Radiation Sources: a brilliant future for Dutch research

Report of the Committee on Radiation Sources

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Contents

1 Executive summary

Assignment and goal of the report
The Governing Board of NWO instated beginning of 2013 a Committee on Radiation Sources with the task to report on the relevance and current state of large facility-based radiation sources (Synchrotrons, (X-ray) Free Electron Lasers and Neutron Sources) for Dutch Science and to investigate which options exist for Dutch research to use and develop radiation sources in the coming years. A more comprehensive picture of the radiation sources infrastructure and use is needed in order to make choices the coming years regarding the Dutch engagement in radiation sources.

Procedure
The committee held several meetings in 2013 in order to discuss the setup of the report. The committee used three sources of information. The first source is the set of answers to a survey that was sent to the most important international radiation sources. The second source is the answers given to a survey sent to Dutch researchers making use of the various radiation sources. And thirdly, the discussions during a central meeting on October 4, 2013 were used for the formulating of the current and future use of radiation sources and the needs of the researchers.

Main general findings concerning radiation sources
The committee emphasizes the importance of all three sources of radiation for Dutch research, and concludes that a large group of scientists must have continued access to these sources and that extra measures must be taken to realize this. Access to and engagement with these facilities is considered absolutely necessary for the Dutch scientific community to maintain its leading international position in various scientific fields.

As developments are rapid, there is a limited window of opportunity to participate in new developments. Engagement by Dutch knowledge centers, universities and industry in the development of new radiation-based facilities and instrumentation is indispensable for keeping up with international progress and scientific research: engagement from early stages onwards gives added value to Dutch science and industry, e.g. in the sense that the Dutch researchers contribute and have influence on new developments.

Specific findings about the need and urgency to engage in current and future sources
The committee concludes from discussions with the user community and by investigating the current state of affairs nationally and internationally that:

A ~ The membership of **ESRF** has the **broad support of the community** and **is considered vital**. The **Belgian-Dutch consortium** has proven to be **a solid platform** to represent the Dutch interests.

B ~ For the other radiation sources and facilities, the committee thinks that **X-ray Free Electron Lasers** and the **European Spallation Source ESS** offer **exciting and unprecedented opportunities** in terms of instrumentation that will lead to scientific breakthrough discoveries in a broad range of the physical and materials sciences.

B1 ~ The committee proposes to engage in FEL research by building a Dutch beam station at SwissFEL. Such activity not only provides the Dutch users with access to an X-ray FEL, it also allows us to construct a facility that will optimally benefit Dutch research activities. **A decision on Dutch participation should be taken early 2014**, as the construction of SwissFEL has started.

B2 ~ The Dutch community should associate to ESS as early as possible, to profit from the jointly executed developmental programs , **to guarantee a return-flow of knowledge and expertise** (human capital: "brain gain") into the Dutch scientific and application community, to influence developmental and operational ESS characteristics to Dutch needs and interests, and to have the necessary access from the very start-up of ESS operation.

C ~ The committee stresses the urgency for the community to get access to neutron facility ILL. **The Dutch community should connect to the world-top neutron facilities in 2014**: we are neither member of ISIS, where we have access limited to the LARMOR beam station, which will become operational only in 2017, nor are we member of ILL, which issued this year new and further restrictive conditions for access.

D ~ The committee proposes to continue **DUBBLE as an important, well-established and well-operated beam line** within ESRF. Funding beyond the time frame of the present allocation should in part originate through **the top sectors chemistry and energy**.

E ~ The committee concludes that a Dutch **standing committee on Radiation Sources** has to be set up, which ideally, should be established by NWO. That committee should be provided with a mandate that would ensure a proper, recognized and undisputed positioning within its strategic, scientific and financial environment. This standing committee should take over the work and recommendations of the current committee.

The Radiation Sources Day meeting held on 4 October 2013 indicated that researchers and industry representatives are interested in working together or at least share new insights. The committee proposes combining aspects of the **Radiation Sources Day** into one annual meeting, possibly with Belgium, organized under the auspices of the standing committee.

Reading Guide

This document consists of the following parts:

2 Introduction to Radiation Sources

Synchrotron- and neutron radiation were originally a side product of high energy research and nuclear physics. These sources have become so important for many aspects of research that in the last decades many radiation sources have been constructed as dedicated facilities for research in a broad range of sciences. As facilities they cover research areas ranging from food science, pharmaceutical science, biology, and polymer science to materials science. These facilities are of such a large scale that their construction and operation is often realized in multi-national collaborations. National and international centers operate under different types of governance but typically they provide access to member and non-member state users based on a peer-review merit system.

The Netherlands hosts no national or international facility for synchrotron radiation but is member of an international consortium that operates the ESRF, Grenoble. Together with Belgium the Netherlands forms the BeNeSync consortium that is a 6% partner of ESRF, which provides access to a wide range of instruments and covers the broad interest of the Dutch community. In addition, the Netherlands operates one beamline at ESRF together with the Flemish Science Organization (FWO) under the DUBBLE program. Meanwhile Dutch users enjoy access to many different synchrotron sources in Europe and worldwide through competitive transnational access programs. Dutch researchers make significant use of radiation facilities that provide access to non-member researchers. While Dutch researchers presently benefit from this peer-review merit system, various facilities are implementing access rules that reflect membership more directly.

The Netherlands has a small neutron source at Delft University of Technology that is currently being upgraded under the OYSTER program and includes a limited number of instruments for research. Dutch scientists make use of various neutron sources in Europe (ILL, Grenoble, ISIS Oxfordshire, BER2 Berlin). New sources have recently become operational in the US (SNS Oak Ridge) and Japan (JPARC).

The construction costs of such facilities are in the order of € 1-2 billion Euro with an operating budget of roughly € 100-200 million per year. This requires careful long-term planning. Several important developments are currently taking place, such as the construction of ESS. The ESRF is undergoing a major upgrade and new sources are being designed and constructed.

For the Netherlands the committee focuses on three topical aspects:

X-rays: Third-generation X-ray sources, such as ESRF, operate with much success and are key to many current and future scientific breakthroughs. Around 10 such facilities are operational in Europe. The upgrade program of the ESRF will ensure a continued leading position in synchrotron-based research. This report will detail the importance of third-generation synchrotrons for a broad range of Dutch scientists.

X-ray FELs: X-rays can now be generated by a totally new process that uses free electron lasers (FELs). These have unique properties in terms of coherence, brightness and time resolution. A limited number of these fourth-generation X-ray sources are being constructed and some have become available. They will not reduce the need for synchrotron sources, but instead offer new and different opportunities for scientific research. This report will specifically mention the construction of XFEL in Hamburg and SwissFEL in Villigen, Switzerland. The committee discusses the opportunities for participating in X-ray FELs.

Neutrons: Europe has had a leading position in neutron-based science with powerful sources at ILL, Grenoble and ISIS, Oxfordshire. Recently, the USA opened a more powerful source SNS at Oak Ridge, and Japan operates the JPARC neutron facility. Europe has engaged in enhancing the performance of its neutron sources to exceed the current world-top by developing a new source at Lund in Sweden, the European Spallation Source ESS. This source is now in the design phase and intends to overtake the performance of the existing sources in Europe, the USA and Japan.

2.1 Access for Dutch Researchers

Access to radiation sources for Dutch researchers depends on the access policy of the facility. In 2009 the American Physical Society, APS, published a very informative report on access to all synchrotron and neutron centers worldwide[1]. While over the last five years, various initiatives have been developed, many aspects of governance and access remain unchanged. There are in general two types of access policies for radiation sources, firstly for **national** facilities and secondly for **international** facilities. Both types of facilities usually request a scientific proposal that is assessed in a peer review process that results in a ranking.

For national facilities access is usually granted in a reciprocal fashion often even without formal agreements. Dutch researchers make use of various national sources even though there is no reciprocity. Important examples are DESY, PSI, APS, ALS, SNS and various others. More details are given in Section 3. International facilities offer access to researchers from member states and with limited access to non-member state researchers.

Dutch scientists currently have access to synchrotron radiation in a number of ways:

a) European Synchrotron Radiation Facility (ESRF)

- By way of the Dutch Research Council (NWO), the Netherlands participates, together with Belgium in the Benesync consortium, for 6 % in the ESRF in Grenoble, France, and thereby have access to the ESRF beamlines

- Together with its sister organization from Flanders (FWO), NWO also operates the Dutch-Belgian beamline (DUBBLE) on a bending magnet (BM26) of the ESRF, with an X-ray absorption spectroscopy (EXAFS, BM26A) and a small-angle X-ray scattering (SAXS, BM26B) station. Renewed in 2012 till 2017.

b) TransNational Access (TNA) in Access to large facilities programmes of the European Union (EU)

BioStruct-X gives access to structural biology facilities, viz. European X-ray crystallography, small angle X-ray scattering, and X-ray imaging beamlines, as well as protein production. 2011-2015

Calipso (Coordinated Access to LIghtsources to Promote Standards and Optimization) gives access to European synchrotrons and free electron lasers, including the Dutch facility (FELIX, Free-Electron Lasers for Infrared eXperiments) at the IMM in Nijmegen. 2012-2016

c) The EMBL (European Molecular Biology Laboratory) Outstation in Hamburg, Germany, provides beam time on protein crystallography and small angle X-ray scattering beam lines at the PETRA ring in DESY, to scientists from member states of EMBL.

- Travel funding for this access can be obtained in the BioStruct-X programme. 2011-2015

d) Access to synchrotron sources within and outside Europe by application, collaboration, or invitation.

International facilities such as ESRF and ILL reported that, "following the review and recommendation for beamtime based on scientific merit, there are some adjustments and balancing of actual time allocated among the member states and associates. At multinational facilities, the aim of adjustments is to bring the percentage of time allocated to scientists from member nations approximately in line with the percentage of funding contributed to the facility budget from member states. In multinational facilities, the need to award beamtime to users from member nations in approximate proportion to the budget provided makes it difficult to allocate time to non-member states beyond an agreed upon percentage."

[1] *Access to Major International X-Ray and Neutron Scattering Facilities*, Committee on International Scientific Affairs of the American Physical Society, 2009

The committee notes in agreement with the APS review[2]:

• Access to all facilities, whether national or multinational, can be obtained by collaboration with a scientist who is from that nation or from a member nation of the multinational facility.

• All proposals at all facilities, with one or two minor exceptions, are reviewed for scientific merit within the same proposal review program. Once reviewed, proposals at ILL and ESRF that do not include a scientist from a member nation are generally limited to 10 % and 5 % of total beamtime, respectively. ILL has recently reduced its access to non-members states and requests that at least 2/3 of the proposing team is from contributing member states.

• At national facilities, there is apparently no declared limit to proposals without a domestic partner. However, essentially all facilities keep track of foreign use of their facilities.

• Use of facilities by foreign scientists from institutions outside the nation is high in Europe, often 50%.

Thus, while it is true that Dutch researchers can apply for beamtime at many sources, it should be kept in mind that:

1. The sources are designed with complementary strengths and most publications are based on results at the few most powerful sources.

2. The Netherlands (together with Belgium) is 6% member of ESRF and this provides access to the entire suite of instruments at ESRF but the Netherlands is not a member of the most powerful neutron source, the ILL, nor of any X-ray-FEL facility.

3. Travel and accommodation expenses are essential for facilities to build communities. While typically no expenses are billed for costs of operating a facility, travel and accommodation expenses are an important aspect for Dutch researchers. The policies of various sources will be detailed below.

2.2 Dutch User Community

The Dutch user community is estimated to be around 400 researchers, who are actively engaged in synchrotron/X-Ray-FEL/neutron science. The community is broad and includes established and starting faculty, ranging from Spinoza Prize winners to recently appointed staff members at most Dutch universities. The community has a bi-annual meeting, together with Belgium, in SYNEW, but the governance is dispersed: the ESRF has a council in which one Belgian and one Dutch researcher are appointed (Ghijsen/Palstra) and the governance of DUBBLE is by a steering committee. For the neutron community, the governance is largely directed through the Delft University of Technology for national projects or engagement in international activities.

There are various committees that are partly organized through Chemical Sciences study groups, membership organizations or ad hoc memberships. They engage in a range of activities to organize meetings on topical developments, initiate courses for PhD students or facilitate access to radiation facilities. Relevant organizations in the field of radiation sources include:

- the *Nederlandse Vereniging voor Kristallografie* (NVK) which is a section of
    - the *Koninklijke Nederlandse Chemische Vereniging* (KNCV)
    - and the *Nederlandse Natuurkundige Vereniging* (NNV)
    - and the national branch of the IUC (International Union of Crystallography)
- the Dutch Association for Crystal Growth
- the *Nederlandse Vereniging voor Neutronen Verstrooiing (NVNV)*
    - is the national branch of the ENSA (European Neutron Scattering Association)
- the national branch of INSTRUCT, INSTRUCT-nl, the ESFRI program for structural biology

[2] APS review, page 45.

While all these activities assist towards building a community, there is currently no overall committee with the mandate to shape future policy and activities. At the nationally organized Radiation Sources Day on 4 October 2013, there was strong support for the appointment of a committee to govern the activities for radiation sources. This committee could act as spokesperson for the community to funding organizations and other organizations and assist in activities that are at the moment performed on an individual basis.

The Dutch user community of radiation sources is made up of the following disciplines and the following researchers make use of radiation sources (this is not a comprehensive list):

a. Materials science / Solid state physics / Hard condensed matter:
Prof. Fred Bijkerk (UT), Dr. Graeme Blake (RUG, VIDI), Prof. Alexander Brinkman (UT, VIDI and ERC Consolidator Grant), Prof. Ekkes Brück (TUD), Prof. Joris Dik (TUD, VIDI 2010), Prof. Andre ten Elshof (UT, VIDI 2005), Prof. Mark Golden (UvA), Prof. Hans Hilgenkamp (UT, VICI), Dr. Erik Kelder (TUD), Prof. Fokko Mulder (TUD), Prof. Beatriz Noheda (RUG), Erik Offerman (TUD, VIDI), Prof. Thomas Palstra (RUG, Director Zernike Institute), Prof. Katia Pappas (TUD), Prof. Theo Rasing (RUN, Spinoza Prize 2008), Prof. Ian Richardson, Prof. Guus Rijnders (UT, VIDI), Prof. Jilt Sietsma, Prof. Elias Vlieg (RUN, Director IMM), Dr. Dr. M. Wagemaker (VIDI, ERC), Prof. Wim van Westrenen (VU, University Research Chair), Prof. Jan Zaanen (Spinoza 2006), Prof. Sybrand van der Zwaag (TUD, Scientific director Delft Centre for Materials).

b. Structural biology / Protein X-ray crystallography:
Structural biology Groups in Utrecht, Groningen, Leiden, NKI; Prof. Jan Pieter Abrahams (Leiden), Dr. Bert Janssen (UU, VIDI), Prof. Piet Gros (UU, ERC advanced grant and Spinoza Prize 2010), Dr. E. Huizinga (UU), Dr. Navraj Pannu (Leiden, VIDI 2005), Dr. Anastassis Perrakis (NKI), Dr, Raimond Ravelli (UU, VIDI), Dr. Holger Rehmann (UU, VIDI), Prof. Titia Sixma (NKI, ERC advanced grant 2009), Dr. Anke Terwisscha van Scheltinga (RUG), Prof. Dirk-Jan Slotboom (RUG, ERC starting grant and VICI); Dr. Andy Mark Thunnissen (RUG); Industry: Joost Uitdehaag (start-up Oss).

c. Polymer chemistry / Soft condensed matter:
Dr. Wim. Bouwman (TUD), Prof. Joke Bouwstra (UL), Prof. Jeroen Cornelissen (UT, VIDI 2005), Prof. Martien Cohen Stuart (WUR and UT, ERC Advanced Grant 2013), Prof. John van Duynhoven (WUR), Dr. P. Kouwer (RUN), Prof. Jasper van der Gucht (WUR), Prof. Ronnie Hoekstra (RUG), Prof. Gijsje Koenderink (FOM AMOLF, VIDI), Prof. Eric van der Linden (WUR), Prof. Katja Loos (RUG, VIDI 2009), Dr. Florian Meirer (UU), Prof. Bert Meijer (TUe, Spinoza 2001 and ERC Advanced Grant), Prof. Gerrit Peters (Tue), Dr. Thomas Schlathölter (RUG), Dr. Nico Sommerdijk (Tue), Dr. Ilja Voets (TUe, VENI, SNF, DSM & AKZO awards), Industry: Dr. H. Tromp, Dr. Arjen Bot.

d. Catalysis:
Professor Harry Bitter (WUR), Prof. Frank de Groot (UU, ERC advanced grant 2013), Prof. Emiel Hensen (VIDI 2007), Prof. Guido Mul (UT), Prof. Rutger van Santen (Tue, Spinoza Prize 1997), Prof. Bert Weckhuysen (UU, Spinoza Prize 2013), Dr. M. C. Feiters (RUN).

e. Instrumentation, Radiation sciences and method development
Dr. Harry van der Graaf (ERC Advanced Grant 2013), Prof. Katia Pappas (TUD); Industry: Dr. Hans Roeland Poolman (ASI), Dr. Josef Uher.

3 Inventory of Dutch Use of International Facilities

This inventory has been drawn up by combining three sources of information. The first source is the set of answers to a survey that was sent to the most important international facilities / radiation sources. The second source is the answers given to another survey sent to Dutch researchers making use of the various radiation sources: the committee received 39 responses from individual researchers (Appendix 4). And thirdly, the discussions during the Radiation Sources Day of 4 October 2013 were also useful for the formulating the current and future use of radiation sources and the needs of the researchers.

In this section the committee addresses the following issues: the use of the different facilities by Dutch researchers, the current funding of the travel costs, the foreseen use of the facilities in the future, the success rate of Dutch applicants and the desires of the different researchers.

Main Conclusions of the inventory

a. Access: The main conclusion is that access of Dutch users to synchrotrons is not a large obstacle as they have a very broad choice of sources worldwide that are available to them through competitive scientific access schemes. The high quality of the research ensures continuous access. For the FEL use, access is limited by the limited available beam time, although Dutch researchers are competitive in applications. For the neutron users access is more problematic because there is no transnational access to the major international facility ILL and very limited access to ISIS, the main pulsed neutron source in Europe. Access to the ILL beam time is mostly limited to collaborations but new regulations are in place, which will regulate this access more and reduce these possibilities even further still. There is access to the smaller sources such as BER2 and FRM2.

b. Funding of travel costs and research: For a significant fraction of users there is support from NWO, ESRF, European projects like BIOSTRUCT-X and CALIPSO and other transnational arrangements like NMI3-II, but not all travel is covered. These arrangements for reimbursement are variable, and there is the danger they might disappear (BIOSTRUCT-X, CALIPSO and NMI3 possibly in 2015, as the new Horizon program has limited options for new calls). All respondents to the web survey and people present on the radiation sources day stress that funding of travel costs and research is important to allow effective usage.

The ESRF has a special program for Macromolecular Crystallography: the Block Allocation Group Proposal (BAG), which is very useful for groups working in this domain, but the number of scientists allowed to travel is often smaller than the number of groups measuring. If the source is outside Europe, the research group often funds the travel costs through its own budget.

c. Success rate: The general conclusion is that the success rate of Dutch researchers is quite high. Some researchers indicated that their success rate is 90-100 % which is confirmed by the numbers given by the international facilities (Appendix 3). The success rate at some facilities is lower when the competition is fiercer.

e. Dutch involvement / Priorities
One of the conclusions during the national Radiation Sources Day is that the Netherlands should participate more actively in the different facilities and that there are opportunities for close collaboration within a chain (researchers, large industry, SME's / manufacturers / funding organizations / ministries). Respondents to the facilities survey and the participants during the Radiation Sources Day have indicated what they think are the priorities per type of radiation source facility. Some facilities indicate that they are open to more Dutch collaboration, for example: "bilateral agreements between Dutch partners and the facility may be considered (e.g. beam time vs. manpower, etc.) Below the priorities are given.

It is clear from the answers to the users survey that the ESRF and DUBBLE are important for a large group of researchers making use of synchrotron radiation; they are mentioned frequently in the survey as important sources and as a priority for further investment. Other synchrotrons mentioned are SLS and DESY. The current priorities when it comes to neutron sources are ILL and ISIS, with a future focus on ESS. The meeting expressed support for becoming a member of XFEL to engage with FEL activities .

f. Foreseen use

In the users survey one of the questions to the Dutch researchers was how they expect their use of sources to be in 5 years: to grow, remain constant or diminish. The 40 respondents were very clear on this matter: 20 researchers expect growth, 18 expect a constant use, and none of the respondents expect that the use of sources for their research will diminish. The Radiation Sources Day discussions also made it clear that the use of radiation sources will remain critical for a large number of researchers over the coming years.

This inventory further focuses on three different sorts of radiation sources: Synchrotrons, Neutrons and X-ray Free Electron Lasers. The users of these sources have formulated a number of conclusions and recommendations per source.

3.1 Synchrotrons

As indicated above Dutch researchers make use of numerous synchrotrons in the world, including facilities in Switzerland, Germany, France, the UK and the USA, and occasionally sources in Singapore or Japan. The synchrotrons primarily used are the ESRF (including DUBBLE), SOLEIL, National Synchrotron Light Source (Brookhaven), Swiss Light Source, Deutsches Elektronen-Synchrotron (DESY), SSRL (Stanford), ALS (Berkeley), MAX IV, ELETTRA and BESSY.

During the Radiation Sources Day all participants in the synchrotron radiation session agreed on the need for a national platform and a standing committee, and the importance of synchrotrons for their research. Other important issues for synchrotron radiation users are:

- Access and travel support (transnational access must be continued)
- Flexibility of the experimental set-up and beamline scientist support, such as provided by DUBBLE
- The possibility to apply for long-term projects, to guarantee beam time for PhD and post-doc projects
- Beamline scientists, with links to the Dutch community, in local ESRF/EMBL groups to support crystallography are needed

3.2 Neutron Scattering

There are few neutron sources in the world and access is currently an obstacle for Dutch users. During the Radiation Sources Day all participants in the neutron radiation session agreed on the need for a national platform and a standing committee, and the importance of neutrons for their research. Furthermore, during the Radiation Sources Day the following conclusions were formulated:

- High priority must be given to the need for "long-term" institutionalized access to the high neutron intensity source of the ILL, and to ESS. This would enable long-term planning e.g. through long term proposals or common PhD programs that are only available to member countries.
- Neutron scatterers use other techniques as well. This is particularly the case for X-ray diffraction, which also belongs to the basic scientific infrastructure of almost every lab. In this context, neutron scattering is used to solve problems that cannot be solved by other means.
- The "more than neutrons" approach is very important: in-situ experiments and advanced data analysis and modeling tools.
- Dutch expertise in the field of neutron scattering is an important "human capital" catalyzing both scientific and technological developments e.g. for spin-out and high-tech companies, such as Amsterdam Scientific Instruments.

3.3 Free Electron Lasers

X-ray Free Electron Lasers are an extension of insertion devices of third generation synchrotrons and are being constructed as independent facilities. They operate under the conditions of Self Amplified Spontaneous Emission (SASE) and provide not only much higher brightness but also much enhanced time resolution. With a given typical velocity of e.g. electron motion, this time resolution can be translated to a high spatial resolution. The extreme brightness requires special attention for the sample configuration and allows the study of structure and dynamics of small samples down to individual molecules. Some facilities have started operating and various other are under construction.

There are currently the following FELs in operation: LCLS (Stanford), FLASH (Hamburg), SACLA (Japan) and FERMI@Elettra (Italy) and under construction: XFEL (Hamburg), SwissFEL (Switzerland) More details about this are given in Section 4.

During the Radiation Sources Day all participants in the FEL session agreed on the need for a national platform and a standing committee, and the importance of FELs for their research. Furthermore, during the central meeting on the 4th of October the following conclusions were formulated:

- FELs have unique capabilities in terms of temporal- and spatial resolution, brilliance and coherence. They present a developing frontier of science and scientific instrumentation, with important links to innovations in e.g., catalysis, electronic/magnetic switching, biology and pharmacy, for example. As a leading scientific country, the Netherlands should also be leading in science using FELs.
- Not only the use, but also Dutch involvement in instrumentation is very important. (or better: a must). This early involvement will advance the science using FELs, but is also very important for innovation. For example, it will provide technical know-how to. The Netherlands and will train people in such complex projects and technologies.
- Developing an expert base is very important for The Netherlands. This would also open up more possibilities and use of Dutch companies of FELs.
- The construction of an X-ray FEL in the Netherlands has been pursued in the past but the discussion on this has been closed. Instead, it is important now to participate in X-ray FEL developments abroad, for example in XFEL Hamburg or SwissFEL. Given the considerable economic interest in this, beside the scientific value, also the Ministry of Economy Affairs could be a natural partner in such an involvement.

4 Facilities under construction

4.1 ESS

ESS is a new international scientific pulsed neutron source to be built in Lund, Sweden. It will be a multi-disciplinary science facility, serving the life sciences, physics, chemistry and materials science, as well as energy and climate sciences.

In building ESS, Europe will retain and maintain the world lead in research activities encompassing the broad areas of science requiring neutron-scattering methods.

ESS will offer neutron beams of unparalleled brightness and higher peak intensity compared to any existing spallation source. ESS will deliver neutrons in long pulses of several milliseconds (nominally 2.86 ms) with low frequency (nominally 14 Hz) to its instrument suite (22 instruments, operational in 2025, later to be extended to 40), thus enabling efficient use of high intensity long wavelength neutron beams. ESS construction costs are circa 1.8 B€, operational costs circa 140 M€ per year (both 2013 reference year). The initial operation is anticipated to start in 2019, with full operation from 2023 onwards.

The proton beam power will be 5 MW, and, compared to ILL and ISIS (2013) ESS neutron scattering instruments will achieve up to 30 times the sensitivity for detecting low signals; compared to SNS and JPARC (2013) ESS will offer up to a factor of 10 times superior beam intensities in experiments with the same resolution for thermal and cold neutrons.

ESS offers neutron beams of high flux, cold and / or polarized neutrons, for faster measurements, smaller samples and wider dynamic ranges, without any deteriorating sample heating, which permits the (sub)atomic level probing of structure-function interactions of for example bio-systems, soft nanostructured- and microstructured materials, materials in chemistry, magnetism and energy, and archeology and geosciences- and earth sciences. The Dutch neutron scientific and application community *needs* the association with the ESS, to prevent losing track of the world-top in materials research. Today’s society, and especially the Dutch high-tech society, strongly depends on knowledge and development in materials, and it just simply cannot afford to lose its ties with Europe's efforts to maintain and expand its strong global position in materials research.

Absence of regulated Dutch ties with the European facilities will result in the Dutch community falling behind the top in (neutron) materials science. Ensuring access is also logical in view of the efforts by the OYSTER programme to get the reactor facilities of Delft University of Technology into a position to support and prepare Dutch developers and users for using top European neutron-scattering instrumentation.

The Dutch community should associate with the world-top ESS as early as possible to benefit from the jointly executed developmental programmes (ESS is under construction, anticipated initial operation starts 2019), to guarantee a return-flow of knowledge and expertise (human capital: "brain gain") into the Dutch scientific and application community, to steer developmental and operational ESS characteristics to Dutch needs and interests, and to have the necessary access as soon as ESS becomes operational.

4.2 XFEL Hamburg

The European XFEL (hereafter referred to as XFEL) is a new research facility that is currently under construction near the site of DESY in Hamburg. It will complement the existing FLASH soft X-ray free electron laser (which covers a wavelength range of 4-45nm), extending the wavelength range down to 0.05nm. The new XFEL installation will become operational in 2015-2016.

Employing a central 2.1 km linear electron accelerator (electron energies up to 17.5 GeV), it will comprise several X-ray beamlines, originating from 3 undulator systems. The SASE 1 and SASE 2 undulators will cover the photon range of 0.4nm to below 0.05 nm (3keV to over 25 keV) and will be used for the SPB (Single Particle Clusters and Biomolecules), the FXE (Femtosecond X-Ray Experiments), the MID (Materials Imaging and Dynamics) and HED (High-Energy Density Matter Experiments), instruments, respectively. The SASE 3 undulator will provide photons with wavelengths of 4.7 nm to 0.4 nm (0.26keV to 3keV), for the SQS (Small Quantum Systems) and SCS (Spectroscopy and Coherent Scattering) instruments. Interestingly, the 'water window' is between 2.3 and 4.4 nm, which is the wavelength range for which water is transparent for X-rays and that is important for biological experiments, for example.

The XFEL system operates with 27,000 pulses per second, with a pulse duration of less than 100 fs. The short pulse duration is interesting for making movies of chemical reactions or studying electromagnetic effects in solid states like the reversal of magnetism. The repetition rate is the highest for XFELs in the world. For many experiments this is advantageous. However, for certain experiments it might also cause complications, as relaxation process can be slower than the time between pulses.

The peak brilliance will be $5x10^{33}$ photons/s/mm^c/mrad/0.1% bandwidth. The average brilliance will be $1.6x10^{25}$ photons/s/mm^2/mrad/0.1% bandwidth, which is about 10,000 times higher than conventional X-ray sources. These X-ray flashes are coherent, as in lasers, allowing special interference techniques et cetera to be used.

Twelve countries are currently participating as members in the European XFEL (Denmark, France, Germany, Greece, Hungary, Italy, Poland, Russia, Slovakia, Spain, Sweden and Switzerland). For their membership they obtain a seat in the XFEL Council, which decides on important issues of the XFEL governance and infrastructure. For the time being, membership does not guarantee a specific access, as access will be determined based on scientific merit. But it may be expected that the membership countries will demand a certain level of access if the pressure on the beam time becomes very high.

The construction costs for the facility have amounted to approximately € 1.15 billion, of which Germany covers 58%, Russia 27% and other international partners between 1 and 3%. The annual operating budget is about € 140 million. It should be noted that a considerable part of the national contributions have been in the form of in-kind contributions. Once the facility has been constructed, and this point has almost been reached, the possibility for in-kind contributions will naturally become more limited. However, as has been indicated by the XFEL management, there is still ample room to enter into a national membership and to contribute, for example, to the construction of new instruments. And even without a national membership, there is a great interest from the side of XFEL in strong interactions with the Dutch research community.

For Dutch researchers, the European XFEL facility will be interesting for the study of processes in biomolecules (e.g. in photosynthesis), making movies of chemical reactions (e.g. in catalysis), unravelling details of electronic correlations and magnetism and creating extreme states of matter (materials at high pressures & high temperatures, of interest for plasma physics and fusion)

4.3 SwissFEL

The SwissFEL installation is currently in construction on the site of the Paul Scherrer Institute in Villigen, Switzerland. It aims to have a first hard X-Ray beam line ('Aramis') ready in 2017, with a second soft X-ray beam line ('Athos') following in 2019.

SwissFEL will cover the wavelength range of 0.1-7nm (Aramis 0.1 - 0.7 nm and Athos 0.7 – 7 nm). The pulse durations will be in the range of 50 down to just a few femtoseconds, which allows for high time resolution. The pulse repetition rate is 100 Hz. The Athos branch will have tuneable polarisation and external seeding thereby presenting the users with full control over the X-ray pulse characteristics. This means that SwissFEL beamlines can be designed and optimised according to the nature of the experiments that the users request. The total construction cost for SwissFEL amount to approx. CHF 275 million, which is mainly covered by the Swiss federal government with a contribution from the Canton of Aargau.

SwissFEL is mainly intended as a national Swiss user facility, with strong interest from the pharmaceutical industry, but will be open for the global research community based on quality and relevance of research proposals.

The SwissFEL management has explicitly invited the Dutch research community to join in the development of measurement stations. With this, it has emphasised that Dutch industry (in particular VDL) is already an important supplier of components for SwissFEL. An advantage of getting involved at this stage in SwissFEL is that the research directions (capabilities of instruments) can be steered according to the Dutch interests and that Dutch engineers can be trained in the hardware of coherent hard X-rays. It should be borne in mind, however, that it will be several more years before SwissFEL becomes fully operational and that in the meantime, access to other X-Ray FELs needs to be acquired.

The PSI has committed in constructing a FEL, driven by science and by business of pharmacy, chemistry, mechatronics and electronics. While the groundwork has started, only one beamline has been designed. The second beamline has been specified to operate in the soft X-ray regime, where Dutch research has considerable interest. This interest has been discussed in a dedicated workshop in April 2013 at FOM. The committee chair has discussed this with PSI and they showed a strong interest in Dutch participation in SwissFEL. The engagement of the Netherlands has various advantages:

-the beamline still needs to be designed in various aspects, which allows full involvement of Dutch companies in developing the relevant components. The can provide these companies with a competitive advantage;

-the construction of a beamline can consist of in-kind contributions, whereas participation in a FEL where the design is almost complete requires a larger cash contribution;

-Switzerland is of a comparable size to the Netherlands, which allows strong involvement in the management, setting directions, priorities et cetera;

- Switzerland has complementary strengths in industries, for example, in pharmaceuticals, soft condensed matter, nanotechnology, which can be used to define a strong suite of instruments;

- Switzerland has a very strong research base, and involvement with PSI can bolster joined research programmes.

The committee strongly urges NWO to explore the options to engage in building a second beamline at SwissFEL, with strong involvement of Dutch industry.

The potential users from the Dutch research community and the scientific interest in X-ray FELs is the same as for the European XFEL in Hamburg stated above.

5 Public-Private Partnerships

The case for engaging in large facilities is not just driven by the science case, but also by sound business policy. A facility, like ESRF, doubles the return on investments in it by additional expenditures in the region on construction, housing, schools, etc. Most importantly, the large-scale facilities utilise and develop cutting edge technology that has the potential to provide the participating industries with competitive advantages. It bolsters a regional innovation ecosystem that attracts businesses and diverse talents. X-ray and neutron facilities as well as other laboratories in Grenoble have resulted in setting up of the Grenoble Innovation for Advanced New Technologies, GIANT, with large companies (STM, Siemens, Schneider), other high-tech companies around MINATEC, Polytec and many start-ups. It also attracts other talents e.g. the Grenoble Ecole de Management. Similarly, the Paul Scherrer Institute, PSI, in Villigen, Switzerland, is fuelled by neighbouring pharmaceutical, chemical, electronic and other companies in the Zurich area. The ESS intends to boost the Copenhagen-Lund-Skåne region with many international companies, forming such a regional innovation ecosystem as well.

Dutch companies profit from Dutch participation in large-scale facilities even when the facilities are not based in the Netherlands. They obviously profit from access to these institutes for their research programmes (e.g. DSM, Unilever, Friesland Foods). Moreover, they can participate in developing and offering various technologies or components to these facilities including components (VDL), electronics (Stork), vacuum, detectors (ASI, Panalytical), and construction. Many of these contributions are prominent in the top sector HTSM under the Advanced Instrumentation programme. An example of the promotion of such activities took place in June 2013 in Grenoble at the GIANT Campus when around 25 Dutch companies participated in the meeting Netherlands@GIANT to promote Dutch industry.

Existing private/public institutions such as CCC (Carbohydrate Competence Center) and WETSUS (Center of Excellence for Sustainable Water Technology) see numerous possibilities for research in directions such as protein folding, enzyme bio-catalysis, colloids, membranes and biobased components. The CCC and WETSUS could act as intermediaries between academic research at X-ray FELs and the companies participating in CCC and WETSUS to lower the threshold to using a large-scale facility such as SwissFEL.

X-ray and neutron sources are by design driving factors for nanotechnology, an area in which Dutch industry is very strong. In the past, this has resulted in programmes such as Nanoned, Microned and NanolabNL, that promoted innovative research in areas of Dutch recognised strengths. Many Dutch companies participated in such programmes. Now, these activities are partly organised under the top sector HTSM. A very visible example is ASML, which manufactures wafer steppers for lithography in the soft X-ray regime, with an interest in X-ray sources, components and materials that operate in the soft-X-ray regime. Many other companies have an interest in the nanometre regime for advanced materials such as NXP, Thales (Hengelo), Tata (Ijmuiden), et cetera. Beyond HTSM, nanotechnology is crucial for soft condensed matter and polymer materials where Dutch companies have a world leading presence: AKZO, Unilever, DSM, Friesland Foods and others. Also, Dutch industry or Dutch subsidiaries of international companies engage in instrumentation (ASI, Panalytical, Bruker, etc.).

Technology development oriented companies such as INCAS[3] and Sensor Universe are ready to meet the challenges posed by the large volumes of data to be handled for X-ray images at high repetition rate.

The X-ray and neutron sources are also crucial in the top sector chemistry for catalysis, hydrogen storage, etc. High-resolution X-ray crystal structures are important for drug design efforts. Although large pharma companies have left the Netherlands, there is still a very vibrant range of SMEs in Leiden and in Oss at the PIVOT park (~20 start-ups), with strong links to university medical chemistry (through the EU-open screen consortium and its Dutch counterpart). In Nijmegen the company Synthon (1400 employees) originally focussed on generics, but it has increasing interest in developing new molecules, which would benefit from PPP constructions. In Wageningen there is a long-standing interest in high-resolution X-ray structures of interest to the Agro/food sector.

Within the Netherlands, public-private partnerships can be initiated by partner industry days, in which mutual interests are explained and illustrated. Industry comprises both users and development-oriented industry. Instrument-developers and/or facility-associated staff can team up with industry in a mutual expression of interests, capabilities, questions and requirements, to identify matching between parties. ILO networks may be of particular importance at this stage.

There are ample possibilities to join forces in approaching funding bodies, e.g. top sectors, roadmaps, or any further programmes, such as e.g. HTSM Advanced Instrumentation, or other (see Appendix 2). Programmes should be initiated as early as possible, to make the possibility to "shape" programme aspects that match the joined perspectives.

The user industry can be accommodated by teaming up with academic partners that have experience with instrument characteristics, sample environment, full back-up in instrument use and data processing. Pilot experiments can start up in the Dutch facilities to become familiar with the samples, the environment and conditions, and the possible outcomes. Final experiments can be jointly executed at top international facilities.

Development-oriented industry should be a partner in approaches and initiatives from the earliest possible moment: their involvement is very relevant not only in "return-of-investment" policies, but also in terms of "human capital" considerations, that is, the influx of high-tech expertise into Dutch industry and knowledge centres.

At present the Netherlands is only a member of ESRF with respect to X-ray, XFEL and neutron facilities and this limits the country's opportunities. The example of Netherlands@GIANT shows that this membership offers opportunities for Dutch companies beyond participating in research programmes. For various sources that are under development, notably XFEL, the progress is in such an advanced state that crucial choices in the design have been made and limited freedom exists to partner in the development of components and instrumentation. For facilities that are not yet fully rounded-off in their design, notably SwissFEL and ESS, there are many opportunities to obtain a leading role in the construction, electronics, detectors, vacuum, and mechatronics, and from these Dutch companies can develop new products. We will elaborate on this further in Section 9.

6 Cooperation with Belgium

Belgium and the Netherlands currently participate in the BeNeSync collaboration and in DUBBLE. BeNeSync has a 6% share in the ESRF and is the shared effort of the countries. In the Dutch-Belgian beamline (DUBBLE) at the ESRF, the Belgian part is covered by the support of the FWO, the Flemish organisation for scientific research.

Belgium does not have any neutron sources but participates in the ILL (the BELPOLSWENI consortium). There are no concrete plans to participate in the ESS yet. Belgium does not have a national synchrotron users organisation. It has a synchrotron radiation contact group (Wallonia only, with guests from Flanders), with representatives of all Belgian Universities. The Federal Science Council (BELSPO) has instituted a National Guidance Committee: European Sources for Synchrotron Radiation and Neutrons (NAC SRN) and recently a committee that will investigate the possibilities to invest in a FEL has been appointed.

Because of the existing cooperation in the ESRF and DUBBLE it seems a natural step to continue looking together with Belgium for other collaborations in the field of radiation sources. A Dutch delegation visited FWO in October 2013 to discuss further collaborations in a general way, not specifically radiation sources. Other incentives to work together might be that the Netherlands and Belgium can join forces. The two countries together represent about 27 million inhabitants and a joint approach would allow a larger group of researchers to be supported.

Another important motive to join forces is the complementary nature of Dutch and Belgian industries. Belgium has large pharmaceutical companies like Janssen Pharmaceuticals, UCB Pharma, GlaxoSmithKline and Roche. The Netherlands has large companies that use chemical and polymer research, like SHELL, DSM, AKZO Nobel.

Belgium is currently looking for possibilities to participate in one of the FELs, XFEL or SwissFEL, and it might be an opportunity to explore this together because a large group of Dutch scientists recommends that this should also be done for the Netherlands.

There are two ways for the Netherlands and Belgium to collaborate: the first is to become a joint member of one of the sources by paying an annual fee, in the same manner of BeNeSync. Another way to work together is to construct and operate a beamline together; in this respect the DUBBLE beamline can serve as an example.

Cooperation between the two countries, therefore, seems an interesting option to explore. We need to explore whether to partner with Belgium as a whole, or only Flanders.

7 Policies in other European countries

In this section, the committee gives a brief account of the policies and measures in three European countries that are somewhat comparable in size, population and in science.

7.1 Switzerland

Switzerland is a country comparable to the Netherlands in many respects (slightly larger in size, smaller in population). It is geographically surrounded by the EU but not a member, and has strong industries (e.g. pharmaceutical) with high added value. The so-called ETH domain includes recognised top institutes (such as ETH Zurich, EPFL Lausanne) and the Paul Scherrer Institute in Villigen. Switzerland has a spallation neutron source (SINQ), a muon source (SμS), a synchrotron (SLS), and a facility for Proton therapy, while an X-ray free electron laser (SwissFEL) is under construction. The funding is mainly from the Swiss Confederation, but there are also private and EU contributions. In 2012 the total budget of PSI was 337.2 million CHF (1 CHF = 0.812 Euro) of which 248.9 million was funded directly by CH and 57. 2 million by the private sector; in fact much of the research funds in the field of (alternative) energy contribute to PSI either directly or by way of the private sector In addition to running and expanding its own facilities, Switzerland is also a member of ESRF (Swiss-Norwegian beamline), ILL, and ESS. Switzerland has a very active Swiss Neutron Scattering Society but does not have a national synchrotron users organisation.

7.2 Sweden

Sweden is a country much larger than the Netherlands but slightly smaller in population, a member of the EU, has many excellent universities and industries with high added value, has/constructs SR (MAX IV) and has neutron (ESS) facilities in collaboration with other European countries, although not necessarily those closest to it. The ESS was started by France, Germany, Hungary, Italy, Latvia, Spain, Sweden, Switzerland and the United Kingdom. The new synchrotron, MAX IV, and its first 7 beamlines are funded by Swedish Research Council, Sweden’s innovation agency VINNOVA, Skåne Regional Council, and Swedish Universities; the eight beamline will be built by Estonia and Finland.

The location of the ESS in the vicinity of Lund makes use of existing expertise of MAXLAB and intends to integrate the Copenhagen-Skåne area as a regional innovation ecosystem using the high academic environment and the business opportunities.

Sweden participates to the ESRF through the NORDSYNC consortium and to the ILL through the BELPOLSWENI consortium. The Swedish Neutron Scattering Society was founded in 2002 and since 2011 Sweden has also a national organisation of synchrotron radiation users

7.3 Austria

Austria has a long tradition in both neutron and synchrotron radiation research with remarkable international scientific visibility in many fields. Austria is a scientific member of the ILL, where it runs a dedicated beam line. Besides the activities in materials science, the Austrian scientific community has developed a unique profile in using neutrons to investigate the fundaments of quantum mechanics and quantum gravity.

Research with Synchrotron Radiation includes material science, physics, chemistry, biosciences, medicine, geology, palaeontology, fine arts, and others; although the country has never built its own national synchrotron source, around 40 research groups with about 140 scientists are actively using synchrotron radiation. Currently, Austria is an associated member at the European Synchrotron Radiation Facility (ESRF) in Grenoble (with a 1.3% financial contribution to the total expenses), and finances and operates the Austrian small-angle X-ray scattering (SAXS) beamline at the ELETTRA storage ring in Trieste. Adding to this, many Austrian groups get and use beamtime at national European sources such as BESSY II at the Helmholtz-Zentrum Berlin, HASYLAB in Hamburg, ANKA in Karlsruhe, MAXLab in Lund, SOLEIL near Paris, DIAMOND in Didcot, SLS in Villigen, and others. For most of these sources, access was regulated via European Transnational Access (TNA) programs. Among all these activities, the beamtime at the ESRF has the biggest share of more than 40%.

On the national level, the Austrian community is organized within NESY (Neutrons and Synchrotron Radiation), a technical committee of the Austrian Physical Society (ÖPG). The major event among the NESY activities is the biannual “NESY Winterschool Planneralm”, a young academics educational program taking place already since 1999. NESY is also represented in the European Synchrotron User Organization (ESUO), coordinating synchrotron issues on the European level.

8 SWOT analyses

8.1 SWOT Analysis Synchrotrons

Strengths

- Provides high quality X-ray radiation with high intensity, wavelength continuum, high collimation, and polarisation X-ray radiation for a variety of applications.
- SR radiation provides essential data in areas of science where the Netherlands is particularly strong such as structural biology, polymers, catalysis, and materials science.
- Quality of radiation properties and read-out continues to improve due to development of better optics and detectors.
- Large numbers of synchrotron beamlines are currently available with different properties for different applications

Weaknesses

- Synchrotrons require continuous upgrades due to radiation damage.
- Competitive research requires further investment in optics and detector technology.
- Although Europe has a large number of synchrotrons, the Netherlands only participates in ESRF (6%, with Belgium). This is therefore the only guaranteed access, except by the EU-stimulated TransNational Access to national synchrotrons.
- The only Dutch experimental facility is DUBBLE at the ESRF. It covers only part of the requirements of Dutch scientists.
- As there is no experimental facility in the Netherlands, the Dutch community and industry has difficulty in recruiting Dutch scientists with experience in synchrotron radiation.

Opportunities

- Continue to participate in ESRF.
- Look for ways to maintain (DUBBLE) or start new experimental facilities (at ESRF or European synchrotrons under construction) that can be tailored to the needs of Dutch scientists.
- Support activities outside DUBBLE as well, such as macromolecular crystallography, with a scientist based at the light source with clear links to the Netherlands.

Threats

- Current high number of synchrotrons may endanger future funding and hence the quality of the beamlines may decline.
- Relatively large dependence on various national synchrotron sources may cause problems if access policies change.
- Lower priority for Transnational Access in EU programmes may limit access.
- Netherlands and Belgium/Flanders might take different decisions on continuation of participation in ESRF and/or DUBBLE in the coming years.

8.2 SWOT Analysis Neutrons

Strengths

- Provides high quality neutron radiation with unique and non-destructive properties. It allows the resolving of isotopes, such as those of hydrogen, by contrast variation and if necessary can work on bulk/buried materials.
- Neutron radiation provides extremely precise data in soft and hard materials science and unique fundamental insights in physics and magnetism.

- The Netherlands has an active community in instrument development. It also has a large number of users who generally use both neutrons and X-ray radiation as complementary methods.

Weaknesses

- The source brightness is low, limiting the use of neutron facilities to large samples and long exposures.
- The facilities are expensive and relatively few are available.
- The instrumentation is complex, requiring intensive scientific involvement in the preparation of the experiment and the analysis of the experimental results.

Opportunities

- The planned upgrade of the Delft neutron facility (OYSTER) will provide knowledge and training.
- The Netherlands has a strong position in instrument development for neutron facilities providing opportunities for public/private cooperation.
- The ESS will provide a major advance in brightness and contributions are still sought.

Threats

- Researchers in the Netherlands have no guaranteed access to international facilities.
- Funding mostly by large research programmes. Less space for personal research initiatives.
- Lower priority for Transnational Access in EU programmes may limit access.
- Very expensive equipment.

8.3 SWOT Analysis Free Electron Lasers

Strengths

- The development of FELs provides impressively advanced X-rays with new levels of brightness, coherence and time resolution. This allows analysis with unprecedentedly small samples, high spatial resolution and analysis of repeatable ultrafast processes.
- FELs can create unique conditions and allow resolution of previously inaccessible structures (e.g. ultra-small protein crystals, high pressures, temperatures).
- FELs provides unique opportunities and novel science in directions where the Netherlands is strongly positioned (condensed matter, catalysis, biology.)
- FELs are of great interest to Dutch industry (including e.g. X-UV optics for ASML, ARCNL).

Weaknesses

- Pulses are so intense that samples are often destroyed by it
- Just a few facilities are available
- Complex instrumentation

Opportunities

- Facilities are strongly welcoming Dutch involvement
- Possibility to contribute to instrumentation (particularly at SwissFEL)
- Opportunities for Dutch industries to develop and provide instrumentation
- Working on and with FELs builds capacity in an important areas of science and instrumentation

Threats

- No membership may ultimately lead to limited beam access
- Insufficient expertise within the Netherlands on these new techniques

9 Motivation for Priorities

a. ESRF / DUBBLE

Synchrotrons
A synchrotron produces high intensity X-ray pulses using a circular storage ring for high energy electrons and specially designed insertion devices to extract synchrotron radiation to the experimental stations. The Xrays cover a large range of wavelengths from soft Xrays (several nm) to hard Xrays (less than 1 nm). The Xray radiation can be used for various spectroscopies, various diffraction techniques and microscopies. These machines are used by a broad range of researchers ranging from structural biology, polymer science, catalysis to materials science and nanoscience.

The European Synchrotron Radiation Facility
The Netherlands participates together with Belgium (BeneSync consortium) for 6 % in the European Synchrotron Radiation Facility (ESRF, Grenoble, France), and operates the Dutch-Belgian beamline (DUBBLE) together with Flanders in a Collaborative Research Group (CRG) on an ESRF bending magnet. The ESRF includes 40 experimental stations which serve researchers from a large variety of disciplines. For all groups of Dutch synchrotron radiation users that participated in our survey (structural biology, soft matter, polymers, catalysis, materials, solid state science) the ERSF is the most important source of synchrotron radiation, ahead of PETRA, SLS, Diamond, SSRL, and Soleil (to name just the synchrotrons that were mentioned more than once).

The Dutch-Belgian Beamline on the ESRF
The DUBBLE beamline features an X-ray Absorption Spectroscopy (EXAFS) and a Small-Angle X-ray Scattering (SAXS) station, with sample environments that are tailored to the needs of the Dutch and Flemish users for catalysis at EXAFS and for polymers at SAXS. Many participants of the survey and of the meeting on radiation sources on October 4 use DUBBLE especially from the field of polymers, soft matter and catalysis and fewer from materials and structural biology. Many indicate it as a priority for the future. DUBBLE is not used for macromolecular crystallography and solid state science. Dutch and Flemish users can apply for experiments on DUBBLE by way of NWO; both the EXAFS and SAXS stations are usually oversubscribed.

Future
The ESRF is in the middle of a series of upgrade programmes by which it is expected to strengthen its position as one of the leading synchrotron radiation sources in the world. In our survey, synchrotron radiation was most often mentioned as one of the top-3 priorities for now and the future, and the synchrotron source most often mentioned explicitly was the ESRF, ahead of SLS, Diamond, and PETRA (including EMBL, DESY). The committee therefore recommends continuation of the Dutch participation in the ESRF as an absolute top priority. Fields/groups that use/will use the ESRF include: spectroscopy/catalysis, Frank de Groot and Florian Meirer (UU); Mineralogy, Wim van Westrenen (VU); Materials, Niels van Dijk (TUD); Graeme Blake (RUG); soft matter, Ilja Voets (TUe); macromolecular crystallography, various groups from UL, UU, RUG, and NKI.

Since the ESRF upgrades are mainly aimed at improving the radiation at insertion devices, the question whether the CRGs will still be able to use bending magnets after the ESRF upgrades is an important concern for the future of DUBBLE. This point has been raised by the Dutch and Belgian delegates in the ESRF council, and in this phase of the plans the answer is reassuring. The Dutch contribution to DUBBLE is funded separately from the ESRF (currently – 2012-2017 - by NWO General Council) and in a different context (with the region of Flanders alone, not with Belgium in BeneSync). Fields/ groups that use/will use DUBBLE at the ESRF include: materials, André ten Elshof (UT), Erik Kelder, Erik Offermans (TUD); biochemistry, Joke Bouwstra (UL); polymers, Gerrit Peters (tuE), Gijsje Koenderink (AMOLF), Jasper van der Gucht (WU), Katja Loos (RUG); soft matter: G. J. Vroege en Andrei Petukhov (UU), Wim Bras (DUBBLE); catalysis: Martin Feiters (RUN), Emiel Hensen (TUe), Harry Bitter (WU).

b. XFEL / SwissFEL

X-ray lasers
X-ray Free Electron Laser facilities such as XFEL and SwissFEL will produce ultra-short and ultra-bright coherent soft-X-ray pulses. They will provide simultaneous access to nanometre length and femtosecond time scales. This will allow nanostructures to be imaged and the dynamics of

nanosystems to be filmed. By recording entire movies it will be possible, for the first time, to observe, understand, and exploit how matter really behaves in space and time, on scales that have largely been hidden so far. Essentially, X-ray FELs can act as *nanoscopes*, with the resolving power and the temporal resolution to truly follow molecular motion. This will open up entirely new research fields across the entire spectrum of natural sciences in three major directions: (*i*) processes of life, with implications in medicine, pharmacy, biology, and chemistry; (*ii*) materials science in the broadest sense, the enabler for present and future high-tech; (*iii*) fundamental interactions of X-ray photons with matter.

The scientific and technological challenges
The challenges that technology and science faced today can be summarised in three concepts: smaller, faster, and more complex. The physical, chemical and biological processes occurring at the smallest molecular scale that define the field of nanotechnology are pivotal to 21st century technologies and research. Progress, innovations and breakthroughs in nanoscience and nanotechnology critically depend not only on our ability to characterise the structure of physical and living matter on the molecular scales but above all to understand how the nanoworld functions and evolves in time. The natural femtosecond timescale of the nanoworld in action is the ultrashort time scale of physical, chemical and biological processes that form the scaffolding of our society. Therefore, understanding and controlling the nanoworld dynamics promises revolutionary opportunities in fundamental and applied physical sciences, chemical sciences and life sciences as well as spin-off and valorisation for huge variety of (nano)technologies.

Necessity
The Dutch basic and applied sciences community needs the association with the novel European X-ray FEL facilities if their world-class position in nanotechnology related fields is not to be jeopardised. X-ray FELs will facilitate Dutch research to visualise chemical reaction pathways in unparalleled detail and to investigate the functioning of proteins and the processes of life in real time. Both are long-term goals in chemistry and life sciences. Major progress in materials research is expected from investigations on the crucial role of domain and strain pattern formation and the dynamics occurring in the complex materials applied in technology. The exploration of coherent switching of magnetic, ferroelectric and structural properties of matter has many applications. Thus, X-ray FELs have the potential to make a revolutionary impact in many scientific and technological fields, including new materials for technology, cell and molecular biology, pharmaceutical developments, energy storage and conversion, catalytic chemistry, et cetera.

Urgency
Within a few years the advent of more X-ray FELs will allow the field to really take off and mature. To maintain and expand the Dutch position in the broad field of X-ray photon research and technology, it should now be associated with the rapidly expanding X-ray FEL as a matter of urgency. The first X-ray FELs in operation were designed to run in the Self-Amplified Spontaneous Emission mode in which one has limited control on the output characteristics. Techniques to improve this situation are now being developed on the fly. The next FELs (XFEL and SwissFEL) will be equipped with a variety of pulse-control techniques currently being developed. To tailor operational characteristics and user stations to the needs of the Dutch researchers, industrial and academic alike, now is the time to associate the Netherlands with one of the FELs that will come on line in a few years' time. In particular, this means enabling Dutch producers of high-tech equipment VDL, ASI, and mechatronics companies to optimally benefit from the calls for tender. Last but not least these extremely complex machines driving front-end technology are an ideal training environment for young scientists. With companies such as ASML moving into the XUV and soft-X-ray regime there will be a strong near-future demand for researchers with corresponding skills and qualifications.

User community
Current users of comparable X-ray Free Electron Lasers (like the Stanford LCLS) from the Dutch research community are, for example, Theo Rasing (Radboud University Nijmegen Spinoza Prize, magnetic switching), Frank de Groot (Utrecht University, spectroscopy), Mark Golden/Hermann Dürr (University of Amsterdam-Stanford, structure-property relations in condensed matter), Ronnie Hoekstra/Thomas Schlathölter (University of Groningen, molecular dynamics). Future users may include, for example; from the area of macromolecular crystals: Bert Jansen (Utrecht University), Dirk Slotboom (University of Groningen), Raimond Ravelli (Leiden University), Piet Gros (Utrecht University), Andy-Mark Thunnissen (University of Groningen), Anastassis Perrakis (Netherlands Cancer Institute), Jan Pieter Abrahams (Leiden University), Titia Sixma (Netherlands Cancer Institute); from the area of catalysis: Bert Weckhuysen (Utrecht University); from the area of condensed matter research: Raanan Tobey (University of Groningen), Peter Schall (University of

Amsterdam), Graeme Blake (University of Groningen), Aart Kleijn (University of Amsterdam).

c. ESS / ILL

Neutrons

Neutrons permit the study of structures and dynamics of atoms and molecules over an enormous range of spatial and temporal scales. Neutrons have no charge, pass easily through most materials, and enable the probing of large or bulk materials and buried interfaces. Neutron-probes are non-destructive, and deposit little energy, which make them gentle and precise. Neutrons are sensitive to magnetic fields and strongly interact with low mass number atoms: this makes them suitable for studying hard, soft, magnetic, biological and other materials under all necessary conditions.

The scientific and societal challenges

Scientific and technological progress is the only long-term driving force for economic growth. ILL is currently at the world top, ESS will bring neutron research into a next generation's brightness, sensitivity and precision. These neutron facilities are necessary to arrive at new materials with new properties and applications, as materials should be synthesised, probed and understood down to (sub)atomic levels in terms of structure, dynamics and kinetics. These facilities can be used where X-rays lack sensitivity due to neighbouring low-mass number atoms or lack of penetrating power. Materials are complex assemblies, and the challenge is to understand the intricate functional interplay of (sub)structures, their functional morphisms and their phase transitions within the full array of relevant ambient conditions.

Necessity

The Dutch neutron scientific and application community needs the association to the European neutron facilities to maintain its world-top position in materials research. Today's society, and especially the Dutch high-tech society, strongly depends on knowledge and development in materials, and it just simply cannot afford to lose the ties with Europe's efforts to maintain and expand its strong global position in materials research. Ensuring access is also logical in view of the efforts by the OYSTER programme to get the Reactor facilities of Delft University of Technology into a position to support and prepare Dutch developers and users for utilising top European neutron scattering instrumentation.

Urgency

The Dutch neutron community is a strong community and has made world-leading contributions for both the development and application domains. Regulated access of Dutch scientists and users to European facilities is very limited (no access to ILL, access to ISIS is limited to one CRG instrument – LARMOR– and only after its completion). To maintain and expand the Dutch position, direct access to ILL should be obtained as a matter of urgency. Furthermore, the Dutch community should associate with the world-top ESS as early as possible to benefit from the jointly executed developmental programmes (ESS is under construction, anticipated initial operation starts 2019), to guarantee a return-flow of knowledge and expertise (human capital: "brain gain") into the Dutch scientific and application community, to influence developmental and operational ESS characteristics to Dutch needs and interests, and to have the necessary access as soon as ESS becomes operational.

The Dutch neutron community

ESS: RID-Delft University of Technology has considerable expertise in neutron reflectometry and diffraction. They provided instrumentation for ISIS for a suite of instruments based on the spin-echo technique. This is a superb design for various experiments and is being realised within the NWO Investment Grant Large programme LARMOR. We think that this expertise can also be exploited also for ESS. Furthermore, in the context of the OYSTER programme, RID-Delft University of Technology is already participating in ESS through the development of instruments to be installed at ESS at instrument commissioning.

The Dutch scientific and industrial neutron community is involved in both the development and use of neutron instrumentation. Dutch neutron beam instrument development is centred in RID-Delft, where it cooperates with industry such as DARE Development, Bayards/Vernooij, IMTECH, Ntl. Instruments and VDL ETG. Also the development in neutron detection systems takes place in both industrial and academic groups (e.g. NIKHEF, ASI, RID, Nedinsco/Technobis). User groups comprise both knowledge centres and industrial companies, such as TU Delft, TU Eindhoven, Wageningen University, DPI, University of Groningen, University of Amsterdam, M2I, Unilever, NIZO, TI Food & Nutrition, SKF, TATA, DSM, ASML, Shell, Hyett, NedStack, ABB, Sudchemie, Yara, Norrit/Cabot and

Roth & Rau. Scientists engaged in and supporting neutron research are among the best the Netherlands has to offer (e.g. Van der Zwaag, Voets (Veni, SNF, DSM & AKZO Awards), Sietsma, Cohen Stuart (ERC Advanced), Palstra, Blake (VIDI), Van der Linden, Wagemaker (Veni, Vidi ERC), Brück, Pappas, Zaanen (Spinoza Prize), Van de Graaf (ERC Advanced).

10 A National Platform and a Panel for Radiation Sources

Standing committee
One of the issues addressed during the Radiation Sources Day on 4 October 2013 concerned the possible joining of the communities engaged in the laser, synchrotron and neutron facilities. The formation of an overarching, standing committee was proposed to enable discussions to take place on issues of both practical and strategic relevance. This proposal was warmly welcomed at the 4 October meeting: an overarching committee to balance and tune ideas and interests was felt to benefit all communities concerned, as it gives relevance, mass, and strength in voicing the views of the entire radiation sources community with its various counterparts.

This committee, the CRS, has further discussed the possibility of this overarching committee at length: for the reasons outlined above, it concludes that a Dutch standing committee on Radiation Sources has to be set up. Ideally, NWO should mandate the establishment of a standing and overarching committee instead of it being set up by users and developers. Such a mandate would ensure a proper, recognised and undisputed positioning of that panel within its strategic, scientific and financial environment. This standing committee should take over the work and recommendations of the CRS.

Ideally, the committee is made up of the following representatives:
- One representative representing the domain of Life Sciences
- One representative representing the Chemical Sciences
- One representative representing the Physical Sciences
- One representative representing "big" industry
- One representative representing SMEs
- One representative from government
- One secretary from NWO

Main tasks:
- Follow up on the conclusions and recommendations made in this report.
- Develop a longer term national strategy for radiation sources and act on it.
- Coordinate, with other relevant national and international networks and platforms, the Dutch use of radiation sources. Examples of networks and organisations are the ILO-net platform, the ESUO, TNO, the NWO divisions, the government ministries.
- Look for additional funding for radiation sources support by investigating public–private partnerships with large Dutch multinationals.

Platform
The Radiation Sources Day meeting held on 4 October 2013 also indicated that researchers and industry are interested in working together or at least sharing new insights. At present there is a Dutch – Belgian biannual meeting with workshops called Synew. This meeting brings together the Dutch and Belgian users of synchrotron neutron facilities. It offers the possibility for the different communities of physicists, chemists, biochemists and other scientists to discuss common problems and the latest possibilities offered at the large-scale facilities currently in use.

The committee proposes combining aspects of the Radiation Sources Day with the Synew meetings into one annual meeting organised under the auspices of the standing committee. This will reduce fragmentation and will give the community one big and important day for researchers, industry representatives and government officials.

11 Conclusions and Recommendations

1. **Regarding Facilities for the Dutch users of Radiation Sources:**

A ~ The membership of **ESRF** has the **broad support of the community** and **is considered vital**. Our membership opens the broad range of all ESRF beam lines to the Dutch users for research opportunities in life science, soft and hard condensed matter, in biomaterials, energy, catalysis, polymers and magnetism and electron transport. The science policy of ESRF, including peer reviewed allocation of beam time, scientific advisory councils, etc., enables current and future scientific breakthroughs. The upgrade of the facility ensures that ESRF will be offering the Dutch user community a world leading facility for synchrotron radiation. The **Belgian-Dutch consortium** has proven to be **a solid platform** to represent the Dutch interests.

B ~ For the other radiation sources and facilities, the committee thinks that **X-ray Free Electron Lasers** and the **European Spallation Source ESS** offer **exciting and unprecedented opportunities** in terms of instrumentation that will lead to scientific breakthrough discoveries in a broad range of the physical and materials sciences. The X-ray FEL offers increased brightness by a factor million and a time resolution in the femtosecond range opening research on the dynamical properties down to individual molecules. These FEL's have grown into separate facilities which will not replace the synchrotrons but enable completely new lines of research ranging from life sciences, energy research to hard condensed matter. **The ESS is the world-top in neutron beam instruments**, and brings neutron research into a next generation's brightness, sensitivity and precision. ESS will open up new opportunities and bring breakthroughs in our understanding of the intricate functional interplay of materials (sub)structures, their functional morphisms and phase transitions, set in the full array of relevant ambient conditions.

B1 ~ The committee proposes to engage in FEL research by building a Dutch beam station at SwissFEL. Such activity not only provides the Dutch users with access to an X-ray FEL, it also allows us to construct a facility that will optimally benefit Dutch research activities. Furthermore, it enables Dutch companies to develop new technologies that are essential and provide them with a competitive advantage in instrumentation related to soft X-ray lasers, including lithography, detectors and mechatronics. While participation in XFEL in Hamburg would provide access to a FEL for the Dutch community, SwissFEL is at a different stage in design. The beam station at SwissFEL will be more developed towards the user. Furthermore, it enables Dutch industry to participate in developing the required technology, which is already largely committed at XFEL. **A decision on Dutch participation should be taken early 2014**, as the construction of SwissFEL has started. The Belgian community has also started discussing its strategy towards FELs **and a consortium with Belgium offers several advantages outlined in the report**.

B2 ~ The Dutch community should associate to ESS as early as possible, to profit from the jointly executed developmental programs , **to guarantee a return-flow of knowledge and expertise** (human capital: "brain gain") into the Dutch scientific and application community, to influence developmental and operational ESS characteristics to Dutch needs and interests, and to have the necessary access from the very start-up of ESS operation. ESS is currently under (pre)construction: 2019 is anticipated as the year of the first neutrons in ESS instruments, the ESS user program is anticipated to start up in 2023 up to its full completion in 2025. Pathway to fund ESS membership may be the Roadmap of Large Infrastructures.

C ~ The committee stresses the urgency for the community to get access to neutron facility ILL. **The Dutch community should connect to the world-top neutron facility in 2014**: we are neither member of ISIS, where we have access limited to the LARMOR beam station, which will become operational only in 2017, nor are we member of ILL, which issued this year new and further restrictive conditions for access. NL membership to ESS starts serving the Dutch user community only in ten years. **Rapid access to ILL is therefore considered as necessary to guarantee Dutch connection to top neutron materials research facilities**. The committee considers the BELPOLSWENI consortium as an opportunity for the Dutch community to become member and get access to ILL. This membership should bridge the time needed for the ESS user program to become operational.

D ~ The committee proposes to continue **DUBBLE as an important, well-established and well-operated beam line** within ESRF. While the beam line could be operated at different stations or facilities, DUBBLE sets itself apart by offering sample environment conditions and measurement /

analysis support. It is optimally designed to support Dutch catalysis and polymer science research. Breakthrough science is not only based on photon beam line instrumentation as such but also on flexible and realistic sample environment. **The research is very well represented through NIOK and DPI initiatives and now within the top sectors chemistry and energy**. Funding beyond the time frame of the present allocation should in part originate through such frameworks. DUBBLE is operated jointly with Flanders through FWO.

2. Regarding policy:

E ~ The committee concludes that a **Dutch standing committee** on Radiation Sources has to be set up, which ideally, should be established by NWO. That committee should be **provided with a mandate** that would ensure a proper, recognized and undisputed positioning within its strategic, scientific and financial environment. This standing committee should **take over the work and recommendations** of the current committee. In this way the work of the committee can be continued and the recommendations given above can be followed up.

~ The Radiation Sources Day meeting held on 4 October 2013 indicated that **researchers and industry representatives** are interested in **working together** or at least share new insights. It offers the possibility for **the different communities** of physicists, chemists, biochemists and other scientists within academia and industry to discuss common problems and the latest possibilities offered at the large-scale facilities in use today or in the future.

~ The committee proposes combining aspects of the Radiation Sources Day into **one annual meeting**, possibly with Belgium, organized under the auspices of the standing committee. This will **reduce fragmentation** and will give the community **one big and important day for researchers, industry representatives and government officials.**

12 Appendix 1: Radiation Sources Day

On 4 October 2013, a Radiation Sources Day was organised to bring together researchers within academia and industry who use radiation sources. Eighty people attended the meeting and they represented the majority of Dutch universities and large companies such as ASML, DSM, BASF, VDL and Unilever.

The meeting had three objectives:

- To provide input for this report

- To talk about the possibility of setting up a radiation source platform

- To bring together the various stakeholders in the field of radiation sources

Professor Thomas Palstra, chair of the advisory committee radiation sources, opened the meeting and gave a brief introduction to the programme, the day's objectives, the advisory report and the possible formation of a National Platform Radiation Sources.

After this presentation the plenary group split up in three groups / sessions: Synchrotron, Neutron and Free Electron Lasers. In the parallel sessions 6 people gave a 10 minute 'pitch' about radiation sources, paying attention to:

- their scientific background

- the facility or facilities used

- support needed: travel costs, beamline scientists

- access, possible advantages of Dutch participation/membership

- public-private / industrial opportunities

- future plans

After the pitches there was a discussion, chaired by the convenor. The group discussed and wrote down a top 3 of recommendations / opportunities. This top 3 was presented during the plenary session in the afternoon.

Before and after lunch there were two guest speakers: Professor Colin Carlile (ESS) and Dr Thomas Tschentscher (XFEL) who both gave the audience insight in the research possibilities at their respective facilities.

After these two plenary presentations the three groups reported to the plenary group. The top 3 of recommendations / opportunities was presented by the convenors. The goal of this plenary session was to discuss with participants the aspects important in shaping the national policy, how to participate in the various facilities, and how to prioritise the scientific needs based on current opportunities.

At the end of the meeting there was a discussion on the setting up of a National Platform Radiation Sources: What role can it play and how should it be structured?

13 Appendix 2: The Dutch Funding / Research Landscape

Top sectors
In February 2011 the Dutch Cabinet initiated a new policy for companies. Nine top sectors were designated in the Dutch economy in which investments will be made to improve the competitive strength of the Netherlands in these areas and consequently boost its prosperity. The new policy means: fewer grants in exchange for lower taxes, fewer and simpler rules, wider access to industrial funding, improved use of the knowledge infrastructure by industry, and an improved link of the tax system, education and diplomacy with industry.

This policy forms part of the government's aim to realise: A top-5 position for the Netherlands in the world's knowledge economies (in 2020); A rise in the Dutch R&D efforts to 2.5% of GDP (in 2020); Top consortia for Knowledge and Innovation (TKI) in which both public and private parties participate to the tune of more than € 500 million and for which at least 40% of the funding comes from industry (in 2015).

HTSM
One of the top sectors is the top sector High Tech Systems and Materials (HTSM); it is a vital motor and booster for a strong Dutch economy. HTSM produces products and services with applications in all other top sectors. The top sector provides key solutions for societal challenges including sustainable energy, more effective healthcare, improved mobility and increased security. The top sector initiates, innovates, develops and produces end products, semi-finished products, components, materials and services for clients throughout the world varying from healthcare, lighting, chips and chip production to laboratory and office equipment, from cars and logistic systems, aircrafts and satellites to the generation, transport and storage of energy, food processing, and security.

The HTSM roadmap – Advanced Instrumentation
The HTSM top sector currently includes several thematic roadmaps. One of these is the Advanced Instrumentation roadmap. It covers the development and realisation of instruments and infrastructure/equipment for big science projects in national and international context, e.g. for CERN, ESA, ESO, ITER, SKA as well as in the development of small series of high-end instruments for scientific, analytical and medical applications or high-end production equipment using e.g. THz-, X-rays or other types of radiation based on novel components (e.g. sensors, photon sources, electronics) emerging from scientific developments.

Most companies that are active in Advanced Instruments use it to strengthen their position in other markets as Advanced Instrumentation facilitates collaborations and industrial innovations by discussing technological questions with companies already at an early stage. The challenges emerging from scientific collaborations push the skills of the staff and may allow for investments in tools and infrastructure that otherwise would be hard to achieve. The cooperation between industries and knowledge institutes is mutually beneficial and is inspiring for both parties. Advanced Instrumentation is a high-performing driver for innovations which can be boosted further, allowing Dutch companies to compete internationally. Advanced Instrumentation also has a strong cross-cutting character: it serves other roadmaps in HTSM as well as other top sectors.

Roadmap Infrastructure
The National Roadmap Large-Scale Research Facilities aims to strengthen the scientific position of the Netherlands by encouraging the development and construction of large-scale research facilities.

Funding from the National Roadmap Large-Scale Research Facilities can be used for:

- development or upgrading of a research facility in the Netherlands with an international status;

- participating in the construction or substantial renovation of an international research facility.

Facilities included in the current National Roadmap can apply for funding for:

a. The integral costs for the development, acquisition/construction and accommodation of the intended facility, or the integral costs of a modification to the facility such that scientific breakthroughs can be achieved with this.

b. The costs (personnel and material) for the exploitation of the requested facility for a maximum period of 5 years. Here exploitation is understood to be the technical maintenance of the facility. Funds for exploitation can only be applied for if funds have also been applied for under a. and if funds for exploitation have not been awarded previously.

c. Membership/participation of the Netherlands in the construction or upgrade of an international facility or project.

NWO Large

The aim of the programme Investment Grant NWO Large is to boost investments in innovative scientific equipment or data collections of national or international importance. Investment Grant NWO Large is meant for the purchase of equipment and for the setting up, linking and enriching of data collections. The NWO contribution is at least € 1,500,000.

14 Appendix 3: Facilities

Synchrotrons
a. ESRF
The ESRF is an X-ray light source for Europe and is located in Grenoble, France, and supported and shared by 20 countries. The facility is used each year by several thousand researchers. Only four synchrotrons worldwide are similar in design and power to the ESRF. The facility includes 40 specialised experimental stations on the beamlines, where physicists work side by side with chemists and materials scientists. Biologists, medical doctors, meteorologists, geophysicists and archaeologists also are regular users. The facility is used by a large number of Dutch research groups, but unfortunately the facility could not provide precise numbers of Dutch users as they use the Benesync consortium as point of reference. The beam time allocated to the Benesync consortium is between 4,7 % and 5,3% of the total allocated beam time. The Benesync community is involved in more than 11% of the ESRF publication output whilst contributing only 5.8% to the ESRF budget, and the average quality of Benesync publications is higher than the ESRF.

Within the ESRF one of the beamlines is a Dutch – Flemish cooperation / beamline called DUBBLE. This cooperation dates back to 1995. One project leader and several beamline scientists operate this beamline. NWO funds the DUBBLE Beamline, together with the Research Foundation - Flanders (FWO). Dutch and Flemish researchers from all disciplines can apply for beam time and can – if granted - carry out experiments using synchrotron light.

DUBBLE	**2008**	**2009**	**2010**	**2011**	**2012**
Number of applicants per year	74	75	79	77	55
Dutch applicants per year	42	53	63	55	39
Total awarded Dutch applicants	32	35	36	34	23

b. Soleil
The SOLEIL site is situated near Paris and was created in 2001 by CNRS and CEA. SOLEIL is among the 40 major scientific establishments in France. The total budget for SOLEIL for 2002- 2012 (construction and setting up) reached € 623 million. This period began with the construction phase, the first important stage being the start-up of the machine and opening of the first beamlines in 2006. The work progressed with the construction of the final beamlines programmed to come into operation by the end of 2012. From 2013, with all the equipment in place, the annual running costs are estimated at around € 62 million.

The facility is open to Dutch researchers and if the proposals are accepted, Dutch researchers can have access to the TNA programme (TransNationalAccess), under certain conditions. Users work at the Utrecht University, University of Amsterdam, Leiden University, University of Twente, the Rijksmuseum Amsterdam and the Groningen Biomolecular Sciences and Biotechnology Institute. In 2012, 13 out of 1855 successful applications were Dutch.

SOLEIL	**2008**	**2009**	**2010**	**2011**	**2012**
Number of applicants per year	1521	1790	2365	2701	2878
Dutch applicants per year	9	9	15	25	20
Total awarded applicants	840	1094	1464	1639	1855
Total awarded Dutch applicants	5	8	6	14	13

c. Max IV
The MAX IV Laboratory was established on 1 July 2010 as a national research infrastructure hosted by Lund University through an agreement between the Swedish Research Council, VINNOVA, Lund University, and Region Skåne. The MAX IV Laboratory is the successor of the MAX-lab national laboratory and includes both the operation of the present MAX I, II, III facilities (MAX-lab) and the MAX IV project that aims to construct the new MAX IV facility at Brunnshög in the North Eastern part of Lund. The Swedish Research Council (VR) provides a major part of the funding for operating MAX-lab. The MAX IV Laboratory is currently operating three storage rings for the production of

synchrotron radiation for both national and international researchers. In addition it is engaged in the construction of a new facility to become operational in 2015 that comprises of two storage rings (1.5 Gev and 3 Gev) and a 3 GeV Linac. The success rate of Dutch proposers is very high considering the heavy oversubscription at the beamlines they have applied to. Dutch research groups are: Eindhoven University of Technology (Applied Physics), University of Groningen (KVI Atomic and Molecular Physics & Zernike Institute for Advanced Materials) and University of Twente (MESA & Institute. for Nanotechnology).

Max IV	**2008**	**2009**	**2010**	**2011**	**2012**
Number of applicants per year	263	279	317	381	358
Dutch applicants per year	2	3	3	4	4
Total awarded applicants	222	254	246	275	274
Total awarded Dutch applicants	1	2	3	4	4

d. Diamond Light Source

Diamond Light Source is the UK's national synchrotron science facility, located at the Harwell Science and Innovation Campus in Oxfordshire. Diamond is a third-generation 3GeV synchrotron light source which has a 1MeV linear accelerator (Linac), and full energy (1MeV-3 GeV) Booster. Diamond has been operational since January 2007, when the first 7 beamlines entered use. The number of operational beamlines will increase to 32 by 2018. Awarded beam time is based on the scientific merit of the proposal. Diamond is 3:1 oversubscribed and so access is difficult. Diamond is open for Dutch users but Dutch researchers do not make much use of Diamond: only 46 proposals were submitted in the last 5 years from a total of around 3600 applications.

Diamond	**2008**	**2009**	**2010**	**2011**	**2012**
Number of applicants per year	392	589	742	881	1027
Dutch applicants per year	5	8	14	7	12
Total awarded applicants	215	322	426	475	560
Total awarded Dutch applicants	2	8	1	3	8

e. Stanford (SSRL)

The Stanford Synchrotron Radiation Lightsource (SSRL), a directorate of the SLAC National Accelerator Laboratory, is an Office of Science User Facility operated for the US Department of Energy by Stanford University. SSRL produces extremely bright X-rays used to study our world at the atomic and molecular level. As one of five light sources funded by the US Department of Energy Office of Science, SSRL enables research that benefits every sector of the American economy and leads to major advances in energy production, environmental remediation, nanotechnology, new materials and medicine. SSRL also provides unique educational experiences and serves as a vital training ground for students in the sciences. The facility is open to all researchers. In 2012 out of 1597 awarded applications 12 were from the Netherlands.

f. BESSY II

The third-generation storage ring BESSY II has been operational since 1999 and provides ultra-bright photon beams from the long wavelength terahertz region to hard X-rays with complete control of the energy range and the polarisation of the radiation. The facility is operated by the Helmholtz-Zentrum Berlin. Dutch researchers make better use of this facility than other facilities and the award rate for Dutch proposals is high. BESSY II welcomes more Dutch applications and is also interested in having a Dutch CRG.

The facility also would like to improve the involvement of the Dutch community by being open to stronger collaborations between Dutch research groups and research groups at HZB. In this respect we suggest that the option for Dutch operated beam lines is an attractive one. Dutch users are from University of Amsterdam, Radboud University Nijmegen, Utrecht University, University of Groningen, Eindhoven University of Technology and FOM DIFFER.

BESSY II	2008	2009	2010	2011	2012
Number of applicants per year	976	977	1236	1106	1161
Dutch applicants per year	7	12	20	18	17
Total awarded applicants	789	828	850	911	880
Total awarded Dutch applicants	6	9	17	13	15

g. DESY (DORIS / Petra III)

PETRA (or the Positron-Electron Tandem Ring Accelerator) is one of the particle accelerators at DESY in Hamburg, Germany. From 1978 to 1986 it was used to study electron–positron collisions. The modification called PETRA-II is a source of high-energy synchrotron radiation and also a pre-accelerator for the HERA. An upgrade initiated in 2007 has been converting it to PETRA III, which is a high-intensity source for synchrotron radiation. As the most powerful light source of its kind, PETRA III offers scientists outstanding experimental opportunities with X-rays of an exceptionally high brilliance. In particular, this fosters research that investigates very small samples or that requires tightly collimated and very short-wavelength X-rays for their experiments. PETRA III started user operation in 2009 and became fully operation in 2012. Lower user numbers for DORIS III in 2008 were caused by a prolonged shut down period, and in 2012 by the final shut down of DORIS III before the end of the year. The facility is used by a number of Dutch research groups.

DORIS III / Petra III	2008	2009	2010	2011	2012
Total awarded applicants (number of users at DORIS/PETRA)	752/none	1434/10	1424/211	1471/630	1302/1019
Total awarded Dutch applicants (number of Dutch users at DORIS/PETRA)	8/none	27/none	44/4	30/22	13/13

h. SLS

The Swiss Light Source (SLS) at the *Paul Scherrer Institute* is a third-generation synchrotron light source. In the design of SLS a high priority was given to the items quality (high brightness), flexibility (wide wavelength spectrum) and stability (very stable temperature conditions) for the primary electron beam and the secondary photon beams. There is open access for Dutch researchers. Around 18 Dutch researchers applied in the last 3 years and they were successful: Delft University of Technology, Eindhoven University of Technology, AMOLF, Netherlands Cancer Institute, Radboud University Nijmegen, University of Amsterdam, University of Groningen, Utrecht University.

The facility indicates that EU access programmes (CALIPSO, BioStruct-X) should continue and that bilateral agreements between Dutch partners and SLS may be considered (e.g. beam time vs. manpower etc.). The facility is used by a number of Dutch research groups (TU Delft, TU Eindhoven, AMOLF, Netherlands Cancer Institute, Radboud University Nijmegen, University of Amsterdam, University of Groningen, Utrecht University).

SLS	2008	2009	2010	2011	2012
Number of proposals per year	656	724	661	778	808
Dutch proposals per year	7	9	18	18	16
Total awarded proposals	492	530	501	563	536
Total awarded Dutch proposals	5	8	14	14	13

i. Advanced Photon Source

The Advanced Photon Source (APS) at the US Department of Energy's Argonne National Laboratory provides America's brightest storage, ring-generated, X -ray beams for research in almost all scientific disciplines. Dutch researchers make little use of the facility: only 11 proposals were successful in the last 5 years. They originated from Delft University of Technology, Eindhoven University of Technology, University of Groningen, Utrecht University and VU University Amsterdam.

APS	2008	2009	2010	2011	2012
Number of applicants per year	2584	3084	3310	3600	4233
Dutch applicants per year	6	11	7	2	1
Total awarded applicants	1415	1749	1994	2210	2509
Total awarded Dutch applicants	2	2	5	0	2

Neutron sources

a. ILL

The *Institut Laue–Langevin*, or ILL, is an internationally financed scientific facility, situated in Grenoble, France. The institute was founded in 1969 by France and Germany, with the United Kingdom becoming the third major partner in 1973. These partner states provide, through research councils, the bulk of its funding. Ten other countries have since become partners. Scientists of institutions in the member states may apply to use the ILL facilities, and may invite scientists from other countries to participate. Experimental time is allocated by a scientific council involving ILL users. The use of the facility and travel costs for researchers are paid for by the institute. Commercial use, for which a fee is charged, is not subject to the scientific council review process. Over 750 experiments are completed every year, in fields including magnetism, superconductivity, materials engineering, and the study of liquids, colloids and biological substances.

Dutch researchers make use of ILL: over the last 5 years 120 Dutch applications were granted; nevertheless, the total number of proposals awarded funding during the last 5 years is more than 10,000. The facility is used by a large number of Dutch research groups (Delft University of Technology, VU University Amsterdam, University of Twente, Utrecht University, Eindhoven University of Technology, Wageningen University).

From 2014 however, access to ILL should be considered as non-existent. ILL recently sharpened policies on beam-time allocation: proposals from non-member states will be blocked automatically if these are not submitted as part of a collaboration with at least two member states (or one member state and the ILL).

ILL	2008	2009	2010	2011	2012
Number of applicants per year	2645	2632	2727	3103	3220
Dutch applicants per year	26	24	21	30	25
Total awarded applicants	2309	2113	2339	2572	2771
Total awarded Dutch applicants	22	21	19	28	23

b. ISIS

ISIS is a pulsed neutron and muon source. It is situated at the Rutherford Appleton Laboratory on the Harwell Science and Innovation Campus in Oxfordshire, United Kingdom and is part of the Science and Technology Facilities Council. It uses the techniques of muon spectroscopy and neutron scattering to probe the structure and dynamics of condensed matter on a microscopic scale ranging from the subatomic to the macromolecular. Hundreds of experiments are performed annually at ISIS by visiting researchers from around the world, in diverse science areas including physics, chemistry, materials engineering, earth sciences, biology and archaeology.

Starting in 2015, Dutch scientists will have guaranteed access to LARMOR during a period of 10 years for 30 days per year. Nominally ISIS will run 5 cycles per year adding up to typically 180 days per year. In each cycle 7 days will be scheduled for Dutch scientists. Three months before the start of each cycle, proposals will be sent in for experiments to be performed in that cycle. A review committee consisting of Prof. Pappas, Prof. Palstra, Dr Voets, Prof. Sietsma, the LARMOR instrument scientist, and with possible administrative support from by NWO, will assess the proposals on the basis of scientific merit and societal relevance and schedule the beam time accordingly.

Dutch scientists have access to the Transnational Access FP7 programme until the end of 2014. After that, there is no access to ISIS. An exception to this is the LARMOR instrument, once this has become operational.

c. SINQ

The spallation neutron source SINQ, part of the Paul Scherrer Institute, is a continuous source - the first of its kind in the world - with a flux of about 1014 n/cm2/s. Beside thermal neutrons, a cold moderator of liquid deuterium (cold source) slows neutrons down and shifts their spectrum to lower energies. These neutrons have proved to be particularly valuable in materials research and in the investigation of biological substances. SINQ is a user facility. Interested groups can apply for beam time on the various instruments by using the SINQ proposal system.

Dutch researchers do not make much use of the facility: 16 Dutch proposals were awarded funding in the last 5 years from a total of more than 1000 proposals. The facility indicates that EU access programmes should continue (NMI3-II) and that bilateral agreements between Dutch partners and SINQ may be considered (e.g. beam time vs. manpower etc.).

SINQ	**2008**	**2009**	**2010**	**2011**	**2012**
Number of proposals per year	275	323	355	403	397
Dutch proposals per year	4	4	8	16	5
Total awarded proposals	169	216	189	220	228
Total awarded Dutch proposals	3	3	2	7	3

Free electron lasers

a. Trieste

FERMI@Elettra is a state-of-the-art, fourth-generation light source, based on a high-gain, harmonic-generation, free electron laser. FERMI was developed to provide ultrashort (10-100 fs) pulses with ultrahigh peak brightness and energies from 20 to 350 eV in the first harmonic. The first three beamlines at FERMI@Elettra are opening up unique opportunities for exploring the structure and transient states of condensed, soft and low-density matter using a variety of diffraction, scattering and spectroscopy techniques.

b. LCLS

The Linac Coherent Light Source at SLAC National Accelerator Laboratory is the world's most powerful X-ray laser. The LCLS's highly focused beam, which arrives in staccato bursts one-tenth of a trillionth of a second long, gives researchers the intensity needed to probe complex, ultra-small structures and the ultrafast pulses required to freeze atomic motions, thus shedding light on the fundamental processes of chemistry, drug development, technology, and life itself. The facility is used by a few Dutch groups: out of 571 successful applications 9 were Dutch.

15 Appendix 4: Respondents to the Survey

- Prof. Jan Pieter Abrahams, Biophysical Structural Chemistry, Leiden University
- Prof. Harry Bitter, Biobased Commodity Chemicals, Wageningen University
- Dr Graeme Blake, Zernike Institute, University of Groningen
- Dr Wim Bras, NWO / DUBBLE
- Dr Wim Bouwman, Neutron and Positron Methods in Materials, Delft University of Technology
- Prof. Joke Bouwstra, Drug Delivery Technology, Leiden University
- Dr Arjen Bot, Unilever Research
- Dr N.H. van Dijk, Radiation Science and Technology, Delft University of Technology
- Prof. André ten Elshof, Inorganic & Hybrid Nanomaterials Chemistry, University of Twente
- Dr Martin Feiters, Cluster for Molecular Chemistry, Radboud University Nijmegen
- Prof. Mark Golden, Van der Waals – Zeeman Institute, University of Amsterdam
- Prof. Frank de Groot, Synchrotron and Theoretical Spectroscopy of Catalytic Nanomaterials, Utrecht University
- Prof. Piet Gros, Crystal and Structural Chemistry, Utrecht University
- Prof. Jasper van der Gucht, Laboratory for Physical Chemistry and Colloid Science, Wageningen University
- Prof. Emiel Hensen, Molecular Catalysis, Eindhoven University of Technology
- Dr Eric Huizinga, Crystal and Structural Chemistry, Utrecht University
- Dr Bert Janssen, Bijvoet Center for Biomolecular Research, Utrecht University
- Prof. Aart Kleijn, University of Amsterdam and FOM/DIFFER
- Prof. Gijsje Koenderink, Biological Soft Matter, AMOLF
- Prof. Frans Leermakers, Laboratory for Physical Chemistry and Colloid Science, Wageningen University
- Prof. Katja Loos, Macromolecular Chemistry and New Polymeric Material, University of Groningen
- Dr Florian Meirer, Inorganic Chemistry and Catalysis, Utrecht University
- Dr Navraj Pannu, Biophysical Structural Chemistry, Leiden University
- Dr Anastassis Perrakis, Macromolecular Structures, Netherlands Cancer Institute
- Prof. Gerrit Peters, Materials Technology, Eindhoven University of Technology
- Dr Andrei Petukhov Physical and Colloid Chemistry, Utrecht University
- Dr Raimond Ravelli, Molecular Cell Biology, Leiden University
- Dr Matteo Savoini, Spectroscopy of Solids and Interfaces, Radboud University Nijmegen
- Dr Peter Schall, Institute of Physics, University of Amsterdam
- Dr Henk Schut, Neutron and Positron Methods in Materials, Delft University of Technology
- Prof. Titia Sixma, Structural Biology, Netherlands Cancer Institute
- Dr Dirk-Jan Slotboom, Biochemistry, University of Groningen
- Dr Andy-Mark Thunissen, X-ray Crystallography, University of Groningen
- Dr Raanan Tobey, Zernike Institute for Advanced Materials, University of Groningen
- Dr Joost Uitdehaag, Netherlands Translational Research Center
- Dr Ilja Voets, Chemical Engineering and Chemistry, Eindhoven University of Technology
- Dr G.J. Vroege, Physical and Colloid Chemistry, Utrecht University
- Prof. Wim van Westrenen, Faculty of Earth and Life Sciences, VU University Amsterdam
- Dr Jianjun Xu, DSM Resolve