue with the individual consortia with a view to strengthening the projects' national organisation and accessibility.

Allocation of grants for the six designated research infrastructures will be undertaken on the basis of the concrete project proposals, any external evaluation of these and subsequent dialogue between the Danish Agency for Science, Technology and Innovation and the individual consortia.

Updating of the Danish Roadmap for Research Infrastructures

The present Danish Roadmap for Research Infrastructures will constitute the 'master plan' for whichever of the initiatives are implemented in the coming years. However, as a catalogue of current needs in the field of research infrastructures, a roadmap is essentially a dynamic document. It may therefore be necessary to adjust and update the roadmap to ensure that it continues to reflect trends and advances in research and the attendant needs for research infrastructures. In connection with the current roadmapping, the academic panels' survey and prioritisation reports have highlighted a number of trends and needs for research infrastructures in the medium term, which are indicative of the necessity of ongoing updating and renewed validation of the needs for research infrastructures.

Prioritised research infrastructures

The following pages present the research infrastructures inscribed on the Danish Roadmap for Research Infrastructures for the short term (table 1), including the prioritisation of projects on the ESFRI roadmap that are of Danish interest (Table 2).

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Table 1. List of research infrastructures inscribed on the Danish Roadmap for Research Infrastructures for the short term (up to 3-5 years)

The table is divided into the six disciplinary fields employed during the roadmapping process. Anticipated grants in 2011 are emboldened. Other initiatives due to be launched in 2011 are italicised.

	Estimated start-up expenses (DKK millions)	Estimated annual operating expenses (DKK millions)	Grants from the National Programme for Research Infra structures 2011. The amount indicates the anticipated maximum grant (DKK millions)
HUMANITIES AND SOCIAL SCIENCES			
Digital Humanities Lab (DigHumLab)	**55**	**5**	**30**
Reorganisation and strengthening of Danish register research	-	10-15	-
ENERGY, CLIMATE AND ENVIRONMENTAL SCIENCES			
Research infrastructure for biodiversity and environmental data	30	6	-
Research infrastructure for biorefinery and biomass conversion technologies	40	5	-
Research infrastructure for collection of data on greenhouse gases	35	9	-
Test Facility for Grid Connection Characteristics of Wind Power Plants	50	5	-
Large-Scale National Wind Tunnel Facility	**130**	**6**	**40**
The European WindScanner Facility - Windscanner.eu *	-	-	-
BIOTECH, HEALTH AND LIFE SCIENCES			
EATRIS - European Advanced Translational Research Infrastructure in Medicine	**30**	**5**	**27**
ELIXIR - European Life Sciences Infrastructure for Biological Information**	-	-	-
Mass spectroscopic proteomics	50	4	-
MATERIALS TECHNOLOGY AND NANOTECHNOLOGY			
Access to MAX IV and other radiation facilities	-	-	-
Danish GHz Solid State NMR Instrumentation Centre	**45**	**1**	**33**
Materials technology research infrastructure	40	5	-
NANOLINE – beamline at the ASTRID2 synchrotron radiation source	30	1,5	-
PHYSICAL SCIENCES			
DANLASE - Danish National Laser Centre	35	2	-
DanSeis - National Centre for Seismic Instrumentation	**30**	**0,3**	**25**
SONG - Stellar Observations Network Group	32	1	-
E-SCIENCE			
Reorganisation and strengthening of Danish e-Science	**70**	**-**	**50**

* Project funded by the DKK 25m grant allocated in 2008 from the National Programme for Research Infrastructures.
** Project funded by the DKK 25m reserve grant allocated in 2009 from the National Programme for Research Infrastructures. This grant is due to be allocated in 2011.

Danish participation in research infrastructures on the ESFRI roadmap

A number of the projects inscribed on the Danish Roadmap for Research Infrastructures for the short term involve Danish participation in and membership of European cooperation on the ESFRI roadmap.

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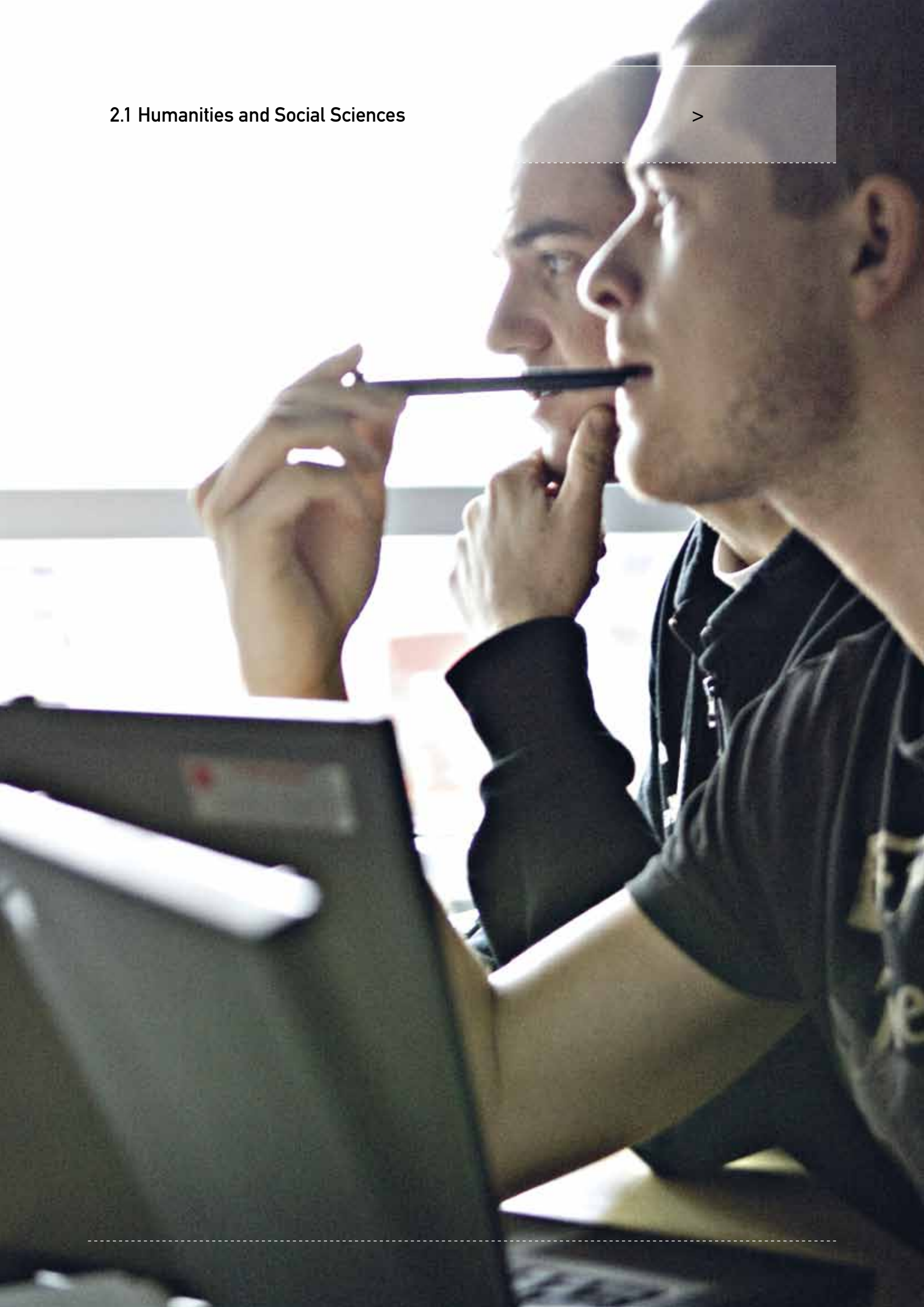
Table 2. List of priority projects with Danish interests on the ESFRI roadmap

The table contains a list of projects on the ESRI roadmap which are of Danish interest for the short term. The table is broken down by the research fields named in the ESFRI roadmap from 2008.
Projects highlighted green are inscribed on the roadmap with a view to immediate Danish participation. Projects highlighted yellow are inscribed on the roadmap with a view to Danish participation for the short term depending on developments in the international project, national interest and funding availability. Projects highlighted blue are lodged with a number of international organisations etc. of which Denmark is a member. Funding of these projects is expected to be covered by the ordinary Danish contributions.

SOCIAL SCIENCES AND HUMANITIES	
CESSDA - Council of European Social Science Data Archives	Considerations going forward concerning Danish participation in and funding of CESSDA will be included in the planned efforts to reorganise and strengthen Danish register research.
CLARIN - Common Language Resources and Technology Infrastructure	Danish membership of CLARIN will be funded by the anticipated grant for the Digital Humanities Lab (DigHumLab) project.
DARIAH – Digital Research Infrastructure for the Arts and Humanities	Danish membership of DARIAH will be funded by the anticipated grant for the Digital Humanities Lab (DigHumLab) project.
ESS - European Social Survey Upgrade	Considerations going forward concerning Danish participation in and funding of ESS-Survey will be included in the planned efforts to reorganise and strengthen Danish register research.
SHARE - Upgrade of the Survey of Health, Ageing and Retirement in Europe	Denmark will be participating in SHARE with a view to execution of phase 1 of the project. The cost of participation will be covered by the University of Southern Denmark. Considerations going forward concerning Danish participation in and funding of SHARE will be included in the planned efforts to reorganise and strengthen Danish register research.
ENVIRONMENTAL SCIENCES	
EPOS - European Plate Observing System	Danish membership of EPOS-ERIC will be funded by the anticipated grant for the DanSeis (National Centre for Seismic Instrumentation) project.
ICOS - Integrated Carbon Observation System	Danish membership of ICOS-ERIC for the short term is dependent on developments in the international project, national interest and options for funding via the Research infrastructure for collection of data on greenhouse gases project.
LifeWatch - e-Science and Technology Infrastructure for Biodiversity and Observatories	Danish membership of LifeWatch-ERIC for the short term is dependent on developments in the international project, national interest and availability of funding via the Research infrastructure for biodiversity and environmental data.
ENERGY	
WindScanner.eu	The expectation is that Danish research environments and the consortium behind Windscanner.dk will spearhead the preparation and development of the European WindScanner project, which was inscribed on the ESFRI roadmap in 2010.
BIOLOGICAL AND MEDICAL SCIENCES	
BBMRI - Biobanking and Biomolecular Resources Research Infrastructure	Considerations going forward concerning Danish participation in and funding of BBMRI-ERIC will be included in the planned efforts to reorganise and strengthen Danish register research.
EATRIS - European Advanced Translational Research Infrastructure in Medicine	Danish participation in the planned transition phase and subsequent membership of EATRIS-ERIC will be funded by the anticipated grant for the Danish EATRIS node.
ELIXIR - European Life Sciences Infrastructure for Biological Information**	In connection with the allocation of the National Programme for Research Infrastructures in 2009 a reserve grant of DKK 25m was earmarked with a view to extending and guaranteeing Danish participation in ELIXIR. The reserve grant is expected to be allocated in 2011, again, depending on the project's development nationally and internationally.
INSTRUCT - An Integrated Structural Biology Infrastructure for Europe	Danish membership of INSTRUCT will be funded by the anticipated grant for the Danish GHz Solid State NMR Instrumentation Centre.
MATERIALS AND ANALYTICAL FACILITIES	
ESRF-upgrade	Danish participation in ESRF (European Synchrotron Radiation Facility)-upgrade will be funded through the ordinary membership fee. The Danish commitment to ESRF will otherwise be addressed in a new Danish strategy for access to X-ray laser, synchrotron and neutron radiation facilities, which is due by summer 2011.
ESS - European Spallation Source	Denmark is a co-host of ESS. ESS Data Management & Software Centre is planned to be sited in Copenhagen.
European XFEL	Denmark has been a member of the European X-Ray Free-Electron Laser Facility (European XFEL) since 2009.
ILL20/20 Upgrade	In 2009, Denmark took out a two-year trial membership of the Institut Laue-Langevin (ILL). Continued Danish commitment to ILL will be addressed in a new Danish strategy for access to X-ray laser, synchrotron and neutron radiation facilities, which is due by summer 2011.
PHYSICAL SCIENCES AND ENGINEERING	
E-ELT - European Extremely Large Telescope	Danish participation in E-ELT is funded via the ordinary membership fee to the European Southern Observatory (ESO).
E-INFRASTRUCTURES	
PRACE - Partnership for Advancing Computing in Europe	Considerations going forward concerning Danish participation in and funding of PRACE will be included in the planned efforts to reorganise and strengthen Danish e-Science.

2.1 Humanities and Social Sciences >



Humanities and social science researchers will to an increasing extent need robust, generally available and internationally geared research infrastructures based on modern information technology. The development of these new tools will significantly advance studies and interpretations of human experiences, actions and decisions and thus lay the foundation for an enlightened civil society, competitive business and industry and an efficient public sector.

Research infrastructures that support humanities research have traditionally been libraries, archives and various museum collections consisting of historical documents, books and periodicals, maps, artefacts, art and other resources dispersed across different national institutions. On a smaller scale there are the university laboratories which are used in humanities research of a more experimental nature, for example, in linguistics, communication and media research.

Research infrastructures serving the social sciences have typically comprised databases containing public registers, including random sample-based questionnaire data, dispersed across various public institutions.

New trends

Not least the digitisation of data has unlocked new potentials for research. Danish authorities and research institutions have for a number of years being stepping up their commitment to providing digital access to analogue materials. In addition, university libraries, archives and museums together with register authorities are now increasingly collecting, registering, preserving and releasing data that were digital in origin.

Both within the humanities and the social sciences and across individual disciplines there is an increasing need to ensure data availability and data preservation in the form of better, easier and more secure access to register data or other types of resources, but equally a need to develop new search facilities and research methods; both in the form of new laboratory facilities for experimental research and in the form of new research infrastructures with digital resources. In addition, there is an increasing need for computing capacity to process mounting data volumes and to perform new complex searches and calculations, and not least increased demand for e-Science skills in humanities and social sciences research environments.

Humanities and social sciences research is often reliant on the public institutions outside the universities that collect, preserve and make large volumes of empirical material available to research. Although increasing digitisation in itself holds vast research potentials, there is a need for greater focus on preserving the research value of the digitisation wave. Museums, archives and libraries have concentrated chiefly on digitising resources in order to make them available for general public access. As for register data, digitisation is driven primarily by the immediate administrative and political requirements of public authorities. The need to collect data of particular relevance to research and to develop specific search and analysis tools for digitised data has not been given the same high priority.

Within archival and library institutions, technological advances now permit full retrodigitisation of texts such as for example Danish medieval manuscripts at the Royal Danish Library. The preservation aspect, in line with the aim to make a given body of work accessible in its entirety is a significant undertaking for these institutions. The research institutions also stand to benefit from such resources being made accessible following their digitisation. However those infrastructures that are proactive in developing new technological frameworks, tools and methods are assessed as being of the greatest importance in future-proofing Danish humanities and social sciences research, education and innovation.

Digital Humanities Lab (DigHumLab)

DigHumLab will serve as the single virtual access point to all relevant digitised resources of relevance to the research areas of the humanities and social sciences in both Danish and European research infrastructures.

DigHumLab will be a national distributed research infrastructure with a very broad base of support, its purpose being to collect, process and distribute digital research material geared primarily to humanities and branches of social sciences research. DigHumLab will give researchers and students a means of searching in, analysing, organising, linking, comparing, sharing and combining resources with analytical tools developed on an ongoing basis in the infrastructure's laboratory facilities. The types of resources that will be included in DigHumLab will consist of text, audio (speech, music, sound and soundscapes), images (still, temporal), physical objects (3D) and combinations of these (e.g. transcribed speech and multimodal data). DigHumLab will moreover comprise laboratory facilities to support experimental humanities and social sciences research with associated development of database facilities and metadata structures.

DigHumLab will be assigned responsibility for operating as the Danish node in, respectively, CLARIN (Common Language Resources and Technology Infrastructure) and DARIAH (Digital Research Infrastructure for the Arts and Humanities). The planning of these two European research infrastructures is well underway and it should be possible to establish both of these formally within a year's time. DigHumLab will to a great extent have the capacity to both influence and benefit from the European cooperation in that the development of standards, methods, search tools etc. can be undertaken jointly and in that tools and methods developed elsewhere can be adopted and adjusted to national conditions.

Consortium partners

Broad research-related interest in and backing for DigHumLab has been registered among all the major universities, archives, libraries and museums. Aarhus University will be invited to supervise the preparation of a concrete project proposal in close conjunction with University of Copenhagen, Aalborg University, University of Southern Denmark and the other participating research institutions.

Funding

Provided that a satisfactory basis can be created for setting up DigHumLab, a grant of up to DKK 30m will be awarded for the project. This grant will be to cover both the establishment of the national research infrastructure together with fees for Danish membership of CLARIN and DARIAH.

Time schedule

It is expected that a concrete proposal for realisation of the project will be in place by August 2011 and that a grant will be awarded shortly thereafter. DigHumLab will be built up gradually over a five-year period.

Reorganisation and strengthening of Danish register research

In order to give added impetus to the positive trend in the availability of register data to researchers, efforts are underway to establish a new and extended organisation of the field of register research. The new organisation will serve as a consolidatory Danish platform for making register data available and viable for research and for strengthening dialogue, integration and coordination in this field.

Denmark, with its comprehensive registers linked to personal identification numbers, is one of the world's best platforms for register research. Given this fact, in 2002, the Minister for Science, Technology and Innovation set up the Coordinating Body for Register Research (KOR), which with the aid of a small National Budget allocation has worked to create frameworks conducive to register research, chiefly through the creation and maintenance of researcher service units run by the Danish National Board of Health and Statistics Denmark. These units have significantly improved the opportunities for researchers to pursue register research.

In connection with the roadmapping process, a number of recommendations have been formulated for the fields of social and health sciences with a view to further strengthening Danish register research.

The field of social sciences is associated with special challenges in linking register and questionnaire form data and prioritisation and funding of longitudinal studies with running expenses over an extended number of years, such as for example recurrent election polls, language surveys, including, where applicable, Danish participation in the ESFRI projects ESS (European Social Survey), CESSDA (Council of European Social Science Data Archives) and SHARE (Survey of Health, Ageing and Retirement).

Healthcare research highlights the need for improved coordination and knowledge sharing among stakeholders in the field of biobanks, the need to ensure register researchers' means of utilising operationally-generated health data drawn from the Danish National Board of Health quality databases, and the need for a multigenerational register to permit mapping of familial relationships between patients in relation to disease and health.

In response to these needs, a committee will be set up and tasked with presenting proposals for reorganisation and strengthening of Danish register research. It is assessed as crucially important to keep to the principle of consolidating the organisation of the field of register research across research fields so that objectives and organisation may be adapted to new opportunities and challenges.

Consortium partners

In summer 2011, KOR is due to invite participants to attend an open and broad-based workshop on the future organisation of Danish register research. The Ministry of Science, Technology and Innovation will subsequently be appointing a committee to present proposals for reorganisation and strengthening of Danish register research.

Funding

The current national budget allocation account for register research is planned to be continued under a new organisational structure.

Time schedule

The committee's proposals are expected to be presented by the end of 2011 so that a new organisation can come into effect during 2012.

2.2 Energy, Climate and Environmental Sciences >

Taken together, energy, climate and environment represent one of the most significant scientific and societal challenges both nationally and globally. Since the energy crisis in the 1970s, the Danish and international research community has amassed ever-increasing scientific insights into energy, climate and environmental issues, as a result of which Denmark currently possesses strong potentials in terms of research, natural resources, society and industry.

Within the next decade it will be necessary to develop new infrastructures in order to sustain and expand existing, strong research environments and underpin strengthened economic growth within socially sustainable frameworks.

In the field of energy and in much of the environmental field, there is a direct link between industrial interests and public-sector research activities. Climate is yet another classical field of research, but for which there is a mounting need for extremely advanced research infrastructures.

Energy and biotechnology

Denmark currently holds a strong position in renewable energy, especially wind energy and bioenergy and also in utilisation of agricultural byproducts. Research infrastructures are needed throughout the chain from laboratory to end users, who in the future are to be supplied with clean energy on demand. Experimental plants are already on stream for testing and implementation of renewable energy sources, but in order to fully unlock the potential of new processes and technologies there is a need for new research infrastructures in which advanced research and experiments can be carried out under conditions scalable to pilot-level plants.

For the short term, there is a need to extend Danish wind tunnel capacity, to develop scanner systems to strengthen research in atmospheric turbulence, together with facilities for testing systems for connecting wind plants to the national grid. Full-scale research wind turbines for testing research results should be considered for the medium term. In the fields of biotechnology and bioenergy, for the short term there is a need for research infrastructures for research in biomass conversion and biorefinery. Research facilities of this kind should be contemplated both in the context of bioenergy and not least be instrumental in replacing a wide range of products – chemicals, polymers, packaging etc. – which currently derive from crude oil.

Energy systems and energy storage are crucial for national conversion to renewable energy. In that connection there is a need for research infrastructures to drive the development of the future energy grid. Given that the energy consumption of buildings accounts for 40% of total energy consumption in the EU, there is equally a need for research infrastructures to develop new tools and components to support the next generation of buildings. Investments in these facilities should be considered for the medium term.

Climate and environment

Threats to biodiversity, eco-quality together with climate change, and the ensuing impacts on the exploitation of natural resources call for new research infrastructures incorporating a wide array of not conventionally allied disciplines and which generally call for large-scale data collection and analysis. There is thus a need to develop infrastructures for biodiversity research and research infrastructure partnerships on greenhouse gas observation and data collection. Both of the last-named research infrastructures – in their links with the ESFRI roadmap; the *LifeWatch - e-Science and Technology Infrastructure for Biodiversity and Observatories and ICOS - Integrated Carbon Observation System* – have distinct international dimensions and the aim is to fund these within the short term. For the medium term there is equally a need for research infrastructures in the form of observatories for research, which will at the same time serve to protect the aquatic and atmospheric environment and promote the competitiveness of Danish agriculture.

When it comes to the Arctic and North Atlantic, there is a need for Danish research environments investigating both the terrestrial and marine environment to participate as key contributors in research infrastructures for data collection and processing. An initiative of this nature will be of great importance and relevance and should

be considered for the medium term in line with international developments in this field. In that context, one of the key factors is access to the necessary ships. It should be noted that Denmark's only ocean-going research vessel, "Dana", which is capable of operating in all waters within the Kingdom of Denmark (including the Arctic and North Atlantic) was built in 1981 and is nearing the end of its life. The Danish Agency for Science, Technology and Innovation will therefore be making a special recommendation for the initiation of discussions, in conjunction with the relevant authorities and universities, concerning plans ahead for when Dana is decommissioned. Similarly, the options for making supplementary grants to the Danish Centre for Marine Research will be considered, with a view to measures such as increased chartering of Danish or foreign vessels.

In that Denmark through its EU membership fees makes a substantial contribution towards the development of the international thermonuclear experimental reactor (ITER), the Danish Agency for Science, Technology and Innovation will in parallel with the roadmapping initiatives be working over the short term to ensure that Denmark is assured of sufficient research and industrial benefit from the European and international collaboration on fusion research.

Research infrastructure for biodiversity and environmental data

A research infrastructure devoted to biodiversity and ecosystem research will, through new and advanced tools for structuring, analysis and effective comparison of vast volumes of biodiversity and environmental data, improve researcher access to and utilisation of data. This research infrastructure will have the capacity to develop advanced analytical and statistical modelling tools and libraries capable of providing new insights into factors impacting biodiversity and ecosystems.

Danish biodiversity and ecosystems research has built up a position of strength through, for example, substantial and rapidly growing data repositories in which research is increasingly carried out via correlation and modelling of data from databases (data mining). Data mining permits the collection, critical evaluation and correlation of data repositories in new contexts in order thereby to gain new insights across traditional disciplines.

A research infrastructure for biodiversity and environmental data will constitute a virtual research lab with an efficient e-Infrastructure for maximising capacity for data storage, data processing, communication and dissemination including access to sufficient storage capacity, high-speed connections and supercomputing facilities for modelling, analysis and simulation.

The e-Science expertise to be built into the research infrastructure will be essential for handling and maximising the potential of the large volumes of data that are streaming in at increasing speed from national and international digitisation and environmental monitoring programs, among other things owing to the technological advances made in remote sensing (registration of environmental data from satellites and aircraft). Aided by increased digitisation, the Danish natural history museums' collections will offer an important contribution to this research infrastructure.

This research infrastructure is to ensure general access to the mounting volumes of Danish and international biodiversity and environmental data and better access to international collaborative projects, and shall thereby also assist in answering questions concerning physical planning, assessment of the impact of climate change on Danish nature, management of natural biological resources such as fish stocks, assessment of changes in loss of biodiversity and the impact of infrastructure projects on natural assets.

This research infrastructure is envisaged as the Danish contribution to LifeWatch (e-Science and Technology Infrastructure for Biodiversity and Observatories), which is one of the projects on the ESFRI roadmap. The research infrastructure is similarly envisaged as a framework for the Danish node of GBIF (Global Biodiversity Information Facility), which is served by a Danish secretariat.

Consortium partners

Based on the feedback from the roadmap proces a infrastructure for biodiversity and environmental data enjoys wide support throughout the Danish research communities. This research infrastructure is envisaged as a national consortium.

Funding

The cost of establishing a research infrastructure for biodiversity and environmental data is estimated at around DKK 30m.

Time schedule

It is estimated that this research infrastructure could be established within four to five years of a grant award.

Research infrastructure for biorefinery and biomass conversion technologies

Biotechnology and bioenergy-related research enjoys strong standing at the Danish universities. A coordinated and extended research infrastructure, capable of ensuring critical mass and uniting university groups within biomass and biological production technologies, will, in close cooperation with the Danish biotech industry, serve to strengthen Denmark's global competitiveness.

This research infrastructure will promote the extraction of fuels, energy and high-value products such as bioactive substances, food ingredients, biochemicals and biomaterials. Products from biorefineries are expected to eventually replace the entire range of products currently derived from crude oil refinery and product differentiation.

Full and integrated understanding of biomass/ cell wall composition, preprocessing, microbial conversion and product differentiation requires advanced and flexible research infrastructure comprising processing, analytical, measurement and bioreactor equipment. This research infrastructure should advance understanding of the biological processes and contribute to optimised conversion and differentiation of biomass and the development of new value added products.

It is important that the research infrastructure is organised in such way as to integrate different processes and disciplines such as microbiology, biochemistry, molecular microbiology, chemical processes, reactor technologies etc. At the same time, it is considered to be most appropriate to organise the research infrastructure with two scientifically related but distinctly delineated action areas; one facility devoted to biomass, characteristics and preprocessing, and one devoted to preprocessing, conversion processes, fermentation and product differentiation. Coordination and national access to the research infrastructure's two facilities will be organised via the formation of a national consortium or the like so that research groups can integrate their activities at both facilities.

Consortium partners

Based on the feedback from the roadmap proces a research infrastructure for biorefinery and biomass conversion technologies enjoys wide support throughout the Danish research communities
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Funding

The cost of establishing the two facilities for this research infrastructure is estimated at approx. DKK 40m.

Time schedule

It is estimated that this research infrastructure could be established within 12-24 months.

Research infrastructure for collection of data on greenhouse gases

Atmospheric greenhouse gases are regarded as a significant cause of global climate change. Access to long-range observation and collection of data on greenhouse gases is vital in extending our knowledge of, for example, the impacts of changes in climate conditions and land use on net greenhouse gas emissions.

A national research infrastructure (field stations, instrumentation etc.) for collecting data on greenhouse gases will be responsible for coordinating Danish membership of the ESFRI *Integrated Carbon Observatories System* (ICOS) project. The object of ICOS is to strengthen and coordinate cooperation on observation and collection of data on greenhouse gases in Europe and adjacent regions. The preparatory ICOS consortium is currently made up of 17 national nodes, including Danish research contingents.

Unlike previous European studies of greenhouse gas balances from terrestrial systems, ICOS also comprises marine systems to permit coverage of atmospheric, terrestrial and marine elements.

The implementation of ICOS in Denmark will be linked to existing research infrastructures, including the Risø National Laboratory for Sustainable Energy mast, the forthcoming mast at Østerild, Risø DTU's measurement station at Sorø field station (responsible for one of the world's longest series of measurements of CO2 exchange between the atmosphere and biosphere), and the recently established field station in Risø DTU's experimental willow plantation, which is currently measuring the greenhouse gas balance achievable from cultivating energy crops.

ICOS will have major strategic importance by virtue of its capacity to provide scientific insights to support the development of technologies and regulatory and operational systems for ensuring that Denmark honours its commitment to reducing greenhouse gas emissions.

Consortium partners

Based on the feedback from the roadmap proces a research infrastructure for collection of data on greenhouse gases enjoys wide support throughout the Danish research communities. The Technical University of Denmark – DTU will be the focal point for a national cooperation on future membership of ICOS.

Funding

The cost of establishing a research infrastructure for collection of data on greenhouse gases is estimated at around DKK 35m.

Time schedule

It is estimated that the research infrastructure could be established within a year of a grant award.

Test facility for Grid Connection Characteristics of Wind Power Plants

The connection of wind power plants to the national grid is a key precondition for utilisation of wind power. The establishment of a test facility for grid connection at the planned national Wind Turbine Test Centre Østerild will pave the way for joint research projects between the research institutions and the wind energy sector. Projects at the facility will be devoted to the development and validation of enhanced characteristics in new wind turbines in relation to national grid connection and interaction with the electricity transmission system.

Next-generation distribution and supply networks will be more complex than those currently in operation. The energy sources will be more diversified and subject to temporal fluctuations, which in the face of consumer stability requirements poses new challenges for grid elasticity. A Danish test facility for grid connection is therefore a key element in realising the ambition for an increased volume of wind power in the national grid.

The test facility will make it possible to emulate different grid conditions and thus test how the turbines respond under such conditions. The Danish Consortium for Wind Energy Research possesses great expertise and will be responsible for wide-ranging scientific use of the facility.

The test facility will be invaluable for both research institutions and the wind turbine industry, which will have turbines installed at the Østerild site. The test facility will clearly also be focal for its owners, operators, sub-suppliers and grid companies.

Consortium partners

Based on the feedback from the roadmap proces the establishment of a test facility for grid connection of wind power plants enjoys wide support throughout the Danish research communities . With project funding from the Programme for Energy Technology Development and Demonstration (EUDP), a feasibility study is currently in progress to address the question of how to organise the facility.

Funding

EUDP has granted DKK 1.1m in funding for the feasibility study for the test facility. The cost of establishing the test facility is estimated at approx. DKK 50m.

Time schedule

It is estimated that a test facility for grid connection of wind plants could be established within two years of a grant award.

Large-Scale National Wind Tunnel Facility

In global terms, Danish aerodynamics research enjoys a strong position and has been crucial for the development of the wind turbine industry. A new, large-scale wind tunnel, catering to increasing demand for precision, air velocity and turbulence will make a crucial contribution to development of next-generation turbine blades and will be a major factor in safeguarding Denmark's research and industrial lead position in wind power.

Trends in emergent wind power technologies are tending towards larger and more intelligent turbines, which will combine to make up the next-generation wind plants. Requirements are now more exacting for effectiveness under variable wind conditions – weak wind conditions, strong wind and with flow conditions varying from near-laminar flow to non-linear turbulent flow and derived coherent flow patterns.

The key technologies revolve around blade design. More efficient geometries require advanced fluid dynamics simulations. Simulations in turn require prior experimental validation, which can only be performed in a flexible state-of-the-art wind tunnel of dimensions to permit realistic scaling to next-generation blades.

There are already a number of wind tunnels in Denmark of varying size and with differing capabilities. These wind tunnels are located at research institutions or within industrial companies. Outside of Denmark, and especially in countries with an aeronautical or automotive industry, there are number of large-scale wind tunnels. However, none of the existing Danish wind tunnels meet anticipated future research requirements and none of the large-scale foreign tunnels offer quasi-atmospheric flow conditions in which wind turbine rotors, terrain and large blade sections can be tested.

The realisation of a major national wind tunnel will require the formation of a consortium broadly composed of the different stakeholders, which will assist with both the financing and running of the facility. Given that Denmark possesses excellent national research-related and industrial expertise in the field of wind energy, the preconditions for effective and profitable utilisation are deemed to be present.

Consortium partners

Broad research-related and industrial interest and backing has been registered for a new large-scale wind tunnel facility. Taking all factors into account and with a view to consolidating and deploying all the existing Danish expertise and capacities on a national platform, the Technical University of Denmark - DTU will be invited to oversee the preparation of a concrete proposal for realisation of the project.

Funding

The total establishment costs are estimated to be in the order of DKK 130-150m. Provided that a satisfactory basis can be achieved for establishing a large-scale national wind tunnel facility, the project will qualify for a grant of up to DKK 40m.

Time schedule

It is expected that a concrete proposal for realisation of the project will be in place by August 2011 and that a grant will be awarded shortly thereafter. The planning and construction phase is estimated to take approx. two years.

The European WindScanner Facility - Windscanner.eu

Turbulence and wind shifts in wind fields are significant determinants for wind turbine lifespan, design and siting. The wind scanner introduces a number of new techniques which will permit remote monitoring and decisively strengthen European research in atmospheric turbulence and other wind factors affecting modern wind turbines.

Measurement and understanding of the three-dimensional and time-variable wind field as it passes and interacts with the rotor on modern mega wind turbines currently pose a scientific challenge. With funding from the National Programme for Research Infrastructure, in 2008, the Technical University of Denmark - DTU, in close partnership with other Danish and international research institutions, instrument and technology manufacturers and the Danish wind industry, is in the process of developing a wind scanner for remote sensing of atmospheric wind and turbulence. Efforts are underway to upscale the project to the European level.

Windscanner.eu will be a distributed pan-European and mobile research infrastructure which, by means of new laser and remote sensing techniques, permits measurements to be made in many types of terrain with unprecedented quality and detail.

Access to the data generated by the wind scanner will be crucial to the capacity of European research to maintain its lead in supplying the best tools for predicting wind and turbulence factors in all terrain types. Windscanner.eu will also contribute to enhanced aeroelastic design of future on- and offshore wind turbines, improve both the productivity and lifespan of turbines and have wide-ranging significance for research and education within wind, turbulence, turbine management and control.

The WindScanner project is included in *European Energy Research Alliance Joint Programme* for wind energy research and is, as the only Danish-led project, inscribed on the ESFRI updated roadmap published in 2011. Over the next few years, a project will be undertaken to extend the European cooperation on the wind scanner and the establishment of a proper distributed research infrastructure.

Consortium partners

Windscanner.eu is expected to be organised as a European consortium of partners from countries such as Denmark, Norway, Germany, the UK, Spain, Portugal and Greece.

Funding

In the allocations from the National Programme for Research Infrastructure in 2008, DKK 25m was granted for Windscanner.dk – a new Mobile Facility for Wind Energy and Turbulence and the development of a windscanner for remote sensing of atmospheric wind and turbulence.

Time schedule

The preparatory phase for Windscanner.eu is expected to take up to three years.

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2.3 Biotech, Health and Life Science >

The biotechnology, health and life sciences research fields are of great significance for Danish society and are key to solving a number of major health-related challenges. Measured in terms of public expenditure, employment and exports, these fields of research are of the utmost importance for Denmark, where adjacent private-sector business and industry comprise the pharmaceutical industry, medicotechnology and biotechnology companies and food production.

For integrated bioscience (biotechnology and life sciences) and health research, close interaction between these fields of research is crucial for new knowledge, innovation and growth. This means that there is a need for a diversified and complex research infrastructure, which, with a view to rapid and optimal production and dissemination of new knowledge, will serve to provide access to a range of advanced technologies and equipment together with data repositories, substance repositories and biobanks and so forth.

A number of the most promising trends in biology, physiology, medicine, biotechnology and pharmaceutical and health research comprise achievements such as the mapping of complete genomes and ecosystems, the development of model organisms and techniques for conducting studies at subcellular and atomic levels. These fields of research are dependent on access to a range of diversified research infrastructures devoted to, for example, the storage and registration of tissue samples, model organisms, advanced imaging and characterisation techniques, clinical test facilities and databases, together with bioinformatics and data processing.

The nature and scale of many of the research infrastructures needed within integrated bioscience and health research means that they would best be established in the form of either networks with specialised and coordinating nodes or as core facilities assembling all the most advanced instrumentation in one place in order to achieve the best balance between investment and use.

Research infrastructure for model organisms

In relation to the organisation of research concerning genetically modified organisms, huge potential is seen in the prospect of Danish participation in the ESFRI INTRAFRONTIER project which is establishing banks of frozen embryonic stem cells from genetically modified mice. Danish membership of the research infrastructure is however on such a limited scale that interested parties at institutional or research council level are expected to be able to discharge the Danish commitment.

Research infrastructures for advanced imaging and characterisation

Recent trends in the field of imaging and characterisation are tending in the direction of increased integration of a number of different techniques and methods for molecular imaging, advanced light and electron microscopy and multimodal scanning. Over time there will be increased demand for coordinated development of units with specific imaging expertise and equipment.

Molecular imaging comprises a number of promising new techniques, the object of which is to visualise processes in cell cultures in live animals and in humans. The development of multimodal (hybrid) scanners combining PET (Positron Emissions Tomography) scanning with CT (Computer Tomography) or MR (Magnetic Resonance) scanning will thus influence the development of new medicines and forms of therapy such as stem cell therapy and gene therapy. All told, the development of research infrastructures for imaging and characterisation holds huge translational potential, which will at the same time serve to support the Danish biotech and pharma industries.

For the short term there is a pressing need to extend Danish infrastructure capacity, particularly within PET scanning with a view to involvement in the establishment of *European Advanced Translational Research Infrastructure in Medicine* (EATRIS).

Within the fields of food, microbiology and plants, there is a large, unmet need in the short term for access to advanced techniques for protein characterisation and advanced proteomics using mass spectrometry.

For the medium term, in the field of imaging there will be high potential in extended access to

core facilities for light and electron microscopy, including through prospective Danish membership of the ESFRI Euro-BioImaging project, and the establishment of a national scanning facility for multimodal imaging of the brain and neurological research.

Within the branches of integrated bioscience and health research which make use of large-scale, often international, radiation facilities, significant technical and research breakthroughs are currently being made which will permit studies of receptors, membrane proteins and large protein complexes.

It is therefore crucial for Danish research to be assured of maximum access to the leading existing and planned research infrastructures devoted to the field of radiation, including, especially, the international facilities MAX IV-synchrotron and European Spallation Source (ESS) at Lund in Sweden, the X-ray free-electron laser facility European XFEL and the Petra III synchrotron in Hamburg as well as the ASTRID2 synchrotron at Aarhus University.

Bioinformatics and data processing

Recent decades have seen a massive increase in the volume and complexity of data generated by various technologies for genome and gene product analysis. This calls for new solutions for processing and integrating complementary data. Among other measures, for the short term this would be achieved through Danish participation in the ESFRI project for biological information - ELIXIR - and through the establishment within the medium term of a national research infrastructure for translation of miscellaneous omics data (genomics, proteomics, metabolomics) into functional biological significance.

Clinical research infrastructures and registers

For clinical research, trial and test facilities with associated clinical research databases and biobanks are important research infrastructures. Clinical and translational research requires permanent and high performance infrastructure in the form of clinical research units in relevant hospital departments which possess the requisite competence and expertise for conducting research projects with patients. Direct involvement of patients in clinical trials requires high-level expertise on regulations, while hospital effectivisation poses a challenge in relation to clinical research and maintenance of key research databases.

Denmark can lay claim to some of the world's best social registers containing personalised data, and also to some of the world's most well-developed biobanks. The mapping of the human genome has facilitated new interdisciplinary studies in which an individual's genome can be correlated with a wide array of register, survey and clinical data. In the interests of expedient research-related utilisation of the many samples and data sources, measures will be initiated to reorganise the entire field of register research across the various scientific fields. This approach reflects the need to maintain and extend integrated access to register research and to safeguard access to utilisation of many different data sources as one of the major strengths of Danish register research. This initiative is described above in Chapter 2.1.

EATRIS
- European Advanced Translational Research Infrastructure in Medicine

Rapid and efficient translation of laboratory findings into pioneering diagnostics, therapy and prevention and, conversely, from clinical observations to novel, basic research poses a major challenge for modern biomedical science. The establishment of EATRIS, a new, distributed European research infrastructure, has been conceived as an answer to this challenge.

EATRIS will consist of a number of unique but complementary centres dedicated to the following major areas: diseases of the cardiovascular system, cancer, metabolic syndrome, brain disorders and infectious disorders.

The EATRIS centres will have access to state-of-art equipment and will act as model centres developing joint programmes for translational research, clinical testing, data processing, quality assurance, and monitoring, and will offer pan-European access, training and teaching and researcher and student exchange programmes.

EATRIS has been in scientific preparation for a couple of years, and the infrastructure is expected to be finally in place by the end of 2012. During a transitional phase until then, there will be opportunities for conducting pilot projects to test, for example, the interaction between the system and its users.

In order to make the best possible contribution to EATRIS, to ensure the deployment of national translational expertise and to achieve critical mass, a Danish EATRIS centre will be established, composed of several relevant parties. The same model is expected to be implemented in a number of other countries participating in the development of EATRIS.

The Danish EATRIS centre will be based on existing Danish positions of strength and will support the Danish pharmaceuticals development industry. The focus will be on translational molecular imaging and the development and implementation of non-invasive and individualised treatment techniques. Given the high pressure on the necessary facilities for PET scanning of experimental animals in Denmark, Danish membership of EATRIS will entail procurement of new PET and PET-MR scanners.

Consortium partners

Based on the feedback from the roadmap proces Danish participation in EATRIS and the establishment of a Danish node enjoys wide support throughout the Danish research communities. The University of Copenhagen will be invited to head up preparation of a concrete project proposal for Danish EATRIS membership in close conjunction with Rigshospitalet – Copenhagen University Hospital, Aarhus University/Aarhus University Hospital and the Technical University of Denmark - DTU.

Funding

Provided that a satisfactory basis can be achieved for Danish EATRIS membership and the establishment of a Danish node, the project will qualify for a grant of up to DKK 27m. This grant will be required to cover both procurement of new scanners and the Danish share of operating expenses for the joint EATRIS secretariat in the Netherlands.

Time schedule

A concrete proposal for realisation of the project is expected to be in place by August 2011 and that a grant will be awarded shortly thereafter. EATRIS is expected to be finally established by not later than year-end 2012.

ELIXIR - European Life Sciences Infrastructure for Biological Information

The mission of the European research infrastructure ELIXIR is to construct and operate a sustainable infrastructure for biological and medical databases and related software tools to support life science research and biotech and pharmaceutical companies across a broad front.

In recent years, the volume of biological information has been increasing exponentially, and advances in various data-generating research techniques have now accelerated to the point where even ordinary laboratory equipment outputs vast volumes of data in a short space of time.

In virtually every branch of biological and medical research, the computer has in recent years taken on great significance, and many basic biological studies such as whole genome sequencing have progressed from being discrete research projects to being a standard research resource. This places great demands on the distribution of bioinformatics expertise and research infrastructures capable of disseminating the latest analytical methods and techniques to research environments on an unprecedented scale.

Danish participation in ELIXIR and the establishment of a Danish node will focus on existing positions of strength within bioinformatics and system biology, including, notably, the development of tools and integration across data types and experimental domains. ELIXIR is expected to be vitally important for a number of other research infrastructures on the ESFRI roadmap involved in production and handling of biological and medical data.

The plan is for ELIXIR to be organised as a special project under the European Molecular Biology Laboratory (EMBL) and lodged with the European Bioinformatics Institute (EBI).

Consortium partners

A broad-based national consortium has been established for the project *The European Bioinformatics Infrastructure – The Danish Node* and a steering group has been appointed, composed of representatives of the Technical University of Denmark – DTU, the University of Copenhagen, Aarhus University and the University of Southern Denmark.

Funding

In the allocations from the National Programme for Research Infrastructures in 2008, DKK 25m was earmarked for *The European Bioinformatics Infrastructure – The Danish Node* in the interests of extending and maintaining Danish participation in ELIXIR.

Time schedule

The earmarked funds are expected to be allocated from 2011 and onwards in the light of the progress made by the European project and subject to agreement between the Danish Agency for Science, Technology and Innovation and the national consortium led by the Technical University of Denmark - DTU.

Research infrastructure for mass spectroscopic proteomics

A national expansion and increased coordination of research infrastructure within mass spectrometry-based proteomics and protein characterisation will be conducive to maintaining Denmark's leading position within microbiology, foods, plants and biomedicine.

Proteomics comprises systematic analysis of proteins and protein-based networks in microbes, cell cultures, tissues and organisms. Quantitative proteomics permit dynamic biological processes and disease progression to be monitored over time, including protein interactions and regulatory mechanisms controlling protein function and activity. Proteomics thus provides insights into basic molecular mechanisms underlying cell evolution and growth, which allows new proteins with biotechnological and clinical potentials to be identified and characterised.

Denmark currently ranks among the world leaders in mass spectrometry-based proteomics with positions of strength notably in technological development of mass spectrometry for analysis of proteins in complex biological samples and the applications of quantitative proteomics such as in studies of fermentation processes, regulatory mechanisms in metabolic processes and cellular communication processes.

At the same time, a number of Danish companies are leading internationally in enzyme-based biotechnology products and protein-based pharmaceutical products, which is predicated on very high-level Danish research and education in protein chemistry and proteomics.

Proteomics research is to a great extent based on the use of costly and advanced mass spectrometers with associated chromatographic systems and data analysis tools. There are consequently a number of research-related and financial advantages to achieving increased coordination among the established protein and proteomics research environments in Denmark in connection with the procurement and siting of state-of-the-art mass spectrometric equipment.

Consortium partners

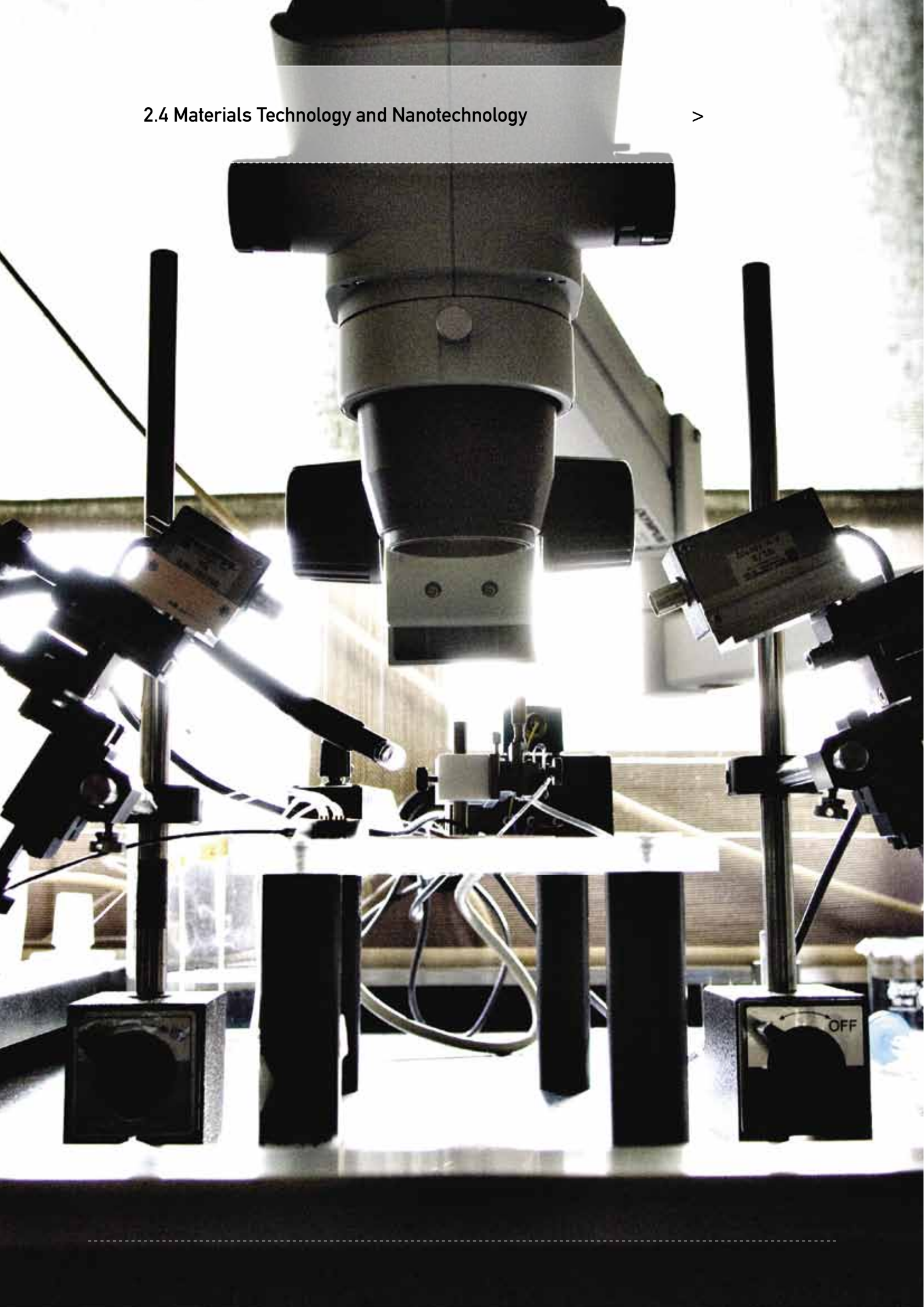
Broad research-related interest in and backing has been registered for a research infrastructure for mass spectroscopic proteomics. Any future grant award will be conditional on the involvement of the existing body of expertise in realising and organising the project.

Funding

The cost of establishing a research infrastructure for mass spectroscopic proteomics is estimated at around DKK 50m.

Time schedule

It is estimated that the research infrastructure could be established within 12 months of a grant award.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Over the last 10-15 years, research in materials science and nanoscience has undergone rapid development. By controlling the atomic structure of materials at the nanolevel, it is now possible to develop new functional materials that are more robust, durable and eco-friendly than those we know and use today. This has meant that electronic circuits for example can now be designed on such a minute scale that they can be injected into the human body and deliver medical treatment with such a targeted action that a preparation is not activated until it reaches the diseased part of the body. Besides their significance for research within a wide range of disciplines, materials science and nanoscience have a huge range of industrial applications and vast innovation potential.

The need for access to state-of-the-art research infrastructures in materials science and nanoscience is not limited to a single type of apparatus. It is however essential in supporting education and the capacity to attract new research talents while sustaining the quality of Danish research across a wide front within the materials and nanofields to ensure access to a range of different instruments for special analysis (characterisation), manufacturing (synthesis) and modelling.

Within the field of characterisation especially, the necessary research infrastructures tend to be so large in scale and so costly that they are established in extension of major international facilities or at selected institutions in Denmark. In other fields, it is possible to establish large-scale national research infrastructures consisting of single units of unique equipment or collections of relatively less costly instrumentation, and finally fields in which there is a need for access to very basic equipment, which the individual research institution or research council is expected to finance.

Access to research infrastructures within radiation and spectroscopy

In the field of characterisation, constant new technical advances facilitate experiments with greater precision and higher resolution. One example would be the new trend in studies of biological molecules under conditions that mimic their natural environment (as opposed to being in the crystalline state which is necessary for detailed structural determination via X-ray scattering).

In a number of analytical methods and techniques for characterisation, the scale of the physical research infrastructure and the scale of the structures under investigation are in inverse proportion to each other. Past experience has shown that new and improved radiation sources result in enhanced potential for materials characterisation. The current trend favours increasingly large-scale facilities capable of generating more intense radiation than in the past and hence permitting more precise analysis and characterisation of materials and nanostructures. The large-scale international research infrastructures due to be established in the coming years in proximity to Denmark, such as the neutron scattering facility European Spallation Source (ESS) and the MAX IV synchrotron radiation facility in Lund, Sweden, together with the X-ray free-electron laser facility European XFEL, in Hamburg, Germany testify to this trend.

It is important that Danish researchers both have maximum access to new radiation sources and techniques nationally, and are given the opportunity to influence the design and construction of, for example, beamlines at large-scale foreign facilities in order to be able to derive maximum benefit from the potentials that are created. For the short term, considerable, widespread interest has been registered in gearing the national initiative to ramping up a number of Danish strengths in the field of characterisation, including the provision of access to research infrastructures devoted to synchrotron and neutron radiation and spectroscopy. Notable research facilities in this field would be the Danish Solid-State NMR Instrumentation Centre and the NANOLINE beamline at the ASTRID2 synchrotron radiation facility at Aarhus University, which is due to be commissioned in 2012.

For the medium term, the need has been expressed for access on Danish soil to a high-resolution imaging secondary ion mass spectrometer, a so-called nanoSIMS, which will be a vital asset for safeguarding Denmark's position within high-resolution materials analysis and biological-medical research.

Moreover, the soon-to-be-established MAX IV is seen as a unique opportunity for ensuring that Danish research gains more rapid and flexible

access to a world class facility. Any direct Danish participation in the development of specific instrumentation at MAX IV holds patent potential for strengthening a number of educational and research activities which will also support utilisation of other future facilities devoted to the field of radiation, such as ESS for example.

In relation to the general mission to strengthen Danish access to foreign research infrastructures in the field of X-ray laser, synchrotron and neutron radiation, including both future facilities such as MAX IV and ESS and already existing research infrastructures such as European Synchrotron Radiation Facility (ESRF) and the Institut Laue-Langevin (ILL) neutron facility in France, along with the Paul Scherrer Institute (PSI) in Switzerland a need has been identified to further describe and specify the basis for the future Danish commitment. To that end, in February 2011, the Danish Agency for Science, Technology and Innovation appointed a scientific advisory group which has been tasked with drawing up a strategy over the course of spring 2011 in which the overall need for Danish access to MAX IV and other radiation facilities is presented in detail and prioritised.

Research infrastructures for synthesis of new materials

Modern facilities for the synthesis of materials and nanostructures are crucial for conducting research that has more direct potential for application. Subsequent analysis of well-controlled synthesisation processes permits researchers to gain an overview of a given material's physical, chemical and biological properties.

Such processes also require a large array of – although compared with large-scale characterisation facilities – relatively inexpensive –techniques for producing anything from functional nanoparticles and nanomaterials (e.g. surface coatings and self-assembling materials) to large construction units.

For the short term, the establishment of a joint virtual materials technology research infrastructure with coordination of existing test facilities catering to the entire length scale from large constructions to micro and nanolevels within a wide range of materials, including building components, metals, composites and polymers has been identified as having high potential.

The exception which proves the rule regarding the scale of investments in the field of synthesis would be cleanrooms, which typically require detached buildings and always a comprehensive air purification system.

For the medium term, there will be a need to upgrade Danish cleanrooms and to upscale process equipment for synthesising structures in materials other than silicon and the development of quantum devices etc. In this context it is important that future investments in this field are coordinated nationally so that costly and complex equipment is not duplicated and that planning of any new cleanrooms is preceded by assessment of whether existing premises will suffice in the interests of preserving critical user mass and minimising operating expenses.

Access to MAX IV and other radiation facilities

The international landscape in the field of synchrotron and neutron radiation is currently undergoing significant changes following the establishment of a number of unique, core facilities in proximity to Denmark. This provides Danish research with promising development potentials but also calls for strategic prioritisation of the resources that are to ensure Danish researchers of access to the facilities.

Within the space of a few years, a new, unique synchrotron radiation facility, MAX IV, will be established in Lund, Sweden, which will also be the site of the coming large-scale European neutron radiation facility, European Spallation Source (ESS). As one of the world's most intense X-ray sources, MAX IV promises to be invaluable for research in materials science and nanoscience and a number of other scientific fields. Together with ESS, MAX IV will create a foundation for one of the world's strongest research infrastructures environments.

Danish researchers are already highly active at the existing, but less intense MAX II synchrotron radiation facility, to which access is granted on the basis of applications for beamtime, which are assessed in international competition. Equally, MAX II is very important for education and training of Danish PhD students and junior researchers in X-ray scattering techniques.

A great deal of interest has been registered among a wide circle of Danish researchers, research institutions and industrial companies in securing access to MAX IV. It is essential for a future Danish commitment at MAX IV, whether this in the form of a Danish financed nano- and energy beamline (powder diffraction and imaging) or by other means, that Danish researchers and research environments are to be assured of access to all the MAX IV facilities.

In connection with the roadmapping process, several scientific panels have drawn up a number of recommendations concerning the need to continue to provide access to a number of existing large-scale foreign research infrastructures, especially in the field of synchrotron and neutron radiation, including the European Synchrotron Radiation Facility (ESRF), the Institut Laue-Langevin (ILL) and the Paul Scherrer Institute (PSI).

Consortium partners

In February 2011, the Danish Agency for Science, Technology and Innovation appointed a scientific advisory group composed of representatives from key research institutions and user environments, which has been assigned to draw up a consolidated strategy for Danish access to X-ray laser, synchrotron and neutron radiation facilities abroad.

Funding

Based on existing experiences and the current funding allocation for this field, the strategy is to contain a consolidated proposal for prioritisation of the national commitment going forward.

Time schedule

The consolidated strategy is due in autumn 2011.

Danish GHz Solid-State NMR Instrumentation Centre

The establishment of a Danish GHz Solid-State NMR Instrumentation Centre will potentially have international impact within disciplines such as materials science and nanoscience and biotechnology. Equally, this research infrastructure will be capable of attracting PhD students and established researchers from strong international research environments to Denmark and will provide a platform for promising industrial partnerships.

Solid-state NMR (nuclear magnetic resonance) spectroscopy is used to determine the structure of biological macromolecules at the atomic level. The technique is relatively new but undergoing rapid development.

The potential applications of NMR spectroscopy are vast and will serve to support Danish research within a number of fields such as materials science and nanoscience, structural biology and energy research. The development of NMR instrumentation with ultra-high magnetic field strengths (GHz: gigahertz), and hence significant enhancements in sensitivity and spectral resolution capability hold unprecedented potential for studies and integrating analyses of materials such as heterogeneous catalysts, hydrogen storage systems, polymers, photovoltaics, sustainable cement-based materials and molecular systems in their natural environments.

The establishment of a national GHz Solid-State NMR Instrumentation Centre and the procurement of an advanced NMR spectrometer configured for both solid-state and solution-state NMR samples will in terms of instrumentation bring the field and Danish research up to the level of the top facilities in the USA, Canada and Europe.

The instrumentation centre will be based on and coordinated with existing Danish centres for NMR spectroscopy at Aarhus University and the Carlsberg Laboratory and will thus immediately from the time of its establishment possess critical mass for advancement of Danish positions of strength in the field.
It is expected that a Danish GHz Solid-State NMR Instrumentation Centre will also be able to join the European bioNMR programme and provide a platform for Danish membership of the ESFRI INSTRUCT project on integrated structural biology.

Consortium partners

Broad research and industry interest and backing has been registered for a Danish GHz Solid-State NMR Instrumentation Centre. Aarhus University will be invited to supervise preparation of a concrete project proposal for this research infrastructure.

Funding

Provided that a satisfactory basis can be achieved for establishment of a Danish GHz Solid-State NMR Instrumentation Centre, the project will qualify for a grant of DKK 33m. This grant will be to cover both procurement of the NMR instrument itself and the fee for Danish membership of INSTRUCT.

Time schedule

It is expected that a concrete proposal for realisation of the project will be in place by August 2011 and that a grant will be awarded shortly thereafter. The planning and construction phase is estimated to take approx. 12 months.

Materials technology research infrastructure

A nationally coordinated research infrastructure with a wide range of complementary instruments etc. for materials synthesis, characterisation and testing. This research infrastructure will underpin and strengthen both Danish research and a number of large Danish companies committed to production in Denmark.

A major challenge within materials technology research at present is to secure the necessary research infrastructure to cater for research in the field across scales, from the minutest nanostructures to full-scale testing of physical components and products such as wind turbine blades.

The increase predicted over the next few years in the use of advanced construction materials such as fibre composites will step up demand for expertise on the durability and lifespan of the materials. This will require realistic and precise models of the materials' mechanical properties, which should be based on experimental work, testing and verification.

Within wind energy for example, the lifespan of offshore wind turbines is a key issue and there is an increasing need to be able to assess and control the lifecycle of existing and new structures, ensure rapid and safe introduction of new and innovative materials and constructions in wind turbine manufacture, and to be able to assess the condition of existing structures and constructions.

Although Denmark has world-leading researchers in materials technology, it has no single research environment currently capable of addressing all of these scientific fields from nanoscale to full scale at the most advanced level. With this in mind, it is seen as an advantage to establish a more closely-knit national partnership of research environments and institutions in the interests of tackling the research infrastructure challenges and issues from nanoscale to full scale.

The equipment requirements for a materials technology research infrastructure will typically not consist of large-scale stand-alone experimental installations but rather a wide array of instruments covering a wide range from microscale production equipment to mechanical testing apparatus.

The users of a nationally coordinated materials technology research infrastructure will, in addition to the institutions that conduct research in advanced materials for structural applications, also include companies seeking to employ the advanced testing and measurement facilities in new design concepts.

Consortium partners

Based on the feedback from the roadmap proces a materials technology research infrastructure enjoys wide support throughout the Danish research communities. Any future grant award will be conditional on the involvement of the existing body of expertise in realising and organising the project.

Funding

The cost of establishing a materials technology research infrastructure is estimated at approx. DKK 40m.

Time schedule

It is estimated that the research infrastructure could be established within one to two years from a grant award.

NANOLINE – beamline at the ASTRID2 synchrotron radiation source

NANOLINE will exploit the new experimental potentials afforded by the extreme brilliance of the radiation from ASTRID2. This will offer a range of new and promising opportunities for materials research and will raise the profile of ASTRID2 as a significant and well-equipped national and international synchrotron facility.

NANOLINE will be developed as a unique beamline incorporating a combination of advanced photoelectron spectroscopy and STM (scanning tunnel microscopy) techniques for characterisation of nanomaterials.

With the combination of capability for determining chemical/electronic structure using photoelectron spectroscopy and geometrical structure using STM, NANOLINE will offer a raft of new opportunities for investigating new, advanced materials such as functional nanomaterials, polymers, nanocatalysts, photovoltaics, molecular electronics and biocompatible materials, which will potentially be crucial for technological progress and innovation.

ASTRID2 is a synchrotron radiation source currently being established at Aarhus University. ASTRID2 received funding from the National Programme for Research Infrastructures in 2008. Following commissioning in 2012, ASTRID2 will generate electromagnetic radiation in wavelengths from visible ultraviolet (VUV) to soft X-rays.

ASTRID2 is distinct from the third-generation synchrotrons constructed in Europe over the past few years, where the focus is on hard X-radiation (DIAMOND in the UK, ALBA in Spain, SOLEIL in France, BESSY II in Germany), in that it fills an international niche in soft X-radiation.

The addition of the NANOLINE beamline, which integrates state-of-the-art synchrotron photoemission techniques with a scanning tunnelling microscope (STM) in the same configuration, underscores ASTRID2's unique international status.

Besides holding vast scientific potential with links to high-profile research in Danish industry, NANOLINE will thus be capable of attracting top international researchers and be invaluable in training MSc and PhD level students.

Consortium partners

Based on the feedback from the roadmap proces NANOLINE enjoys wide support throughout the Danish research communities.

Funding

The cost of establishing NANOLINE is estimated at approx. DKK 30m.

Time schedule

It is estimated that NANOLINE could be established within one to two years from a grant award.

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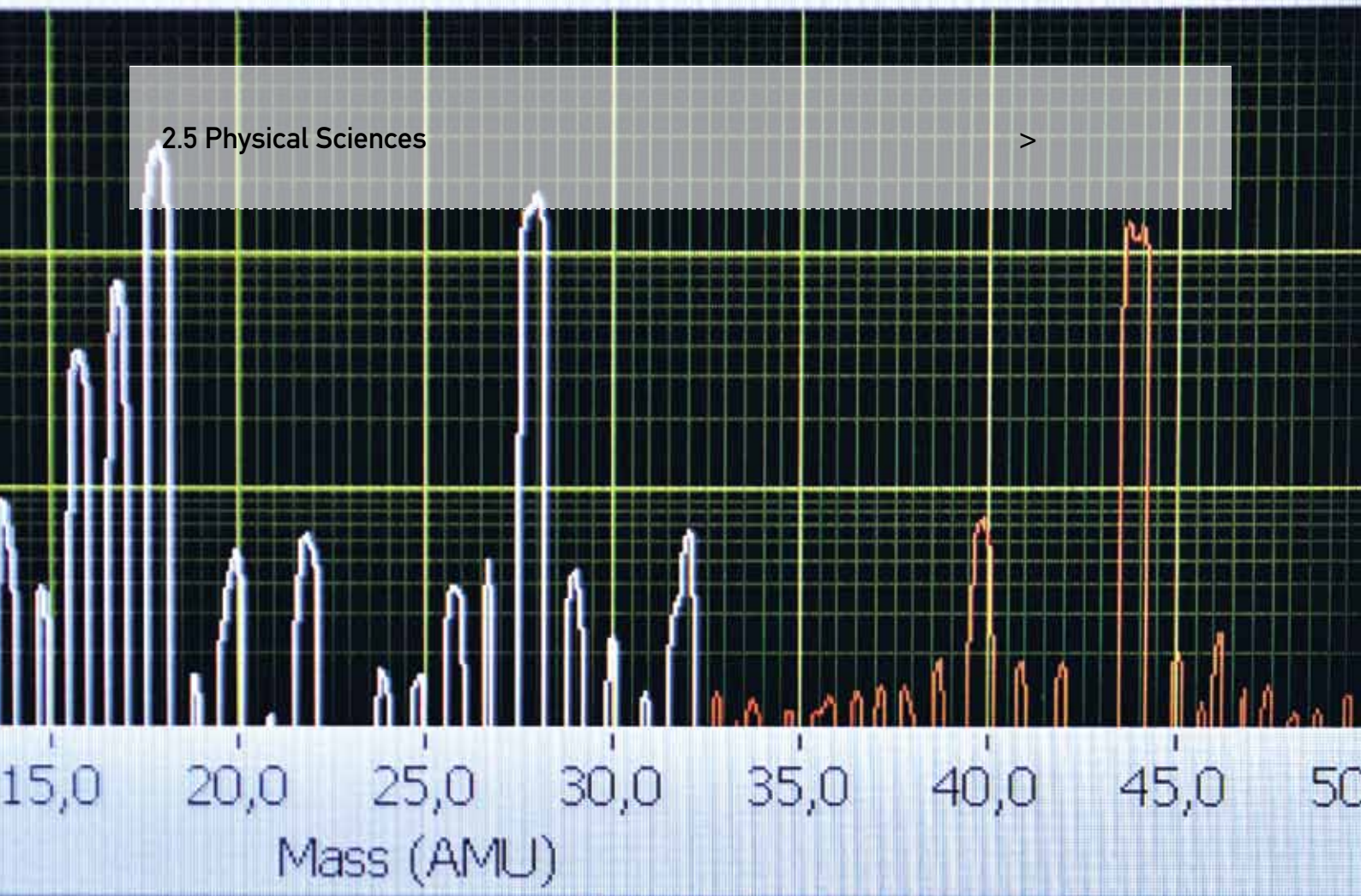
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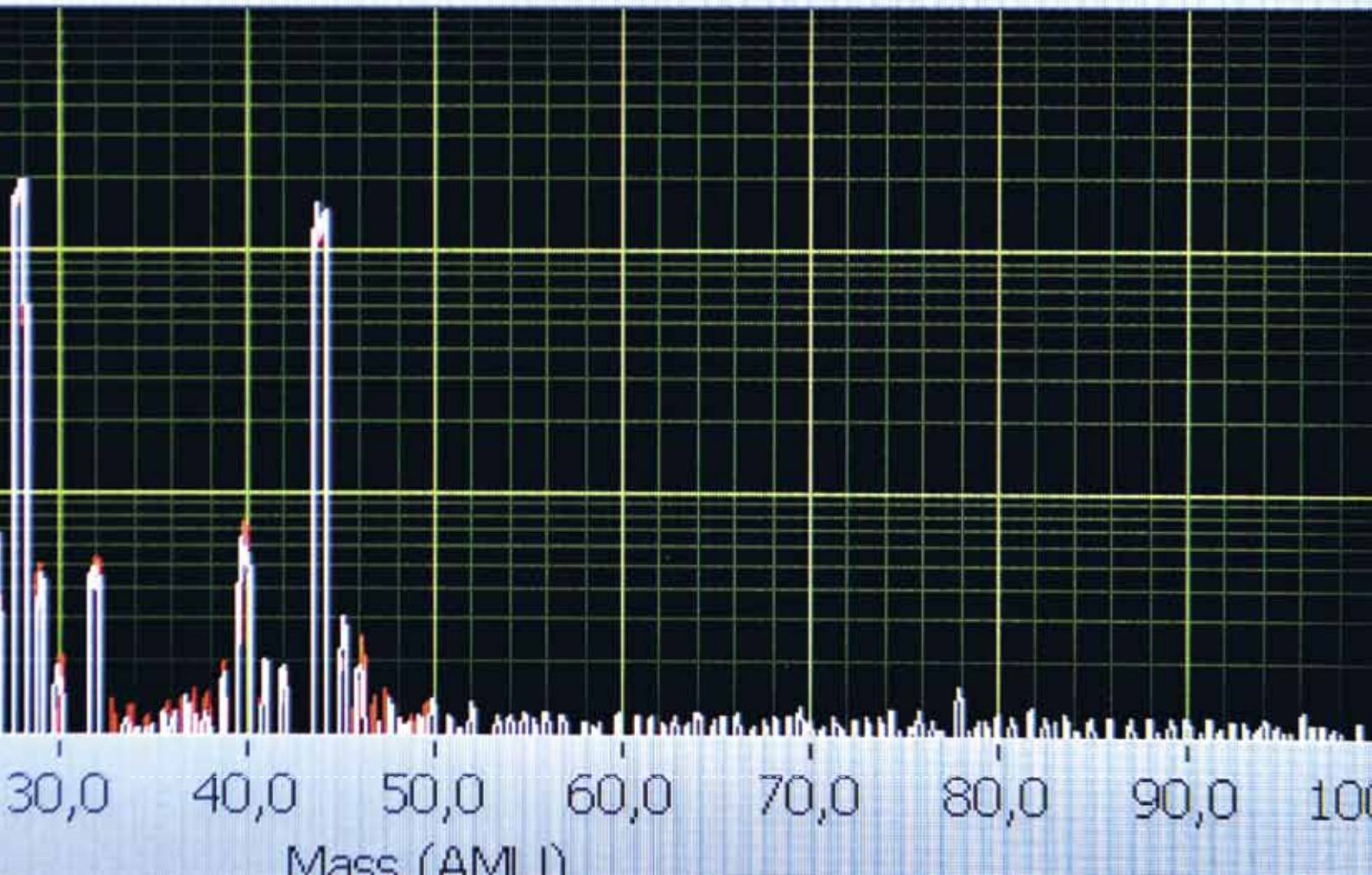
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Physics, astronomy, geophysics and adjacent disciplines deal with the science of some of nature's largest and smallest entities. Research breakthroughs in these fields have great influence on our world picture and self-perception. Current research trends in the field of astronomy concern topics such as dark matter, the Big Bang theory and detection for planets resembling our own. Particle physicists attached to European Organization for Nuclear Research (CERN) may now be close to unravelling one of the natural world's most fundamental mysteries: why elementary particles and hence everything in nature has a certain weight. Similarly, general geophysical research is currently altering our understanding of our own planet's inner structure and dynamic evolution, which may have implications for earthquake risk assessments and climate studies for example.

International cooperation on research infrastructures

Investigation of the components of the natural world requires access to unique research infrastructures, which will entail such complexity, scale and cost that it far exceeds the capacity of single nation, and can thus solely be achieved through international cooperation.

Danish researchers are playing key roles in research that is increasingly associated with novel, experimental, computational and observational methods and technologies, and which require access to the most powerful accelerators, the biggest and best telescopes and so forth.

It is a vital condition for Danish high-level research that Denmark maintains long-term membership of the large-scale international research infrastructures such as CERN, the European Space Agency (ESA) and the European Southern Observatory (ESO). Alongside scientific utilisation of these existing facilities, it is equally important to work effectively to ensure that the large membership fees to the greatest possible extent result in Danish industrial spin-offs, in order that performance in a number of promising fields of research may be monitored continuously with a view to supporting long-term strategic planning of Danish memberships of international research infrastructures.

Maximise use of Danish memberships

One key precondition for maximising the benefit from the Danish memberships of international research infrastructures such as CERN, ESA and ESO is having the opportunity to make an active contribution to the design, development and construction of instrumentation, beamlines and detectors for example, and subsequently maintaining their functional capability. Such proactive participation will in some cases be a necessary 'admission ticket' to involvement in the most attractive projects, and there may be considerable added advantages for research in the shape of guaranteed and privileged access as well as commercial advantages from making Danish in-kind contributions in the shape of equipment donations.

In relation to Danish membership of ESO, extensive backing has been registered for development of the next-generation telescope for terrestrial observational astronomy, dubbed the European Extremely Large Telescope (E-ELT), which features on the ESFRI roadmap. With its 42-metre diameter and a range of technological innovations, the sensitivity and resolving capacity of E-ELT promises a qualitative leap over existing astronomical facilities worldwide. Danish participation in E-ELT is expected to be financed chiefly via the ordinary Danish membership fee.

Danish research is currently exceedingly well-equipped for active participation in the large-scale international infrastructure cooperation, although a number of structural problems are seen to exist in the Danish research funding system in terms of long-term funding of participation in instrument development, Danish researchers' access to and use of the research infrastructures and the retention of technical expertise which, all told, make it difficult to ensure maximum benefit for Denmark.

In order to ensure the long-term stability and diversified technical competence necessary to promote Danish commitment to instrument development etc. there is a need to consolidate and coordinate the requisite technical expertise. The Danish Agency for Science, Technology and Innovation is encouraging representatives from interested research institutions to convene to discuss the possibility of establishing a national alliance

on the development of equipment and coordination of in-kind donations to international research infrastructures in all fields of research.

National and medium-scale international research infrastructures

Danish researchers also benefit extensively from a number of medium-scale facilities realised through Nordic cooperation – such as the Nordic Optical Telescope (NOT), or at the international level, but with relatively small contributions from the majority of the participating countries, e.g. International Ocean Drilling Programme (IODP).

For the short term, a need has been registered for Danish participation in medium-scale research infrastructures within the geosciences and astronomy, which hold great research potential if Denmark, in conjunction with other countries, is able to contribute to a pool or group of instruments.

In the geosciences, this applies to Danish participation in a European alliance on seismic instrumentation via an extension of the Danish funding for seismographs (DanSeis) and in astronomy, to Danish involvement in the international research structure Stellar Observations Network Group (SONG) through the construction of two telescopes.

Finally, for the short term, great potential is seen in building up a national laser laboratory (DANLASE). Laser technology is a crucial part of the experimental equipment in a wide array of technical and scientific disciplines. In view of recent years' technological advances in this field, there is every indication that the significance of lasers is set to increase in the coming years. Modern laser systems permit increasingly finer precision, a greater coverage and higher intensity. At the same time, the systems are becoming smaller, are more flexible and thus more viable for new applications in both research and industry.

DANLASE
- Danish National Laser Centre

DANLASE will be an interdisciplinary national research infrastructure which will decisively strengthen the continued development and use of advanced laser light sources within a range of research fields. DANLASE will be of wide-ranging national interest to both research and industry and will naturally be allied with the comprehensive and promising international collaboration among national laser laboratories.

Laser technology is a crucial element in the experimental equipment required by a wide array of technical and scientific disciplines, from chemistry and medicotechnology, cell studies, the synthesis and processing of nanomaterials, environmental monitoring to basic research in relativistic physics, nuclear physics, solid-state physics and photonics.

In view of recent years' technological advances in this field, there is every indication that the significance of lasers is set to increase in the coming years. Modern laser systems permit increasingly finer precision, a greater coverage and higher intensity. In spite of the fact that laser technology constitutes a key research infrastructure for a range of research fields, Denmark does not have a national laser facility to coordinate expertise on, and the development of, new, advanced laser technology and its applications in research and industry.

The establishment of a research infrastructure devoted to state-of-the-art laser technology will provide a full array of equipment in Denmark to cater for the entire spectral range from extreme ultraviolet to far infrared, time scales from subfemtoseconds to seconds together with high spatial resolution for depicting, for example, subcellular systems and thermal nanomovement and for combining spatial and spectroscopic information.

DANLASE should continue building on the well-functioning collaboration that exists nationally and internationally. It will be important to ensure that the Danish research infrastructure focuses on unique apparatus and that, through partnership with foreign facilities, unnecessary duplication and parallel activity can be avoided. To that end, a logical move will be to apply to join Laserlab Europe, a consortium of European laser research infrastructures.

Consortium partners

Based on the feedback from the roadmap proces DANLASE enjoys wide support throughout the Danish research communities. This research infrastructure is envisaged as a national consortium. Any future grant award will be conditional on the involvement of the existing body of expertise in realising and organising the project.

Funding

The cost of establishing DANLASE is estimated at approx. DKK 35m.

Time schedule

It is estimated that DANLASE could be established within a year of a grant award.

DanSeis - National Centre for Seismic Instrumentation

Seismology is the most important method of determining structures and physical parameters in the interior of the Earth and thereby in understanding the Earth's dynamics and evolution. Over a number of years, Danish researchers have gained a strong standing in international seismology, and the research field would be given further impetus through the establishment of a national centre for seismic instrumentation.

In recent years, Danish geoscience and seismology has made a strong contribution to international research in the field with a number of notable seismological findings and through interpretation of the findings of integrated geophysical and geodynamic models of processes in the Earth's interior, including their significance for geological processes at the surface. This field of research thus has major implications, not only for pure science, but to a great extent also for natural resource detection and exploitation, as well as for climate research.

The establishment of a National Centre for Seismic Instrumentation (DanSeis) should provide a decisive boost to Danish research in this field. To that end, the primary need is for extension of the pool of seismographs for use on land and on the ocean floor, to which Danish researchers currently have access via Geocenter Denmark. A total of 130 new seismographs will double the existing pool of seismographs and in terms of quality will pave the way for new research breakthroughs. This is because the existing pool is optimised for experiments on controlled sources, whereas the new equipment will be used primarily for measurements where actual earthquakes are the sources. Equally, the new equipment will constitute one of the only instrument pools internationally for use offshore, which will bring Danish researchers to the fore in enabling them to perform new and promising experiments. DanSeis will thus not only be important for pure geophysics and geology, but will also be of great value in assessments of earthquake risk, climate studies and detection of minerals and hydrocarbons.

DanSeis is expected to be affiliated with the Danish contingent of EuroArray, the seismological instrumentation component of the *European Plate Observation System* (EPOS), which has been inscribed on the ESFRI roadmap.

Consortium partners

Based on the feedback from the roadmap proces DanSeis enjoys wide support throughout the Danish research communities. With a view to assembling and deploying all the existing Danish expertise and capacities in a national consortium, the University of Copenhagen will be invited to supervise preparation of a concrete proposal for realisation of the project.

Funding

Provided that a satisfactory basis can be created for setting up DanSeis, a grant of up to DKK 25m will be awarded for the project.

Time schedule

It is expected that a concrete proposal for realisation of the project will be in place by August 2011 and that a grant will be awarded shortly thereafter. The planning and construction phase is estimated to take 1 - 2 years.

SONG
- Stellar Observations Network Group

Extended participation in the international research infrastructure Stellar Observations Network Group through the construction of two telescopes will strengthen Danish lead positions in asteroseismology and studies of other planetary systems.

Asteroseismology and exoplanetary research are concerned with studies of the structure and evolution of stars and the identification of plants around stars other than the Sun.

Research in fields of asteroseismology has been making rapid advances in recent years and it is now possible, through, for example, observations of oscillations on stellar surfaces, to gain a better understanding of the complex physical processes that govern stellar structure and evolution, and thereby also a better foundation for the very large branch of astrophysics that is based on knowledge of fundamental stellar properties. At the same time, there has been a dramatic increase in discovery of exoplanets using the so-called microlensing method, which increases the potentials for discovering the first planetary systems resembling our own solar system and which will contribute to greater understanding of the role of life in the Universe.

The leading role of Danish research in asteroseismology and exoplanetary research – two highly competitive fields in the international arena – would be given even greater standing through a stronger Danish commitment to the international research infrastructure Stellar Observations Network Group (SONG). A strengthened SONG commitment would also support and complement Danish researchers' use of the existing observation facilities at centres such as ESO and NOT.

In its concept and function, SONG is thus distinctly different from other astronomical research infrastructures currently under development. Whereas the aim for the majority of telescopes is to increase the precision of observations, e.g. the capacity to measure less distinct and more remote objects in the Universe, SONG will optimise the observation of all types of phenomena subject to temporal variation. Once fully established, the SONG global network of a total of eight dedicated robotic telescopes at locations dispersed across the southern and northern hemisphere will permit continuous observation for days, weeks or months of asteroseismic activities, and exoplanet searches.

The first of the total of eight telescopes is currently being mounted at the Teide Observatory on Tenerife under a Danish/Spanish partnership. Future technical challenges mainly concern development of the coordinated control of multiple telescopes.

Consortium partners

Based on the feedback from the roadmap proces SONG enjoys wide support throughout the Danish research communities. A national partnership already exists on participation in the research infrastructure between the University of Copenhagen and Aarhus University.

Funding

It is estimated that the construction of two new SONG telescopes could be accomplished at a cost of approx. DKK 30m.

Time schedule

It is estimated that two new SONG telescopes could be established within three years of a grant award.

2.6 e-Science >

Within the last couple of decades, the use of computer technology in science, e-Science, has progressed from being a tool for the few (typically confined to the technical and natural science disciplines), to being the third essential element of the scientific method – a supplement to theory and experimentation/observation. e-Science, denoting the collection, processing and use of scientific information in computerised form, is the fastest growing field in modern science.

The concept of e-Infrastructure comprises scientific resources and facilities based on computer technologies; the collection of data, the transportation and storage of data electronically, data processing and tools for visualisation and simulation. The principal elements of e-Infrastructure are electronic networks and dedicated grid facilities, high-performance computer facilities and databanks.

It is to be expected that increased use of e-Science over time will result in considerable cost-reductions in the research process, e.g. via various forms of remote access to costly equipment or through the use of simulations which to some extent may eliminate expensive laboratory experiments.

Needs and new trends

In the space of a few years, by virtue of the rapidly increasing capability for computation and linkage of data made possible by current computer technologies, it is likely to be difficult to conduct scientific studies at the highest level without involving computers in one way or another for computation or database searches across disciplinary divides and national borders.

e-Infrastructure needs are mounting up and the number of users is growing appreciably as e-Science becomes increasingly integral to all the scientific disciplines. This gives rise to increased demand for user support and training for the many researchers working in sciences that have not traditionally employed e-Science tools.

As computer technology has made it possible to generate, compute and store vast data volumes, requirements are increasing for computer facilities capable of processing these data and making them viable for research in terms of computation and digital visualisation and modelling. These challenges are already pronounced within fields such as climate research, materials technology, nuclear physics, systemic biology and chemistry.

A prevailing trend is for research to be increasingly interdisciplinary and transnational in its organisation so that data that was formerly scattered among many different sources is now being collected and distributed in virtual networks. These networks foster unprecedented scientific potentials and ensure the rapid and cost-efficient dissemination of research data.

International trends

Danish e-Science and its associated e-Infrastructure depend on developments in the world around us. It is essential for Danish e-Infrastructure to continually maintain a high international level, and for advances to match the pace of those in the other European countries. Every one of the projects inscribed on the ESFRI roadmap will be dependent on a strong e-Infrastructure. Danish participation in international research cooperation thus entails that e-Infrastructure and user skills at all times live up to international standards.

In order to ensure Danish researchers access to some of the largest computing facilities in the world, the plan is for Denmark to join PRACE (Partnership for Advancing Computing in Europe). PRACE is a pan-European High Performance Computing service and aims to offer researchers in Europe continuous access to some of the world's most powerful computers. Owing to rapid technological advances, computers have a very short life before they are no longer competitive. The PRACE solution is a long-term investment programme involving all the partner countries to ensure that Europe is continually in a position to offer researchers access to the most powerful computing resources in the world. PRACE's first production system, JUGENE, is installed at Forschungszentrum Jülich, Germany. JUGENE is currently the ninth most powerful computer in the World, with a capacity of 1 Petaflop.

Of particular interest to Denmark is the establishment of the coming European research infrastructure, European Spallation Source (ESS), which will be sited in Lund, Sweden. Denmark will be co-hosting ESS, and will be responsible for establishment and operation of the ESS Data Management and Software Centre (ESS-DMSC), which will be located in Copenhagen. ESS-DMSC will provide services for all scientific and technical activities at ESS in connection with computation and data storage. The existence of ESS-DMSC is expected to have very positive impact on Danish research. The plan is to build up a staff of approx. 70 IT and simulation experts, who will cover all aspects of data collection, data processing, simulation and visualisation. In order to maximise the benefit of the Danish investment in ESS, it will be essential in the establishment phase itself to build competences in e-Science in a broad sense. Conversely, it is equally important that the competences and experiences amassed in connection with the establishment and operation of ESS-DMSC are disseminated and applied throughout the Danish e-Science landscape.

Reorganisation and strengthening of Danish e-Science

A new, consolidated national organisation will be established that will possess the requisite resources and competences for supporting Denmark as an e-Science nation. The organisation will develop new funding instruments for responding to the challenges surrounding high-performance computing facilities, network connections, provision of advice/guidance and training to new users, storage of scientific data and cloud computing.

Scientific and technological advances entail that investments in computer technologies are relatively short-lived, which makes it a challenge to continually provide researchers with access to the latest tools and services they require in order to pursue research at the highest international level. In order to meet these challenges, and make efficient use of public-sector resources, there is a need for new funding instruments, ongoing strategic assessment and increased joint national coordination and governance. A new national organisation for e-Science will be conditional on the involvement of researchers from many different branches of science, as well as decision-makers at the individual research institutions and at central-government level.

For a number of years, the Danish national e-Infrastructure has been based primarily on two organisations: the Danish Research Network, which hosts network connections between Danish research institutions (and via NORDUnet connections to institutions abroad), and the Danish Center for Scientific Computing (DCSC) which supplies Danish researchers with computing power and large data repositories. In the interests of ensuring Danish e-Science of favourable development financially, technically and scientifically, efforts will be made to bring the Danish Research Network and DCSC under a joint board. The preliminary plan is for the new organisation to accomplish the following:

- contribute to formulation and implementation of a consolidated Danish e-Science strategy
- contribute to coherence and synergy between the research institutions' activities and to more explicit division of responsibilities between national and local activities
- perform those tasks currently performed by the Danish Research Network and DCSC
- ensure cost-effective solutions in line with advances in the field
- support training and advisory activities in the field, including establishing and operating a national centre of excellence for e-Science
- handle Danish membership of international cooperation, including NORDUnet, Nordic Data Grid Facility (NDGF), ESS-DMSC and PRACE.

Consortium partners

The Danish Agency for Science, Technology and Innovation appointed a committee in spring 2011 composed of key stakeholders with a view to preparing the statutes for the new organisation.

Funding

The present National Budget accounts for the Danish Research Network and DCSC are expected to be continued until a new organisation can come into effect. In addition to these existing National Budget allocations, provided that a satisfactory basis can be created for establishing the new organisation, the project will be eligible for additional funding of DKK 50m for launch of the new activities under the organisation. The DKK 50m should in principle cover a three-year running-in period. The details of funding allocations will be agreed in connection with preparation of the new statutes.

Time schedule

The plan is for a decision regarding the statutes for the new organisation to be adopted by September 2011 so that a new organisation can come into effect from January 2012.