SIZE AND SUITABILITY

INVESTING STRATEGICALLY IN LARGE-SCALE RESEARCH FACILITIES

April 2013

Contents

SUMMARY

This report addresses the question which strategy the Netherlands should follow with regard to public investments in large-scale research facilities and optimal use of these facilities. The Ministers of Education, Culture, and Science, and of Economic Affairs asked the AWT to develop this report, taking account of current policies to promote specialisation in Dutch universities and research institutes, industrial policies to promote 'top sectors', current developments in European research policy, and the greater emphasis in European policy making on regional specialisation.

The purpose of this advisory report is to help the Dutch government to base its investment decisions on a strategic vision on long term needs. The relevant public resources include the funds that the Netherlands Organisation for Scientific Research (NWO) has available for major research facilities, as well as the budgets that universities, public research institutes, government departments and other public sector bodies use for this purpose. The strategic vision ideally focuses on the position and development of Dutch research in a European and global framework. Furthermore, it should be in line with the areas of specialisation of public research organisations, the ambitions of the 'top sectors', and the tackling of societal challenges. Finally, the vision should not only focus on the importance of research facilities for science and education, but also on their economic and societal importance, and on issues of efficiency and continuity.

To ensure that a strategic approach will be developed, the AWT recommends that the Ministers of Education, Culture, and Science, and of Economic Affairs set up an independent permanent Committee on Large-Scale Research Facilities. Its task would be to oversee and coordinate investments, for which proposals generally originate bottom-up. The committee should make sure that those deciding on investments in major research facilities take a broad-based view and give the various selection criteria their proper weight. More specifically, the AWT proposes that decision makers should look in five directions:

- **Look around:** at the European and global playing fields, for possible public and private sector partners;
- **Look ahead:** at the entire life span of facilities and their lifetime costs;
- **Look up:** at the required quality of facilities, given their intended purpose;
- **Look down:** at the possibilities for public-public and public-private cooperation in the development and use of infrastructure;
- **Look in the mirror:** at how facilities fit in with the specialisation pattern and development strategy of universities, research institutes and regions.

To promote a broader-based view during the evaluation of investment options, the AWT recommends a gradual selection process, in which various areas of expertise (science, innovation, and business) are involved at different stages. Finally, the AWT urges the ministers to create the preconditions necessary for the work of the Committee on Large-Scale Research Facilities. First of all, an inventory of the large-scale research infrastructures in the Netherlands should be made. Secondly, universities, research institutes and 'top sectors' need to specify what their strategies mean in terms of demand for large-scale research facilities. Finally, the use and performance of such facilities should be monitored and evaluated regularly.

1. INTRODUCTION

Access to high-quality research facilities is essential for success in research. For a research community, having outstanding facilities is of great importance to attract the best researchers. Such facilities also stimulate both higher education and local enterprise.

Thus, it is important to put careful consideration into public investments in research facilities. In times of increasing demands and ever-smaller budgets for facilities, this is a major challenge. There is a growing demand for small infrastructure (mainly computers, software, and laboratory equipment), which research institutes provide themselves. But the need for large-scale research facilities is also on the rise, as is the need for digital networks that link distributed facilities. This advisory report deals with such large-scale facilities.[1]

The Dutch government invests in large-scale facilities for academic research through NWO (Netherlands Organisation for Scientific Research, i.e., the Dutch research council), which has an annual budget of around forty million euro for this purpose. This amount is distributed among a variety of projects by means of calls for proposals. The submitted applications are assessed by a temporary committee of experts. In addition to this, all kinds of public and private sector parties invest in research facilities. Institutes such as TNO (Netherlands Organisation for Applied Scientific Research), DLO (an organisation for applied agricultural research), and the GTIs (four institutes dedicated to applied technological research) invest primarily from the budgets they raise themselves. In the past, substantial resources from FES, a former fund financed by revenues from the Dutch gas fields, were also used for investing in large-scale facilities.

The purpose of this report is to put forward suggestions for drastically improving this investment process. It deals with such matters as who is to be involved in the process, for what purpose, when, with what information, and under which conditions. The report also addresses how to apply the various selection criteria in the investment process.

REQUEST FOR ADVICE

The Ministries of Education, Culture, and Science, and of Economic Affairs have asked the AWT how the Netherlands can best tackle its need for large-scale research facilities. In summary, the request for advice reads as follows:

What is the best strategy for the Netherlands to pursue with regard to investing in and using large-scale research infrastructure, at national, European, and global level?

The Ministries specifically ask the AWT to consider this theme in the light of: i) the policies to promote specialisation in Dutch universities and research institutes, ii) the development of the 'top sector' industrial policy, iii) the push from Europe for region-based 'smart specialisation', and iv) the developments in European research policy, especially Horizon 2020 and the identification therein of 'grand' societal challenges.[2]

THE FOCUS OF THIS REPORT

The provision of large-scale research infrastructure involves the convergence of two complex challenges. One is about *investing*, and the other is about *coordinating*, or even *integrating*.

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[1] The terms 'research facilities' and 'research infrastructure' are used interchangeably.

[2] The full request for advice is included in this document as Annex 1.

Providing large-scale research infrastructure requires decisions on large sums of money. To make such investment decisions, it is necessary to compare entirely different options. How do you evaluate the importance of investing in a radio telescope or a nano laboratory against that of investing in a database or a synchrotron? This can only be done by examining the extent to which the various investment options meet certain criteria. Long lists of these can be assembled (and indeed, this has been done by various countries that have developed roadmaps for this type of investments).[3]

The provision of large-scale research infrastructure also requires coordination. This can concern coordination within a country. For example, coordination is required to connect facilities in different locations and to enable them to communicate with each other, or to enable researchers from different organisations to access each other's facilities. It can also mean cross-border coordination, in order to make use of foreign facilities or to allow researchers from other countries to access Dutch infrastructure. Furthermore, coordination can involve bringing together the various funding flows for the construction of facilities. Finally, coordination can deal with cooperation between public and private-sector parties for the purpose of developing, building, financing, running, and using infrastructure together. Such coordinating of initiatives and funds can sometimes lead to full integration of plans and resources.

Major investment challenges usually involve major coordination issues. A large investment in research infrastructure can require long-term commitment on the part of developers, operators, managers, users and financers. However, major coordination challenges do not always require huge amounts of money to be invested. Sometimes the rates of utilisation and the amount of return on investment from infrastructure facilities can be raised solely by better coordination in a network, by harmonising standards and interfaces, or by involving more public or private agents.

DEMARCATION

This report is about the strategy the Dutch government should pursue with regard to investing in research infrastructure . The report only deals with large facilities which require extensive investments that go beyond what individual research institutes can afford. The report does not discuss the coordination of smaller infrastructural investments that research organisations fund themselves.[4]

The report deals with large facilities that are paid for out of public funds, and which are therefore, in principle, intended for non-commercial research. The government finances such large-scale research infrastructure for various reasons: scientific progress, supporting policy development and the functioning of the public sector, and precompetitive applied research. Facilities aimed at scientific progress are often located at universities or 'para-university institutes'.[5] Infrastructure that is used for supporting policy can be found at the RIVM (National Institute for Public Health and the Environment) or at the CBS (Statistics Netherlands), as well as at TNO. Facilities for precompetitive applied research are located at, among others, TNO, DLO and the GTIs.

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[3] See Annex 2 for the criteria that are used in the Netherlands and Germany for putting together the roadmap.

[4] Without coordination, competing research institutes may individually invest in equipment with a capacity which exceeds their own needs. The result is that too much equipment is purchased, and that each machine remains underused. The question whether coordination by the government is needed in order to improve the effectiveness of such investments made by research institutes is not addressed in this report.

[5] Para-university institutes directly resort under the Royal Netherlands Academy of Arts and Sciences or the NWO. The latter in particular were set up around large-scale research facilities.

Not included in this report are the investments required for the maintenance and development of the generic digital research infrastructure in the Netherlands. This is the system of computers and connections that is used for exchanging, analysing and storing data currently as provided by SURF (the collaborative organisation for ICT in Dutch higher education and research). This infrastructure is a basic facility for a wide range of research activities, and has to be of a high quality. Exactly how high this quality level should be and how it should evolve over time are complex issues that go beyond the scope of this report. We confine ourselves to the observation that the generic digital research infrastructure is facing a structural shortage of financial resources.[6] The accessibility of the generic digital infrastructure, methods of financing, and dealing with big data also fall outside the remit of this report. The report concentrates on investments in infrastructure for more dedicated research purposes.

Finally, the scope of this report goes beyond the investments funded by the Research Council (NWO) in the context of the national road map. The AWT believes that the Netherlands needs an overall strategy for investments in major research facilities which includes every budget that is available for this purpose.

MORE SPECIFICALLY

It is not easy to describe exactly what large-scale research facilities are or to count how many there are in the Netherlands. The concept includes many different facilities: expensive laboratories and equipment, but also extensive databases and research collections. There are single-sited facilities, distributed facilities, and virtual facilities. Components of distributed and virtual facilities are generally connected to each other via communication networks, and may be located in different countries.

The AWT defines a large-scale facility as one that is too expensive for an individual university or research institute to finance by itself.[7] This is not a precise definition, not in the least because research organisations differ in terms of financial means and have different policies, and because some major facilities are built up gradually over a number of years (e.g. data collections, or a clean room that is gradually filled with equipment). In terms of orders of magnitude, this report deals with facilities with a value of more than five to ten million euro.

In 2008, the Rathenau Institute estimated that the Netherlands had a public capital stock of large-scale research infrastructure with a replacement value of around 3.5 billion euro.[8] It is difficult to calculate an average depreciation period because of the diverse nature of the facilities. However, to give some idea of the size of the relevant amounts, a conservative estimate would be twenty years. A depreciation of five per cent per year would imply a need for 175 million euro of investments every year to prevent the stock of facilities from shrinking.[9] NWO has forty million euro per year at its disposal. Since there are no indications that the availability of research facilities in the Netherlands is falling sharply, there must also be other financers that

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[6] The 'ICT-regie' (2009) report analyses the needs for a generic digital research infrastructure and estimates the annual funding required for this to be around 63 million euro. By curtailing ambitions, this amount has since been reduced to 37 million euro. No provisions have been made for this for the next few years: there is a structural deficit of eight to ten million euro per year (SURF, 2012).

[7] This brings the AWT in line with the definition used in the Nijkamp (2005) report, which was adopted in Rathenau (2008).

[8] Rathenau (2008) employs an operational definition of large-scale research facilities and on this basis gives a picture of the facilities available in the Netherlands at the time: see Annex 3.

[9] By way of comparison, the Nijkamp (2005) report estimated that 100 million euro would be needed every year to meet the demand for large-scale research facilities for academic research. This estimate took no account of the needs for facilities for applied and policy related research.

spend large sums on major infrastructure.[10] There is no overview of the amounts concerned, but together they must exceed the resources of NWO by far. Public sources of funding other than NWO are universities' and para-university institutes' own resources, those of university medical centres (UMCs), of public institutes for applied research, of government departments, regional governments and local authorities, and the European Union.[11]

METHOD

The AWT has answered the ministers' questions on the basis of an analysis of Dutch practice and a comparison to policies in several other countries. To that end, we studied relevant documents and interviewed experts. Technopolis highlighted the common practices in a number of other countries, in a study commissioned by the AWT. The boxed texts with information about common practice in the United States, Canada and Australia are based on this study.[12] We shared the most important findings and our thoughts on ways forward in a workshop with experts from a science background, from the private sector and from the public sector, and used this input to strengthen our analysis and recommendations.

[10] The table in Annex 3 also shows that there are many public research facilities in the Netherlands that are not financed by NWO resources.

[11] European resources for new research facilities have so far concerned limited amounts from FP7 (Capacities programme) and the structural funds (ERDF). For the time being, EU resources are not so much intended for the financing of new research infrastructure as for linking and joint use of major research facilities from different countries. However, the financing of the construction and operation of major research facilities is being discussed in the EU. The EU is also encouraging the development of European Research Infrastructure Consortia (ERICs), for which a specific legal framework has been created. See ec.europa.eu/research/infrastructures for more information.

[12] See Technopolis (2013), Zuijdam, F., Nooijen, A., Rijnders-Nagle, M., 'Vergelijkende studie naar het beleid ten aanzien van grote onderzoeksfaciliteiten', available (in Dutch) on the AWT website.

2. DECISIVE DEVELOPMENTS

It is no surprise that the ministries have asked the AWT to examine the question of investments in large-scale research infrastructure again. Much has changed since the last time the AWT considered this issue.[13] Certain developments have prompted the need for adjustments to the investment process. The three most important developments are set out below.

CONTINUING GLOBALISATION

A first relevant development is the continuing globalisation of science. Research groups all over the world now work in networks and researchers themselves are increasingly internationally mobile. This has intensified both cross-border cooperation and international competition. More and more research systems, including not just those from the countries of continental Europe, but also from countries such as Japan, South Korea, China, and India, are being integrated into the dominant Anglo-Saxon research system.

The ever intensifying international cooperation in science has led to research facilities becoming increasingly interlinked. This is happening for instance in the case of biobanks in various European countries and beyond. Links of this kind are creating worldwide distributed facilities. Interconnecting research facilities is often a capital- and labour-intensive process, because it necessitates harmonisation. Standards, interfaces and communication protocols have to be developed and procedures implemented that regulate access to facilities.

Greater competition has resulted in research groups and universities having to stand out more internationally. They are being challenged to identify and invest in their key competences. In research, a national specialisation profile is being created in an international context. Consequently, it is important when making investment decisions to look more closely than before at their relevance to the chosen competence profile. How does a particular research facility fit into the specialisation strategy of the university or institute concerned? How does it fit the knowledge and innovation strategy of the Netherlands as a whole (i.e., is it relevant to certain 'top sectors' or to societal challenges)?[14] The larger the international playing field and the number of parties involved, the greater the need for a clear and more integrated profile. High-quality research facilities can play a key role here. They attract top-level researchers and can have significant side-effects in terms of innovative economic activity and spin-offs.[15]

In this context, it is important not only to look at the return on having and maintaining specific research facilities, but also at what their development and construction mean for the relevant institutes, businesses, and regions. Developing infrastructure can encourage local businesses to develop more generally applicable expertise and to innovate. Thus, research facilities can have a positive influence on a particular regional investment climate.

Another consequence of the greater globalisation of science is that it has become much more important to look at what is happening in Europe and elsewhere when making investment decisions. Most major infrastructures are not unique. Similar facilities may exist or be being planned in other parts of the world. If these facilities are primarily meant to generate certain scientific breakthroughs (and related innovative applications), then the investment process can be compared to a race in that there can only be one winner.

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[13] See AWT (1992) and AWT (2000).

[14] The Dutch government has designated nine R&D-intensive industries as 'top sectors'. Industrial policy targets these industries in particular in order to boost the international competitiveness of the Dutch economy.

[15] For example, see Technopolis (2011).

The expected return on investment depends very much on the number and quality of the competitors in the race. For an investor it is not a good idea to take part in a race with many competitors. In that case it is better to seek out opportunities to work together. Often, however, facilities are more generic in nature and can be used for different types of research. In these cases, it can be wise for a research organisation to invest by itself.

Scientific progress often does not depend on having the very latest generation of infrastructure available. With certain facilities, new versions featuring an increase in capacity, speed, or accuracy, follow in quick succession.[16] Newer is not always better – one should invest in facilities that are fit for purpose. Thus, to ensure that resources are spent efficiently, it is important to specify what a facility is going to be used for and what level of quality and flexibility are needed to meet these requirements. In cases where the technological development of facilities proceeds at a very fast rate and access to the latest generation of equipment is really necessary, it is important to seek opportunities for joining forces with global leaders and possibilities for investing together.

In Europe, the ESFRI roadmap is an instrument intended to coordinate investments in major research facilities. The ESFRI list makes the plans in various European countries more transparent, and forms an initial step towards coordination. The process by which the list is created is bottom-up in nature. Representatives of member states jointly set down priorities on the basis of peer reviewed proposals submitted by academics. Given the way in which the ESFRI list is drawn up, it can best be used as a source of information and as a vehicle for cooperation. However, the list does not provide a strategic framework for individual member states to determine what they need and how they can best position themselves in Europe. Thus, it is up to the countries themselves to develop a strategic vision that expresses what they need for certain scientific fields, from an innovation perspective, or for economic and societal development. Such carefully thought-out visions by the member states, can in due course form the basis for a comprehensive European strategic framework for investments in large-scale research infrastructure.

INCREASING NEED FOR CAPITAL

A second reason for re-examining the investment process is the growing demand for research infrastructures. Technological progress has led to research becoming increasingly capital intensive. Though this may have resulted in greater productivity and speed of research, it also leads to a rise in the demand for equipment and facilities. The increased demand, in turn, evokes more supply of facilities and further technological development in this field.

Consequently, it is increasingly important to take account of prospective costs when investing in infrastructure developments. Not just development and start-up costs should be estimated, but also operational costs over time, possible costs for upgrading, and the costs for decommissioning at the end of the life cycle.

Another consequence of the greater demand for capital for infrastructure is that the various sources of funding are frequently insufficient on their own. Universities and research institutes often do not have the total resources necessary for major infrastructure at their disposal and the same goes for many businesses. At the same time, both public and private-sector budgets will continue to drop during the next few years as a result of the economic crisis. Thus there is an even greater need for cooperating, coordinating, and combining of funding from various sources, including public resources.

There are successful examples of this, which can serve as models for structuring collaborative partnerships and for granting access to infrastructure. For instance, the Holst Centre, a collaborative partnership between TNO

[16] An example is that of supercomputers, as well as equipment for DNA sequencing and NMR spectrometers.

and the Flemish IMEC, does not only employ its own research facilities, but also regularly uses those of Philips Innovation Services. The Center for Imaging Research and Education (CIRE), a joint initiative between Eindhoven University of Technology and Philips, is a laboratory that bundles public and private facilities for research and innovation in medical imaging and provides related training facilities for researchers.

Research organisations – not just universities, but also TNO, DLO, and the GTIs – have their own resources. Private companies can contribute towards the investment costs as partners. Various ministries, provinces and regions have plans and often funding available for facilities. Banks may also be willing to contribute, subject to certain conditions, and foreign partners may be prepared to participate. In general, however, there is a lack of overview of the opportunities and a lack of ability to coordinate.

EFFICIENCY

A third reason for examining the investment process relates to certain signals from recent experiences in investing in major research facilities. These suggest that greater efficiency can be achieved by altering the process. One well-known issue is that investment decisions are regularly taken without a solid business case having been worked out.[17] In due course, this results in shortfalls, making it necessary to cover costs by making use of the general resources of universities and research institutes. In such situations, operational costs can have a considerable impact on general budgets and severely limit both capacity to invest and flexibility.

Another familiar phenomenon is the tendency to maintain established facilities, without properly evaluating whether follow-up investments are actually efficient. At the start of an infrastructural facility, there is often too little focus on how its continuity is to be guaranteed as it ages and upgrades may be needed.[18] Equally, there are often no sunset clauses with regard to how a facility is to be decommissioned.

Furthermore, there are indications that the current investment process leads to overlap, overcapacity, and underutilisation. This investment process is bottom-up in character. Academics use investment proposals to compete for funding from various sources. As well as funding from their own faculty and institute, they seek assistance from NWO, from regional authorities, provinces or government departments, from private sources, and from Europe. The process is more or less opaque, with many players on both sides of the table. This lack of transparency and coordination leads to an overlap in investments, and therefore to overcapacity and underutilisation. The quality of the Dutch research infrastructure is high but, according to experts, its utilisation rate is low by international standards.[19] In some cases, attempts are made to address this by using public facilities for commercial purposes in order to close the operational gaps.[20]

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[17] The observation that insufficient attention is given to a good business case comes from, inter alia, the committee that assessed the applications made in the context of the last NWO call. There was a widespread acknowledgement of this among both the participants in the workshop and the members of the AWT. The involvement of organisations for applied research like TNO, which have more experience in working out businesses cases than do universities, could lead to better business cases.

[18] In the case of biobanks, for example, the necessary follow-up investments are often considerable, but this is frequently not addressed in the original proposals.

[19] The suggestion that many research facilities are underused has been confirmed to us on several occasions. Solid data are lacking, however (which ought not to be the case – we return to this in the recommendations). Impressions relate to specific cases. MRI scanners, for example, which can cope with an uptime of 75 per cent, are said not to exceed an average uptime of twenty per cent.

[20] If private operators are also active on the commercial market, it is important to safeguard against distortion of competition.

It is important to note that these are indications. There is no comprehensive overview of available large-scale research facilities, and there are no systematic evaluations of their effectiveness and yield. There is a lack of transparency with regard to both investments and payoffs. Lessons can be learned here from other countries: in recent decades, many have developed useful expertise when it comes to providing large-scale research infrastructure. Some countries have gained more experience than the Netherlands in the use of foresight as an instrument in the decision-making processes, in working out business cases, targeting investments to societal needs (grand challenges), cooperating with the private sector and mobilising private capital, and carrying out cross-border investment projects.

3. FINDINGS AND CONCLUSIONS

Today, investments in large research facilities tend to be driven by passionate researchers who demand advanced equipment with which they hope to reach the forefront of knowledge development. This is especially the case in the competition for NWO-resources, but also regarding inclusion in the ESFRI roadmap. Indeed, the science case, the facility's potential contribution towards excellence in science, is usually the predominant selection criterion. Other important criteria are usually mentioned, but do not play an important part decision making in practice. A more balanced approach is necessary. Both assessors and applicants should give greater weight to these other criteria.

In addition to NWO and universities, public institutes for applied research and businesses also invest in large-scale research facilities. Their motives for doing so are more instrumental and commercial. Therefore, they look primarily at the innovation case, the contribution a facility can make towards new applications of knowledge and technology. Currently, there is hardly any coordination between the NWO process and these investment processes. The rising demand for investment and the increasing scarcity of resources does make such coordination desirable, though.

Of course the science case is of great importance when facilities are primarily aimed at advancing science. Similarly, the innovation case should predominate when deciding about proposals for facilities intended for knowledge valorisation and product development. Likewise, an application for a research facility to support public policy should be judged on its own merits. This, applications should be assessed primarily according to their contribution towards their main goal. Additional points can then be earned by achieving good scores for the other criteria.

CONSIDERING ECONOMIC IMPACT[21]

In Canada, federal financer Canada Foundation for Innovation (CFI) and the Large Infrastructure Fund of the state of Ontario give due weight to the economic and societal significance of investment proposals. For CFI, the scientific importance, the strengthening of the innovative capacity and the competitive benefits all carry equal weight in the assessment procedure. In the case of the last two criteria, for example, the assessors look at the effects on (multidisciplinary) cooperation within Canada and with parties in other countries, at the contribution to the international position of Canadian science and innovation, at the creation of an innovative learning environment and the transfer of acquired knowledge and research results to end-users, at the degree to which the various involved parties are entering long term commitments regarding the management and use of the facility, and at possible benefits for policy and quality of life.

In Ontario, the economic impact is appraised by considering to what degree the research facility will lead to more investment and jobs, to new products and services, and to more private R&D and strengthening of industry. To that end, those submitting proposals are asked to include a Commercialization Implementation Plan. This plan should describe the practical application of research results and the potential for knowledge transfer to industry, an underpinning of claims regarding the commercial potential, a strategy and timetable with regard to commercialising the research results, a market analysis, and a description of licence agreements and strategic alliances (planned or otherwise), backed up if necessary by statements from businesses. In order to calculate the societal impact, the potential effects on society in general are considered, as well as on particular themes like health, the environment, the quality of government policy, and the quality of life. Where

[21] Based on Technopolis (2013).

the country’s international competitive position is concerned, the consequences for its scientific and economic development are examined.

Now that resources for research facilities are becoming ever scarcer, the economic and societal impact increases in weight when allocating resources. In Canada, this is being promoted by explicitly including these factors in the application procedures. This has led to a growing awareness among academics drawing up proposals for facilities. They are encouraged to think carefully, from the very start, about the possible economic and societal impact of their research, and about the opportunities for enhancing that impact.

Just as different applications have different aims – relating to science, innovation, or both – so do sources of funding. Obviously, it is important that financial resources are used for the purpose for which they are intended. NWO resources and university resources are primarily intended to serve science. Public resources from organisations like TNO, ECN, Deltares, and RIVM are for supporting innovation or public policy. However, for the sake of using public resources efficiently, these budgets should be deployed with a view to the overall picture.

It requires transparency, a clear overview, and coordination to link the various funding sources to the different investment options, thereby enabling public resources to be used efficiently and the various public goals to be served effectively. No strategic framework currently exists to achieve this. No-one has a clear view of: i) which large-scale research facilities are available in the Netherlands, how they are used and what they produce, ii) what is needed, given the developments in the various research fields and development strategies (the specialisation strategies of universities and institutes, the national strategies such as those expressed in the ‘top sector’ policy, the approach to societal challenges, including those in the context of the European Horizon 2020 programme), and iii) the total extent of plans, proposals, and applications being developed in the field.

4. RECOMMENDATIONS

In the light of the above, the AWT recommends that decisions on public investments in large-scale research facilities should be based on a strategic and comprehensive overall view of the future needs of the Netherlands. This view should be strategic in the sense of identifying goals to be aimed for, and comprehensive in the sense of looking at the scientific, economic, and societal significance of research facilities. The strategic vision should be based on an inventory and evaluation of the available facilities, of developments in relevant research fields, and of the strategies and long-term policies of all relevant parties.

It is primarily important here that the current bottom-up investments processes, which are focused on the science case and on encouraging scientific progress, be embedded in a broader strategic framework. The framework should serve not just scientific progress, but also innovation. It is intended as a basis for the assessment of such matters as: i) strategic alignment (with institutional specialisation patterns, 'top sectors', and regional ecosystems),ii) potential commercial value (the innovation case, comprising both direct effects and influences on the business climate), iii) the potential significance for societal challenges, iv) the business case (including the operating costs, continuity safeguards, and budgets for replacement investments or, in due course, for decommissioning), and v) positioning in Europe and the world.

The AWT recommends setting up a permanent and independent Committee for Large-Scale Research Facilities. This committee should ensure that a strategic framework is developed and oversee and coordinate the various bottom-up investment processes. In particular, the AWT believes that decision makers should take a broad-based view and look in five directions:

- **Look around:** towards the European and global playing fields, towards possible public and private sector partners;
- **Look ahead:** at the entire life span of facilities and their lifetime costs;
- **Look up:** at the required quality of facilities, given their intended purpose;
- **Look down:** at the possibilities for public-public and public-private cooperation in the development and use of infrastructure;
- **Look in the mirror:** at how facilities fit in with the specialisation pattern and development strategy of universities, research institutes and regions.

It is important to structure the decision-making process so that those involved indeed look around, ahead, up, down and in the mirror, and that the information this yields resonates in a the selection process. Below, the AWT elaborates on this advice in three recommendations. The first sets out what is meant by 'taking a broad-based view'. This recommendation shows *what* should happen according to the AWT. The second recommendation deals with *how* this should be done, namely by organising the decision-making process differently. This is the main recommendation in this advisory report. The third recommendation is about creating the right conditions.

RECOMMENDATION 1: ON LOOKING IN FIVE DIRECTIONS

The AWT recommends to the Ministers of Education, Culture, and Science, and of Economic Affairs, that they ensure that all relevant criteria are given appropriate consideration when investment decisions on large-scale research facilities are taken. This requires the assessors and applicants of investment proposals alike to look at a wide range of criteria, and work out the relevant cases (including the innovation case and the business case). This applies not only to funding by NWO, but also to resources from elsewhere. Specifically, the AWT recommends taking a more extensive view, in five directions, each of which is explained below.

A. LOOKING AROUND

Evaluate investment options from a European and global perspective. Start the assessment process on the basis of an analysis of international developments, focusing on:

- The expected and hoped-for progress in the relevant fields, key technologies or societal challenges, both in Europe and elsewhere in the world.
- Research groups all over the world that are active in the relevant field, their long-term strategies and past and planned investments in infrastructure.
- The advantages and disadvantages of various alternatives to solo investment, including investing with foreign parties, linking up to foreign facilities, or allowing foreign research institutes to link up to Dutch facilities.

Applicants should identify, through foresight, the information that is needed for an application to be evaluated in such a broad context. A survey of potential future scientific and technological developments should be a key part of the science case.[22]

B. LOOKING AHEAD

Pay greater attention in the decision-making process to the business case. A realistic business plan is necessary in order to safeguard the continuity of the use of a facility. In principle, fund only upfront investment costs, and set clear requirements regarding the expected coverage of operational costs by owners and users. Take a long-term view, focusing specifically on:

- How operational costs are expected to develop (depending on, among other things, the capacity utilisation, technological development, and learning processes), the margins of uncertainty regarding this cost development, the sources for covering the operating costs, the firmness and time span of the commitments for covering these costs.
- The extend to which costs are passed on to users. Clearly, such matters as personnel costs and variable costs should be charged to external users, perhaps via an hourly rate. On top of that, costs should also in principle be charged to cover capital depreciation.
- The potential for financing with debt capital, given that a solid business case can open up opportunities for getting financial institutions (such as the European Investment Bank) to participate.[23]

THE BUSINESS CASE: A FEW PRINCIPLES

The AWT believes it important that a number of principles be borne in mind when business cases are assessed. Deviation from these principles should only be possible if there are very good reasons for doing so. The principles are:

- State resources are only to be used for covering the costs of construction of large-scale research facilities. Operating and maintenance costs should come from research organisations' own resources. Universities and research institutes should expect to make a financial commitment if they receive state funding for their facilities. Also, the operating costs are strongly affected by the way in which a facility is used. It is

[22] Australia, Japan, and South Korea make systematic use of scientific technological surveys for this purpose.

[23] The European Investment Bank has a Risk Sharing Finance Facility (RSFF) that could play a role here.

important that universities and research organisations have a clear incentive to keep these costs as low as possible.

- Government funding for university research should not be used for investing in the construction of large-scale research facilities. This money should be used for what it is meant for: covering the costs of the research itself.
- Research facilities should be depreciated at a realistic rate. If depreciation is to slow and no precautions are taken, this will jeopardise continuity. To prevent this, realistic depreciations should be included in the calculations of the user costs of the facilities.
- Full costs, including depreciations, should be passed on to external users of facilities. Not doing so not only leaves a gap in the operating budget and breeds a continuity problem, it also effectively amounts to a hidden subsidy of commercial activities from public resources (an inadvertent form of industrial policy). In addition, subsidising rates in public facilities leads to distorted competition if private operators are active on the same market.
- If public facilities are used to offer commercial services to external parties, the European rules regarding competition and state support apply. This implies that the services should be offered at normal market rates or, if there are no market rates, against full costs plus a reasonable profit margin.[24]

The prevailing (international) market rates for services involving the use of large-scale research facilities are often considerably lower than the full costs: ‘the market is unable to bear the full costs’. This can be the result of all kinds of market distortions. In these cases, the minimum rates to be applied are determined by European law.

In principle, full costs should be passed on to external users. Powerful reasons should be put forward where this is not done. If market prices are such that integrated costs cannot be passed on, a conclusive operations plan should set out from which other sources these costs are to be covered.

C. LOOKING UP

A facility should be fit for purpose – and no more than that. Do not automatically assume that investments will only give the best possible scientific (or economic or societal) return if the infrastructure in question meets the highest standards in terms of quality, flexibility, and technological innovation. Adapt quality requirements to the objectives for which the facilities are to be used. Bear in mind the rate at which new generations appear on the market that achieve better performance at lower cost. The faster that rate, the shorter the period of depreciation. Functionality is an important criterion. When determining the required standards, take account of the positive side-effects that expanding technological boundaries could have in terms of learning, but remember also the additional risks involved.

D. LOOKING DOWN

Actively mobilise public institutes of applied research (TNO, DLO, and the GTIs) and private parties to take part and invest in major research infrastructure for scientific purposes, whenever relevant.[25] Direct participation by these bodies has significant advantages over the provision of services to external parties against commercial rates. Advantages are:

[24] See European Commission (2006).

[25] In Japan, industry is closely involved with investments in major research infrastructure, while in Australia, a private fund actively helps finance large-scale research facilities.

- Direct participation brings commercial knowledge and management skills into the operations of infrastructural facilities. This strengthens the focus on the solidity of the business case.
- A wider range of participants helps spread risk.
- Participation limits the usual difficulties that research institutes face when attempting to cover full costs in the rates they charge.[26]

Such advantages can be included as positive aspects in the assessment of investment options of consortia in which a public institute of applied research is taking part (or is the coordinating body), This will enhance the competitive position of the application.

E. LOOKING IN THE MIRROR

Consider how well a potential investment will fit within the research profile of the universities and research institutes concerned. Investment plans should also be assessed in relation to the national 'sector plans' (chemistry, physics, biology, mathematics, et cetera) and to the development plans of the top sectors. Only invest in infrastructure that strengthens a research organisation's development strategy. Granting an investment should depend on the long-term commitment of the institute.

In relation to this, look particularly at the university's or institute's academic development policy, as reflected in investments in and recruitment of personnel and in scientific databases and data processing capacity. Also examine planned investments in supporting functions (data scientists, programmers, technicians and facility managers). Investments in equipment and expertise are complementary. Wherever possible, complement infrastructural investments with flanking policies that strengthen this increase in capacity.[27]

Also take account of the spillover effects investments in large-scale research facilities may have on the local business climate – the regional 'ecosystem' and the 'top sectors' represented in it. Such benefits can be the extra turnover that local businesses gain as a result of the investments, both when the facilities are being built and when they are being used. But benefits also lie in the positive effects on firms' ability to develop and innovate.

A NATIONAL AGENDA AS THE BASIS[28]

Like many other countries, Australia has drawn up a national road map for investing in large-scale research facilities. The starting point for this road map was the Australian innovation agenda 'Powering Ideas – An Innovation Agenda for the 21st Century', which proposed the establishment of a separate council for large-scale research facilities. The national roadmap is organised around the priorities of science policy as set down in 'National Research Priorities' (NRP), namely: i) Environmentally Sustainable Australia, ii) Promoting and Maintaining Good Health, iii) Frontier Technologies for Building & Transforming Australian Industries, and iv)

[26] This is related to the fact that infrastructural facilities of this kind are often characterised by asset specificity: after the investment has been made, the investor depends on the willingness of the client to pay for the services (where the latter often has more 'outside options' than the former).

[27] Germany has complementary policies that connect the development of top-level talent and the encouragement of cooperation and cluster formation to large-scale research facilities. The *Verbundforschung* enables leading academics at German universities to use these facilities. The *Exzellenzinitiative* assists in the recruitment of top-level talent for research, strategic development, and the formation of clusters.

[28] Based on Technopolis (2013).

Safeguarding Australia. The priority Understanding Cultures and Communities was added specifically for the investment road map.

These priorities have economic and societal, rather than scientific, objectives. They are similar to the Grand Challenges of the European Commission in Horizon 2020. The research facilities on the road map are intended to contribute to research for economic and societal purposes. More generic facilities have also been included as part of the development of an eResearch Infrastructure.

A broad-based consultation process involving not just academics, but also other interested parties, took place in preparing the road map in 2011. The idea was that it is important to improve the links between science and national objectives. Using the NRP themes as the guiding principles for the road map more or less guarantees those links. This in turn strengthens the relevance of science, and connects science policy to other government policy areas. At the same time, it boosts the awareness of the importance of research to attain national ambitions.

RECOMMENDATION 2: ON A BETTER ORGANISATION OF THE PROCESS

The AWT advises the Ministers of Education, Culture, and Science, and of Economic Affairs to develop a top-down strategic framework which embeds the existing bottom-up processes of public investments in large-scale research facilities. This should ensure greater clarity about national preferences, as well as better coordination and more coherence. To achieve this, the AWT recommends firstly that an institutional structure be created within which coordination can take place and, secondly, to reorganise the selection process of investment options.[29]

A. THE STRUCTURE

Bring public funds for major research infrastructure (from government bodies and public financers –NWO, the Royal Academy, the various government departments, provinces, and local authorities) together in one, integrated process. Institutionalise this process by the formation of a permanent and independent Committee for Large-Scale Research Facilities, based at NWO and responsible for:

- Developing a strategic vision on investments in large-scale research infrastructure, based on surveys and analyses of scientific, economic, and societal developments and ambitions, and the consequent need for facilities.
- Developing an overview of established large-scale research facilities and safeguarding the transparency of investment processes.
- Effectuating coordination between public financers of major research facilities (including external financers and research organisations) and coordination of the various processes that lead to the selection of investment options (and where useful, integrating these processes or putting them under joint supervision).
- Assessing the compatibility of planned investments (and those that have already been carried out) with the help of the strategic framework.

[29] It should be pointed out here that it is important that care be exercised in coordinating investments in public research facilities that are also used for providing commercial services to third parties, as this could conceivably be regarded as market sharing, which is forbidden under European and Dutch competition laws.

- In the context of ESFRI, promoting and contributing towards the development of a European strategic framework, analogous to and consistent with the strategic framework being advocated for the Netherlands.

The committee should ensure: i) transparency regarding which public resources from which source are available for large-scale research facilities, and for what purpose, ii) transparency regarding which research organisations are claiming what combination of public resources, and iii) that financers coordinate their investments and, where appropriate, combine them.

If the committee is housed at NWO, it will have direct access to relevant information and expertise, which will make it more effective and keep the costs down. The costs of improving the investment process by setting up the proposed committee are expected to be low, compared to the expected benefits of having more effective and efficient investments.

B. THE ASSESSMENT PROCESS

Divide the process for assessing investment options into phases and involve, a wider range of experts and interested parties in each next step. Start with experts who can give a technical evaluation and an assessment of either the scientific merits of a proposal (science case), or its value for engineering and innovation (innovation case), depending on the objectives concerned. Ask them to select and rank investment options that offer sufficient potential. In the next stages, involve experts who can evaluate the business case and strategic aspects (the role of a particular investment in the strategy of the proposing institutes or of the Netherlands as a country; the importance of a facility from a societal perspective).[30]

PHASED ASSESSMENT IN THE US[31]

In the US, the National Science Foundation (NSF) funds about twenty per cent of federally funded academic research. It has around one billion dollars a year at its disposal for investments in large-scale research facilities, and has final responsibility for the overview and management of the facilities portfolio.

Academics initiate investments in facilities. The decisions are taken by the board of the NSF on the basis of recommendations by panels set up for that purpose. It is not just the qualities of the proposals being submitted that are considered during the decision-making process. Account is also taken of competing proposals and existing facilities. Applications pass through an evaluation process that consists of various phases.[32] The process starts from a draft proposal that is elaborated on step-by-step. Every phase in the process leads to an evaluation, and every positive assessment to a request for more details as input for the next phase.

In the first phase, 'horizon planning', proposed projects are evaluated in terms of their scientific value (the science case), and with regard to their overall fit into the NSF facilities portfolio and their relevance to the mission and strategic plans of the NSF. Any collaborative partnerships considered are taken into account, as are the challenges raised by the project, and the feasibility of the anticipated timetable. During the next phase,

[30] Foreign examples: CFI in Canada operates a process in which a proposal passes through four assessment phases. Flemish-speaking Belgium and the United Kingdom make a distinction between the evaluation of scientific merits and the business case of an investment proposal.

[31] Based on Technopolis (2013).

[32] See also the diagram on page 8 of the NSF Large Facilities Manual (2013).

‘conceptual design’, in which a design of the project is requested, the first version of the business case is assessed. This involves an examination of, among other things, an outline project plan for the development of the facility, the construction and operation of the facility, and the risks involved. The focus in the third phase, ‘preliminary design’, is on working out the technical aspects of the construction of the facility, with due attention to the details of the timetable and the budget, the division of responsibilities among the various parties, the risk analysis, and the projected operating costs. The fourth phase, ‘final design’, is the final evaluation stage before a project is put forward for funding. This is followed by the construction and launch of the project. A review is then held every year to see whether a facility is still relevant to the portfolio of the NSF, and therefore still deserving of its support.

It is not only the NSF that operates a phased evaluation procedure. The step-by-step procedure of the Canadian federal financer of large-scale research infrastructure, CFI also involves applications being evaluated in successive phases by increasingly broad-based committees. A panel of scientific specialists is gradually supplemented with experts on issues of research management, technological development, and economic and societal valorisation. In the Flemish part of Belgium, there is a separate evaluation of scientific merits of facilities applied for in the Hercules programme (Hercules Science) and of their commercial aspects (Hercules Invest).

RECOMMENDATION 3: ON CREATING THE RIGHT CONDITIONS

The AWT recommends the Ministers of Education, Culture, and Science, and of Economic Affairs that they ensure that conditions are created that allow a Committee for Large-Scale Research Facilities to function effectively. The committee should be able to dispose of reliable information about the current stock of large-scale research facilities in the Netherlands. It should know what budgets for research infrastructure are available and be informed on the strategies of research organisations, local and regional authorities and ‘top sectors’, and on the results of previous investments in facilities.

A. KNOWING WHAT EXISTS AND WHAT IS POSSIBLE

Make an inventory of what is available in the Netherlands in terms of large-scale research infrastructure, and what parts of it are publicly funded. Examine the significance and quality of Dutch facilities in a European and global context. There is no clear picture of which facilities exist, since when, and how intensively they are used. The same is true of the various public and private funds used for investing in large-scale research facilities. Information of this kind enables sound decisions making on new investments. It also helps to better coordinate the use of existing facilities and, in certain cases, to establish links between facilities and enable them to cooperate.

B. ENABLE STRATEGIC CHOICES

Require ‘top sectors’ to clarify which investments in large-scale research facilities are important to them and where the desired facilities should be located (i.e., at which university or institute for applied research). Ask them to focus strongly on foresight in their innovation road maps, and to clearly specify their technological ambitions. Demand that they identify their future needs regarding these facilities, and coordinate their plans and initiatives across sectors.

Additionally, talk to research institutes about deepening their specialisation strategies. In order to ensure that national investments in large-scale facilities are in keeping with institutes’ strategies, institutes must have a clear and pronounced profile.

C. LEARNING FROM EXPERIENCE

Permanently record how large-scale research infrastructures are used and evaluate investment decisions ex-post. Monitor and evaluate existing large-scale research facilities in terms of their usefulness, utilisation rate, and contribution to strategic objectives (like excelling in key disciplines or key technologies). Analyse experiences and investigate the extent to which results deviate systematically and persistently from the original forecasts. Use these evaluations to inform investment decisions in the future.

Thus adopted in The Hague, April 2013

Professor U. Rosenthal (chairman)

Dr. D.J.M. Corbey (secretary)

ANNEX 1: REQUEST FOR ADVICE ON LARGE-SCALE RESEARCH FACILITIES

Scientific progress in every field depends on talent and on state-of-the-art research infrastructure[33] with which excellent and ground-breaking research can be carried out. Setting up and maintaining large-scale research facilities[34] in this infrastructure involves high costs, which individual research groups, and indeed individual countries (especially smaller ones), cannot afford. This is why the ambitions and investment plans for large-scale research facilities of this kind are, to an increasing degree, being coordinated at national or international level.

Many countries would like to have or use such large-scale research facilities, because they form a focus for international cooperation and high-quality research, and because they act as a magnet in attracting talented individuals from all over the world. Moreover, the accumulation and maintenance of capital-intensive facilities has a direct effect on local economies by generating economic activity and high-level jobs, during both the time they are being set up and operated. The development of large-scale research facilities also frequently leads directly or indirectly to important innovative spin-offs.

At European level, the wishes and plans for many of the large-scale research facilities are coordinated in the European Strategy Forum for Research Infrastructures (ESFRI), which was set up in 2002, and which since 2006 has published regular updates of the roadmap for large-scale research facilities that should be completed in the next ten to fifteen years. ESFRI is responsible for setting the joint priorities and for integrating the scientific initiatives for infrastructures that come from the various countries. The most recent update was in 2010 and consisted of 38 projects.[35]

Partly as a result of the ESFRI roadmap and an advisory report by the 'Innovation Platform' (Nijkamp, 2005, 'Kennisambitie en researchinfrastructuur'), initiatives have been coordinated at national level using 'national roadmaps for large-scale research facilities'. The first of these was set up in late 2008 by the Van Velzen Committee, of which an update (based on the recommendation of the Meijer Committee) appeared on 28 February 2012.[36] The Dutch roadmap sets out the priorities of Dutch initiatives, which are in keeping with the ESFRI roadmap and which are created in European or global partnerships, as well as of initiatives that are considered to be primarily important to the Netherlands. The roadmap provides for a funding proposal for a period of four years from a budget allocated to the NWO (the Dutch Research Council). Although the national roadmap and the ESFRI roadmap give a good idea of new and developing major shared facilities for research, there are also infrastructural facilities that remain out of sight because they are funded from sources other than the NWO.

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[33] The term 'research infrastructure' refers to facilities, resources and related services that are used by the academic community in order to carry out high-level research in every field. This definition, which is used by the European Commission, (Regulation 723/2009 of 25 June 2009) covers the following: the most important equipment and instruments that are used for scientific ends; knowledge-based resources such as collections, archives or structured academic information; infrastructures based on information and communication technology, such as grid networks, computers, software and connections, as well as other equipment that is essential for excellence in research.

[34] The term 'research facilities', which is used in the Dutch road maps, will be used in the advisory report. This is synonymous with the aforementioned term, 'research infrastructure', which is used by the EC.

35 They require a total of around €13 billion for setting up. It is estimated that the cost of maintaining these facilities will be €1.5 billion per year.

[36] Presented to the Dutch House of Representatives on 2 March 2012, ref. 384258.

The process of balancing priorities and planning the funding of large-scale research facilities within a limited resource framework is complex. There are various reasons for this. The facilities included in the roadmaps differ widely, because they are oriented towards a variety of academic questions and themes. The facilities range from more traditional single sites to distributed and virtual facilities located across numerous countries, and from those that are important to individual disciplines or sub-disciplines to those from which every discipline can benefit, such as e-infrastructures. As a result, the costs of building, operations, and maintenance, as well as the duration of the construction and the economic and societal benefits, vary enormously. In addition to the academic excellence criterion, there is now greater pressure for investments to be made in relation to the 'top sector' policy. At European level, the issue of coordination has now been raised in 'Horizon 2020'. The advisory report by Meijer Committee (2012) emphasises that the relationship with existing infrastructure in GTIs and businesses could be strengthened.

In that connection, the AWT has been given the following request for advice:

What strategy should Dutch science and innovation policy follow with regard to investments in large-scale research facilities at the national, European, and global level, in order to optimise both research infrastructure in the Netherlands and access to foreign facilities for Dutch researchers?

This raises the following questions:

- What trends and developments are apparent at an international level, and what challenges and opportunities will arise for the Netherlands as a result? Can lessons be learned from other countries as far as policy on the planning of large-scale research facilities is concerned? If so, what?
- What policy and strategy should the Dutch government adopt in order to respond as effectively as possible to these trends and developments (such as Horizon 2020)? What is the best way to respond to European policy aimed at large-scale research infrastructure?
- Can the prioritisation and planning of government investment in large-scale research facilities, which often have a long-term character, be linked to societal issues, 'top sector' policy, and regional development planning(smart specialisation), which often have a shorter time horizon? If so, how can this link be constructed? What lessons can be learned here from demand-driven investments in the past and in other countries?
- How can the planning and development of new large-scale facilities for research be sustainably integrated into the existing research infrastructure, bearing in mind the profiling of universities and existing facilities such as the GTIs?
- Is improved coordination and/or the mutual use of publicly and privately funded large-scale research facilities desirable and possible at Dutch or European level, and if so, how?
- How can the balance between sufficient renewal and sustainability (such as the contribution for operations and maintenance) be safeguarded?
- How can the importance of relatively new large-scale basic facilities (such as e-infrastructures – data systems) be guaranteed and how should they be dealt with in view of the increasing importance of big data and safeguards for 'open access'?
- Is coordination between research programmes and investments in large-scale research facilities at Dutch or European level desirable and if so, how can this best be achieved?

ANNEX 2: CRITERIA FOR INCLUSION IN ROADMAPS: TWO EXAMPLES

NETHERLANDS

Proposals were assessed on the basis of the following eleven criteria:[37]

1. The likelihood of scientific breakthroughs (science case)

Innovation is dependent on scientific breakthroughs. If major investments are to be made in research facilities, those facilities should produce a greater likelihood of scientific breakthroughs in the research field concerned, or at least aid in that process.

2. The potential for 'brain gain' (talent case)

Top research talent is essential to any knowledge-driven economy. Highly talented researchers will only come to the Netherlands – or remain here – if they are offered an attractive and challenging working environment. Advanced research facilities are vital in this respect.

3. Social and commercial relevance (innovation case)

Research facilities are necessary for business and industry and for innovative public bodies. Large-scale research facilities act as a magnet for new knowledge and expertise, creating an excellent climate for companies both large and small. To maintain broad public support in the Netherlands and the wider European Union, especially as regards additional funding, it is important that such facilities should, wherever possible, reflect the top sectors designated by the present Dutch government and current hot social issues in the Netherlands and Europe at large.

4. Collaboration and competition (partnership case)

Large-scale research facilities are embedded in wide-ranging networks. Research at such facilities is conducted via national and international networks. Moreover, facilities with a large critical mass ensure synergy between knowledge workers. The establishment of a large-scale facility calls for effective agreements between the partners (in the Netherlands and elsewhere), reached via a governance and management model.

5. Financial aspects (business case)

Innovation costs money. The cost of bringing a facility of international importance to the Netherlands and operating it here, or of participating in an international research facility outside the Netherlands, will exceed the available budgets. Careful budgetary analysis is therefore essential.

6. Technical feasibility/technical challenges (technical case)

Since new facilities inevitably involve risks, it is important to know whether it is technically possible to construct the proposed facility. It is also a good idea to estimate the technical challenges because these may constitute additional reasons for or against embarking on the establishment of the facility.

7. Possible focus for the Netherlands

The following questions will be asked:

[37] See NWO (2012).

a. Is the Netherlands an international leader in the field concerned?
b. Can the Netherlands achieve a unique position in this field or part of it?
c. Even if foreign research groups are the international leaders in the field, are there reasons to invest in the proposed facility and so to enter into competition with them?

8. Critical mass

Large-scale research facilities exist mainly to serve the needs of researchers. This means that investment needs to be focused on facilities in those fields where the Netherlands has a good supply of top researchers, both as regards quality and numbers. It also means that there must be guaranteed access to the facility for external researchers. The results of recent external assessments should also show that Dutch research groups are international leaders in their fields.

9. Embedding

Large-scale international research facilities need to be financially and institutionally embedded within the Dutch knowledge infrastructure. This also applies to large-scale international research facilities in which the Netherlands does not play the leading role. Such institutional and financial embedding can be demonstrated by, for example, the concentration of research groups within the Netherlands, the presence of Dutch research groups within European networks, and the investment made by Dutch government authorities in the relevant research field, for example through the Economic Structure Enhancement Fund (FES).

10. Proven willingness to collaborate

The large-scale research facility must strengthen collaboration between the Dutch research groups concerned in the relevant field of research. To achieve this, it is essential that the facility is properly managed and cooperation well-organized. The research groups concerned can confirm their will to collaborate financially as well as otherwise by earmarking a certain percentage of their research budget for the operation of the large-scale research facility concerned.

11. Reflection of social trends

It is important to pay attention not only to scientific and economic aspects but also to national social developments and trends. This can be done by, so far as possible, reflecting present/future policy frameworks and scientific priorities in the Netherlands and the European Union.

GERMANY

The German *Wissenschaftsrat* proposes the following criteria for inclusion in the German roadmap:

If possible and useful, please reinforce your information on the four dimensions of evaluation (scientific potential, utilization, relevance for Germany as a location of science and research, feasibility) also with quantitative data.

1. Scientific potential

1.1. What is the significance of the research infrastructure? Which issues of the relevant field(s) of research can be addressed via the research infrastructure? Which new fields of research could be made accessible through the planned research infrastructure? Which alternative ways have been explored to scientifically work on these research questions or fields of research? Please answer these questions with a short report against the background of the present state of research.

1.2. For which field(s) of research is the research infrastructure of relevance? What significance does this project have for the development – at the moment and on the long run – of the field(s) of research? What would the consequences for the field(s) of research be if the research infrastructure was not supported?

1.3. Which scientific and technological innovations are expected of the research infrastructure? Will new co-operations be supported within and beyond the discipline due to the planned research infrastructure?

1.4. Which possible modes of operations will be opened up by the planned research infrastructure? Can these change within the course of the lifetime of the infrastructure (multipurpose platform), or is it a specific infrastructure?

1.5. What are the differences between the planned and other existing or planned research infrastructures? Please specify competing and complementary research infrastructures from all over the world in the appendix. In case of an overlap, what is the additional benefit? Are synergies made use of?

2. Utilization

2.1. Who will use the planned research infrastructure? Please define the size of the user groups, their disciplinary and institutional origin, preferably differentiated by their intensity of utilization. Does the capacity of the planned infrastructure fit to the size of the expected user group? Are new user groups supposed to be attracted by the new research infrastructure? Do concrete expressions of interest of institutions exist? How big is the percentage of international users? Why is the international community of users interested in the research infrastructure? Are companies interested in the research infrastructure?

2.2. What impact will the planned research infrastructure have on the use of other already existing research infrastructures?

2.3. How will the access to the planned research infrastructure be organised? The choice of research projects respectively the authorised people is based on which criteria? Will access procedures vary for users from different countries or institutions? Will the operating of the research infrastructure be co-financed via user fee

2.4. Which expertise is required for the utilization of the planned research infrastructure? How will it be ensured that users actually have this expertise?

3. Relevance for Germany as a location of science and research

3.1. Does the planned research infrastructure follow up on the strengths of Germany's research or does it compensate a weakness? In what respect does it strengthen Germany's research? How does the planned research infrastructure support the medium- and long-term visibility and attractiveness of Germany as a location of science and research within the European and international context, especially with the new generation of academics in mind?

3.2. For which German scientific institutions (universities/non-university research institutes) is the planned research infrastructure of importance? Which role does the research infrastructure play especially for the training of the new generation of academics?

3.3. How does the planned research infrastructure fit into the whole field of research infrastructures in Germany, in Europe and world-wide? How is it related to existing German research infrastructures that are competing or complementary? Please add a list of competing and complementary research infrastructures of the field from around the world which already exist or are planned in the appendix. How have the preparation, construction and operation of these research infrastructures been coordinated with the institutions?

3.4. How can the research infrastructure help Germany address the grand challenges? Have measures been arranged for the support or activation of the realization of concrete solutions?

3.5. In case of an international project: What position does Germany have (leading position/taking over important work packages)? Have the interests of Germany been adequately taken into account within the concepts?

3.6. Where does the exceptional political significance of the planned research infrastructure for the German science and research landscape additionally lie?

4. Feasibility

Technical requirements

4.1. Are there technical innovations necessary for the realization of the research infrastructure? Which steps are planned for these?

4.2. Have technical alternatives – also in respect of cost-benefit-aspects – been checked? (Justification required not only in terms of the general financing but also from a technological point of view)

4.3. Are preliminary studies necessary? If this is the case, are these already scheduled or planned? (For completed preliminary studies cf. III.1.2)

4.4. Are there special requirements for e-infrastructures? If so, which plans exist for the provision of it and how is it embedded into the national and European landscape of e-infrastructures?

Institutional requirements

4.5. Why is the hosting institution interested in becoming the headquarters of the planned research infrastructure project? How is the new research infrastructure integrated into the long-term strategy of the hosting institution (and the cooperating institutions)? How will the hosting institution get involved (including the financial support)?

4.6. If the project is part of a research network or some other project-like research association: How is it guaranteed that the project outlasts the existence of the association?

4.7. What kinds of scientific expertise already exist within the hosting institution regarding the field(s) of research that is/are related to the research infrastructure? Please quote five relevant publications of scientists of your institution of the last five years.

4.8. Which technological expertise is necessary for the preparation, construction and operation of the research infrastructure? Which skills do the involved have? (For maintenance staff cf. 4.11)

4.9. Which concepts of governance – if applicable also for different implementation phases – have been developed?

4.10. In case of a totally new construction will existing facilities of the hosting institution be abandoned? To what extent could costs be reduced?

4.11. Do any ethical and/or legal issues need to be taken into account concerning the construction, operation and decommissioning of the project? Any environmental consequences? How high is the risk of modification or abortion due to ethical, legal or environmental reasons? What method has been planned as to clarify the issue at an early stage and to come to a decision?

Personnel requirements

4.12. Which personnel capacities in the scientific and technological (maintenance staff) area do the involved have? If these are not sufficient for the preparation and respectively the operation, what concepts for the recruitment have been developed?

4.13. How will you recruit and train the new generation of academics? Do any concepts exist? Do any co-operations with (further) universities exist?

ANNEX 3: LARGE IN THE NETHERLANDS

One of the reasons why it is difficult to define what exactly constitutes large-scale research facilities is the fact that there are facilities of many different types.[37] In the past, research facilities were primarily technological hardware, like telescopes, laboratories and research ships. Nowadays, it also includes databases and other types of research collection, distributed systems, and software models. The greater diversity of facilities is related to the digitisation of research and the development of e-science.[38] This diversity makes it awkward to determine what exactly is 'large'. For that reason, the Rathenau report uses seven features to determine whether a facility is large:

1. The initial investment and any renewal or replacement investments exceed the capacity of an individual department, institute, or funding programme.
2. A large-scale facility has high potential learning, network, and cluster effects.
3. A large-scale research facility has its own research group and support staff (technical and administrative).
4. A large-scale research facility is institutionally embedded and has its own management model that describes the role of the various parties, the periodic evaluation, the ownership, the cost-model, and the accessibility of the infrastructure.
5. Large-scale research facilities are nationally or internationally, rather than locally, oriented, and are based on collaboration.
6. Some large-scale facilities are unique in the Netherlands or even in the world.
7. Research facilities are accessible for outside users, whether for payment or not, and are attractive to researchers from abroad and the private sector.

Using these criteria, the 2008 report produced a list of 66 facilities, which is shown below for illustrative purposes. The report gave a very rough estimate of the value of these facilities of a total of 3.5 billion euro. Even though this is an approximation (and it excludes a number of facilities whose value could not be estimated), it nonetheless gives an idea of the relevant orders of magnitude. The report estimated that the distribution of the value of the facilities across the various academic fields was as follows: more than sixty per cent was for natural science and technical research; ten percent was for medical research, information technology and astronomy each; collections and social sciences accounted for a few percentage points of the overall value.

Because the facilities are so varied in character, it is not really feasible to make general comments about life spans (technical and economic) or depreciation periods. These range from five years (in the case of the inventory of a clean room, for example) to more than 25 years (in the case of biobanks, for example, or collections and databases, or radio telescopes).

The following table gives an overview of the large-scale research facilities identified by the authors of the Rathenau report in 2008.

Facility	Owner	Location
AGOR	FOM	Groningen
BIG GRID	NWO NCF	Various

[37] This annex is based on Rathenau (2008).

[38] See for example AWT (2011).

Bijvoet Center for Biomolecular Research	UU	Utrecht
Biomedical Primate Research Centre (BPRC)	BPRC	Rijswijk
Netherlands Statistics	Netherlands Statistics	Voorburg
Central Veterinary Institute	WUR	Lelystad; Wageningen
CESAR Observatory	Consortium	Cabauw
DANS	KNAW	The Hague
DAREnet	KNAW	The Hague
Delft Software Systems	Deltares	Delft
Desdemona	TNO	Delft
Deltares goten- en stromingslaboratoria	Deltares	Delft; Marknesse
DNW Wind tunnels	DNW	Emmeloord
F.C. Donders Centre for Cognitive Neuroimaging	RU Nijmegen	Nijmegen
GeoBrain	Deltares	Delft
GeoLab	Deltares	Delft
High Field Magnet Laboratory	RU Nijmegen	Nijmegen
High Flux Reactor	JRC/NRG	Petten
Ion Beam Applications Centre	UU	Utrecht
IR User Facility FELIX	FOM	Nieuwegein
KNMI Meetnet	KNMI	De Bilt
Royal Library of the Netherlands	Royal Library	The Hague
Laser Centre Vrije Universiteit (LCVU)	VU	Amsterdam
Life courses in context	IISG	Amsterdam
Life Science Trace Gas Exchange Facility	RU Nijmegen	Nijmegen
Lifelines	UMC Groningen	Groningen
Low Frequency Array (LOFAR)	ASTRON	Dwingeloo; Borger-Odoorn
MARIN Bassins	MARIN	Wageningen
MARIN Simulatoren	MARIN	Wageningen
MARIN Software tools	MARIN	Wageningen
MESS	UvT CentERdata	Tilburg
NanoLab NL	NanoNed	Groningen; Enschede;Delft; Eindhoven
National Archives of the Netherlands	National Archives	The Hague
National Herbarium of the Netherlands	National Herbarium	Leiden
Naturalis	Naturalis	Leiden
Nederlands Referentielaboratorium (Laboratory for Infectious Diseases and Screening)	RIVM	Bilthoven

Nederlands Vaccin Instituut	NVI	Bilthoven
Netherlands Bioinformatics Centre (NBIC)	NBIC	Various
Netherlands Metabolomics Centre	NMC	Various
Netherlands Proteomics Centre	NPC	Various
Nijmegen Centre for Advanced Spectroscopy	RU Nijmegen	Nijmegen
NIOZ	NIOZ	Texel
NLBIF/GBIF	UvA	Amsterdam
NLR Laboratoriumvliegtuigen	NLR	Amsterdam
NLR Simulatoren	NLR	Amsterdam
NLR Testfaciliteiten en engineeringfaciliteiten	NLR	Amsterdam
PALGA	Stichting PALGA	Utrecht
Parelsnoer (national infrastructure for biobanks)	NFU	Various
Pilotlijnkristallijnsiliciumzonnecellen en –modules	ECN	Wieringerwerf
PSI-lab	FOM	Rijnhuizen
Reactor Institute Delft	TU Delft	Delft
RIVM Luchtmeetnet	RIVM	Various
Sanquin	Sanquin	Amsterdam
SARA	SARA	Amsterdam; Almere
Spinozacentrum	AMC, UvA; VU; NIN-KNAW	Amsterdam
SRON	SRON	Utrecht
SURFnet6	SURFnet	Utrecht
TRAILS	UMC Groningen	Groningen
TuBaFrost	Erasmus MC	Rotterdam
VeHIL	TNO	Helmond
Virtual Laboratory for e-science	VL-e consortium	Amsterdam; Groningen;Dwingelo
VISTA	LUMC, UMC, Utrecht, RU Nijmegen	Leiden; Utrecht; Nijmegen;Duisburg/Essen
Wageningen NMR Centre	WUR	Wageningen
Windturbinetestpark Wieringermeer	ECN	Wieringermeer
WMC Kennis- en testcentrum	ECN	Wieringerwerf
WSRT	ASTRON	Dwingeloo

FOM = Foundation for Fundamental Research on Matter

NWO NCF = Netherlands Organisation for Scientific Research – National Computing Facilities Foundation

UU = Utrecht University

WUR = Wageningen University and Research Centre

KNAW = Royal Netherlands Academy of Arts and Sciences

DNW = German-Dutch Wind Tunnels

RU Nijmegen = Radboud University Nijmegen

NRG = Dutch Nuclear Research Centre

KNMI = Royal Netherlands Meteorological Institute

VU = VU University Amsterdam

IISG = International Institute of Social History

RIVM = National Institute for Public Health and the Environment

NIOZ = Royal Netherlands Institute for Sea Research

UvA = University of Amsterdam

NLR = National Aerospace Laboratory of the Netherlands

ANNEX 4: WORKSHOP PARTICIPANTS

Workshop in the context of the preparations of the advisory report on policy for large-scale research infrastructure on 24 January 2013.

Participants	Organisation
Businesses	
Jacques Joosten	DSM
Emmo Meijer	FrieslandCampina / AWT
Leon Sintnicolaas	NXP
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Jan van den Biesen	Philips
Teun Graafland	Shell
Rob Hamer	Unilever
Thomas Grosfeld	VNO-NCW
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Wouter Los	LifeWatch
Bas Buchner	MARIN
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Ruben Kok	Netherlands Bioinformatics Centre (NBIC)
Rob Klöpping	Nikhef / CERN
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Colja Laane	TKI Life Science and Health, NGI
Dave Blank	Universiteit Twente, MESA$^+$ / AWT
Hans de Jonge	VSNU
Government	
Patrick Schelvis	EZ

Jos Engelen	NWO
Cas Maessen	NWO
Anko Wiegel	NWO
Richard Derksen	OCW
Jeanette Ridder	OCW

Other

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Edwin Horlings	Rathenau Instituut
Anke Nooijen	Technopolis
Frank Zuijdam	Technopolis
Paul Diederen	AWT
Victor van Rij	AWT

ANNEX 5: INTERVIEWEES

Businesses

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Thomas Grosfeld	VNO-NCW

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Bas Buchner	MARIN
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Jan Mengelers	TNO
Bernard de Geus	TTI Green Genetics

Public policy

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Annemarie Johanson	EC, DG Research & Innovation
Brigitte Sambain	EC, DG Research & Innovation
Paul Tuinder	EC, DG Research & Innovation
Maarten Kool	EZ
Rene Kok	EZ
Patrick Schelvis	EZ
Tibbe Breimer	EZ

Marjan van Meerlo	EZ
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Cas Maessen	NWO
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Other

John Marks	Consultant
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