Diversity in use broadens the benefits of ESS

Swedish Research Council

VINNOVA

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Dnr 3.2-2022-05131
ISBN 978-91-88943-71-2

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Foreword

ESS and MAX IV are strategically very important for Swedish research and innovation, and for strengthening our role as one of the world's foremost knowledge nations. The facilities will provide Sweden with unique conditions for conducting excellent research and create new opportunities for collaboration between academia, industry and the public sector in order to achieve solutions for sustainable societal development.

The Government's vision is for ESS and MAX IV to form the cornerstones of a world-leading centre for life and materials science. It is a long-term investment, with an implementation that involves the entire country and requires efforts from many stakeholders in several sectors. The Government has commissioned the Swedish Research Council and Vinnova to coordinate national initiatives aimed at ESS and MAX IV. In order to link our authorities, the Office for ESS and MAX IV was established in the spring of 2020 as the common platform from which the assignment will be implemented.

A holistic perspective and effective anchoring are ensured through the establishment of the Council for the Office for ESS and MAX IV, which consists of representatives from organisations from the Swedish research, education and innovation societies.

This report is written by a working group within the Council of the Office for ESS and MAX IV and has special focus on ESS. The purpose is to investigate and give recommendations for how the access to research infrastructures should be designed in order to create preconditions for both the very best research and for Sweden’s and Europe’s opportunities to contribute to solving the global societal challenges and improve their competitiveness. The report provides concrete and useful advice and a number of recommendations for improving non-academic accessibility to research facilities. The Swedish Research Council, Vinnova and other stakeholders should take these into account in the continued work of creating the best possible conditions for the research that uses ESS, MAX IV and other research infrastructures.

On behalf of Vinnova and the Swedish Research Council, we would like to thank the authors for their very thorough work.

Stockholm, November 2022

Darja Isaksson

Director General

Vinnova

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Director General

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Summary

Sweden is investing large resources in research infrastructure, including the European Spallation Source ESS and the MAX IV laboratory. To get the best return from these investments, their use must be broadened and increased, even if the main user of research infrastructures always will be academia. One way of doing this is to involve industry and the public sector to a greater extent in the research that takes place at the facilities, both as suppliers to the facilities and as users of them.

With this report, we want to make some recommendations about what a modern and effective accessibility policy, for ESS in particular, could look like. This would broaden the use of the facility, and thereby increase the benefits of investments already made and also future investments in research infrastructure. However, an accessibility policy is not enough to make full use of the investments made in research infrastructure facilities such as ESS and MAX IV. We therefore hope that facilities, universities and funding bodies, separately or together, make use of the insights collected for this report.

The recommendations in brief

Governance

- Decide on an accessibility policy for ESS that includes non-academic users
- Update the ordinance governing MAX IV to also include access to the facility for non-academic users

Follow-up

- Develop a system for follow-up and evaluation that includes both bibliometric data (publications), type of user, effects in the form of utilisation, societal relevance and economic competitiveness, and the extent to which data are reused

Awareness and knowledge

- Intensify marketing of the facilities, especially to non-academic users
- Design, implement and finance a long-term training programme that integrates all technologies available at ESS and MAX IV

Open data

- Develop effective ways to enable open access to and reuse of data (FAIR) for research, taking into account the privacy requirements of private users

Stimulating structures

- Set up neutral nodes for user support before, during and after measurements

- Consider incentives to increase the number of mediator companies as well as targeted calls that stimulate collaboration between academic and non-academic parties

Application processes

- Develop and make decisions on an accessibility policy for ESS that includes non-academic users
- Update the ordinance governing MAX IV to also include access to the facility for non-academic users
- Update the accessibility policy for MAX IV
- A modern accessibility policy should be designed so that assessment criteria and type of assessor co-vary with the type of use intended within each pot.

A model for how the distribution of beamtime between academic and non-academic users could look can be found in Chapter 5.

Funding methods

- Set aside resources for funding beamtime at ESS and MAX IV for non-academic users

1 Introduction

1.1 Purpose

The purpose of this report is to investigate and give recommendations on how the access to ESS in particular should be designed, so that it creates preconditions for both the very best research and also providing Sweden and Europe with opportunities to contribute to solving global societal challenges and improve Sweden's and Europe's competitiveness.

1.2 Goals

The goal is to inspire the relevant decision-makers to implement a modern accessibility policy for ESS that contributes to increasing and broadening the use of the facility for industrial parties, the public sector and for collaboration projects between industry, the public sector and academia. Hopefully, the report recommendations can also be used by other Swedish research infrastructures that are already in operation, for example MAX IV.

1.3 Background

Major resources are being invested around the world to solve global challenges and contribute to the digital transformation. Following COP 26 in Glasgow, it is clear that radically increased investments are needed in the climate area. Russia’s invasion of Ukraine makes it clear that investments are needed to reduce the resource dependency, in particular in the energy sector, and to contribute to security and political stability in Europe and the world.

New research results are a crucial necessity to achieve success in these areas. They are also needed to safeguard the competitiveness of business. Over the last 15 years, the competitiveness of Sweden and Europe, measured in GDP or industrial refinement value, has continually been declining compared to that of both USA and China. New business opportunities are, of course, being created for companies and organisations that are leaders in their fields, but without powerful investment in new research resources and increased and more efficient use of existing resources, the gap continues to be at risk of increasing.

Research and development in interaction with different societal sectors play a crucial role in achieving success. The exceptionally quick development of vaccines against COVID-19 is an excellent example of collaboration between academia, business and politics. Advanced materials and processes for their development play key roles in all sectors, not least for our fight against climate change. The EU has realised that materials and new processing technology are very important; of the six industrial alliances that have been started within the framework for Horizon Europe to date, five relate to these advanced materials. The recent large investment by Knut and Alice Wallenberg Foundation in

material science for a sustainable world is another example. Furthermore, the development that is taking place in the north of Sweden, with companies such as Hybrit, H2 Green Steel and Northvolt, are clear examples of how new materials and new production methods for these can contribute to and speed up the transition to green technologies. Life science also has a great need to be able to analyse and design materials in a way that has not existed before. These advances are often in the intersection between health, sustainability and biomaterials.

What is happening in the world around us also impacts on the EU's views on research, development and sovereignty, for example in the IT area, where the EU very recently announced a very large initiative called "European Chips Act", with an investment of more than 40 billion EUR focused on digital sovereignty.

Successful research is to an ever-increased extent dependent on access to research infrastructure, such as advanced laboratories, observatories, measuring stations, systematically constructed databased, etc. The policy paper "Optimising the operation and use of national research infrastructures" (OECD Publishing, August 2020) presents a number of recommendations that in relevant areas align well with this report.

Sweden is currently investing major resources in research infrastructure within the materials science area, such as the neutron research facility ESS and the synchrotron light facility MAX IV. These facilities require major investment expenditure, and also considerable operating expenditure, and therefore they must both be of high quality and have a high capacity in order to accommodate users not only from the academic world but also from business and other parts of the public sector.

MAX IV, starting its operation in 2016, is indeed involved in interesting projects to enhance non-academic use of the facility. One example is Treesearch, a national initiative where the academic and industrial sectors work together with private foundations and central government to create a world-leading open research environment for the future bioeconomy. Treesearch coordinates and supports the research into new materials from forests. All researchers and research projects at Swedish universities are able to join and participate in Treesearch. The Wallenberg Wood Science Centre is the core of the research activities in the platform. Part of the Treesearch platform is a dedicated beamline for this sector, ForMAX at MAX IV.

It is, of course, important that the foundation and motives for investment in research infrastructure are maintained, namely to contribute to excellent research. At the same time, room must be given for strategic research focusing on the global challenges, the green transition, collaboration between business, the public sector and academia, industrial research and also for training the researchers and leaders of the future.

1.4 Utilising and creating value

The research and innovation system is complex, and includes several different components – all are important building blocks of a larger whole for society. In definition terms, it is possible to make a distinction between knowledge-generating initiatives and utilisation, where the first relates to the striving for knowledge, and the second to the striving for societal added-value.

In a research context, added value is often defined as that which generates more efficiency or effectiveness in society, in the form of increased returns per krona paid in tax, for example more efficient healthcare methods, improved products or services, increased biological diversity, reduced environmental impact, etc.

If benefit is defined as per above then all knowledge does not translate into benefit. This does not mean that the knowledge is not valuable, just that in the context mentioned it is just knowledge/knowing. Knowledge is needed for innovations, but knowledge can also be created from some already-created benefit (for example how the steam engine led to thermodynamics, or how dynamite led to explosives chemistry).

Most of the activities in academia relate to knowledge-generating activities, but also, to an increased degree, to utilisation. Most of the activities in other societal sectors relate to utilisation, but also to some knowledge-generation.

The main user of research infrastructure will probably always be academia, but by opening up to other societal sectors, the raison d'être of the research infrastructure is strengthened. The part of the non-academic sector that carries out knowledge-generating activities needs to get access to the best research tools to support innovations, inventions and/or development. For this reason, it is important that research infrastructures become accessible also to other societal sectors than solely academia.

The dualist viewpoint that knowledge-generation and value-creation differ also means that the way of assessing these different entities should also differ, both in terms of the criteria used and of who makes the assessment.

At a research council, applications are primarily assessed by academics, while at an innovation agency, applications are to a greater extent assessed by persons with an entrepreneurial background or persons from industry. Different assessment panels will also be needed when it comes to different categories of applications for beam time. If, for example, there is a pot of beam time aimed at strategic research with a potential future use, the assessment panel should be mixed with expertise from different sectors, and a relevance criterion should be added to the assessment.

2 ESS – a toolbox for advanced research and development

The European Spallation Source ERIC (ESS) is a neutron spallation facility jointly owned by 13 member countries, which is now being completed in Lund, in order to start receiving users in 2028.

ESS is specifically designed for materials research, where the microscopic structure, dynamics, properties, and behaviour of a wide variety of materials during differing environments or processes is studied. With this new knowledge, completely new or optimised materials can be tailored for very different kinds of applications. This also means that each component, product and solution can be refined and become even more efficient, environmentally friendly, or have a longer life. With the help of instruments, objects can be studied at atomic and molecular level, as well as in real time and under varying levels of moisture, magnetism, temperature and pressure. Neutrons penetrate the material studied without changing its characteristics, which enables great flexibility in testing environments and studies of fragile testing materials (such as biological samples).

In addition to the 15 instruments now being built, there are concrete plans for a further 7. ESS is constructed to be able to handle up to 38 instruments. With these instruments and neutrons, researchers will, for example, be able to:

- investigate the response of materials to deformation, stress and changes in materials under circumstances that are similar to industrial processes and use, as well as mapping tensions in constructions and components
- reproduce the inner structure of complex components and large samples, statically and in operation
- investigate surfaces, thin films and layers, and study magnetic phenomena, which helps us to understand, for example, mechanisms in cell membranes and improve data storage
- study quantum magnets and super-conductors, and functional materials such as fuel cell membranes and nanomaterials in order to achieve sustainable energy solutions, for example
- study atomic interactions for liquids and biomaterials, with applications in areas such as medicine, the environment and quality control
- study surface chemistry and characteristics of layers and interfaces, which is important in research into biological membranes, medicine supply systems, cosmetics and foods
- provide better understanding of fundamental biological processes, such as energy production in cells, or how medicines attach to target proteins
- follow kinetic processes and investigate structures, dynamics, and the function of liquids, colloids, gels and polymers, and also biological materials in order to improve these.

2.1 Academic and industrial networks

Through the construction of MAX IV and ESS, the Swedish engagement in using advanced research infrastructure has increased, both in academia and in the business sector. Networks have been formed to utilise the potential. Lund Institute of Advanced Neutron and X-ray Science (LINXS) is developing a national competence centre, networks for researchers and a think-tank for educating future generations of neutron and synchrotron light users. Among the existing actors are the Swedish Neutron Education for Science and Society (Swedness), the Swedish Neutron Scattering Society (SNSS), the Swedish Synchrotron Users Organisation (SSUO), the Association for Synchrotron Radiation Users at MAX IV (FASM) and Big Science Sweden (BiSS).

Within the business sector, several initiatives and activities are in progress, aiming to get closer to the technology and competence of ESS and MAX IV. Metalbeams, which is organised by Jernkontoret (the Swedish Steel Producers' Association), RISE and the metal research institute Swerim, is a platform that aims to increase the metal industry's opportunities to make effective use of ESS, MAX IV and Petra III in Hamburg, by stimulating collaboration between industry, institutes and academia. InfraLife, a project funded by the Swedish Research Council, aims to increase knowledge of and facilitate access to ESS, MAX IV and SciLifeLab in Stockholm for academia, industry and also health and medical care. The infrastructures are collaborating in this project with the industry organisations SwedenBIO and LiF, and also the innovation programmes Swelife and MedTech4health. The national arena MAXESS, a collaboration between ESS, MAX IV, RISE, Science Village Scandinavia and Centre for X-rays in Swedish Materials Science (CeXS) at KTH Royal Institute of Technology among others, will facilitate industry's use of ESS and MAX IV, and also promote new partnerships between industry and academic experts.

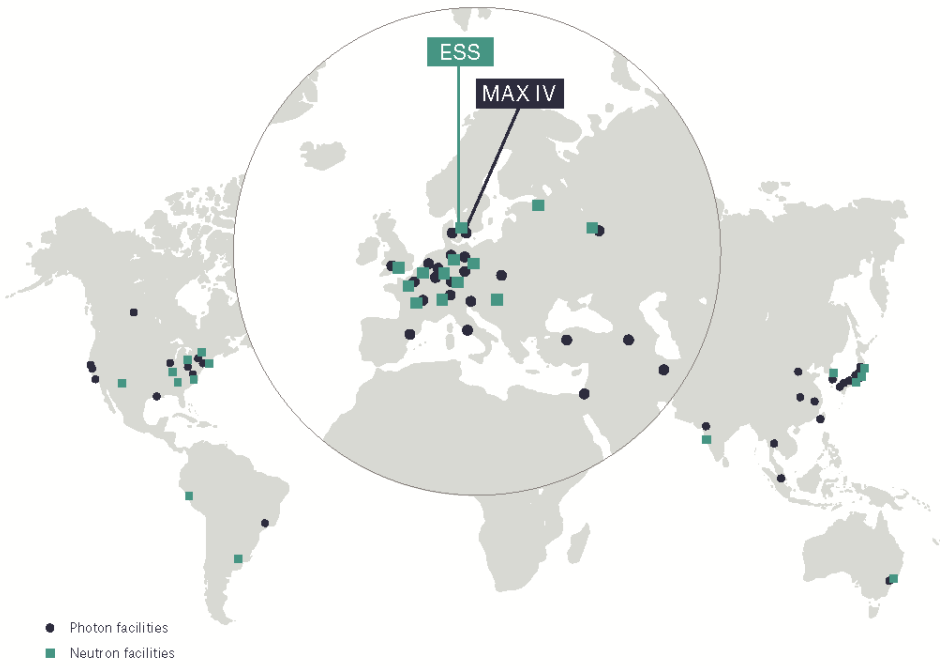
Long-term projects that address societal challenges and educational initiatives to enable better utilisation of advanced research infrastructures, as the examples above, are dependent on funding that is equally long-term.

3 Contemporary environment analysis

To gain an overview of how the work of increasing the non-academic use of research infrastructure is going, we looked at what is happening in the EU, and also contacted a number of facilities. We asked the facilities what the process for access by industry is like, how the effects are measured, and what the key factors are for increasing non-academic use of photon and neutron facilities.

The take-home message based on the analysis is that to be able to attract more industry and public sector users, understanding their needs are crucial. The need for adapted access models, assessment criteria and assessment panels, as well as a high level of data security and rapid access to the research infrastructures are some of the conclusions that can be drawn. However, a "standard access model" or a "standard user support model" that fits all types of research infrastructures is not feasible due to the diversity of both the research infrastructures, different support needs and differing levels of expertise within the user groups.

3.1 Neutron and photon facilities around the world



There are just under 50 neutron research facilities and just over 60 synchrotron light and free electron laser facilities around the world. ESS is the most recent addition to the neutron sources, and uses the spallation method to generate neutrons. MAX IV is the first fourth-generation synchrotron light facility, but

has already been joined by others, for example through the upgrading done at ESRF.

3.2 The European neutron and photon landscape

3.2.1 ESFRI

ESFRI, the European Strategy Forum on Research Infrastructures, is a strategic instrument to develop the scientific integration of Europe and to strengthen its international outreach. The competitive and open access to high quality research infrastructures supports and benchmarks the quality of the activities of European scientists, and attracts the best researchers from around the world. ESFRI operates at the forefront of European and global science policy and contributes to its development by translating political objectives into concrete advice for research infrastructures in Europe.

ESFRI has established a European Roadmap for research infrastructures (new and major upgrades, pan-European interest) for the next 10–20years. It stimulates the implementation of these facilities, and updates the roadmap as needed. The European Spallation Source (ESS) has been in the European Roadmap since the first issue was published in 2006.

As pointed out in the ESFRI roadmap, there has always been a close interaction between research infrastructures, industry and small and medium-sized enterprises (SMEs). Industrial users in search for innovative solutions using innovative methods are attracted with tailor-made services or services that build on well-established analytical techniques. Research infrastructures are clearly linked to industrial ecosystems and to partnerships and industrial alliances. However, there is still potential to reinforce and structure these links and to strengthen the role of research infrastructures in other areas by:

- developing more standardised techniques, a stronger modularity and interoperability across platforms, and services, using multi-messenger science
- strengthening industrial research and innovation and the long-term sustainability of laboratories
- developing new research infrastructure services tailored to industrial needs, in particular in areas linked to key EU policy priorities;
- reinforcing the role of industry liaison officers at research infrastructures

3.2.2 ENRIITC

The ENRIITC project aims to build a permanent pan-European network of industrial liaison officers (ILOs) and industrial contact officers (ICOs) and enable industry to become a full partner of research infrastructures, whether as a user, a supplier, or a co-creator. ENRIITC supports the establishment of strategic, cross-border partnerships between industry and research infrastructures. The primary objectives of ENRIITC are:

- establish a sustainable European network of ILOs and ICOs, which enables mutual learning
- map collaboration potential between research infrastructures and industry
- develop and refine strategies and best practices to foster these collaborations
- raise awareness among industry for collaboration opportunities at research infrastructures, and demonstrate impact

ENRIITC brings together 11 Partners and more than 60 Associates from around Europe. Apart from ESS (partner), Sweden is represented by Big Science Sweden (partner), BrightnESS-2 (associate) and Vinnova (associate). The network represents diverse scientific areas, industrial sectors and geographical regions. The project runs from January 2020 to December 2022 and delivers work package reports during this time.

3.2.3 LENS

In Europe, there is a world-leading network of international and national neutron sources serving a scientific community of more than 5 000 researchers with over 32 000 instrument days per year. Nine of these form a strategic non -profit consortium, the League of Advanced European Neutron Sources (LENS), with the aim of strengthening European neutron science by enhancing collaboration among the facilities. LENS places emphasis on the relationship between user communities and funding organisations, continuous improvement of source facilities, optimising resources between and aligning policies among partners - all to ensure excellence to the communities they serve. ESS is one of the funding partners.

3.2.4 LEAPS

Science at synchrotron radiation and free electron laser (FEL) facilities plays an essential role in the discovery and characterisation of advanced materials, biomaterials and living matter, and Europe has achieved global leadership in this field. These facilities serve a very broad scientific community of more than 30 000 researchers in Europe, and attract some of the brightest minds worldwide.

The League of European Accelerator-based Photon Sources (LEAPS), is a strategic consortium of synchrotron radiation and free-electron laser user facilities in Europe. Its primary goal is to actively and constructively ensure and promote the quality and impact of fundamental, applied and industrial research carried out at each facility to the greater benefit of European science and society. MAX IV is one of the funding partners. LENS is a partner to LEAPS.

3.3 How do you get access to the research infrastructure?

Academic users apply for time to carry out experiments and measurements through calls issued by the research facilities, usually two per year. The applications are assessed (peer reviewed) by international expert panels within the different research disciplines. It normally takes between six and twelve months from the time of submitting the application to the researcher getting time at a beamline or an instrument.

Non-academic users are welcome to apply for beamtime in the research infrastructures' open, general calls. This is then usually done together with one or several partners from academia, as non-academic users often need the competence that exists there. In addition to this, most research infrastructures offer various standard variants for access, aimed at industry and other non-academic users:

- Proprietary access – the user pays for the time used and the research results are confidential, which may be particularly important if this a critical for the business.
- Quick access – time that has been set aside in advance for industrial users, where access to beamlines or instruments can be given at short notice. This is important for R&D activities or process development, for example, where quick answers to changes made are needed.
- Director or Instrument access – dedicated time at a beamline/instrument that a person responsible (director or beamline manager) can allocate without any previous application process.

There are also other options for non-academic users to gain access to research infrastructure, for example via central nodes, mediator companies, research institutes, or collaboration projects. See Chapter 4.2.

A new and interesting proposal system is being launched at PETRA III from autumn 2022. It has two points of entry: Regular proposals with scientific focus, and Regular proposals with socio-economic focus. In this way, PETRA III opens up for impact in both areas. More information on this new initiative can be found at desy.de.

3.4 Research infrastructures investigated

Eleven facilities or institutes were selected for closer study, which all have in common that they have documented positive results of their efforts to increase accessibility for non-academic users, primarily from industry. These are highlighted as benchmarks in the accessibility work linked to ESS, but can also serve as inspiration for other research infrastructures.

Key components of the accessibility work have been identified and the most important are summarised in Chapter 4.

3.4.1 ISIS and Diamond (UK)

Contact persons ISIS: Christopher Frost - STFC UKRI and Graham Appleby - STFC UKRI. Contact person Diamond: Elizabeth Shotton, Head of Industrial Liaison.

The ISIS Neutron and Muon Source is located in Oxfordshire, UK, and is owned and operated by the Science and Technology Facilities Council (STFC), which is part of UK Research and Innovation (UKRI).

The Industrial Collaborative Research and Development (ICRD) Scheme is an access mode in addition to the long-standing peer-review process, called Direct Access, and the proprietary access mode, which is paid for and confidential. The ICRD programme was established in 2011 as a more flexible access route for industry to perform measurements at ISIS in addition to the existing standard routes, recognising the different needs of industrial research. The assessment of proposals is based on economic impact. ICRD requests additional information for proposal submissions that have been found useful in reviews of economic impact and in the creation of the documents required for further funding of instrument development.

ICRD has approximately 1 per cent of all beamtime at ISIS per year. The programme equated to approximately 50 days of beamtime (out of a total 430 beamtime days during the period 2011 to 2020) allocation by the ICRD Scheme across the whole ISIS instrument suite.

For those industrial users who were able to quantify benefits (46 per cent of proposals as of 2016), they together forecast more than 500 million GBP in additional income or savings for the participating companies and their supply chains[1]. In several cases, benefits are anticipated to accrue each year, for many years into the future, suggesting that this group of current ISIS experiments may help secure or expand national economic activity by several billions over the next decade.

Key points to attract and keep users:

- Beamtime is free at point of use
- Beamtime may be obtained very quickly
- One criterium for getting access is the experiment's potential economic benefit to the UK

The results remain confidential during the period of the experiment and the subsequent data analysis. For each experimental proposal, a company must demonstrate that it has deployed in-kind matching funding of the cost of the ISIS beamtime needed. The interest from industry is growing, and most interested companies are large. Approximately 95 per cent of all projects opted for not paying for beamtime and allowing data to become non-confidential, as it is for normal, peer-reviewed beamtime.

Diamond Light Source is the UK’s national synchrotron science facility, located at the Harwell Science and Innovation Campus in Oxfordshire. It is a not-for-profit limited company funded as a joint venture between UK Research & Innovation (UKRI) and Wellcome Trust. Diamond provides national science infrastructure that is free at the point of use. Primary facilities are the national synchrotron along with the cryo electron microscopy at the Harwell Campus, all available to researchers through a competitive application process, provided that published results are in the public domain.

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[1] https://www.isis.stfc.ac.uk/Pages/ISIS-Lifetime-Impact-Report.aspx

Academic projects which have some sort of industrial engagement are estimated to be of the order 40 per cent of all projects. Direct industry use is around 7-8 per cent and varies by beamline. Diamond Industrial Liason Office offers a range of access points for non-academics:

- Full service - includes experimental design, data collection and data analysis.
- Mail-in data collection - send in the sample(s) and Diamond staff collects the data, or:
- Remote access - send in the sample(s) and collect the data from home.
- Proprietary access and peer review as per normal.

3.4.2 MAX IV (Sweden)

Contact person: Magnus Larsson, Industrial Relations Office

MAX IV is part of Lund University and opened in 2016 as the first 4th generation synchrotron facility. MAX IV offers hard and soft X-rays and is developed based on the experience Sweden has through MAX-lab (MAX I, II and III) operating in Lund 1985-2015.

It is a priority for MAX IV to establish an Industrial Advisory Board, and this will be even more important in view of the plans to develop new access modes, such as a specific call for industrially relevant experiments. MAX IV is committed to supporting and advancing research for Swedish and international industries, especially those aiming to develop a more sustainable future in concert with the UN and global Sustainable Development Goals. Six out of fourteen beamlines at MAX IV are used by industry today and about 20 per cent of the open beamtime is declared as industry-academic collaboration. According to an agreement with the Swedish Research Council, MAX IV can have up to a total of 10 per cent industrial (proprietary) use.

MAX IV has approximately ten different access modes, some of which are listed here:

- Open: Open for applications two times per year, the results shall be published
- Privileged: For example, Treesearch and DanMAX (peer review access that is allocated to a grouping that has invested in MAX IV’s operation and construction)
- Fast access: Both Open and Proprietary, and both entail a quick process
- Fast access, sample feasibility: Quick measurement to understand whether the sample is measurable or not
- Proprietary access: Industry that pays for beamtime and is not required to publish (business critical) research results

Discussions are in progress on whether either opening an access mode where the evaluation criterion is industrial impact, or to give the review panels that evaluate the applications new directives, and/or to expand the review panels with persons who have industrial and entrepreneurial competence. This is to enable beamtime to be allocated based on a broader concept linked to societal benefit.

At MAX IV the number of industrial users is growing, and for 2021 the total hours of proprietary time were 556, distributed over 6 different beamlines, as compared to 2018 when 43 hours was proprietary time. In the same year, approximately 19 500 hours of open beamtime were used for academic research, distributed over 13 beamlines.

3.4.3 NIST, NCNR och n-Soft (USA)

Contact persons: Ronald L. Jones, Director nSoft Consortium, Lead User Facility Partnerships and Paul Butler, NCNR.

The National Institute of Standards and Technology (NIST) was founded in 1901, is now part of the U.S. Department of Commerce, and operates in two main locations: Gaithersburg, Maryland, and Boulder, Colorado. NIST jointly operates research organisations in four additional locations, explicitly established to promote cross-disciplinary collaborations that accelerate research results.

The NIST Center for Neutron Research (NCNR) is a national resource for industry, universities, and government agencies, and focuses on providing neutron measurement capabilities to the US research community.

nSoft is a consortium designed to deliver technology and expertise within the neutron-based community to US/based industrial researchers. Within the nSoft environment, researchers from member companies participate in publicly accessible research led by NIST staff at the NCNR and across the campus. The director of nSoft also leads industrial access for NIST efforts at four US-based synchrotrons: the Stanford Synchrotron Radiation Lightsource (SSRL), the Advanced Light Source (ALS), the Advanced Photon Source (APS), and the National Synchrotron Light Source II (NSLS-II).

Key points to be managed to attract and keep users:

- turnaround time
- proposers do not have their hands tied about what they can actually say publicly
- a lack of expertise in the company
- industrial partners help develop new instruments and methods

The main route to acquiring beamtime through the open proposal system works well for academics with projects often spanning many years. This route is, however, not as suitable for industry due to the need for faster turnaround and the protection of intellectual property (IP). The turnaround time to be approved in open proposal rounds that occur twice yearly is in the order of 6 months. The long uncertainty of the process and the rather low success rate - industry proposals are usually stripped of the details that makes them interesting (due to intellectual property protection) - makes this route a poor option. In addition, opting for buying proprietary time is also hard for most companies, due to a general lack of expertise within the company.

At NCNR several beamline instruments and sample environments have been built within industry partnerships. NCNR has lower rates for proprietary beamtime than similar facilities, partly because of US law. It is meant to be "full cost recovery," so that the government is not making money from the company but also so that the taxpayer is not subsidising the company. The rate is currently (2021) slightly more than 5000 USD per day, depending on the beamline.

NCNR has many chemical engineering students spending time at the facility, both engaged directly in nSoft projects and in other projects. Many of these students get jobs in industry and take the knowledge of what they can do with neutrons with them, and will then often negotiate either a research agreement (to do a joint project with a group at NIST), join nSoft, and/or buy and use proprietary time.

Success in industrial models is hard to quantify. A simple metric is the number of companies in a consortium or visiting your facility. However, a high number of companies does not automatically yield more impact. nSoft and NCNR prefer longer, deeper relationships with a small set of companies. Quantifying impact is very difficult to do, even for the companies themselves. In situations where it is often useful to be quantitative, the model at ISIS where access is based on economic impact is good. This forces the company to publicly quantify the impact. By connecting company-defined impact to access, there is a risk of arbitrary inflation of the numbers, and access is biased to very large companies.

For nSoft, success means new measurement capabilities (methods) that result from industrial collaboration and engagement. Before engagement with new collaborators, nSoft assesses whether the methods proposed are important to industrial collaborators in general, will help general users advance high impact science, are in demand within the general user community and whether NCNR will be able to support these methods for general users (cost to operate, existing expertise, etc).

nSoft also looks at membership qualitatively, answering whether they are retaining companies for “long” periods of time, whether members are hiring people to work on neutron techniques and if the collaboration is supported by multiple units within the company, or whether the proposed project is a niche project for a single principal investigator. nSoft tries to optimise its model to give the best answers to all of the questions, but it is qualitative only. This is how nSoft evaluates success.

There are no strategy documents available on the nSoft website. Public strategy documents are often employed to justify its funding. NIST is already funded and obligated to pursue these types of activities by the US Congress as part of their agency mission. By far the most funding of nSoft comes from NIST; industry fees are typically small supplements. This approach is intentional to keep NIST from adopting service roles rather than its preferred role as the dominant collaborator. For NIST, industrial access is designed to help NIST better deliver its mission.

The primary outputs at nSoft are new measurement capabilities for the broader user base rather than the economic impact resulting from helping a company build a new product. With that said, companies engage in the type of collaboration offered at nSoft because they are able to better develop new products, but that is not a specific goal for nSoft and nSoft is not assessed based on those types of results. nSoft's internal strategic planning is based on available resources, annual feedback from reviews, rea- time feedback from partner companies, and most importantly, the evolving priorities of NIST.

3.4.4 PSI (Schweiz)

Contact persons: Johan Millard, Head of Technology Transfer and Markus Frei-Hardt, Technology Transfer Manager.

The Paul Scherrer Institute (PSI) is located in Villigen and Würenlingen, Switzerland. PSI is primarily financed by the Swiss Confederation and operates large scientific research facilities, such as the Swiss Light Source SLS, the free-electron X-ray laser SwissFEL, the SINQ neutron source, the SμS muon source and the Swiss research infrastructure for particle physics, CHRISP.

Non-academic users have two entrances to PSI; Technology Transfer, a portal to SLS, and ANAXAM focusing on SINQ and SLS. Approximately 10 per cent of the beamtime is used by industry.

Key points to attract and keep users:

- link industry and beamline scientists
- first point of contact
- manage intellectual property rights
- the whole supply chain
- joint ventures industry, institute and academia
- on-site network of industries

The Technology Transfer (TT) team supports industry with information and advice. It acts as a link between a potential interested company and the corresponding scientist at PSI. For the industrial partner, the TT office represents the first point of contact and the facilitator to the research at PSI. In-house TT supports the parties involved in contractual and administrative matters, and manages the intellectual property rights. If necessary, the TT office advises and supports scientists in commercially exploiting their inventions and results in spin-off companies. The goal is to create an ecosystem where TT plays the role of enabler and supporter at several levels, rather than being in the driver's seat.

New knowledge created at PSI in areas such as energy, material sciences, structural biology or medicine benefits both Swiss society and industry. Joint ventures with other research institutes, universities and industry promote the transfer of knowledge: through the acquisition of staff trained or technologies developed at PSI; through the training at PSI of people based in another country; through the exchange of staff for limited periods of time; and finally, through patents and licences.

Park Innovaare close to PSI offers a network in which companies, small amd medium-sized enterprises, start-ups and PSI can work together in an optimally profitable way to optimise production processes and advance the development of innovative products and bring them to market. The campus is currently under construction and will be ready for companies to move in by the end of 2023.

ANAXAM is an ecosystem and facilitator based on industry members' needs and interests. It has been working since late 2019 by buying beamtime, which is then sold to the industry.

3.4.5 Soleil (France)

Contact: Philippe Deblay, Head of Industrial Connections

Soleil is a synchrotron facility located near Paris, France. The facility is managed as a public company according to French law. The members of the Soleil company are the CNRS (National Centre for Scientific Research) and the CEA (Alternative Energies and Atomic Energy Commission). The facility is an associate member of the University of Paris-Saclay.

Key points to attract and keep users:

- beamline performance
- quality of services provided by the beamline scientific staff and by the sales team
- administrative and legal procedures as simple and light as possible (the industrial user must devote most of its activity to the experimental part), without reducing the effectiveness of these procedures.

Access to Soleil's beamlines is open to scientists coming from all over the world, and the facility receives proposals submitted by scientists from academic institutions as well as researchers and engineers from commercial organisations and private companies. Access at Soleil comes in three variations:

- Public access for users whose proposals have been evaluated by a peer review committee and whose results are open for publication (which is mandatory). There are two calls for these kinds of projects per year. The experiments are normally performed 6 to 12 months after submission of the proposal.
- Proprietary access for users requesting rapid access and/or confidentiality without peer review process, and full intellectual property rights to clients.
- Collaborative access for users that work in collaborations with beamline teams, with sponsored staff (PhD, post-doc, trainees, etc.) and external funding.

The proprietary access is specifically tailored to suit industrial users; this specific access is used for approximately 85 per cent of the industrial experiments carried out at Soleil. About 150 industrial experiments were carried out in 2021 by proprietary access, which is a decrease of about 15% compared to the pre-COVID situation. Success, that is, societal or economic impact, by industrial users is achieved through the following:

- Immediate satisfaction of the industrial user regarding the experiment (R&D or quality control steps).
- Loyalty of the industrial user, that is, renewal of industrial engagement from one year to the next (R&D or quality control steps).
- Feedback from the industrial user on the new product, service or process resulting from the industrial experience(s) carried out at Soleil (manufacturing or sales steps). However, this feedback is very difficult to obtain.

3.4.6 ESRF and ILL (France)

Contact: Ed Mitchell, ESRF Business Development Office

The European Synchrotron Radiation Facility (ESRF) and Institute Laue-Langevin (ILL) are located in Grenoble, France. ESRF is a synchrotron facility supported by 13 member countries and eight associated countries. In August 2020, ESRF opened its completely rebuilt X-ray source, ESRF-EBS (Extremely Brilliant Source), the world's first fourth-generation high-energy synchrotron.

The Institute Max von Laue-Paul Langevin (ILL) is an international research centre managed by France, Germany and the UK along with 11 scientific member states. The ILL provides industrial users with privileged access to a broad and world-leading array of highly specialised neutron instruments, supported by the expertise of scientific and technical staff. Samples or devices can be studied under conditions that simulate operational conditions thanks to a wide range of sample environment equipment.

ESRF and ILL collaborate closely on many initiatives, for example the doctoral programme InnovaXN, which brings together the expertise of large-scale research infrastructures with the research and development needs of European industry. Both institutes offer different modes of access depending on the level of confidentiality the industrial client requires.

The newly founded "Grenoble Battery Hub" is a partnership for an emerging European industry with the founding partners ESRF, ILL and the French Alternative Energies and Atomic Energy Commission (CEA). The aim of this partnership is to accelerate research and innovation to make the next generation of batteries more efficient, safer, cheaper and more sustainable. ESRF and ILL provide regular access to the beamlines as requested for the projects selected on the basis of scientific excellence. CEA provides its facilities and experts. The Grenoble Battery Hub is linked to the European initiatives "BIGMAP", co-funded by the European Union's Horizon 2020 programme, and BATTERY 2030+. The next step for the Battery Hub is to open to the European battery research and development community to advance research in support of the European Green Deal, the UN Sustainable Development Goals and the European Action Plan on Batteries.

ESRF has a Technology Transfer office dedicated to promote the use of ESRF technologies to benefit society. ESRF has approximately 30 per cent industrial

users, including industrial-academical cooperation, and approximately 130 proprietary users per year.

Key points to attract and keep users:

- Cash income target. In 2016, a target of 1.6 million EUR was set as a request by the 21 member countries. The cash income target for 2021 is 2.7 million EUR and should increase by 5 per cent annually. This is the ESRF Technology Transfer office's only official key performance indicator, and has proven very important in stimulating industry-related activities at ESRF; a main driver internally.
- The research program InnovaXN is the second most important effort in engaging industry.
- Case studies are published on the website and are useful for spreading information and showcasing possibilities at ESRF.

The Industry Liaison Unit (ILU) is the focal point of industrial activities at ILL. The objective of the unit is to bridge the gap between ILL, a facility largely oriented towards academic research, and industry as an actor in projects that benefit from neutron techniques. Annual income from proprietary access averages 270 000 EURover the last few years, with about 12 unique customers a year. ILU fosters and supports research collaboration with resaerch technology organisations and industry (bi-lateral projects, European or national projects). The InnovaXN programme is the largest effort in engaging industry. ILL publishes case studies on dedicated webpages to show case possibilities for industry related topics.

3.4.7 European XFEL

Contact person: Antonio Bonucci, In-Kind Contributions Supply Chain Manager & Industrial Liaison Officer

The European X-Ray Free-Electron Laser Facility GmbH is an international facility founded by twelve participating countries. The construction started in early 2009 and the user operation began in September 2017. The 3.4-kilometre-long facility runs from the DESY campus in Hamburg to the town of Schenefeld in Schleswig-Holstein. At the research campus in Schenefeld, teams of scientists from all over the world carry out experiments using the X-ray flashes.

Key point to attract and retain users:

- The insight that the observation at European XFEL is not possible with any other technique and that such observation can support the innovation context to develop enabling technology.

European XFEL offers the following access modes: user access, priority access, and management contingency. European XFEL does not offer beamtime to industrial users if their experiments can be carried out elsewhere. In this case, European XFEL suggests synchrotrons or other research infrastructure

possibilities. Therefore, European XFEL works mainly with industrial users on the development of challenging experiments, with high uncertainty of the result.

The collaboration is done using a co-creation approach, whereindustry offers knowledge, assets and parallel characterisations on the sample, sample handling or sample environment side. Due to this limitation, European XFEL does not provide a business or a service offer, but industrial collaboration. If, in the future, it is possible to standardise experiments, as it is currently done in synchrotron facilities, then European XFEL might propose such services and likely even industrial proprietary access. Access modes specifically tailored to suit industrial users are either considered as industrial collaboration, with beamtime granted within management contingency, or as a user access mode. European XFEL had three industrial users in 2021.

To measure industrial user success, that is, societal or economic impact, case stories are used, as well as following up on how the observed system was relevant for the development of a new technology platform and how many companies are using such a technology platform for their product portfolio. This tracking requires time, in particular for the currently attractive field that is structural biology. This is measurable with an internal tool of intellectual property and collective intelligence, with direct information from the company, or investment tracking.

3.5 Facilitators

3.5.1 RISE

Contact persons: Pernilla Walkenström, Division Manager Materials and Production and member of the Council for the Office for ESS and MAX IV and Niklas Lorén, Project Leader.

RISE is Sweden’s research institute tasked with strengthening Swedish industry. It has around 130 testbeds, many overarching research fields, and turns over 3.4 billion SEK per year. Initiatives aimed at large-scale research infrastructure, with support from the Swedish Research Council, have been in progress for several years, and the goal of the activities is to help industry gain access to research infrastructures and to integrate these in RISE’s toolbox.

RISE functions as a link between industry and the facility, and has long experience of making facilities accessible. Its offering covers the entire value chain: from preparation via measurement to interpretation of data. RISE is active in industry-proximate research projects, builds up business models and entry-level environments, and also trains application experts. RISE currently employs six experts, of which one specialises in neutron research. RISE often works thematically, with focus on questions from industry, such as SuMo Biomaterials, a centre funded by Vinnova.

Highlighting the opportunities at research facilities such as ESS and MAX IV can be compared to “nano”, an area that is now well-known and much used,

through a large-scale initiative at the end of the 1990s. Industry was interested then, but it took a long time before they ‘joined the nano train’. To increase knowledge about the facilities, repeated information aimed directly at well-established companies and sectors of industry is a must. There is great need for communication aimed at research directors and chief executives, as it is they who in the end must be willing to invest resources.

Key points for non-academic users:

- Industry cannot wait for ordinary proposal rounds; instead, the cycles need to be one per month instead of one per six months.
- Opportunities at research infrastructures need to be made more visible through success stories. This can be done by RISE, higher education institutions, collaboration partners, Vinnova’s pilot projects and the Swedish Research Council’s accessibility initiatives. According to RISE, it is unclear who is responsible for ensuring that knowledge about the facilities increases. RISE takes its own initiatives and has important contacts, but has no clear mandate for this,
- Open or purchased beamtime depending on the product development phase. During the early phase, academic beamtime is fine, but if it is getting closer to an application, then companies wish to be as confidential as possible.
- It is sometimes difficult to get academic beamtime, due to complex but undefined questions. RISE proposes that beamtime panels (peer review panels) should include persons from both industry and academia, possibly two different calls with differing focuses.
- RISE works primarily pre-competitively today. If the pointedness of the question is increased, getting closer to business-critical information and enhancing the company’s competitiveness is easier. The pharmaceutical industry has good awareness of the facilities and has a lot of proprietary beamtime, while other sectors are inexperienced and therefore very pre-competitive.
- Initiatives such as Vinnova’s competence centre result in us getting more users at the facilities.

3.5.2 BiSS

Big Science Sweden (BiSS) is Sweden’s Industrial Liaison Office (ILO) serving Swedish industry, academia, institutes, and the big science facilities in which Sweden is a member state. BiSS' technical specialists review procurements from the research facilities, working actively and strategically in considering which member companies could be interested in a specific procurement. They then alert the relevant companies, and guide them through the tender procedure and technical specifications. Member companies have access to training sessions, seminars, conferences, study visits, and participation in large trade fairs. A company aiming to join the Big Science Sweden network must already be a supplier to research facilities or sectors with correspondingly high levels of technical specifications, such as aerospace, oil and gas, nuclear, robotics, or medtech. Today, the network comprises more than 230 qualified suppliers and partners.

3.5.3 Mediator companies

CAROTS exists within the framework for the Interreg Baltic Seas Region Programme. The aim of CAROTS is to establish a new type of small and medium-sized companies – commercial analytical research organisations (CAROs) – which provide services in various areas. CAROs will help companies to benefit from the knowledge and potential of researchers and research facilities in the Baltic Sea region. As mediator companies, they will make it easier for companies to access advanced research infrastructure (ARI) and scientific expertise that is needed to solve analytical tasks in areas such as new materials, nanotechnology or life sciences, and thereby speed up innovation considerably.

The aim of CAROTS is also to initiate a testbed in the Baltic Sea region for a new type of intermediaries between industry and analytical research infrastructure. CAROTS aims to involve private capital – by investing in CAROs – in the collaboration between industries and publicly owned research infrastructure.

In Europe, there is great potential for further companies of this type, and CAROTS is now implementing a start-up school to inspire and help researchers to start mediator companies (scientific service companies), which can support industry in getting access to research infrastructure, such as ESS and MAX IV.

There are not many Swedish mediator companies, and they do not cover all research fields and there is therefore great potential for improving this service to industrial companies. Known companies are CR Competence and Uppsala Synchrotronix (both involved in CAROTS) and also SARomics Biostructures and Scatterin.

4 Key components for increased accessibility

Through the contemporary environment analysis, a number of key components have been identified that are particularly important for increasing accessibility to large research facilities for non-academic users. The key components that are relevant for the Swedish facilities, primarily ESS but also MAX IV, are described below.

4.1 Governance

Fit-for-purpose governance creates preconditions for a research facility to broaden its accessibility. Without a clear mandate from the principal, funding body or owner, it is difficult to open up to non-academic use. Such governance exists to some extent, but can be improved. To enable the decision-making bodies of the research facilities to drive questions about access in non-traditional ways, the principal or owner needs to have a clear but not detailed target, which is followed up regularly.

The latest Government research bill, "Forskning, frihet, framtid – kunskap och innovation för Sverige", establishes that “to enable internationally competitive research to be carried out, Swedish research infrastructure needs to be strengthened. This requires both more funding and fit-for-purpose organisation and governance.” The bill also states that “The innovation system shall be reinforced with initiatives relating to, among other things, strategic innovation programmes, research institutes, test and demonstration environments, as well as lowered thresholds for utilisation and commercialisation. These initiatives contribute to addressing societal challenges, utilising research results and strengthening Sweden as a knowledge nation.”

The mandates of higher education institutions include collaborating with the surrounding society for mutual exchange, and working towards ensuring that the knowledge and competence that exist within the higher education institution are of benefit to society. Högskolelag (1992:1434).

The ESS Statutes state that access to the facility shall be given to European and international researchers as well as to other relevant users, following evaluation of scientific excellence and feasibility, and based on an access policy adopted by the Council. Such a decision was made by the ESS Council in 2015 at an overarching level, which now needs to be updated.

The ordinance (1994:946) relating to MAX IV states that the laboratory shall be accessible for researchers from higher education institutions and other research institutions in Sweden and for international researchers. It does not mention non-academic users. However, the special terms and conditions issued by the Swedish Research Council state that MAX IV shall enable and stimulate use of

the infrastructure by industry, that MAX IV is entitled to charge user fees for such use, and that up to 10 per cent of the user time at each beamline should be made available for non-academic users when there is demand.

4.2 Follow-up

Measuring the effect of investments made requires follow-up, and this is true also for research infrastructure. The number of users, number and type of publications, and utilisation of research in the form of improved or new materials, products and processes are some well-known ways of measuring effectiveness. This needs to be done continuously, not just over time at ESS and MAX IV, but also in relation to other national and international research facilities that Sweden is funding, to enable evaluation of the societal benefit that investment in research infrastructure produces.

One of the difficulties of measuring effects of investments in ESS and MAX IV is that it often takes a very long time for basic research – which forms most of the research carried out at these facilities – to be converted into something that can be characterised as being of societal benefit. On the other hand, the research carried out by industry and the public sector, sometimes in collaboration with academia, should be at a higher technology readiness level (TRL), and therefore more quickly become useable and valuable in terms of being converted into improved products or processes. Measuring societal effects is well-known to be difficult. One way of doing so is by using 'impact stories', which do not provide any volume measurement, but provide an idea of the value being created, and can serve as inspiration for others.

The product development that occurs within Swedish suppliers to major research infrastructures should also be evaluated, as this also contributes to increasing Sweden's competitiveness. This is today done to some extent by Big Science Sweden, and through reports ordered by the Swedish Research Council.

4.3 Awareness and knowledge

To ensure that the facilities' research opportunities benefit a broader range of users, academia, institutes, industry and society have to know what tools are on offer, and how they are best used.

Responsibility for increasing awareness of ESS and MAX IV rests primarily with the facilities themselves. But institutes and higher education institutions – in particular those that have experience of using synchrotron and neutron facilities – have responsibility for increasing awareness of the facilities as well, as this benefits their own research activities. Likewise, funding bodies of the facilities have a responsibility to increase awareness, as this leads to increased use, which in turn entails "greater returns" on investments already made.

The Government mandates given to the Swedish Research Council and Vinnova concerning coordination of national initiatives for ESS and MAX IV and establishing a national technology park function in conjunction with ESS and

MAX IV should also entail some responsibility for these public agencies to increase awareness of the facilities. The same applies for each of the two public agencies' mandates (via appropriations letters) to make research infrastructure accessible for non-academic users.

However, in addition to users from academia, institutes and industry being aware of the facilities, they also need to have sufficient knowledge to be able to use the tools on offer. Training in methods and techniques is therefore a significant part of increasing awareness and use of ESS and MAX IV, and here higher education institutions have an important task, as do also research funding bodies for funding doctoral students and graduate schools.

A well-implemented technology park function can become an important entry-level environment for companies in different regions of Sweden to contact the right persons to collaborate with to use the research infrastructure. This must be combined with the education mandate that higher education institutions have, as mentioned above.

Several initiatives within the method and technology training area are being implemented, for example by Swedish Neutron Scattering Society (SwedNESS), Lund Institute of Advanced Neutron and X-ray Science (LINXS) and the Röntgen-Ångström Cluster. SwedNess has provided training aimed at ESS users since 2016, and in March 2022 recommended that the Swedish Research Council requested funding from the Government of 150 million SEK for a special initiative to continue the graduate school during the period 2025–2029. The Swedish Research Council's special terms and conditions state that MAX IV shall "take a leading part in the development and training of the Swedish user community that uses synchrotron-based methods, for example by arranging periodic user meetings and taking responsibility for other relevant training initiatives". For many years, MAX IV has conducted summer schools, where students are given overarching knowledge about the methods and techniques used, and also provided time at the facility for experienced users who arrange methodology courses for university students. It would be much more valuable if some of these initiatives were carried out jointly by ESS and MAX IV. MAX IV has also started a new educational project, PRISMAS, in collaboration with Swedish universities. Important work is also carried out at higher education institutions, as experienced users teach and train their students, so that these in turn can use ESS and MAX IV.

Employing doctoral students in industry is a further example of how awareness and knowledge about research infrastructure can be increased and broadened, and produces added value straight away for those companies that fund such doctoral students. Postdoc positions at ESS, MAX IV and similar international research facilities can also provide an important addition that increases awareness of and knowledge within synchrotron and neutron research. Vinnova has funded projects for increased competence for doctoral students within neutron and synchrotron technology.

It should be noted that training is not mentioned in either the statutes for ESS or the ordinance for MAX IV, and that the research facilities therefore do not have such a mandate from their owners, which is a problem.

4.4 Open data

Incredible amounts of data will be produced at ESS and MAX IV. ESS is expecting to store ten petabyte of data per year when the first 15 instruments are in steady-state operation, that is by 2028. MAX IV is currently storing around two petabyte of data, and is expecting this to increase by one petabyte (10^{15} byte) per year. Enabling 'reuse' of these data is yet another way of increasing the effectiveness of investments made, which is also in line with the EU's data strategy. This would not just benefit academia, but also industry and the public sector.

The Swedish Research Council's special terms and conditions for MAX IV state that "research data and software developed at the infrastructure shall be made openly accessible as soon as possible". MAX IV is running the DataStaMP project, which aims to support the ambition for the European Open Science Cloud (EOSC) and correspond with the principles for FAIR research datathat is, to make it possible for both humans and technology to find, access, interoperate and reuse the scientific data produced at the facility.

ESS has a policy for scientific data adopted by the ESS Council in 2017, which deals with storage of data, open access to data, and also interoperability, including structure of data and metadata. This policy needs to be updated in some parts, in view of the latest development of general policies for the management of open data, such as EOSC.

4.5 Stimulating structures

To stimulate use of research infrastructure by the business sector and to increase the willingness and ability of employees to move between academia, industry and the public sector, structures that encourage and enable this are needed.

Neutral nodes and actors where collaboration and knowledge exchange can take place are important, and should be located across the whole of Sweden. These can also function as entry-level environments and provide support to industrial researchers before, during and after experiments and measurements at ESS and MAX IV. The technology park function (see Chapter 4.2) can become an important node if designed in a way that really makes it easier for researchers from industry to gain the right knowledge to use, and also gain access to, ESS and MAX IV.

Likewise, research institutes, such as RISE, and mediator companies, such as SARomics Biostructures, Uppsala Synchrotronix, Scatterin and CR Competence, are important for increasing industry's awareness and use of ESS and MAX IV. An initiative to increase the number of mediator companies, and broaden the number of areas in which they work, would be welcome, as these

are a competence pool with persons who understand the conditions of both industry and academia. In this context, CAROTS start-up school is an interesting initiative that has started its second series. In the first series, which ended in June 2021, three out of the total ten participants were from Sweden, and representatives from both CR Competence and Uppsala Synchrotronix took part as teachers.

Innovative support from funding bodies, such as "Research Infrastructure Fellows" from the Swedish Foundation for Strategic Research (SSF), which aims to highlight and fund key persons who engage themselves in the development of instruments and equipment, are also stimulating factors.

For Swedish suppliers of equipment to large research infrastructures, in Sweden and internationally, there is Big Science Sweden, which for a number of years has had the mandate to be Sweden's Industrial Liaison Office, and has achieved good results.

4.6 Application processes

For ESS, which only enters its operational phase in 2028, there is still no policy document describing how the allocation between academic and non-academic users shall be done. For MAX IV, the Swedish Research Council's special terms and conditions state that 10 per cent of the time at each beamline should be made available for non-academic users.

In addition to clear directives from the funding bodies, processes linked to applications for beamtime at ESS and MAX IV need to be designed in a way that favours both scientific excellence and also scientific, non-academic needs. This means that the committees that review applications need to have the relevant knowledge and competence to also assess industrial and socially beneficial relevance, and not just academic excellence. This, of course, places demands on adapting the assessment criteria to include these aspects.

This also means that models for access that correspond to the needs of industry and society at large are required, that is, fast access that does not follow the academic application cycle, which normally consists of two calls per calendar year, where the experiment is usually carried out one year after the application was submitted.

It should be possible for an applicant to choose whether the experimental results are to be confidential or published, and for this decision to be made after the results from the experiments or measurements are completed. If the results are published, the user is not charged a fee for the beamtime, in the same way as for academic researchers, while if the results are not published, then a fee equivalent to normal proprietary access will be charged.

For industrial users who use proprietary access, data security is extremely important, and this must be possible to ensure by the facilities.

4.7 Funding methods

To increase the number of non-academic users and expand the use of large research facilities to new areas, new funding models are required.

For experienced non-academic users, normal proprietary access is not a problem – they know what they are paying for, and usually achieve research results that justify the expense. For first-time users of ESS or MAX IV, it can be difficult to justify the expense of proprietary access in advance, as they might not fully understand what results they can expect.

There are several promising initiatives for increasing the proportion of companies and organisations that use research infrastructure together with academia. One of these is the strategic innovation programmes (SIP) funded jointly by Vinnova, the Swedish Energy Agency and Formas. Another is the calls for making research infrastructure accessible that Vinnova and the Swedish Research Council jointly issue.

For reasons of competition, there are rules for how financial activities can be funded[2]. Government support rules only apply when the recipient of support is a company. The permitted support level is dependent on the size of the organisation and type of support. For example, more support is permitted when it is support for research, development and innovation, where basic research can receive 100 per cent support. If the value of the support is less than 200 000 EUR, support can also be given for up to 100 per cent "de minimi" of little importance (cannot be stacked above a period of 3 years). When it comes to industrial research, then – in addition to de minimi support or basic research support – part of the total value of the beamtime can be given as a grant, provided:

1. At least two companies are collaborating, of which at least one is a small or medium-sized enterprise (SME), or the collaboration is carried out in at least two member states, or the collaboration is carried out in one member state and in one EES state, and none of the companies is responsible for more than 70 per cent of the total project costs entitled to support.
2. One company collaborates with one or more research organisations, and the research organisations are responsible for at least 10 per cent of the costs entitled to support, and are entitled to publish their own results.
3. The results of the research project gain considerable spread through conferences, publication, open databases or fee-charging or open software.

(Taken from Vinnova: Support levels, definitions, etc. for grants according to Vinnova's funding regulations.)

The share of the support according to 1, 2 and 3 above varies between a maximum of 50 to 80 per cent, depending on the size of the company. Beamtime is given as support to companies as follows:

[2] https://www.vinnova.se/sok-finansiering/regler-for-finansiering/statligt-stod/

- Full support if the sum of the value of the beamtime is less than 200 000 EUR.
- Full support if the beamtime relates to basic research.
- Part support according to 1, 2 or 3 as per above.

This links to the access group's proposal for non-academic access to beamtime via the "Strategic" and "Fast track", see the table in Chapter 5.6.

We consider that there is reason to review whether large-scale research infrastructure of this type could be kept out of the government support regulations. The argument for this is that the primary purpose of the facilities is research, even if a small part of the use relates to innovation and development. This is, of course, an issue that is outside our remit, and probably belongs at a high level of decision-making within the EU.

One idea that should be investigated is whether Sweden and the other member states of ESS can establish a strategic pot for beamtime, with a requirement for user groups to be composed of users from academia, industry and society as a whole. This is now being discussed intensively in the EU.

5 Recommendations

5.1 Governance

To optimise the societal effects of the investments in ESS and MAX IV, both to promote excellent research and to contribute to solving societal challenges and increasing competitiveness (or value creation), the governance of the facilities needs to be clarified, resulting in overarching and clear mandates relating to these aspects, and for non-academic access to ESS and MAX IV. This requires joint decisions by the member states on the ESS Council on its access policy, and for the Government to update the MAX IV ordinance.

5.2 Follow-up

A system for follow-up and evaluation, with clear methods and definitions, of Swedish and international research infrastructures should be developed. Not only bibliometrics (number of users and publications) need to be measured, but effects in the form of utilisation, societal relevance and economic competitiveness, as well as the affiliation of the user, should also be stated. Re-use of research data collected should be another parameter in such an evaluation. Collecting this information should be the responsibility of the facilities, however, the aggregation of it should be done at national level, for example by a suitable funding agency, such as the Swedish Research Council.

5.3 Awareness and knowledge

Increased awareness of the facilities and the tools that these supply leads to increased use, which is one of the measures of effectiveness and success that both ESS and MAX IV are assessed on. Outreach to stakeholders on the facilities is therefore a management issue, and should be prioritised. It is especially important to reach out with information to potential users from industry or the public sector, as these may have difficulty assessing the value of using the research facilities in relation to the cost.

Training in the methods and techniques used at the facilities contributes to increased awareness, and means that more researchers from a broader variety of scientific fields can use ESS and MAX IV. A long-term educational programme in the form of relevant method courses, integrating all techniques available at ESS and MAX IV, should be designed jointly by the facilities, universities and the user organisations FASM, SSUO and SwedNESS. A good example on how this can be done is the European Hercules programme. This should be funded via new appropriations to suitable public agencies, for example the Swedish Research Council, the Swedish Energy Agency, Formas, the Swedish Foundation for Strategic Research, or Vinnova.

5.4 Open data

Demands from research and society for open access to FAIR data are increasing. ESS and MAX IV should develop effective ways of contributing to open access to and re-use of data for research. For Sweden, the responsibility for making data accessible lies with the researchers carrying out the research, and their universities. ESS and MAX IV should therefore both develop methods that make it easier for researchers to accomplish this at their higher education institution or institute, and also clarify for both appropriation providers and the higher education institutions or institutes where the responsibility lies. Data from measurements taken and experiments done in collaboration between academia and industry, as well as from industries using regular beamtime (non-proprietary), should also be open and FAIR. Given the Swedish law on public access to information, a well thought-through process needs to be established to safeguard proprietary users' secrecy.

5.5 Stimulating structures

To increase and broaden the non-academic use of ESS and MAX IV, nodes should be established where support is provided before, during and after experiments and measurements. These should be part of the technology park function that Vinnova has been tasked to establish, but also consist of mediator companies and research institutes. Technology parks need to be established and distributed regionally and have sufficient funding to be able to maintain key persons (at least part-ime) in all regions.

The SESAM project**,** funded by Vinnova and lead by Uppsala University in collaboration with Lund University, Stockholm University and RISE**,** aligns well with parts of what is proposed in this document. The project's vision is to bring together the majority of universities and research institutes in Sweden with open laboratory infrastructure for research on a unified, legal and functional process for making them available. Close attention to the work done in this project is recommended when making changes to enhance the use of research infrastructures.

Incentives and support for researchers who are willing and able to start up mediator companies should be considered, and here CAROTS is an example of how this can be done. It is important that these organisations have key persons, who understand both the facilities, their instruments and research potential, as well as industrial logic. This emerged clearly from the contemporary environment analysis (for example PSI), see Chapter 3. In addition to the technology parks, directed calls, by Vinnova and/or similar sectorial bodies, to stimulate academic and non-academic collaborations through coordinated applications for beamtime can further promote these important cross-sector activities.

5.6 Application processes

It is clear that ESS, MAX IV and corresponding facilities have research, or even basic research, as their primary purpose, that is, generating knowledge. However, given the size of the societal investments, the part of the use of the facilities that may relate to utilisation, innovation and development should also be stimulated in order to justify the investments. ESS and MAX IV will impact on Sweden's and Europe's future competitiveness for up to 50 years into the future, and are therefore very strategic investments that should be greatly cared for, with a broad-based approach.

The application model we propose has two ordinary standard pots as the foundation: peer-reviewed access according to academic assessment, and purchased time at cost price respectively. The facilities should set targets for the proportions of purchased time; we think that 10 per cent of the total available beamtime is a good target, and similar to some corresponding international facilities (see Chapter 3).

We also make the assessment that a further "strategic" pot, and a "fast track" pot may be good ways of broadening the opportunities for use.

The strategic pot aims to stimulate collaboration between academic and non-academic parties. If such teams are set up, they can apply for a beamtime pot (targeting perhaps 5 per cent), where competition for beamtime is slightly lower, and the criteria and assessment panels are expanded compared to the academic standard pot. We propose, in addition to the standard scientific criterion, a relevance criterion for how the research contributes to Europe's future competitiveness, and an assessment panel consisting of academics and entrepreneurs, with around half of each.

This type of assessment is already being done by strategic actors in the research system, such as the Swedish Energy Agency, Formas, the Swedish Foundation for Strategic Research, and Vinnova. Having assessment panels with a mixture of competences in addition to purely academic ones is key for strategic assessments.

The final pot, "fast track", aims to give non-academic parties the option to determine, post festum, whether the results of the beamtime shall be proprietary or not. This pot (target of perhaps 5 per cent) is set aside solely for non-academic parties, with less competition for beamtime than the ordinary academic pot, and with faster assessment of the applications. The goal is to give non-academic users an efficient means of driving their innovation processes forward, and enabling them to use these advanced tools. The assessment criteria should also be expanded here, to include industrial and societal relevance, and the assessment panel should consist of a majority of industry and societal representatives, as well as of academics.

The infrastructures should also be able to 'incubate' new initiatives relating to challenges that require several actors to collaborate. There is already discussion between ESS, MAX IV and SciLifeLab to constitute such a platform within the

framework for InfraLife. The starting point is a societal challenge and a theme, which then gathers together researchers, the infrastructures and industry to find the solutions.

Our proposal for a model for application processes at ESS (and an updated model for MAX IV) is summarised according to the table below to satisfy the needs of both academic and non-academic researchers, each on their own, or in collaborative projects. Pot size percentages below are roughly estimated target values. Please note that additional modes can of course be added, depending on each specific research infrastructure and its strategic opportunities (see Chapter 3.3). Please also note that for the alternatives "Strategic" and "Fast track", government support regulations may come into force as described above in Chapter 4.7.

Access mode	Applicants	Beamtime pot size	Review criteria	Review committee
Regular, peer-reviewed	Open for all, must be openly published	All, minus the modes below (depending on other usage)	Purely scientific	Academic
Proprietary	Industry & society	Max 10 %	n/a, Direct access	n/a, Bought time
Strategic	Mixed*	Max 5 %	Science + strategic relevance (for Europe)	Academic + entrepreneurs
Fast track**	Industry, society and/or research institute	Max 5 %	Science + industrial and/or societal relevance	Academic + industry and/or society

*At least 1 co-applicant must be non-academic (i.e. from industry, society or research institute)

**After the experiment is done, the industrial/societal partner can choose to use results proprietorially and pay for the beamtime cost post festum (or otherwise publish results openly)

5.7 Funding methods

Funding to enable new non-academic users to pay for beamtime at ESS and MAX IV is needed, preferably via regular and synchronised calls from Swedish research funding bodies. For example, Vinnova is now setting up a new structure of their strategic innovation programmes, SIP 2.0, that will be slightly broader in scope compared to the existing SIP 1.0. It would be reasonable to assume that some of the new programmes will contain aspects where the broad area of materials sciences will be addressed. Collaborative research utilising the facilities ESS and MAX IV as well as other research infrastructures should be promoted in the calls for SIP 2.0.

6 Glossary

Word	Explanation
Access	Access (time) to instruments or beamlines
Beamline	Experiment station at MAX IV
Beamtime	Time at an instrument or beamline, during which the user carries out experiments or measurements.
FAIR	In 2016, the 'FAIR Guiding Principles for scientific data management and stewardship' were published in Scientific Data. The authors intended to provide guidelines to improve the Findability, Accessibility, Interoperability, and Reuse of digital assets. The principles emphasise machine-actionability (i.e., the capacity of computational systems to find, access, interoperate, and reuse data with none or minimal human intervention) because humans increasingly rely on computational support to deal with data as a result of the increase in volume, complexity, and creation speed of data.
Instrument	Experiment station at ESS
Normal access	Access (time) to instruments or beamlines that the user does not have to pay for, but that requires the user to publish their research results, usually in a scientific journal or a doctoral thesis. Applications are peer-reviewed.
Peer-review	A process where applications for time at an instrument or a beamline is reviewed by internationally recognised researchers within the same field to prioritise these based on scientific excellence.
Proposal	Application (for beamtime)
Proprietary access	Access (time) to instruments or beamlines that the user pays for. This means that the user (usually from industry) does not have to publish their research results, which may be business-critical. Applications are not peer-reviewed.
Research infrastructure (RI)	A facility where researchers use tools and techniques such as synchrotron light, neutrons, free electron lasers, electron microscopes, cryo-EM or large databases. Examples of

Word	Explanation
	research infrastructures in Sweden are MAX IV and ESS, famous international ones are CERN, ESRF and ILL.
User	Researcher or research team who uses one or more instruments/beamlines at a research infrastructure

ESS and MAX IV are strategically very important for Swedish research and innovation, and for strengthening our role as one of the world's foremost knowledge nations. The facilities will provide Sweden with unique conditions for conducting excellent research and create new opportunities for collaboration between academia, industry and the public sector in order to achieve solutions for sustainable societal development.

This report is written by a working group within the Council of the Office for ESS and MAX IV and has a special focus on ESS. The purpose is to investigate and give recommendations on how access to research infrastructures should be designed to create preconditions for the best research and for Sweden's and Europe's opportunities to contribute to solving the global societal challenges and improving their competitiveness. The report provides a number of concrete and useful pieces of advice and recommendations in order to increase non-academic accessibility to research facilities.