The
Danish Council for
Strategic Research

Evaluation of the strategic research programme NABIIT

Final evaluation report
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Evalueringen af Det Strategiske Forskningsråds (DSF) bevillinger til forskning i nano-, bio- og IT-teknologi (NABIIT-programmet) er gennemført i 2012 af et uafhængigt ekspertpanel bistået af konsulentvirksomheden Damvad. Panelet bestod af koncerndirektør, ph.d. Søren Isaksen, NKT Holding A/S (formand), professor og direktør Gabriel Aeppli, London Centre for Nanotechnology, England samt professor Fredrik Höök, Institut for Anvendt Fysik, Chalmers Tekniske Universitet, Sverige.

Evalueringen omfatter 36 projekter, som har modtaget i alt 320 mio. kr. fra Det Strategiske Forskningsråd.[3] Bevillingerne er givet i perioden 2005 – 2008, og på evalueringstidspunktet var 19 af de 36 projekter afsluttede.

Samlet anbefaler panelet meget kraftigt, at *programmet fortsætter*. Rådet håber, at det vil afspejle sig i, at Folketinget afsætter bevillinger til en fortsættelse ved de kommende finanslovsforhandlinger.

Panelet konkluderer, at programmet er et *velfungerende og vigtigt program*, som har leveret forskningsresultater af meget høj kvalitet. Panelet mener, det er for tidligt at udtale sig om de kommercielle resultater, fordi de typisk først vil komme senere, ofte efter 10 år.

Bevillingerne har allerede resulteret i adskillige *videnskabelige gennembrud.* Produktiviteten målt som videnskabelige publikationer pr. støttekrone er høj både sammenlignet med dansk og international målestok. Rådet vil fortsat stille høje krav til den videnskabelige kvalitet.

Panelet fandt en betydelig grad af *multidisciplinaritet* i forskningsaktiviteterne.
Endvidere anerkender panelet, at DSF allerede har bidraget til styrket *interdisciplinaritet* i forskningsaktiviteterne, dvs. samarbejde hvor forskerne samarbejder om et projekt, hvor de i fællesskab har udviklet metoder og processer. DSF er enig med panelet i, at multidisciplinaritet og interdisciplinaritet ikke er et mål i sig selv, men et middel der kan bidrage til at styrke forskningens anvendelsesmuligheder.

DSF vil særligt i opfølgningen på bevillingerne være opmærksom på, om projekterne i tilstrækkelig grad udnytter potentialerne ved multi- og interdisciplinær forskning. Problemstillingen vil også fortsat indgå i vurderingen af ansøgningerne.

Det er vigtigt at være opmærksom på, at DSF's opgave er at støtte forskning, som kan bidrage til løsning af væsentlige samfundsudfordringer, herunder bidrage til forskeruddannelse og uddannelse af kommende kandidater. Derfor er et væsentligt formål med forskningen også at generere ny viden, som kan anvendes i det offentlige og det private.

Panelet konkluderer, at *forskeruddannelsen* i NABIIT-programmet er *excellent*, og her fremhæves især styrken ved, at forskeruddannelsen foregår i et multi- og interdisciplinært forskningsmiljø. Dette er

3 Termen "projekt" anvendes som samlet betegnelse for forskningsaktiviteterne. Der er givet bevilling til to centre (store bevillinger på ca. 30 mio. kr.), to alliancer (mellemstore bevillinger op til 15 mio. kr.) og 32 projekter (bevillinger på mellem ca. 3 mio. kr. og 12 mio. kr.). Her bemærkes, at beløbet inkluderer overhead, som udgjorde 20 procent frem til 2007, hvor det udgjorde 35 procent og derefter udgjorde 44 procent fra 2008.

meget væsentligt, da godt halvdelen af rådets bevillinger anvendes til forskeruddannelse.

Det er panelets opfattelse, at det er for tidligt at vurdere de *teknologiske og kommercielle* gennembrug allerede fem år efter de første bevillinger er givet, da de kommercielle resultater først kan forventes noget senere, ofte efter 10 år. Panelet vurderer, at sandsynligheden for teknologiske og kommercielle gennembrud generelt kan øges ved i højere grad at involvere private virksomheder og ved at involvere dem fra projektets start. Både i denne evaluering og i tidligere analyser har de deltagende virksomheder angivet, at formålet med de projekter, de deltog i, var at generere viden.

DSF har allerede taget skridt til, at der i forbindelse med midtvejsstatus for de enkelte projekter skal være større fokus på den mulige anvendelse af forskningsresultaterne, herunder særligt de teknologiske og kommercielle anvendelsesmuligheder, men også den mulige anvendelse i den offentlige sektor.

Panelet konstaterer, at 43 procent af de publicerede artikler var publiceret sammen med *en eller flere internationale samarbejdspartnere*. Det er udtryk for rådets bevidste prioritering af det internationale samarbejde.

Det er panelets vurdering, at bevillingerne fra DSF har været af væsentlig betydning for *opbygning og udvikling af nye danske forskergrupper* og panelet er kritisk over for det politiske krav om, at DSF ikke må kræve mere end *10 procent i medfinansiering* fra universiteterne.

Panelet vurderer, at *samarbejdet internt i projekterne* og det *internationale samarbejde* er på niveau med, hvad der findes i tilsvarende internationale programmer.

Jeg vil gerne benytte lejligheden til at takke panelet for en interessant evalueringsrapport, som har givet rådet nogle gode input til at fortsætte arbejdet med fokus på, at den strategiske forskning skal skabe størst mulig værdi for det danske samfund gennem offentligt-privat samarbejde, tværdisciplinær forskning, brugerinddragelse, samarbejde på tværs af universiteter og internationalt samarbejde.

Peter Olesen
Det Strategiske Forskningsråd
Formand for bestyrelsen

21. februar 2013

Foreword

The grants given by the Danish Council for Strategic Research (DSF) for research in nano-, bio- and IT technology (the NABIIT Programme Commission) were evaluated in 2012 by an independent panel of experts from the consultancy firm Damvad. The panel comprised Søren Isaksen, Ph.D., Group Executive Director and CTO, NKT Holding A/S (chair), Professor Gabriel Aeppli, Director of the London Centre for Nanotechnology, UK, and Professor Fredrik Höök, the Department of Applied Physics, Chalmers University of Technology, Sweden.

The evaluation covers 36 projects which have received a total of DKK 320 million from the Danish Council for Strategic Research.[4] The grants were awarded in the period 2005–2008, and at the time of the evaluation, 19 of the 36 projects had been concluded.

Overall the panel strongly recommends the *continuation of the programme*. It is the Council's hope that the Parliament will comply with this wish by earmarking funds for the continuation of the programme in the Government's upcoming budget negotiations.

It is the conclusion of the panel that the programme is an *efficiently run and important programme* that has generated research findings of very high quality. The panel feels that it is too early to draw conclusions on the commercial outcome of the programme, as these results typically do not appear until later on, often after a period of 10 years.

The grants have already resulted in a number of *scientific breakthroughs*. The productivity measured in scientific publications per DKK of funding is high compared to both Danish and international standards. The Council will maintain its exacting requirements regarding scientific quality.

The panel found a significant degree of *multidisciplinarity* in the research activities, recognising that the Council has already contributed to improving the *interdisciplinarity* of the research activities, i.e. collaborations where researchers join forces on a project to develop methods and processes. However, both the Council and the panel agree that multidisciplinarity and interdisciplinarity are not goals in themselves, but a means to increasing the range of applications of the research.

The Council intends to pay close attention to whether the projects exploit the potentials of multidisciplinary and interdisciplinary research sufficiently, especially when following up on the grants. This issue will also continue to be considered in the assessment of applications.

It is vital to be aware that the Council's aim is to support research that can contribute to solving significant societal challenges and that this includes contributing to research training and the education of upcoming graduates. Another of the research's

4 The term "project" is used as an umbrella term, describing the research activities. Grants were awarded to two centers (large grants of approx. DKK 30 million), two alliances (medium-sized grants of up to DKK 15 million) and thirty-two projects (grants of between DKK 3–12 million). It should be noted that these figures include overheads, which made up 20 percent until 2007, when they represented 35 percent, and since 2008 44 percent.

key objectives is to generate new knowledge that can be employed in both the public and private sectors.

It is the panel's conclusion that the *research training* offered by the NABIIT programme is *excellent*, deeming it a strength that the training takes place in a multidisciplinary and interdisciplinary research environment. This is very significant as more than half of the Council's grants are put towards research training.

The panel estimates that it is much too early to assess the *technological and commercial* breakthroughs just five years after the first grants were made as the commercial results cannot be expected to be visible until much later, often after 10 years. They assess that the likelihood of achieving technological and commercial breakthroughs can generally be increased by involving of private-sector companies to a greater extent and involving them from the start. Both in this evaluation and in previous analyses, the participating companies have indicated that the aim of the projects they participated in was to generate knowledge.

The Council has already taken steps in connection with the mid-term reports to increase focus on the possible applications of the research findings, in particular the technological and commercial applications, but also the possible applications in the public sector.

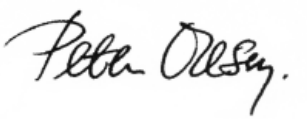
The panel has ascertained that 43 percent of the published articles were published together with *one or more international collaborative partner*.

This reflects of the Council's conscious decision to make international collaboration a high priority.

It is the panel's assessment that the grants from the Council have been of significant importance to *building and developing new Danish research teams* and the panel is critical of the political requirement forbidding the Council to require more than *10 percent in co-financing* from the universities.

They estimate that the *internal collaboration on the projects* and the *international cooperation* are on a par with similar international programmes.

I would like to take this opportunity to thank the panel for an interesting evaluation which has given the Council some excellent input for our continued work with focus on ensuring that strategic research generates the greatest possible value for Danish society through public-private partnerships, interdisciplinary research, user involvement, collaborations among universities and international cooperation.



Peter Olesen
Danish Council for Strategic Research
Chair of the Board

21 February 2013

Executive summary

This report presents the results of the evaluation of the strategic research programme "Interdisciplinary Use of Nanotechnology, Biotechnology and Information and Communication Technology" (NABIIT).

The evaluation, which was commissioned by The Danish Council for Strategic Research (hereafter also referred to as the "Council") under the Ministry of Science, Innovation and Higher Education, has been carried out by an independent, international peer review panel, assisted by the Danish consultancy firm, DAMVAD.

The purpose of the evaluation of NABIIT was to assess the extent to which and how (1) the specific objectives of the programme have been fulfilled and (2) the programme has contributed to fulfilling the general objectives for strategic research, as formulated by the Danish Council for Strategic Research.

The NABIIT programme was established based on a political ambition to benefit industry and society through combined research on and application of nanotechnology, biotechnology and information and communication technology (hereafter ICT). The programme ran from 2005 to 2008, both years included. It awarded 36 grants for a total grant sum of just below 318 million Danish kroner. These grants were given to 32 strategic research projects, two strategic research centres, and two strategic research alliances.

At the time of evaluation, just 19 of the 36 activities funded by NABIIT had been completed. All remaining activities are expected to reach completion by the year 2014. As a result, the evaluation can only assess the preliminary outcomes of research activities supported by NABIIT, i.e. those outcomes that had been achieved at the time of evaluation.

The evaluation panel has defined five main evaluation themes: 1) Research quality, 2) Interdisciplinarity (and the combined use of technologies), 3) Breakthroughs, innovations and commercial exploitation, 4) Training of young researchers and 5) Development of Danish research environments.

The main conclusions and recommendation of the evaluation panel are stated in the following.

Overall, the panel considers the NABIIT programme to be a well-functioning and important, high-quality research programme. The combination of the three technologies – nanotechnology, biotechnology and ICT – aimed at solving societal challenges is both relevant to the research community and to society. It is also in line with research trends seen in leading research environments elsewhere in the world. The panel strongly recommends that the NABIIT programme is continued.

In all programmes and research communities, there is scope for improvement. Therefore, this evaluation report mainly focuses on areas where there is a possibility for improvement and thus to further increase the positive impact of the NABIIT programme. The conclusions and recommendations of the panel should been seen in this light.

The panel found the **scientific quality** of the research activities funded by NABIIT to be of high quality and clearly above average. In addition, the panel concluded that scientific *productivity*, measured as the number of publications per krone invested by the NABIIT programme, to be high by national as well as international standards.

Available data moreover indicated the scientific *impact* of the research produced by NABIIT-funded projects, as indicated by citations to publications, is above average by national standards and on par with comparable international research groups.

Taking the general quality of Danish research into account and the type of research area, the evaluation panel however believes that there is room for strengthening the impact of the research funded by NABIIT even further. A move towards a higher level of interdisciplinarity, thought leadership and greater focus on application perspectives is likely to support such an improvement.

Most projects have a multidisciplinary approach to their research involving participants from different fields working on a joint research topic from within their own field while including knowledge and insights from other fields. Nonetheless, the panel saw a few cases of truly novel combined uses of the technologies emphasised in NABIIT, that is, nanotechnology, biotechnology and ICT.

Several projects have delivered **scientific breakthroughs**. In contrast, the number of **technical breakthroughs** is low, and the **commercial benefits** of the projects are – at least until now - very limited. This is likely to be due to the limited time that has passed since the programme was initiated, but in the assessment of the panel a somewhat weak involvement of private companies as well as a lack of sufficient value-adding support from technology transfer offices (TTO's) at the participating universities also plays a role. Challenges relating to commercialisation are, however, not unique to NABIIT and are faced by other countries as well.

Moreover, the panel observed that in many cases, company participation in NABIIT-funded projects did not seem to be aiming at solving important issues for the company, but rather to build fundamental insights on more generic issues.

In the experience and opinion of the panel, commercial outcomes of the programme are likely to be improved by having more equal and committed participation by industrial partners and by placing more emphasis on the pursuit of issues that are core to companies' R&D activities. The programme is believed to benefit from more attention to such factors at the reviewing process.

Education and training of young researchers by the NABIIT programme appears to be excellent. In particular, multi- and interdisciplinary interaction in the projects funded by NABIIT seemed to provide a valuable platform for education and training of young scientists.

Furthermore, young researchers in NABIIT-funded projects seem to be very content with their positions and their base at Danish universities. The panel saw little evidence of young researchers from the NABIIT programme establishing and demonstrating their intellectual independence. The panel, however, highlights that this challenge appears to be generic to Danish universities and hence span the boundaries of the NABIIT programme.

The panel advises the Council to maintain its strong emphasis on Ph.D. and post.doc training and to take steps to encourage more independent research efforts to better prepare young scientists for their subsequent research roles in academia or industry.

Concerning the **development of Danish research environments**, the panel finds that grants from NABIIT appear to have helped to open new research fields and establish new research groups, which underlines the relevance and value of this type of research programme. Moreover, NABIIT-funded projects appear to have given rise to a number of follow-on projects and activities. The panel suggests the Council to give priority to stimulating and supporting spin-off projects from NABIIT projects, as this is likely to increase the ultimate value created by the initial grant, for example by giving projects the possibility of applying for a follow-up grant to pursue novel research projects that emerge from the original project.

In conclusion, given the success of the existing programme, the panel believes that there is a need in the Danish research portfolio for a continuation of a NABIIT-like programme, and such a programme will benefit by having a stronger focus, enforced through the reviewing process, on the stated aim to deliver highly esteemed results with application perspectives and a clearer emphasis on the combined use of new technologies.

01 Introduction

This report presents the main results of an evaluation of the strategic research programme "Interdisciplinary Use of Nanotechnology, Biotechnology and Information and Communication Technology" (NABIIT).

The evaluation, which was commissioned by The Danish Council for Strategic Research under the Ministry of Science, Innovation and Higher Education, has been carried out by an independent, international peer review panel, assisted by the Danish consultancy firm DAMVAD.

The evaluation panel consists of three experts appointed by the Council for Strategic Research:

- Søren Isaksen (chairman), Group Executive Director, CTO, NKT
- Gabriel Aeppli, Professor and Director of the London Centre for Nanotechnology
- Fredrik Höök, Professor in Biological Physics, Chalmers University of Technology.

See appendix 11.1 for a short bibliography of the panel members.

Professor Kenneth A. Dawson, Director of the Centre for BioNano Interactions at the University College Dublin, was initially part of the evaluation panel but had to step down for health reasons.

Box 1.1. Purpose of the evaluation

(1) To assess the extent to which and how research funded by NABIIT has yielded breakthroughs through combinations of nanotechnology, biotechnology and ICT that can create future opportunities for innovation in industry and solutions to societal challenges within e.g. the areas of health, environment and energy.

(2) The extent to which and how research activities supported by NABIIT have helped to fulfil overall goals for strategic research, notably to promote: (a) research of high international standing, (b) increased interaction between public and private research, (c) cross-cutting (interdisciplinary) research, (d) the internationalisation of Danish research, (e) postgraduate education and researcher training, and (f) the strengthening of Danish research environments.

Box 1.2. Overview of the NABIIT programme

The NABIIT programme was established based on a political ambition to realise and utilise new opportunities for research and innovation through combined research on and application of nanotechnology, biotechnology and information and communication technology (hereafter ICT). The programme ran from 2005 to 2008, both years included. It awarded 36 grants for a total grant sum of just below 318 million Danish kroner. These grants were given to 32 strategic research projects, two strategic research centres, and two strategic research alliances (please see section 4.2 for a description of these three instruments). These 36 research activities will be collectively referred to as "projects" in the text, even though they include two centres and two alliances. Please see appendix 11.4 for an overview of the 36 projects.

At the time of evaluation, just 19 of the 36 projects had been completed. All remaining 17 projects are expected to reach completion by the year 2014.

Responsibility for the implementation and administration of the NABIIT programme was carried by the Programme commission on Strategic Growth Technologies under the Council for Strategic Research.

Source: Adapted from Ministry of Science, Education and Higher Education, *Terms of reference for evaluation of the strategic research theme Interdisciplinary Use of Nanotechnology, Biotechnology and Information and Communication Technology (NABIIT),* 26 January 2012.

02 Aims and methods of the evaluation

2.1 Purpose of the evaluation

The purpose of the evaluation of NABIIT, as stated in the terms of reference for the evaluation,[3] was to assess the extent to which (1) the objectives of NABIIT have been fulfilled and (2) the programme has contributed to fulfilling the general objectives for strategic research, as formulated by the Council for Strategic Research.[4]

The aims of the evaluation were to assess the results of the NABIIT programme as a whole, not the results achieved in the individual projects or research groups supported by the programme.

Specifically, the evaluation panel were given the task of assessing:

— The extent to which and how the research funded by NABIIT has yielded breakthroughs through combinations of nanotechnology, biotechnology and ICT that can create future opportunities for innovation in industry and solutions to societal challenges within e.g. the areas of health, environment and energy.

— The extent to which and how research activities supported by NABIIT have helped to fulfil overall goals for strategic research, notably to promote:

  — Research of high international standing
  — Increased interaction between public and private research
  — Cross-cutting (interdisciplinary) research
  — The internationalisation of Danish research
  — Postgraduate education and researcher training
  — The strengthening of Danish research environments.

It is important to note that the NABIIT programme must be evaluated based on the degree to which and means by which it has *fulfilled* the objectives set for the programme. As the objectives are under ongoing development and have changed since the establishment of the NABIIT programme, the evaluation will primarily assess the degree to which and means by which NABIIT has *contributed* to meeting the overall goals for strategic research and, when appropriate, also comment on the changes that have been made.

2.2 Evaluation questions and themes

Based on the requirements specified in the terms of reference and the evaluation panel's interpretation hereof, a list of evaluation themes were formulated. These themes have been refined throughout the evaluation process and have been instrumental in focusing data collection and analysis.

Table 2.1 on the following page presents the five evaluation themes, along with key indicators for each theme. These evaluation themes also form the backbone for the structure for this evaluation report, which addresses one evaluation theme in every chapter.

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3 Ministry of Science, Education and Higher Education, *Terms of reference for evaluation of the strategic research theme Interdisciplinary Use of Nanotechnology, Biotechnology and Information and Communication Technology (NABIIT),* 26 January 2012.

4 The general objectives for strategic research have been formulated over a period of several years and were under continuous development during the NABIIT programme period. These general objectives are described in their current form in a 2012 brief from the Danish Council for Strategic Research, *Strategic research – Principles and Instruments,* 1 January 2012, which is available from the Council's webpage.

Table 2.1. Evaluation themes, key indicators, and their relationship to evaluation questions

Evaluation theme	Key indicators	Main evaluation questions addressed
Research quality *(Chapter 6)*	— Scientific productivity and scientific impact — Novelty and thought leadership — Broad dissemination of research results (to the academic community, to the general public, and to the private and/or public sector)	To which extent has NABIIT contributed to the overall goal for strategic research to advance *research of high international standing*?
Interdisciplinarity (and the combined use of technologies) *(Chapter 7)*	— Degree of interdisciplinarity — New, combined uses of the technologies	To which extent has NABIIT contributed to *breakthroughs* through *combinations* of nanotechnology, biotechnology and ICT that can create future *opportunities for innovation* in industry and *solutions to societal challenges*?
Breakthroughs, innovations and commercial exploitation *(Chapter 8)*	— Scientific and/or technical breakthroughs — Patents, licenses and spin-off companies — Innovations, i.e. new or significantly improved products, technologies, methods, processes or equipment — Actual or expected applications and other realised or expected outcomes for the private and/or public sector — Collaboration with users	To which extent has NABIIT contributed to the overall goal for strategic research to promote *cross-cutting (i.e. interdisciplinary) research initiatives*? To which extent has NABIIT contributed to the overall goal for strategic research to promote *increased interaction between public and private research*?
Training of young researchers *(Chapter 9)*	— Training of young researchers through Ph.D. and post. doc. fellowships — Recruitment and mobility of young researchers	To which extent has NABIIT contributed to the overall goal for strategic research to contribute to *postgraduate education and researcher training*?
Development of Danish research environments *(Chapter 10)*	— Impact on participants' research activities and competences — Supplementary/subsequent funding of research activities — Characteristics and outcomes of collaboration within NABIIT projects — Internationalisation — Researcher mobility — Acquisition and efficient use of research infrastructure	To which extent has NABIIT contributed to the overall goal for strategic research to contribute to a *strengthening of Danish research environments*? To which extent has NABIIT contributed to the overall goal for strategic research to support the *internationalisation* of Danish research?

DAMVAD 2012

2.3 imitations

By June 21, 2012, when data for the evaluation was collected, just 19 (53 percent) of the 36 projects funded by NABIIT had been completed;[5] the majority of these projects were only recently completed (i.e. in 2011 or 2012). Moreover, 17 projects (47 percent) are still ongoing and expected to be completed between 2012 and 2014.

This has the following important consequences for the evaluation. First, the evaluation can only provide a *partial picture of the results* of research activities supported by NABIIT, i.e. those results that had been obtained at the time of evaluation. However, ongoing projects and, to a lesser extent, also completed projects are likely to be generating results (for example scientific publications, Ph.D. graduates, patents etc.) for some time to come.

Second, the evaluation cannot fully and hence reliably measure the broader *effects* of NABIIT that the results of the programme will give rise to in the long term. Such broader effects may take years to materialise, and may for example take the form of contributions to long-term developments in science or technology, substantial changes in the organisation or activities of partners in the funded projects, growth in industry or major developments in the public sector's use of science and technology. Such long term effects cannot be estimated in this evaluation.

In consequence of this, the evaluation panel has chosen to take a predominantly qualitative approach to the assessment of the preliminary results and outcomes of the NABIIT programme.

5 A project is deemed completed when the final report has been submitted to and approved by the programme commission.

A central aim of this evaluation is moreover to assess the degree of *additionality* created by the NABIIT programme, that is, to assess the changes brought about by the programme in comparison with the same amount of money distributed through other channels and directly to the individual research groups. Such changes could for example be in the form of added research inputs (e.g. if the NABIIT grants have attracted additional funding to the research projects supported and/or to the research area as a whole). Additionality can also take the form of desirable changes in behaviour (e.g. more collaboration across disciplines or between academia and users in the public or private sector, or new ways of managing complex, interdisciplinary (research activities) or in research outputs (e.g. increased research capacity through the education of young researchers, the development of scientific breakthroughs, innovations etc.).

On the one hand, the fact that the evaluation of NABIIT took place when the programme was still ongoing has the stated drawbacks with regards to measurements of the effects of the programme. On the other hand, it has had the beneficial impact on the quality of insights gained through surveys and interviews conducted in connection with the evaluation, as participants had the projects relatively fresh in mind. It was evident during interviews with participants of completed projects that the memory of what happens in research projects has a fast decay rate.

2.4 Data and methods

The evaluation panel was responsible for conducting the overall assessment of the NABIIT programme based on documentation gathered during the course of the evaluation process.

The independent consulting firm DAMVAD carried the primary responsibility for the development of the evaluation design and methodology, and for conducting data collection and analysis. DAMVAD also served as secretariat to the panel throughout the evaluation process, including the drafting of the evaluation report. Nonetheless, the panel takes full responsibility for the conclusions drawn in this evaluation report.

The assessments and recommendations of the panel, which are presented in this report, are based on the sum of data and insights collected through five distinct studies that have been undertaken in connection with the evaluation of the NABIIT programme.[6] The results of these studies are described and documented in separate reports.

For an overview of the five studies, please see box 2.1.

6 According to the terms of reference for this evaluation, case studies of two NABIIT-funded projects were to be undertaken with the aim of communicating examples of projects that promote public sector innovation, an important topic in Danish innovation policy. Additionally, the terms of reference also requested the development of five "profiles" delving into selected themes in the NABIIT programme. Because the aim of both the case studies and the profiles was to highlight and communicate selected themes in the NABIIT programme, they do not form part of the documentation for the evaluation. The evaluation panel has not in any way been involved in these activities, which have been undertaken by DAMVAD.

Box 2.1. Background studies and data

1. A desk study of aims, instruments and grants under NABIIT, undertaken by DAMVAD. The desk study consists of three parts 1) Review of background documents, 2) Analysis of calls for applications, and 3) Analysis of the project portfolio.

2. A self-assessment survey among project participants. Three survey questionnaires were administered: one to academic participants, one to industry participants, and one to international participants. 125 out of 154 organisations participating in the 36 NABIIT-funded projects contributed resulting in an overall response rate of 81 percent. The survey was undertaken by DAMVAD, but the evaluation panel played an instrumental role in the development of the self-assessment survey questionnaire. An analysis of additional funding applications from and grants to participants in NABIIT projects was also performed.

3. A bibliometric analysis of scientific publications, undertaken by DAMVAD. The bibliometric analysis was based on exhaustive lists of peer reviewed journal publications that appeared in peer reviewed scientific journals as a direct result of activities supported by NABIIT grants. The scope of the bibliometric analysis did not enable a comparison of the level of e.g. publication productivity and impact in comparable research programmes in other countries.

4. An analysis of researcher mobility, undertaken by the Ministry of Science, Innovation and Higher Education. This report presents and outlines statistical impressions of the volume, composition and vertical and horizontal mobility of NABIIT project participants, based on a registry analysis. The analysis comprises just under 400 individuals, who at one time or another participated in NABIIT projects.

5. Interviews with nine projects and centres funded by NABIIT, undertaken by the evaluation panel, assisted by DAMVAD. The nine projects included the two strategic research *centres* and seven strategic research *projects*. The seven projects were selected based on their distribution across grant holders at three Danish universities: University of Copenhagen, the Technical University of Denmark, and University of Aarhus.

Additional selection criteria included the size of the grant from NABIIT, whether the projects were completed (with priority being given to completed projects), the degree of public-private collaboration, and collaboration with both small and medium sized firms as well as large international companies.

For each project, separate interviews were conducted on-site at the universities with multiple participants, including the grant holder and other senior scientists, young researchers (i.e. Ph.D.s, post.docs) and, whenever possible, company participants.

The nine interviewed projects are listed below.

Arrays of Nanoscopic Biosensors on Surfaces
Grant size and period: 11.9 million kr.; 2005-2011
Grant holder: Professor Thomas Bjørnholm, University of Copenhagen (note: Thomas Bjørnholm was the grant holder, while Dimitrios Stamou administered the grant on a daily basis.)
Partners: University of Copenhagen, IBM Zürich, Semasopht, Sophion BioScience, 7TM Pharma, Radiometer, AQUAPorin, Novozymes

Centre for Antimicrobial Research CAR
Grant size and period: 27.5 miliion kr.; 2008-2014
Grant holder: Professor Michael Givskov
Partners: University of Copenhagen, Technical University of Denmark, Universität Zürich, Teknologisk Institut, LEO Pharma

Centre for Pharmaceutical Nanotechnology and Nanotoxicology
Grant size and period: 28 million kr.; 2008-2014
Grant holder: Professor Seyed Moein Moghimi
Partners: University of Copenhagen, Technical University of Denmark, H. Lundbeck, Nordic Vaccine Technology, LiPlasome Pharma

A Nanotechnological Approach to Studying Interactions of Biological Macromolecules
Grant size and period: 6.7 million kr.; 2005-2011
Grant holder: Professor Jörg P. Kutter
Partners: Technical University of Denmark, Universtity of Copenhagen, Novo Nordisk

Nano-technology for ultra-high-speed optical communications (Nano-Com)
Grant size and period: 5.9 million kr.; 2006-2011
Grant holder: Professor Palle Jeppesen
Partners: Technical University of Denmark, OFS

Metalloprotease sensitive drug delivery systems for treating cancer and inflammatory diseases
Grant size and period: 7.8 million kr.; 2007-2012.
Grant holder: Associate professor Thomas L. Andresen
Partners: Technical University of Denmark, Bioneer

Computational models and tools for drug discovery (COMODO)
Grant size and period: 7.8 million kr.; 2006-2011
Grant holder: Associate professor Christian Nørgaard Storm Pedersen
Partners: Aarhus University, University of Copenhagen, Molegro, Nuevolution

Development of new metal-oxide and -sulphide catalysts
Grant size and period: 8 million kr.; 2006-2012
Grant holder: Professor Flemming Besenbacher
Partners: Aarhus University, Haldor Topsøe, Image Metrology, SCF Technology

Nano- and Bio-functionalised Surfaces for Biofilm Prevention
Grant size and period: 8 million kr.; 2007-2012
Grant holder: Professor Niels Peter Revsbech
Partners: Aarhus University, Teknologisk Institut, Alfa Laval

All five studies have made valuable contributions to the evaluation report. The evaluation very much benefitted from gaining dual insights into the projects by combining self-assessment surveys with selective interviews with a broad range of participants.

In particular, the evaluation panel underlines the value of on-site visits and stresses that this approach is in line with international best practice within evaluations of this type, where such visits play a crucial role in gaining insight into research projects and into the impacts of the programmes that fund them.

The panel moreover emphasises the significance of talking to both senior and junior scientists, as well as company participants, to gain greater insight into the activities and outcomes of the individual projects. A thorough understanding of the true value of a project in the form of research quality, potential impact to industry or society, interdisciplinarity, participants' interdependency, and the role and benefits of such projects for young researchers can be much more reliably assessed when complementing self-assessment surveys with face-to-face interviews of participants.

03
Main conclusions and recommendations of the panel

Although almost half of the projects funded by the NABIIT programme had not been completed at the time of evaluation, the panel finds that it is possible to make some relevant and significant observations on the overall performance and outcomes of the programme.

Overall, the panel considers the NABIIT programme to a well-functioning and important, high-quality research programme.

In all programmes and research communities, there is scope for improvement. Therefore, this evaluation report focuses on areas where there is a possibility for improvement and thus to further increase the positive impact of the NABIIT programme. The conclusions and recommendations of the panel should been seen in this light.

Evaluation of the NABIIT programme
The main conclusions regarding the NABIIT programme can be summarised as follows:

- Scientific production and quality of the projects funded by the NABIIT programme is considered to be high and clearly above average.
- Scientific impact of publications from projects funded by the programme is satisfactory. The panel believes, however, that there is potential to improve the impact even further by aiming for a higher degree of interdisciplinarity and by targeting top international scientific journals.
- Education and training of young researchers by the programme appear to be excellent, primarily due to benefits from the versatile education provided by interdisicplinary projects.
- Several projects have delivered scientific breakthroughs. The number of major technical breakthroughs, however, is low. Until now, the commercial benefits of the projects are very limited. As the evaluation has been undertaken just five years after the launch of the NABIIT programme, it is too early to conclude on the commercial impact of the research undertaken. In the experience and assessment of the panel, the full commercial effects cannot be expected to materialise in a programme of this nature until approximately ten years after the research activities took place. Nonetheless, results of the self-assessment surveys and interviews undertaken in connection with the evaluation point to a need for promoting greater focus on possible applications of ongoing research.
- The panel recommends a balanced use of small and large grants. While large grants enable ambitious, interdisciplinary projects with critical research mass and extensive user involvement, small grants play an important role in allowing researchers to explore promising research avenues *before* establishing large scale research projects.

Additional, overall reflections from the panel
In connection with the evaluation of the NABIIT programme, the panel spent a significant amount of time examining this scientific area in Denmark. The observations made by the panel have given rise to some more general reflections, which lie beyond the scope of the terms of references for this evaluation, but which nonetheless hold great importance for the research areas addressed by the NABIIT programme.

First, there appears to be a general need to stimulate and create means by which young, talented researchers in Denmark can start their own research careers. The panel saw little evidence of young researchers establishing and demonstrating their intellectual independence, as many young scientists consistently researched and published in collaboration with senior scientists, notably their academic advisors. The panel believes that this could have a negative impact on the future supply of outstanding scientists in Denmark. While ensuring this supply is not the responsibility of NABIIT, the programme could play a role in supporting the early careers of young researchers.

Second, the current technology transfer system in Danish universities does not appear to be effective in supporting the application of research. Participants in NABIIT funded projects consistently pointed to the technology transfer system as a major obstacle to the commercialisation of research results. This problem is common to most countries,

but nonetheless an important issue which must be remedied in order for the full potential of research programmes like NABIIT to be realised.

Third, there seems to be a potential in establishing a world-class focal point for biomedical engineering in Denmark, which could be realised through a merger of existing strengths in engineering at the Technical University of Denmark and biomedical research at the University of Copenhagen.

The conclusions and recommendations of the panel are presented in table 3.1 on the next page and in more detail in the subsequent chapters of this report.

Table 3.1. Main conclusions and recommendations of the evaluation

Evaluation theme	Main conclusions	Key recommendations from the panel
General reflections and recommendations from the panel	Smaller project grants can play an important role in allowing scientists to explore new research paths, methods, means of interdisciplinary collaboration, or cooperative relationships with industry *before* committing substantial amounts of funding and time to large research projects and centres. It is the panel's observation from site visits that small, well-focused projects can have a high impact.	Small grants should be preserved; the Council should not only award large grants and be careful to have the right balance between small and large grants.
	Centres are particularly appropriate for new interdisciplinary areas addressing important and challenging problems to be solved, where the scientific partners have demonstrated extraordinarily high potential in delivering solutions to solving such problems and where there is also a strong industrial and/or societal interest in exploiting such solutions. More selective and ambitious use of centre grants would allow for e.g. higher degree of interdisciplinarity, more focus on commercialisation (the whole "value chain"), closer collaboration with users and better training of young researchers	Reconsider the use of *centre* grants to make them more selective, ambitious and demanding – both with regard to quality and relevance in the form of industry importance or solving societal needs. A way could be to use the project grants as the basis for centre qualification, thus creating a highly competitive environment among project grants and grant holders to have the potential to qualify for a broader and more long-term type of centre grant. A way to differentiate between centres and projects could also be to give centre activities a chance of an increase in funding on the level of 20 – 30 percent at a midway evaluation, where certain achievements, like increased industry participation, have been reached.
Research quality *To which extent has NABIIT contributed to advancing research of high international standing?*	In the assessment of the panel, the scientific *quality* of publications from NABIIT-funded projects is clearly above average. Moreover, the *productivity*, measured as the number of publications per krone invested by the NABIIT programme, appears to be high by national as well as international standards.	The evaluation panel is of the opinion that the overall level of ambition of the programme as a whole and of the individual projects supported by NABIIT both could and should be higher as the panel believe the basis for higher performance is there. A move towards a higher level of genuine interdisciplinarity and greater focus on application perspectives is likely to support such an improvement. This should be backed by more room for risk taking in the projects and thus also in the prioritisation and review process. These recommendations are expanded upon in subsequent conclusions and recommendations.
	It is the assessment of the panel that the level of scientific impact of the research produced by NABIIT-funded projects seems to be above average when comparing to similar research groups in Denmark and average when compared to similar, groups funded by research grants in comparable countries.	
	In two of the seven research projects interviewed by the evaluation panel, there was clear evidence of true thought leadership, which by definition means setting a novel agenda on the stage of world science and technology. Taking the overall quality level of Danish research within NABIIT relevant fields into account, there should be potential for increasing the overall degree of though leadership in projects funded by NABIIT.	A clear focus on promoting thought leadership in the call for applications as well as in the subsequent peer review and selection process is likely to improve this ratio and thus result in a higher degree of thought leadership, by prioritising activities aspiring to deliver new and ground-breaking results and with significant application perspectives. Such factors should play a significant role in the reviewing and the prioritisation process.
	Based on the panel's observations from the self-assessments provided by the participants in the NABIIT-funded projects, the majority of the projects have engaged in some degree of dissemination targeted toward non-academic audiences. However, the degree and form of these activities vary greatly from one project to the next.	The Council should continue to prioritise and encourage public dissemination. Dissemination activities, however, should not be explicitly addressed in the calls or the peer review process, but instead be included as an obligation as part of the funding contract.

Interdisciplinarity (and the combined use of technologies) *To which extent has NABIIT stimulated (a) more interdisciplinary research and (b) novel combinations of nanotechnology, biotechnology and ICT?*	The panel found limited evidence of high degrees of interdisciplinarity (defined as research activities where the ability to find a solution to key tasks is dependent on interlinked contributions from different research disciplines) in the research projects interviewed. This, however, is not a challenge that is unique to NABIIT but also faced by other similar research programmes in the rest of the world.	The panel believes that a strong focus in the programme on the stated aim to deliver highly esteemed results with application perspectives should stimulate more interdisciplinary proposals and activities within the projects.
	The panel only saw few cases of novel, combined uses of two or more of the three specific technologies. Again, this is a general challenge in the research community, and not specific to the NABIIT programme.	The Council should place a stronger emphasis on the combined use of technologies, and work at interfaces between technologies in the review process.
Breakthroughs, innovations and commercial exploitation *To which extent has NABIIT (a) contributed to breakthroughs through novel technological combinations that can create future opportunities for innovation in industry and solutions to societal challenges, and (b) to which extent has NABIIT stimulated increased interaction between public and private research?*	Both projects and centres are delivering substantial scientific results, but the commercial impacts and number of breakthroughs are low, until now. In the assessment of the panel, this is primarily due to weak involvement of private companies and a lack of value-adding support from technology transfer offices (TTO's) at the participating universities. However, it is important to keep the timing in mind and in the assessment of the panel; commercial results can only be expected from NABIIT-type projects after approximately 10 years. Nonetheless, the evaluation indicates a lack of attention (by both public and private participants) on facilitating the commercial application of their research.	In the experience and opinion of the evaluation panel, the outcome of the projects is expected to be positively influenced in nearly all aspects by having more equal, engaged and committed participation by industrial partners. Industry involvement in the projects is recommended from the outset of the project (as this, in the panel's experience, increases the likelihood of having committed and significant collaboration with industry partners).This should not be a definite requirement as certain important research fields having high application potentials could still be at such a premature level that significant industrial participation is difficult to obtain in a small country like Denmark.
	In most cases, company participation did not seem to be aiming at solving important company issues. Rather, the majority of company partners appeared to participate in NABIIT projects to build fundamental insights and engage in generic, precompetitive research.	Commercial benefits are likely to be improved by involving companies to a higher degree in the projects and by focusing on issues core to companies' research and development activities.
	The type of company participation varies greatly across the projects.	More attention should be allocated in the evaluation of applications concerning the type and degree of company participation. For example, if company participation is prioritised, care should be taken to avoid pseudo-commercial participation, e.g. where authorised technological service institutes participate as de facto technical research partners but are presented as industry partners. Similarly, reviewers should pay particular attention to the degree of involvement and commitment of company partners in projects.
	There is very limited participation by public sector users in the projects. Nevertheless, many projects have potential societal benefits, e.g. through improvements in health care, food technology, ICT etc.	There seems to be no reasons for a change in the programme in order to better meet societal needs, except to improve commercial impact as per the previous recommendation.
Training of young researchers *To which extent has NABIIT contributed to postgraduate education and researcher training?*	Multi- and interdisciplinary projects are excellent tools for educating young scientists. Interviews indicate that multi- and interdisciplinary interaction in the projects funded by NABIIT provide an excellent platform for education and training of young scientists .Young scientists operated primarily within their own field, but appeared to gain significant insight and networks into other, relevant research disciplines. In the panel's experience, these are valuable qualities in preparing young scientists for future careers in both academia and industry. Young researchers in NABIIT-funded projects seem to be very content with their positions and their base at Danish universities. There was little evidence of young researchers establishing and demonstrating their intellectual independence, as many of the respondents consistently researched and published in collaboration with senior scientists, notably their academic advisors. It is however important to note that this conclusion may be biased by the fact that the panel only met young scientists who had remained in the research groups where they undertook their NABIIT-funded PhDs or post.doc fellowships.	The Council should continue to have a strong focus on Ph.D. and post.doc education. In the experience of the panel, demonstration of intellectual independence - e.g. in the form of single-authored publications - is a key parameter when deciding for recruitment in international research institutions. In view of this, a stronger focus on supporting young scientists who aim at setting their own research agenda is recommended. In addition, a research programme such as NABIIT could enforce special efforts in the form of smaller projects, aimed at boosting scientific independence of young scientists aspiring for assistant professorships. Such programmes should be designed so they become highly prestigious with e.g. award-like structures.

	Several young scientists interviewed did not know that their research position was funded through the NABIIT programme.	The Council should take steps to increase identification with the NABIIT programme through joint activities comprising both team building activities and courses with participation of young scientists, both within and across the different projects funded by the programme.
	Most young researchers will leave academia to take up positions in the public or private sector. The projects interviewed by the panel, however, appear to predominantly train their young researchers for a career in academia. Again, this conclusion may be biased by the fact that the panel met exclusively with young scientists who are still at the institution, where they undertook their NABIIT-funded Ph.D. or post.doc fellowship.	The Council could initiate courses or other joint activities for young scientists that are part of a NABIIT-funded project in order to train their mind-set to be fit for both academia and the industry. Moreover, a greater degree of involvement of company partners in projects, as recommended above, would also contribute to the training of young scientists associated with NABIIT-funded projects in priorities and approaches to work in industry.
Development of Danish research environments *To which extent has NABIIT contributed to a strengthening of research environments, including an increased internationalisation of Danish research?*	Based on insights gained from the self-assessment survey and interviews, grants from NABIIT have helped to open up new research fields or establish new research groups.	Research programmes like NABIIT are highly relevant. The efficiency could be further improved by bringing the collaborating parties closer together.
	NABIIT-funded projects have given rise to a number of follow-on projects and activities.	The Council should give priority to stimulating and supporting spin-off projects from NABIIT projects, as this is likely to increase the ultimate value created by the initial grant. In the experience of the panel, and based on the insights gained from the self-assessment survey and the interviews, the Council could achieve this by giving projects the possibility of applying for a follow-up grant to pursue novel research projects that arise from the original project.
	It is the impression of the panel that the overall level of interaction in the projects, national as well as international, is acceptable and similar to what is found in comparable programmes in other countries. The panel also observed a high degree of variation in the level of and approaches to collaboration among project partners. In-depth analysis of the projects interviewed indicated that there is an unrealised potential to strengthen the degree of collaboration among participants in projects. For example, there were few projects which involved co-authorship among several/all of the participating research groups. In the experience of the panel, this indicates that such collaboration was lacking; this conclusion was moreover substantiated in several interviews.	The panel recommends that projects become more aware of the need and benefits from close collaboration when conducting true interdisciplinary research.
	There are obstacles in Denmark, as in several other countries, for mobility between academia and the public or private sector.	
	There were examples of investments in expensive hardware and research infrastructure that seemed to be clearly influenced by funding of projects within the NABITT programme.	The Council should take steps to ensure that future programmes through highly application specific objectives stimulate the integration of other disciplines at the centres where large infrastructure investments in specific areas have been made.

DAMVAD 2012

04 About the NABIIT programme

4.1 Background

The NABIIT programme was established based on a political ambition to realise and utilise new opportunities for research and innovation through combined research on and application of nanotechnology, biotechnology and ICT.

A key motivation behind the programme was the expectation that novel, synergistic combinations of the three technologies can help address key societal challenges in e.g. the health sector and in regards to the environment. In addition, new developments in research on the three technologies were expected to yield results and technological advances of relevance to a number of key business sectors where Denmark holds a strong international position, e.g. in biotechnology.

The programme was hence established with the purpose to identify and develop future opportunities for commercial innovation and solutions to societal problems through combinations of nanotechnology, biotechnology and ICT.

The NABIIT programme was managed and administered by the Programme Commission on Strategic Growth Technologies.

4.2 Grants and instruments

As stated in chapter 1, a total of 36 projects have received support from NABIIT during the programme period 2005 to 2008. At the time of data collection, 19 of the 36 projects had been completed.[7]

Figure 4.1. Completed and ongoing projects

DAMVAD 2012

In total, NABIIT has supported 36 projects distributed across three types of instruments:[8]

- 32 strategic research projects (granted in the period from 2005 to 2008, both years included)
- Two strategic research alliances (2007)
- Two strategic research centres (2008).

Where specific instruments are not specified in this report, the term "project" is used to refer to all 36 research activities that have received NABIIT funding. Table 4.1 shows the distribution of the 36 grants by the research institution that the grant holder was affiliated with at the time of application.

Table 4.1. Grants, by type of instrument and by affiliation of grant holder (at the time of application)

	Alliances	Centres	Projects	Total
University of Copenhagen	1	2	7	**10**
Technical University (DTU)*	1		10	**11**
University of Aarhus**			10	**10**
Roskilde University			2	**2**
IT University of Copenhagen			2	**2**
Southern Danish University			1	**1**
Total	**2**	**2**	**32**	**36**

DAMVAD 2012

* Includes the national research laboratory RISØ, which merged with the Technical University of Denmark in 2007

** Includes the national research laboratory *Dansk Jordbrugsforskning*, which merged with the University of Aarhus in 2007

7 A project is considered completed when the final report has been approved by the programme commission.

8 For more detailed information on these instruments, please see The Danish Council for Strategic Research, *Strategic research – Principles and Instruments,* 1 January 2012.

Box 4.1. presents the three different types of instruments that is included in the NABIIT programme. The description below is based on how the instruments are described in 2012 and thus not how they were during the years where the NABIIT programme grants were granted. The instruments have evolved over the years.

Box 4.1. Three instruments

Strategic research projects are expected to find solutions to a relatively restricted set of research issues and promote participants' development of interdisciplinary expertise while contributing to innovation among stakeholders in the public and private sectors. They have a duration of 3-5 years and are eligible for upwards of DKK 10 million in funding from the Council.

Strategic research centres are employed where there is a need for research environments of a high scientific standard focused on developing solutions to complex problems. Research management should be given high priority, and interdisciplinary research is expected to build innovation and entrepreneurial potentials. Centres are expected to develop into internationally leading research environments and to continue their collaborative activities with public, private and international partners when funding ceases.

They have a duration of 5-7 years and are eligible for upwards of DKK 30 million in funding from the Council.

Strategic research alliances are used when there is a need to create alliances between scattered, small-scale research environments in Denmark and relevant public, private and international actors to find solutions to societal challenges. Alliances must ensure that the parties to the alliance pursue its principal objectives and that the research activities are undertaken in a genuine collaboration. They have a duration of 5 years and are eligible for 15-20 million in funding for research and networking activities.

Source: Based on The Danish Council for Strategic Research, *Strategic research – Principles and Instruments,* 1 January 2012

4.3 Size of grants

The variety in the size of grants awarded under the NABIIT programme can be seen in table 4.2. The average size of NABIIT grants was 8.8 million.

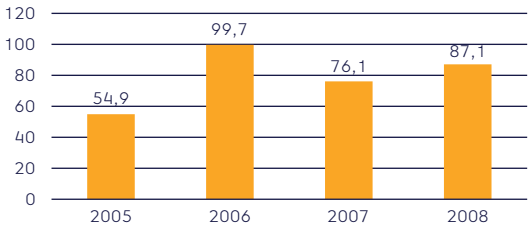
Table 4.2. Grant size (minimum, maximum, average and total), by instrument (in million DKK)

	Min.	Max.	Ave.	Total
Centres	27.5	28.0	27.7	**55.5**
Alliances	9.2	15.0	12.1	**24.2**
Projects	3.4	11.9	7.4	**238.1**
Total	**3.4**	**28.0**	**8.8**	**317.8**

DAMVAD 2012

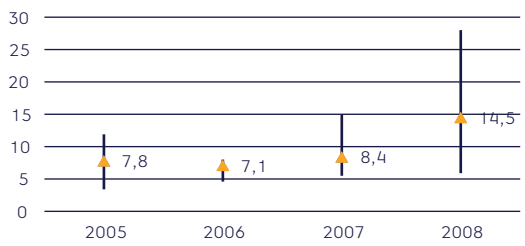
While the total amount of funds granted on a yearly basis by NABIIT has remained relatively stable during the programme period (cf. figure 4.2.), there were however substantial year-to-year differences in the minimum, maximum and average size of grants (cf. figure 4.3). These differences are in large part due to the establishment of the two strategic research networks in 2007 (awarded DKK 9.2 and 15 million in Council funding) and the two strategic research centres in 2008 (awarded DKK 27.5 and 28 million).

Figure 4.2. Total NABIIT grants, by year (in million DKK)



DAMVAD 2012. N = 36 grants

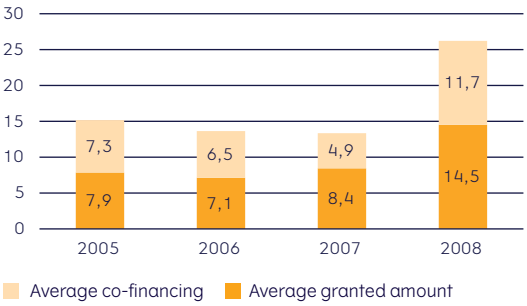
Figure 4.3. Size range and average size of NABIIT grants, by year (in million DKK)



DAMVAD 2012. N = 36 grants

The programme commission behind NABIIT has emphasised co-financing as part of the assessment criteria for projects, alliances and centres. The figure below thus shows the average size of grants in each year compared to the average size of co-financing per grant awarded in that year. The provision of co-financing has remained relatively stable over the evaluation period, save for a decrease in 2007 and a substantial increase in 2008. The latter is explained by the fact that funding was granted in 2008 for two large strategic research centres, which also involved considerable co-financing from participants.

Figure 4.4. Average amount of co-financing (in million DKK)



Data provided by Ministry of Science, Innovation and Higher Education 2012, N = 36 grants

4.4 Participants

In total, 158 organisations have participated in the 36 projects funded by NABIIT. Projects have between two and nine participating organisations[9]. On average, four organisations participate in each project.

Approximately two-thirds of the participants were university departments or research groups or, in a few instances, hospitals. Private companies account for the rest of the participants; this category also includes interest organisations representing particular industry sectors and authorised technological services institutes (that is, not-for-profit research organisations operating on commercial terms).

9 These numbers are based on the original grant applications; as such, there may have been subsequent changes to some of the projects that are not reflected here.

05 General reflections and recommendations from the panel

This chapter presents some general conclusions and recommendations that the panel wishes to highlight based on its evaluation of the NABIIT programme. These conclusions are presented in a separate chapter, as they cut across the selected evaluation themes discussed in the subsequent chapters of the report. The conclusions and recommendations presented here should thus be seen as overall recommendations to Council for Strategic Research and the Programme commission on Strategic Growth Technologies that is responsible for NABIIT and for other related research programmes.

5.1 Both small and large grants are needed

Conclusion: *Smaller, focused projects have clearly shown their merits*.

Recommendation: *Continue to provide smaller grants, also below 10 million kroner, and use performance on these to determine suitability for larger grants in promising areas.*

The panel has seen good examples of smaller projects being very efficient in delivering outstanding results through a clear focus on specific challenges. They have been able to demonstrate proof-of-principle that can be attractive to certain industries. Small project grants can play an important role in allowing scientists to explore new research paths, new methods, new means of interdisciplinary collaboration, or new cooperative relationships with industry *before* committing substantial amounts of funding and time to large research projects and centres.

The panel recognises that the Council's effort in promoting interdisciplinary research projects that can address societal challenges in collaboration with industry often also calls for large-scale grants with a longer time horizon. However, the panel believes that a continuous stream of smaller grants should be seen and promoted as an excellent opportunity to create a very competitive environment for qualification to larger centre-type grants.

Moreover, it can be easier for researchers to work closely together on a specific challenge if they are working in a small constellation of partners, whereas large grants tend to involve larger groups of collaborators. Smaller projects thus play an important role in promoting diversity and enabling experimentation, and could therefore play an important role in creating a foundation for larger, subsequent research ventures.

The panel has also seen examples of smaller projects that have allowed young scientists to explore new research paths, thereby laying an important foundation for their own future research career. The panel observed a general need to stimulate young talented researchers to step up and create their own research agenda (see section 9.3); the Council could play a role in providing this stimulation by encouraging young scientists to apply for smaller grants.

The panel wishes to point out that a move from smaller to larger grants has been seen elsewhere in Europe, for instance in the United Kingdom. In the observations of the panel, large grants concentrate funds in the hands of a small number of individuals. This can make it more difficult for young researchers to establish their own research careers. Moreover, it can have the adverse effect of reducing diversity in the overall research portfolio, by decreasing the availability of smaller grants for the exploration of new research paths. The panel underlines that their recommendation should be seen in light of the Council's decision to prioritise larger grants that can lift more ambitious projects and involve more partners. This represents a decision to move away from small grants and towards larger grants. Today, the Council only supports projects with a minimum size of 10 million DKK in public funding. This approach naturally leads to conservative choices of projects and principal investigators, and reduces opportunities for larger risk-taking within smaller budget envelopes.

Notwithstanding the above, there are also good arguments to simultaneously provide larger grants that enable the establishment of research centres

with greater critical mass, broader research targets, and a longer lifetime, e.g. up to 10 years. The panel thus suggests the Council to pursue a balanced approach to grant size, which can enable both small and large grants.

In connection with larger grants, the panel moreover recommends putting provisions in place to prevent rent seeking by senior scientists, e.g. co-authorships related only to financial intermediation.

5.2 Greater differentiation between centre grants and project grants

Conclusion: *Centres are particularly appropriate for new interdisciplinary areas addressing important and challenging problems to be solved, where the scientific partners have demonstrated extraordinarily high potential in delivering solutions to solving such problems and where there is also a strong industrial and/or societal interest in exploiting such solutions.*

Recommendation: *Use the project grants as the basis for centre qualification. Create a highly competitive environment among project grants and grant holders to have the potential to qualify for a broader and more long-term type of centre grant.*

The panel has only met with two strategic research centres, as only two such centres have been funded by the NABIIT programme. In the following, the panel draws on their experience to present some more general reflections on how centre-type grants can be most effectively deployed as instruments for strategic research. Overall, the panel recommends a high degree of differentiation between the requirements and expectations of project grants and centre grants.

A key aim of the NABIIT programme was to yield commercial breakthroughs through combinations of nanotechnology, biotechnology and ICT that can create future opportunities for innovation in the industry and solutions to societal needs.

The panel shares this ambition. It is the viewpoint of the panel, based on their experience, that much of today's ground-breaking research takes place at the interfaces between different disciplines, and that the objective of such research is to look for answers to major problems requiring a solution. This is illustrated by the fact that publishing in high impact journals requires researchers to focus less on the technicalities of their research and more on the broader context and implications of their research for addressing problems of importance to industry and society.

The outcome of research is to some degree unpredictable. Nevertheless, it is the panel's opinion that centre grants should be used in situations where the needs and chances for meeting such high ambitions have been somewhat documented. Hence, there must be a solid basis for thorough peer review of the aspiring projects focusing on i) the importance of the issues to be addressed by a centre, ii) the robustness of interdisciplinarity in the activities constituting the core of the centre and iii) the likelihood that the partners will be able to meet the goals.

The stated objective of the NABIIT programme is to fill a role in the middle of the innovation value chain, that is, somewhere between basic science and application[10]. To fulfil this role, research activities supported by the programme must focus on a specific research objective in a well-defined area and, at least to a certain degree, address issues in the entire value chain.

According to the panel, requirements and the level of ambition as well as the scale and scope of activities should be increased for a centre investment to be justified and to support the attainment of the objectives set for the programme.

The panel suggests that requirements to obtain a centre grant should be:

- The grant holder must have demonstrated out-standing performance as manager of application-relevant and interdisciplinary research projects.
- Industry participants should be intimately involved in the centre's activities *and*, when possible, co-located on campus.
- The entire value chain – including business development – should be represented in the centre and addressed by the management of that centre. This would allow centres to pursue commercialisation activities that cannot realistically be pursued under project grants.
- The centre should have its own expertise (or immediate access to such expertise) required to help in commercialising research results. In connection to this, the panel suggests that it should be possible to set aside a small portion of the funding to pay a fraction of the salary for someone acting as a "business developer" for the centre. The embedded developer (within the project) should be responsible for commercialisation of the research results, including patents and licenses, formulating business plans, marketing and private sector fund raising for next step developments. The panel saw a positive example at DTU of such a business driven advisory function which seemed to stand in contrast to other, more remote administrative or legal approaches to technology transfer.

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10 The objectives for the NABIIT programme are founded within
the concept of research quality of the Council for Strategic Research, which is based on three equivalent criteria: the relevance, potential impact and academic quality of research.

The panel strongly emphasises that the centres should also have a high level of co-financing from the university. The current maximum commitment of 10% co-financing[11] is inadequate. Setting such a limit in large strategic research ventures is against the very basic idea behind strategic research funding; namely the idea to set up mechanisms to motivate and drive the public research community in a direction considered of strategic value to the nation. The stronger the motivation of the research community to direct its activities in such a direction, the better it is.

As part of a centre grant, the rectors of the universities involved should provide the physical space to enable co-location where demanded, and agree on the financing and other practical arrangements to enable this. This could also help enforce and increase interdisciplinary research collaboration.

The panel did not meet the two strategic research alliances funded by NABIIT during the interview week. However, having a look at the description of alliances; "*alliances are used when there is a need to create alliances between scattered, small-scale research environments in Denmark and relevant public, private and international actors to find solutions to societal challenges*" the aim of the NABITT programme of delivering breakthroughs based on interdisciplinary activities could be a challenge for such type of instrument. The panel further wish to convey a word of caution relating the amount of instruments that is offered in programmes like NABIIT. It may cause confusion with too many different alternatives. Additionally, energy should be focused on promoting the real aim of the programme which is to enforce excellent science with high application perspectives and not different forms of instruments.

In the experience of the panel, assessment criteria are important in differentiating a research programme from other funding agencies and programmes. However, care must be taken not to set out conflicting criteria or promote "box ticking". By "box ticking", we refer to situations where applicants design their proposals primarily with a view to meeting as many explicit or implicit criteria as possible, rather than focusing on what would create optimal conditions for the proposed research project. In the course of the interviews, the panel observed several examples of what could be considered "window dressing" with the purpose of making the application more likely to fulfil what is believed to be important criteria in the evaluation process. Examples observed by the panel include:

- Several projects involve what the panel considers to be pseudo-company type of participation. This indicates that the criterion of industry participation is often not sufficiently evaluated and prioritised in the review process. It appears that the evaluation of the relevance dimension, quality, commitment and participation of the industrial participants are not subject to the same thorough evaluation as are the academic participants.
- In one of the grants, a group (from the same university) which was not convincingly relevant to the overall activity was invited to join, where the objective clearly seemed to be to raise the scientific reputation of the application.
- The criteria of requiring involvement of at least two distinct scientific areas (nanotechnology, biotechnology or ICT) seems only rarely to have led to true interdisciplinary work and instead resulted in multidisciplinary projects with modest levels of interactions (see section 7.1). The panel agrees that the vision of working at the interfaces between the three disciplines is a good idea, given that this is where the international research community is headed and also where future technologies are likely to emerge. If there is a lack of qualified true interdisciplinary proposals, smaller monodisciplinary projects should be preferred to "artificially constructed" multidisciplinary projects.

As a way forward, the panel proposes that the Council is very clear in its communication, evaluation and prioritization of applications. One way of handling this could be to clearly state what minimum requirements for a centre grant are, for example:

- The application concerns a research activity within one of the three defined areas (nanotechnology, ICT or biotech).
- The objective of the research activity is clearly targeting a solution to answers on major problems that could lead to a very clear application perspective, if successful.
- Has true and engaged participation from industry partners or the like having a sincere interest in exploiting a positive outcome of the research activity (not only measured by their funding contribution but also through their expectations regarding further application possibilities).

11 According to "Aftale om fordeling af globaliseringsmidlerne tilforskning og udvikling 5. november 2008", the Council for Strategic Research can at most require 10% in co-financing of grants from public research institutions. Such institutions may provide additional funding, but the Council is not allowed to take this into account in the assessment of proposals.

06 Research quality

6.1 A high level of scientific productivity

Conclusion: *It is the assessment of the panel that the productivity of projects funded by NABIIT, as indicated by the number of publications per krone invested by the NABIIT programme, appears to be high by national as well as international standards.*

Scientific productivity refers to the amount of research produced in NABIIT-funded projects, as indicated by the volume of articles that have been published in scientific journals.

It should however be noted that it was not possible for the panel to determine the extent to which the level of productivity is affected by cross-subsidies. The research presented in the publications reported is likely to have been directly or indirectly supported by other sources of research funding, e.g. from other programme commissions under the Council for Strategic Research, from the Council for Independent Research or from other public and private research funding bodies, including the EU.

Data on scientific publications from the 36 projects that have received funding from the NABIIT programme was collected from the grant holders in June 2012. A total of 455 journal publications were reported. 389 (85 percent) of these 455 publications reported could be retrieved from Thomson Reuters Web of Science, a bibliometric database, which indexes publications in leading international peer reviewed scientific journals.

The 19 projects that had been completed at the time of evaluation generated 288 (63 percent) articles. By comparison, the remaining, ongoing 17 projects have published 167 (37 percent) articles.

Not surprisingly, completed projects have produced close to twice as many publications as ongoing projects, as completed projects have, on average, 15.2 publications, compared to 9.8 for ongoing projects (cf. table 6.1).

It should however be noted that there is a large degree of variation in the number of publications generated by the 36 projects. For example, as can be seen from table 6.1, so far the smallest number of journal articles to have come out of a completed project is 4, while the highest number of publications from a NABIIT-funded project is 43.

Moreover, as the final publications from completed projects are submitted to and accepted by journals, and as ongoing projects approach completion, the total number of publications from NABIIT-funded projects is likely to increase substantially.

Table 6.1. Number of journal publications reported

	Total	Min.	Max.	Ave.
Completed projects	288	4	43	15.2
Ongoing projects	167	1	38	9.8
Total	455	1	43	12.6

Source: DAMVAD 2012 based on the bibliometric analysis

Table 6.2. Average cost per publication from NABIIT funded projects (in DKK)

	Total	Min.	Max.
Number of publications in Web of Science	251	138	389
Total funding in DKK	143.433.996	174.403.345	317.837.341
Cost per publication in DKK	571.450	1.263.792	817.062
Number of publications per million DKK	1,75	0,79	1,22

DAMVAD 2012 based on the bibliometric analysis and funding data from NABIIT

Table 6.2 presents information on the number of scientific publications (in Web of Science indexed journals) produced by NABIIT funded projects in relation to the amount of funding granted by the NABIIT programme. The table shows that completed projects have, on average, generated 1.75 publication per million krone, while ongoing projects have (so far) produced 0.79 publications per million krone. It should however be noted that ongoing projects are expected to generate more publications, ultimately leading to a higher number of publications per krone of financing. In the assessment of the panel, this amount of publications is reasonable, but the panel emphasises that this kind of calculation must be seen in relation to other results generated by the projects, such as innovations and commercial applications and patents.

6.2 Scientific impact is internationally competitive

Conclusion: *Based on the data available, it is the assessment of the panel that the level of scientific impact of the research produced by NABIIT-funded projects is above average when comparing to similar research groups in Denmark and average when compared to similar, groups funded by research grants in comparable countries.*

Recommendation: *Given the level of talent in the Danish research community and the quality of the NABIIT programme, the panel believes that it is possible to raise the impact of NABIIT funded research even further. The panel therefore urges funded academics to aim for top international journals, for example by increasing the level of genuine interdisciplinarity and focus on application perspectives in projects. This move could be further stimulated by an increased willingness to take risks in the prioritisation and review process by the Council*.

Scientific impact refers to the impact of a given research project on the scientific community, typically as indicated by the number of citations awarded to publications presenting the results of this research or to the journals in which these publications appear.[12]

Three approaches to assess impact have been chosen. The first uses the so-called Danish authority lists of scientific journals and their distinction between "top level" and "other" journals. The second approach is based on the Journal Impact Factor (JIF) scores assigned to scientific journals indexed in Thomson Reuters Web of Science. The third approach is based on the number of publications in journals from the Nature Publishing Group (NPG).

Assessment based on the Danish authority lists. Authority lists developed for use in the Danish bibliometric research performance indicator (which is used to distribute base funding to university departments based on their scientific performance) can be used as an indicator of the quality of the publications from NABIIT-funded projects.

These lists, which were developed by expert groups appointed by the Ministry of Science, Innovation and Higher Education, identify key scientific journals and categorise them as "level 1" or "level 2" journals. Level 2 publications are defined as the top 20 percent of journals in their field.
Based on this classification, 184 (47 percent) of the journal publications from NABIIT-funded projects appeared in top journals, the so-called "level 2"-journals in the Danish authority lists. This applies to 52 and 38 percent of publications from completed and ongoing projects, respectively (cf. table 6.3).

Thus, the proportion of level 2 publications is considerably higher than the top 20 percent that they are intended to represent in the authority lists. These results indicate that the quality of research produced in NABIIT-funded projects is higher than the average research quality in the Danish scientific fields concerned, which should also be the case as the projects have been selected based on a competitive peer review process.

Table 6.3. Scientific articles, by the "authority list" level of the journals in which they appeared

	Publications from completed projects		Publications from ongoing projects	
	No.	*Pct.*	*No.*	*Pct.*
Level 2 ("top level") journals	131	52%	53	38%
Level 1 journals	107	43%	62	45%
NA*	13	5%	23	17%
Total	**251**	**100%**	**138**	**100%**

DAMVAD 2012 based on the bibliometric analysis performed for the evaluation. * NA (Not Available/Not Identified) indicates that the journals were not included on the national authority list.

12 Typically, the scientific impact of publications would be assessed through an analysis of the citations. A robust citation analysis however requires a three-year window from the time of publication to allow for a reliable estimation of the impact of a given publication. It was not possible to obtain such a window for this evaluation, as the NABIIT programme ran from 2005 to 2008, and most of the scientific articles generated by NABIIT-funded projects have therefore been published within the past few years.

Assessment based on JIF scores. Scientific impact can also be indicated by the Journal Impact Factor (JIF) scores assigned to all journals in the Web of Science database.

109 (28 percent) of the publications from NABIIT-funded projects that could be identified in Web of Science appeared in journals that have a JIF score of 5 or higher. 13 percent (49 articles) appeared in journals with a JIF score of 7.5 or higher, as indicated in table 6.4.

Table 6.4. Scientific articles, by the JIF scores assigned to the journals in which they appeared

	Publications from completed projects		Publications from ongoing projects	
	No.	*Pct.*	*No.*	*Pct.*
0 > JIF > 4	150	60%	70	51%
4 > JIF > 5	30	12%	30	22%
5 > JIF > 7.5	40	16%	20	14%
7.5 > JIF > 10	19	8%	10	7%
JIF above 10	12	5%	8	6%
Total	**251**	**100%**	**138**	**100%**

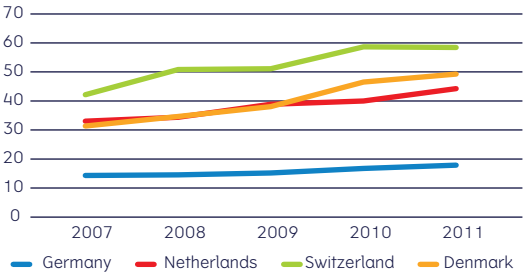
DAMVAD 2012 based on the bibliometric analysis performed for the evaluation.

Measured on impact, Danish research is significantly above world average in fields like physics, chemistry, engineering and biochemistry in general.

Assessment of publications in NPG journals. Figure 6.1 illustrates how Denmark as a whole ranks relative to Germany, the Netherlands and Switzerland, when comparing the volume of scientific articles published in Nature Publishing Group (NPG) journals. NPG journals comprise prestigious journals within chemistry, clinical practice and research, earth and environment, life sciences and physical sciences. NPG comprises some of the top journals within bio- and nanotechnology; thus, publications in NPG journals can be seen as an indicator of the performance of the projects.

The figure shows that when publications are normalised relative to population size, Denmark appears to be performing below Switzerland, on par with Holland and above Germany.

Figure 6.1 Number of scientific articles in NPG journals (2007-2011) normalised by population size



Based on data collected from Web of Science by the Ministry of Science, Innovation and Higher Education 2012. Based on the number of articles with one or more authors from the indicated country

In total, six articles that have been published as a result of NABIIT-funded projects are included in a journal from the NPG journals.

It is the assessment of the panel that a research programme such as NABIIT ought to have a higher representation of NPG journals within the country's combined volume. Additionally, the panel encourages the research communities to increase their ambition in the publication of research results and to aim for journals within the NPG.

International co-publication
According to the bibliometric analysis, 168 articles (43 percent) were co-authored by one or more international collaborators.

The top ten countries that NABIIT projects have co-published papers with are listed in table 6.5.

Table 6.5. Top ten countries* that NABIIT projects have co-published scientific articles with

For completed projects	For ongoing projects
USA	Poland
Netherlands	England
France	Germany
Germany	Israel
Sweden	Finland
China	France
England	Sweden
Italy	Hungary
Japan	Italy
Spain	Singapore

DAMVAD 2012, based on data from Web of Science.
* Ranked by number of articles including one or more authors from that country

Potential for even higher scientific impact
It is the assessment of the panel that publications from NABIIT-funded projects could and should aim for an even higher level of scientific impact for two reasons. First, these scientists have been selected by the NABIIT programme based on the quality of their research ideas and their academic track record. As such, their work is expected to have a high scientific impact. Second, NABIIT has encouraged interdisciplinary work, and high impact scientific journals generally favour interdisciplinary work.

The panel wishes to stress, however, that the first publications in new and emerging areas do not always reach high impact journals. Hence, if the programme aims at renewing science and promoting ground-breaking research, caution should be taken towards placing too much emphasis on short term impact.

The panel observed that many of the research groups interviewed seemed to be heavily focused on "technicalities" of their own research field and paid less explicit attention to the ultimate applications, commercial value and benefits to society from their research. However, in the experience of the panel, publishing in high impact journals requires researchers to focus less on the technicalities of their research and more on the broader context and implications of their research in addressing problems of importance to industry and society. It is the assessment of the panel that the granted research projects should place a stronger focus on addressing the (societal) problems to be solved and less on technicalities within the individual research groups. In the opinion of the panel, this will also strengthen the impact of publications from projects funded by the NABIIT programme.

It is moreover the assessment of the panel that if the projects also had a higher degree of true interdisciplinarity in their research activities, they would have a higher chance of being able to publish in highly prestigious journals.

The Council could stimulate and support ambitions to achieve even higher scientific impact by for example calling for greater focus on solving real and important problems and on greater interdisciplinarity in the review and selection of research proposals. This also requires a greater willingness to take risks – by applicants as well as reviewers.

6.2 Thought leadership

Conclusion: *In two of the seven research projects interviewed by the evaluation panel, there was clear evidence of true thought leadership, which by definition means setting a novel agenda on the stage of world science and technology. Taking the overall quality level of Danish research within NABIIT relevant fields into account, there is a potential for increasing the overall degree of thought leadership in projects funded by NABIIT even further.*

Recommendation: *A clear focus on promoting thought leadership in the call for applications as well as in the subsequent peer review and selection process is likely to improve this ratio and thus result in a higher degree of thought leadership by prioritising activities aspiring to deliver new and ground-breaking results and with significant application perspectives.*

In the assessment of the panel, two of the seven research projects interviewed appeared to be defining entirely new research agendas and to be world leaders within their respective fields. Both of these projects had a very clear application perspective and a clear and related research agenda. One of these projects, which from a funding point of view was a fairly small project, actually delivered outstanding results in two quite different directions. To the surprise of the panel, this activity was later not prioritised as the foundation for a centre activity, even though the research group had applied for a subsequent centre grant**.**

Based on the interviews and self-assessment reports, it is the assessment of the panel that many of the projects focus on research areas that are the subject of current research trends or "fads" in the scientific community. The areas targeted in NABIIT-funded projects are, however, deemed by the panel to be important research areas in terms of both their scientific potential and their commercial relevance.

The panel also observed that some projects were more multidisciplinary than interdisciplinary and "constructed" in a way so as to fulfil formal requirements by somewhat superficially involving different fields and gratuitously including researchers for their track records. This has lead the panel to make a recommendation that lowering the formal constraints for projects might be a good way to further improve the quality and outcome of the funded project activities.

On an anecdotal note, the panel observed that a surprisingly high number of both senior and junior participants in the NABIIT funded projects have been awarded grants from the European Research Council (ERC). Though data on the total number of ERC grants obtained by NABIIT funded scientists was not available, this is a positive indication of thought leadership in the projects.

6.3 Broad dissemination of research results

Conclusion: *Based on the panel's observations from the self-assessments provided by the participants in the NABIIT-funded projects, the majority of the pro-*

jects have engaged in some degree of dissemination targeted toward non-academic audiences. However, the degree and form of these activities vary greatly from one project to the next.

Recommendation: *The Council should continue to prioritise and encourage public dissemination. Dissemination activities, however, should not be explicitly addressed in the calls or the peer review process, but instead be included as an obligation as part of the funding contract.*

Findings from the desk study and the review of the calls for applications reveal that broad dissemination of research results is an area that was given increased attention in later NABIIT calls.

In the self-assessment survey, some scientists indicated that they have developed webpages to present information on and disseminate scientific results from their NABIIT funded projects. The self-assessments also reveal that most dissemination activities are targeted towards industry or the general public, and employ communication channels such as talks, participation in non-academic conferences, teaching, publications in the popular press or trade journals, and various forms of popular scientific magazines or shows on radio or television. Examples provided in the self-assessment survey are:

— Blogs and popular science webpages (e.g. videnskab.dk)
— TV shows with emphasis on science (such as Danskernes Akademi)
— Press releases and articles in popular press (e.g. in Ingeniøren)
— Courses and public lectures
— Exhibitions or lectures at "Experimentarium" (a Copenhagen-based science centre).

Through the self-assessments, the panel has observed how many different dissemination activities the projects have initiated. In the opinion of the panel, it can be difficult to assess the quality of this type of popular scientific dissemination and to determine whether or not the dissemination is adequate. Instead, the panel wishes to emphasise that dissemination to the general public is important and should continue to be prioritised as part of the research programmes. However, dissemination to the public is not and should not be considered a core activity of research projects. The panel therefore suggests that dissemination requirements targeted at the general public should not be part of the calls for applications and thus should also be kept out of the peer review process. Instead, and along with the grant, projects should be obligated to disseminate their research results, and this obligation should be part of the funding contract. The programme commission and the secretariat supporting the programme commission should also play a role in supporting and assisting the projects in their dissemination efforts.

The panel suggests that dissemination via the web could receive greater focus for the projects as it offers a channel to reach a broad and international audience. Webpages are the most important means for communicating with industry and also with the general public. Moreover, data on traffic to the website can provide valuable information on the stakeholders of a research project.

It is the experience of the panel that individual webpages for small projects is not, however, always the right solution. Instead, the panel emphasises the importance of research groups having webpages that are well-functioning and frequently visited by a broad audience. Therefore, the panel suggests that the projects should be more proactive in disseminating their research results through this channel.

Costs incurred in connection with maintenance of a website can even be covered by NABIIT-type grants, either as part of the overhead costs or as a separate expense. For example, in some Swedish strategic research grants, 3 percent of the total grant sum is earmarked for activities related to project management, technology transfer and dissemination, such as upkeep of a web presence.

07 Inter-disciplinarity and technological convergence

7.1 Projects are multidisciplinary, but the degree of interdisciplinarity can be improved
Conclusion: *The panel found limited evidence of high degrees of interdisciplinarity (defined as research activities where the ability to find a solution to key tasks is dependent on interlinked contributions from different research disciplines) in the research projects interviewed. This, however, is not a challenge that is unique to NABIIT but also faced by other similar research programmes in the rest of the world.*
Recommendation: *The panel believes that a stronger focus in the programme on the stated aim to deliver highly esteemed results with application perspectives should stimulate more interdisciplinary proposals and activities within the projects.*

During the interviews, the panel observed that there is a lack of co-publication and co-patenting among project partners from different research disciplines. This indicates a lack of true interdisciplinary work. Indeed, the panel observed a substantial degree of *multidisciplinary* collaboration within the projects interviewed. In other words, most of the research groups participating in the projects appeared to be working on common research topics from within their own fields.

These conclusions are supported by findings from the self-assessment survey among academic participants. As illustrated in figure 7.1, more than half of the academic participants in NABIIT projects who contributed to the survey indicated that research collaboration in their projects takes the form of *multidisciplinary* collaboration, i.e. involving participants from different fields working on a joint research topic from within their own field while including knowledge and insights from other fields.

Just over one fifth of academic respondents indicated that the different participants in the project engaged in *interdisciplinary* collaboration that is, worked closely together on a joint research topic through the use of processes and methods that they have selected and developed together. Such interdisciplinary collaboration was also found in a few of the interviewed projects.
Finally, one fifth of the respondents stated that participants from different research fields work on a joint research topic but within their own field of research, and thus engaged in limited interaction between research fields.

The Council for Strategic Research and the programme commission have strengthened their focus on interdisciplinarity in the NABIIT programme.
The panel supports this priority. It is the perception of the panel that the focus in today's strategic research on a global scale is very much directed towards trying to find answers to fundamental problems and with a clear ambition to find new solutions. Additionally, the complexity of the problems to be solved entails that most answers are to be found at the interfaces between different technologies or by intimate use of combinations of different technologies.

7.2 Technology convergence
Conclusion: *The panel only saw few cases of novel, combined uses of two or more of the three specific technologies. Realising the potential from technology convergence is not an issue which is specific to NABIIT, but a more general challenge in this field of research, which programmes such as NABIIT may help address by pushing for more ambitious attempts to solve important problems through novel combinations of existing technologies.*

Recommendation: *The Council should place a stronger emphasis on the combined use of technologies and work at interfaces between technologies in the review process.*

A key objective of the NABIIT programme was to identify and develop new combined use of nanotechnology, biotechnology and/or ICT. In the panel's assessment, however, the programme has had a negligible effect on the combined uses of the three technologies. There is a global convergence between these technologies, but few of the projects were cutting edge in their approach to combining the technologies.

The panel notes that if the interdisciplinary aims of the programme had been rigorously enforced, many of the interviewed projects that received funding from NABIIT would not have been funded under the programme.

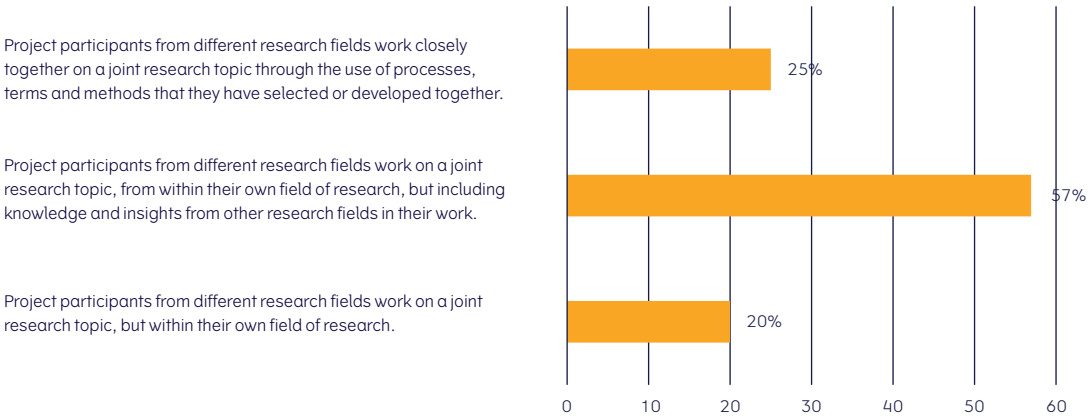
The challenge of identifying and undertaking research on novel combinations of nanotechnology, biotechnology and ICT is not, however, specific to the NABIIT programme but a general challenge for the international research community in these fields. Moreover, the panel recognises the effort that has been invested by the Council to promote more interdisciplinary research and increased technological convergence; realising such changes in the scientific community is a lengthy process, which the NABIIT programme appears to have contributed to. Continued and increased efforts in this regard are however recommended.

The aim to stimulate new technological combinations is still a "live issue" and thus relevant for efforts to increase the competitiveness of Danish research and industry. This is particularly true as both nanotechnology and ICT are technologies that must be seen in an application perspective. In other words, these technologies must be brought into use in combination with other technologies for their full potential to be realised.

For instance, combinations of nanotechnology and ICT are creating new opportunities for health care and planet care. Such innovations are being pursued under similar funding calls by commercial competitors of Denmark, including European nations such as the United Kingdom.

To stimulate increased convergence of technologies through the NABIIT programme, the proposal and the reviewing process would have to be restructured accordingly. According to the panel, ensuring convergence of technologies is the responsibility of the review process. This can for example be achieved by ensuring that relevant users from e.g. industry are involved in the projects, to inspire and guide new uses of the technologies, and by ensuring that all necessary areas of expertise are represented among the academic participants in the project.

Figure 7.1. The nature of interdisciplinary collaboration in NABIIT, according to academic participants



Source: DAMVAD 2012 based on the self-assessment survey. N (academic participants) = 72

08 **Breakthroughs,** innovations and commercial exploitation

8.1 Many good scientific results and some scientific breakthroughs achieved, but low level of commercial impact

Conclusion: *Both projects and centres are delivering substantial scientific results, but the commercial impacts and number of breakthroughs are low. In the assessment of the panel, this is primarily due to a weak involvement of private companies and a lack of value-adding support from technology transfer offices (TTOs) at the participating universities.*

Recommendation: *In the experience and opinion of the panel, outcome of the projects is expected to be positively influenced in nearly all aspects by having more equal, engaged and committed participation by industrial partners. Industry involvement in the projects is recommended from the outset of the project (as this, in the panel's experience, increases the likelihood of having committed and significant collaboration with industry partners).This should not be a definite requirement as certain important research fields having high application potentials could still be at such a premature level that significant industrial participation is difficult to obtain in a small country like Denmark.*

The panel underlines that breakthroughs should include both scientific and technological breakthroughs. *Scientific breakthroughs* hold great importance for research groups and thereby for Denmark, as they increase the international visibility of research groups and improve their funding opportunities and recruitment possibilities. In parallel to this, *technological breakthroughs* hold importance for industry and/or society.

The projects funded under the NABIIT programme appeared to deliver a good level of scientific results and also several scientific breakthroughs. For example, in the assessment of the panel, four of the seven projects and two centres that were selected for interviews by the panel were considered to have generated significant actual or potential scientific breakthroughs.

Most of these scientific breakthroughs have not been generated because of new combinations of nanotechnology, biotechnology and/or ICT.

By comparison, the panel found evidence of very few technical breakthroughs from the majority of the projects funded by NABIIT, based on insights from the interviews and on the assessments of project participants as described in the self-assessment survey. This may to some degree also be influenced by the time frame as the majority of projects funded by NABIIT are still ongoing or only recently completed. In the assessment of the panel, research funded by programmes such as NABIIT can be expected to result in commercial products approximately ten years after the research has been undertaken. As such, it is possible that some of the scientific results achieved in the projects will contribute to technological breakthroughs in the future.

The vast majority of academic participants in the self-assessment survey, however, indicated that their project was not expected to yield commercial results. Many academic participants further underlined that commercialisation was never an explicit objective of the project, which indicates that a basic objective of the NABIIT programme was not well communicated and prioritised in the execution of the projects. In the self-assessment survey, only a few academic participants stated that results of their projects have been commercialised, typically by the industrial partners in the projects, or that they are currently making efforts to commercialise results.

In view of the lack of technical breakthroughs and commercial attention, it is not surprising that few innovations[13], patents, licenses or spin-off companies have emerged from NABIIT-funded projects.

In the experience of the panel, technical breakthroughs and commercial applications thereof can take years to emerge from research projects. However, it is important for research projects to pay explicit attention to aspects of their research that warrant patent protection from the outset of the project. Patents signal and protect the potential

13 Innovations are here defined as new or significantly improved products, technologies, methods, processes or equipment.

breakthroughs and applications can emerge relatively early on. Indeed, the first patent applications may even be filed in connection with the development of the research proposal, particularly if industry partners are closely involved in the project.

For the research funded by NABIIT to be able to result in commercial inventions in approximately ten years, the panel believes that it is necessary for the projects to have a vision and a plan for how their research will have an impact a decade into the future. In the experience of the panel, such plans are difficult if not impossible to formulate without close collaboration with industry.

On a related note, it became apparent to the panel during the course of the interviews that the majority of projects are very much dominated by the university partners. The projects and the objectives of most projects seem to be defined by the university researchers, after which relevant companies are invited and added to the projects primarily to meet the requirement of having company participation in the projects.

The panel underlines that a much stronger participation of commercial partners in the formulation of the aim, content and execution of the projects is likely to improve the commercial outcome of these projects. The panel suggests that industry participation should be encouraged and recommended from the beginning of the project. However, there should be a possibility of including industry participation at a later stage in the projects where research results are more likely to be closer to application. Therefore, industry participation should not be a definite criterion from the start of the project.

In the experience of the panel, establishing long-term and close collaboration between academia and industry requires the attention of high-level people - that is, people who have the authority to make decisions and commitments. For strategic research programmes, like NABIIT the aim in the industry-related projects shall therefore be to ensure industry participation at as high level as possible and to address very important issues for the industry partner(s).

The interviews and self-assessment also showed that academic participants experience a large number of barriers to commercial exploitation of their research results, which are not connected specifically to the NABIIT programme but which nonetheless appear to affect researchers' motivation and incentives to pursue the commercial application and exploitation of their findings from the NABIIT-funded projects.

In particular, the panel noted that the TTO system in the participating universities was criticised by the majority of the scientists for not adequately or sufficiently supporting commercialisation of research results. There seemed to be a need for a more business driven approach rather than an administrative and legally driven approach to TTO.

The criticism was especially related to the speed, the level of competence and efficiency of the universities technology transfer offices.

The Department of Nanotechnology at DTU, however, seemed to have developed a practical solution to circumvent some of the technical transfer difficulties by having an employee with a relevant technical and commercial background who participated in a quick and qualitative evaluation of ideas and functioned as a liaison to potential industrial partners.

The panel believes that technology transfer cannot occur effectively through non-experts. This argues for "embedded technology transfer" rather than a centralised TTO, that is, where individuals with both scientific insight and commercial experience are embedded in the research departments or groups from which technology transfer is to take place.

Overall, it is the perception of the panel that the universities' technology transfer offices have not been effective in supporting (potential) innovations in NABIIT-funded projects. Universities are an important contributor to innovation, but should not see intellectual property or simple services to industry as a source of revenue. Moreover, because of a combination of the breadth of technologies covered, HR policies incompatible with market value and subservience to university politics technology transfer offices at universities are rarely efficient "middle men" in the transfer and commercial exploitation of scientific research results.

The self-assessment and interviews also pointed to other barriers to increased commercial exploitation of results from NABIIT-funded projects. These barriers comprised a lack of capital and/or incentives for academics to pursue to commercial exploitation. Other respondents explained that the market for potential applications of their research were either too immature or non-existent, or pointed to difficulties in converting their research results to commercial products. Finally, numerous respondents argued that the research in their projects was too fundamental to be expected to yield commercial results in the short run.

The panel stresses that outstanding science and commercialisation often go hand in hand, but universities should mainly focus on producing outstanding science. Outstanding science should in this connection also be seen as state-of-the art

engineering that may bring about both scientific breakthroughs of the highest possible impact, including patentable inventions, and projects well suited for prototype-generating activities that are at the border to commercialisation and well suited for industrial collaborations.

8.2 Almost no contribution to public sector innovation – but potential contributions to solutions to societal problems

Conclusion: *There is very limited participation by public sector users in the projects. Nevertheless, many projects have potential societal benefits, e.g. through improvements in health care, food technology, ICT etc.*

Recommendation: *There seems to be no reasons for a change in the programme in order to better meet societal needs, except to improve commercial impact as per the previous recommendation.*

Just two of the 36 projects funded by NABIIT had direct involvement of potential public sector users in the scientific and technological research performed. Two additional projects counted university hospitals among their participants. Aside from these projects, public sector users played no role in NABIIT projects. Moreover, a cursory review of the titles of the 36 projects, for example, reveals that only very few projects are dealing with issues relating to medical research. The panel thus noted that medicine as a field of research seems to be underrepresented in NABIIT projects, as compared to similar programmes in other countries.

A meaningful involvement of and connection with the medical profession is central to creating commercial results from this type of projects. The panel has not observed many partnerships with medical schools or hospitals in the NABIIT programme, and would therefore like to encourage such collaboration.

The underrepresentation of medicine in the NABIIT programme is likely explained by a general lack of a strong presence of medical research in discipline-crossing research. Programmes such as NABIIT can promote greater interaction among medical research and other areas of research, but only to a certain effect. For the full potential of the Danish research environment to be realised, the panel believes that it would be a strong move to combine strengths from existing research environments in bioengineering at the Technical University of Denmark and biomedicine at the University of Copenhagen into a joint physical centre that can serve as a national focal point for world class biomedical engineering.

In spite of the lacking involvement of the public sector in the NABIIT programme, it is the assessment of the panel that much of the research undertaken has some degree of relevance for the public sector in that it may contribute to new solutions to important challenges to society. For example, academic respondents in the self-assessment survey referred to potential positive implications of their research for public health, the environment or food quality and safety.

In certain specific areas, for example within the field of interaction of new nanomaterials with living matters, there is a risk of very undesirable interactions taking place. In the assessment of the panel, these types of issues also seemed to be adequately addressed in the projects under NABIIT.

8.3 Limited contribution to private sector innovation

Conclusion: *In most cases, company participation did not seem to be aiming at solving important company issues. Rather, the majority of company partners appeared to participate in NABIIT projects to build fundamental insights and engage in generic, precompetitive research.*

Recommendation: *Commercial benefits are likely to be improved by involving companies to a higher degree in the projects and by focusing on issues core to companies' research and development activities.*

As stated in section 8.1, NABIIT-funded projects have, at the time of evaluation, generated very few technical breakthroughs. It follows from this that the projects have (at least thus far) made a very limited contribution to innovation in the private sector. This was further supported by the statements provided in the self-assessment survey among company participants. However, as mentioned in section 8.1, it is important to keep in mind that the NABIIT programme has only been running for five years, and it is therefore not possible to make a reliable assessment of the impact of the programme on commercial innovation.
Nonetheless, most company respondents stated that the projects they participated in either have not yet or are not expected to yield commercial results. Moreover, most of the company participants stress that the main purpose of the projects, they have contributed to, was to yield new knowledge, and not necessarily to generate innovations or other commercial outputs. Just one fourth of company respondents indicated that their project have generated or are expected to generate results that can be exploited commercially.

According to company participants that contributed to the self-assessment survey, the main benefits of participating in NABIIT projects are as follows:

— Better and deeper understanding of the existing research areas

— Further development of key research areas
— Adoption of new methods, applicable to the company's business areas
— Obtained new technical skills or competences
— The project made it possible to test ideas, which would not otherwise have been possible to test.

It is the experience of the panel that companies prefer educated talents generated by universities more than the knowledge or inventions that originates from projects such as those financed through NABIIT. A key motivation for companies is thus to participate in projects where they support education. Hence, the results of commercialisation could be seen in this light.

Nonetheless, based on the interviews with the selected projects, it is the assessment of the panel that much private sector participation, unfortunately, was only weakly linked to important business issues and core R&D themes for the larger companies. Moreover, responses in some cases indicated that the company participants were rather aiming to meet personal research goals than addressing important and prioritised company challenges.

The panel is of the opinion that projects in their overall scope as well as in their contribution to commercial successes would benefit from having a stronger involvement from industry at management level and being focused on issues and areas that are key to industries.

8.4 Projects involve company participants – but there is great variety in the types and degree of involvement of these firms

Conclusion: *The type of company participation varies greatly across the projects.*

Recommendation: *More attention should be allocated in the evaluation of applications concerning the type and degree of company participation. For example, if company participation is prioritised, care should be taken to avoid pseudo-commercial participation, e.g. where authorised technological service institutes participate as de facto technical research partners. Similarly, reviewers should pay particular attention to the degree of involvement and commitment of company partners in projects.*

The NABIIT programme, like the Council for Strategic Research in general, has placed a great deal of emphasis on securing co-funding from private sector participants. This is based on the idea that partners who provide significant co-funding are more likely to be committed to the project and to participate actively in both its design and completion.

The evaluation indicated great variety in the types of firms that participated in NABIIT projects. Companies in the projects included both R&D intensive global industry leaders and two-person start-up companies whose living and survival were virtually based on the funding received from the project.

Of the 36 projects funded by NABIIT, 28 projects have had one or more company participants, while 6 involved collaboration with a technological service institute (the so-called "GTS institutes").

The panel found the fact that the role of the technological service[14] institutes are not always clear. They are formally registered as non-public participants, but occupy different functions.

The panel observed in the interviews that, in some projects, the technological service institutes appeared to participate as extensions of the academic research environment rather than as companies and having a strong focus on the funding aspect, resulting in rather artificial constructions. This should be seen in view of the fact that these participants in the evaluation were presented as industrial partners.

The evaluation panel therefore advises the Council for Strategic Research, when evaluating company involvement in grant applications, to be clearer on the diversity among types of company participants, and that different types of participants lead to very different types of projects and output of projects. It is also important to evaluate the degree and nature of participation from industry. Unfortunately, as stated in section 8.3, large companies generally did not appear to collaborate on core areas of their activities. This can to some degree be explained by IPR and competitiveness concerns. It is however the panel's opinion that the Council should do its best to set up a supportive framework and stimulate companies to collaborate on core activities in programmes such as NABIIT.

Generally speaking, according to the self-assessment surveys conducted among academic and company participants, users contribute to NABIIT projects by providing feedback and participating in scientific discussions, particularly in the initial phases of the project. Many users take part in defining goals and testing results or prototypes, in the development phase of e.g. materials, or in the joint

14 Technological service institutes are not-for-profit organisations that engage in applied research and offer technology based services to firms on commercial terms (particularly to small and medium sized enterprises). Approximately 10 percent of the technological service institutes' income is direct public funding, aimed at stimulating the diffusion of the results of scientific and technological research to a broad population of firms. In addition, the institutes apply for public funding from Danish and international sources.

scientific publications of results from the project. Company participants are more likely than their academic counterparts to be responsible for the application or commercial exploitation of research results, when this is relevant.

However, the surveys also indicated that while 90 percent of academic participants contribute to core research activities in NABIIT-funded projects, the same only holds true of 43 percent of company participants. Indeed, some academic respondents also experienced that users from industry were too disconnected or too loosely affiliated with the project to make a significant contribution to their joint efforts.

Based on the inputs from the interviews and the self-assessment surveys, the panel suggests that the Council enables company participation to take place in different steps. It is the assessment of the panel that it *can* be difficult to combine state-of-the-art research with company participation. In order to promote stronger industry participation and to ensure the application of research results, the panel suggests that projects and centres should be asked to consider and given the opportunity to more strongly engage companies in the second phase of the project if results are promising and company participation has not been included at an earlier stage in the project. This decision could be based on the mid-way evaluation of the project. At the same time it is the panel's perception that there may only be a few projects where companies have an incentive to participate in projects at such a late stage where they are not able to participate in the definition of the research direction. Thus, the panel suggest that most effort is allocated to providing a supportive framework for company participation from the outset of the projects, given that commercialisation of research results continues to be a firm objective of research programmes such as NABIIT.

09 Training of young researchers

9.1 A significant contribution to education and training of researchers

Conclusion: *Young researchers have gained valuable education and training due to NABIIT.*

Like the rest of the Council for Strategic Research, the NABIIT programme placed particular emphasis on the education of young researchers. Approximately 65 percent of the research funding granted by the programme commission behind NABIIT is dedicated to Ph.D. and post.doc positions.

According to responses to the self-assessment survey, in the 36 projects that were awarded a grant from the NABIIT programme:

- 73 academic participants hired a total of 146 Ph.D. students and 97 post.docs (or, on average, 2 Ph.D. students and 1.3 post.docs) in connection with their NABIIT-funded projects
- 35 company participants hired a total of 8 Ph.D. students and 7 post.docs

9.2 Young researchers gain from multidisciplinary collaboration

Conclusion: *Multi- and interdisciplinary projects are excellent tools for educating young scientists. Young scientists operated primarily within their own field, but appeared to gain significant insight and networks into other, relevant research disciplines. In the panel's experience, these are valuable qualities in preparing young scientists for future careers in both academia and industry.*

Recommendation: *The Council should continue to have a strong focus on Ph.D. and post.doc education.*

The interviews with selected projects indicated that collaboration across disciplines occurs to a large extent through interaction between young researchers.

While senior scientists in the NABIIT-funded research projects shaped the overall design of the projects, the projects are to a large extent undertaken by the Ph.D. students and post.docs recruited for the projects. This is in line with the overall focus on researcher education and training in the Council for Strategic Research.

As stated above, interviews suggested that much of the communication and collaboration across disciplinary boundaries in NABIIT projects takes place through interaction among young researchers. Interviews indicated that while these young researchers generally worked within their own fields, they were regularly and to a significant extent engaged in exchanges of research materials, discussions of results and joint seminars with both junior and senior scientists from other fields.

The young researchers interviewed by the evaluation panel generally indicated their belief that the quality of their training had been strengthened by the fact that they had participated in a NABIIT-funded project, precisely because this provided them with access to and regular interaction with researchers from other fields. Students appeared to benefit tremendously from the interaction between disciplines.

9.3 Young researchers were content – and expressed limited ambition

Conclusion: *Young researchers in NABIIT-funded projects seem to be very content with their positions and their base at Danish universities. There was little evidence of young researchers establishing and demonstrating their intellectual independence, as many of the respondents consistently researched and published in collaboration with senior scientists, notably their academic advisors. This should not be seen, however, as a particular challenge for the NABIIT programme, but as a general shortcoming of young researchers in Denmark in the research fields addressed by NABIIT.*

Recommendation: *A research programme such as NABIIT could enforce special efforts in the form of smaller projects, aimed at boosting scientific independence of young scientists aspiring for assistant professorships. Independence could further be strengthened through more single-authored publications by young scientists, which the panel highlights as a key parameter in recruitment decisions in internationally competitive research institutions. The programme should be designed so as to become highly prestigious with e.g. award-like structures.*

Most of the young researchers that the panel met, both those of Danish and non-Danish nationality, were very content with their positions at the Danish universities. This was especially prominent concerning research themes and affiliations, but they expressed little interest in advancing e.g. to management positions in academia or industry. Similarly, they did not express interest in moving to new research themes or taking up positions at research institutions outside of Denmark. Long-term ambitions were generally speaking very modest and unclear.

The panel is aware that the observations made above could to a certain degree be biased by the fact that the young researchers that participated in interviews had either stayed on at the institution after the end of the NABIIT-funded project or were still involved with the project. The panel did not meet the young researchers who moved to other places after the completion of their participation in the NABIIT projects in the interviews with young scientists.

The panel is concerned that there was so little evidence of young researchers establishing and demonstrating their intellectual independence, particularly due to the lack of mobility among young researchers in the NABIIT-funded projects. Additionally, the panel believe this situation may be influenced by a potential gap in the funding structures where post.docs tend to get their permanent positions at universities by working closely together with a more senior professor that is successful in bringing in large grants – and not by demonstrating independence.

In several of the research groups that the panel met, there was a tradition of senior scientists consistently co-authoring publications by junior researchers. To promote the development of intellectual independence and long-term career development among young researchers, this practice should be discouraged. The panel believe this is part of a general shortcoming in the Danish research fields addressed by NABIIT, where the funding system in reality prevents younger researchers from establishing their own independent career. Although this challenge is therefore not specific to NABIIT, programmes such as NABIIT can play a role in addressing the need for greater independence among young researchers.

For example, the panel suggests that positive reinforcement could be provided through fellowship programmes, e.g. from the Council for Strategic Research that allow young researchers to establish research activities and build new groups of their own within strategic research areas. This could also help to encourage attracting researchers from abroad or from industry. The panel suggests that such a fellowship programme could also have a special focus on providing funding for young researchers returning from academic positions abroad or from positions in industry[15].

For inspiration on special programmes for young scientists with the potential to become professor, the panel suggests to look into the Swedish Foundation for Strategic Research and their programme "Individual Grants for Future Research Leaders" that has been successful in promoting young researchers.

The panel suggests that the Council should track the career development of the young researchers that participate in NABIIT-funded projects, e.g. in comparison with students funded by other means, with the aim of comparing how effective NABIIT is for the development of careers relative to other programmes. The aim of this would be to see if the NABIIT programme has fostered scientists that choose careers that differ from the average career potentially funded by other available sources.

Concerning the origin of the Ph.D.s and post.docs associated with the NABIIT-funded projects, findings from the self-assessment survey indicate that more than half of the academic Ph.D. and post.doc positions were filled with persons recruited from foreign institutions. All company-hired Ph.D. students were recruited from Danish institutions, but half the post.docs were recruited from abroad.

In order to strengthen international orientation and mobility among researchers, the panel suggests the construction of an open post.doc programme linked to existing projects with a common call and the announcement made known around the world, thus stimulating top scientists to choose to join leading groups in Denmark. It is the assessment of the panel that this could lead to increased international mobility and a strengthening of Danish research environments.

9.4 A potential to increase identification with the NABIIT programme

Conclusion: *Several young scientists did not know that their research position was funded through the NABIIT programme.*

Recommendation: *The Council should take steps to increase identification with the NABIIT programme through joint activities comprising both team building activities and courses with participation of young sci-*

15 This raises certain challenges, e.g. as someone with a background in industry may have a difficult time returning to academia because of the lack of publications and other dimensions of academic track records.

entists, both within and across the different projects funded by the programme.

Several of the young researchers interviewed were not aware (at least at the outset of their employment) that they had been funded by a NABIIT project. This indicates that the research theme in the project proposal itself does not represent a high priority for the research groups concerning dissemination of the function of the project in the overall work of the research group in general and in relation of the education of the young scientists in particular.

Based on the panel's experience, identification with research programmes by young researchers increases the likelihood that the aims of the programme will be kept in mind and therefore met. The panel thus suggest to increase identification with the NABIIT programme by including teambuilding activities for all project participants (especially young researchers), particularly at the start of a project. This could be supplemented by including common activities such as courses on project management, workshops, international trips etc. Courses on project management would not only strengthen the association with the NABIIT programme but also provide the young researchers with specific tools that will assist them in future research ventures. During the interviews, the panel was made aware by young scientists that courses on project management were requested.

Moreover, the Council for Strategic Research could host networking events for young researchers across projects funded by the Council. This could also promote greater cross-fertilization of ideas across research activities funded by the Council. Additionally, networking activities could help stimulate interdisciplinary interaction within the NABIIT programme, and potentially across research programmes.

9.5 Young researchers must be trained for positions both in academia and industry

Conclusion: *Most young researchers will leave academia to take up positions in the public or private sector. The projects interviewed by the panel, however, appear to predominantly train their young researchers for a career in academia. Again, this conclusion may be biased by the fact that the panel met exclusively with young scientists who are still at the institution, where they undertook their NABIIT-funded Ph.D. or post.doc fellowship.*[16]

Recommendation: *The Council could initiate courses or other joint activities for young scientists that are part of a NABIIT-funded project in order to train their mind-set to be fit for both academia and the industry. Moreover, a greater degree of involvement of company partners in projects, as recommended above, would also contribute to the training of young scientists associated with NABIIT-funded projects in priorities and approaches to work in industry.*

A key priority and goal of the Council for Strategic Research is to contribute to postgraduate education and researcher training. During the interviews, the panel observed that this task was taken very seriously by all projects and, as indicated in the previous sections, the panel assesses that the training of young researchers appears to be very well functioning. However, during the interviews, the panel also observed that their training and education primarily concern academic disciplines tailored for a career in academia. The panel also saw examples of the opposite where professors were assisting Ph.D.s and postdocs in becoming aware of the possibilities within the competences and know-how they acquired during their education in the NABIIT-funded project and the wider application options. Additionally, the panel observed that some, but few, professors were very direct in providing career advice for Ph.D. students when terminating their position as a Ph.D. This was mainly related to whether or not they were suited for a career in academia, but also served the purpose of promoting a career in the industry.

The panel suggests that the orientation within future career opportunities should be strengthened among young researchers. This should be done by raising the awareness among young researchers on the applicability of their research education.

Subsequently, there is a greater need for training a broader skill set among young researchers that will allow for a more smooth transition from academia to industry after termination of their research position. The panel thus suggests that special courses for Ph.D.s and post.docs in their first years should be included as part of the NABIIT programme. The courses could cover themes such as project management, R&D portfolio management, career planning, innovation and application of research results etc. The courses should be designed in such a way that it has relevance for both academia and industry. The panel suggest that the courses should be run by a panel of principal investigators from the funded projects in order to ensure the quality and the relevance of the course.

Another suggestion by the panel concerning young researchers' training and integration across aca-

16 This conclusion may be influenced by the fact that the young researchers interviewed had either stayed on at the institution after the end of the NABIIT-funded project or were still involved with the project.

demia and industry concerns a public-private post.doc programme. This suggestion is inspired by both the Novartis programme and The Danish National Advanced Technology Foundation's industrial post.doc programme. The purpose of such a programme is that it allows post.docs to work closely with both academia and industry and thus keep an option open in both sectors. The programme should be based within the Council. It should be announced as a common programme for the projects that are funded as prestigious post.doc positions where the likelihood of getting international applicants is present. The panel assesses that this would provide an important tool for programmes such as NABIIT in order to ensure the bridge between academia and industry for young researchers.

10 Development of Danish research environments

10.1 Impact on participants' research activities and competences

Conclusion: *Based on insights gained from the self-assessment survey and interviews, grants from NABIIT have opened up new research fields or establish new research groups.*

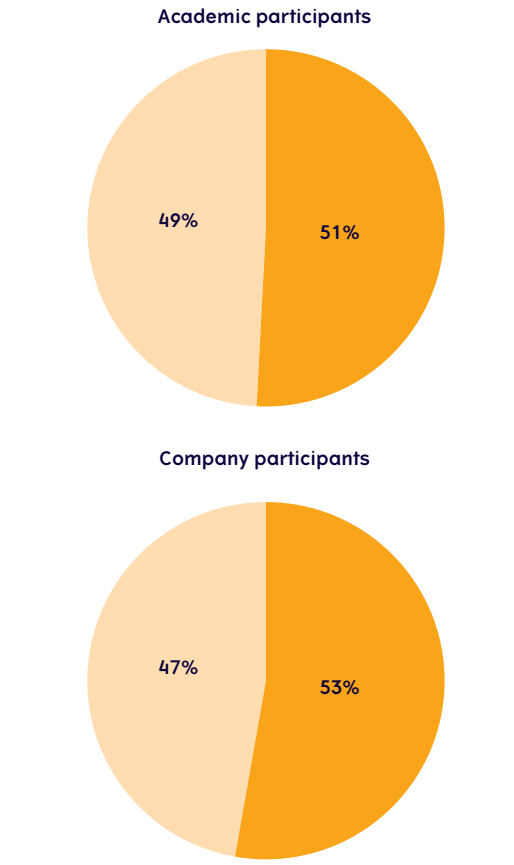
Recommendation: *Research programmes like NABIIT are highly relevant. The efficiency could be further improved by bringing the collaborating parties closer together.*

Insights from the self-assessment show that for both academic and company participants; about half of the projects are based on new research ventures, while the remaining projects represent a continuation or extension of key existing research activities in the participating organisations. This is depicted in figure 10.1.

Both academic and company respondents in the self-assessment survey were asked whether they would have sought funding elsewhere in the absence of funding from NABIIT. 15 and 13 percent of academic and company participants, respectively, would have sought funding for the same project elsewhere. Half of all participants would have sought alternative funding for a similar or related project. 40 percent of academic and 37 percent of company participants would have abandoned their project had it not been for the funding through NABIIT. This indicates that NABIIT funding has played a significant role, enabling projects that might not otherwise have been undertaken.

In fact, academic respondents in the survey stated there are no or few other adequate sources of funding for multi- or interdisciplinary projects, particularly when these are large-scale projects and when company participants are involved.

Figure 10.1. Is the project within a new research area or related to established research areas?



Source: DAMVAD 2012 based on the self-assessment survey.
N (academic participants) = 76, N (company participants) = 38

The self-assessment survey among academic respondents indicates that scientists assess that there is an impact on the research activities and competences when participating in a NABIIT-funded project. In particular, they highlight the following themes as the main benefits to the research activities:

- Enabled expansion into a new research field
- Strengthened research capacity and/or core competences (e.g. application of new theoretical areas and methods; consolidation of existing research activities etc.)
- Stronger international profile and greater visibility in the academic community
- Improved ability to engage in interdisciplinary research and/or combinations of technologies

In the interviews, the scientists participating in the projects explained that NABIIT has played a central role in the long-term development of critical mass at the research centre. In this connection, the NanoScience Centre at the University of Copenhagen and iNANO at the University of Aarhus was mentioned. DTU has succeeded in building up a strong engineering environment at DTU Nanotech.

The panel recognises the impact that the scientists express as a result of the participation in the NABIIT-funded project. However, the panel wonders if the funding for the projects could have been spend more efficiently if research groups to a larger extent were able to combine their core competences within the individual projects. This could be in relation to application and innovation in the biomedical sphere that requires combining competences in fundamental scientific research, (e.g. from Copenhagen University) with engineering (e.g. from DTU).

The panel further suggests that such competences should be brought together in a physical unit which particularly can pose a challenge when they span university boundaries.

10.2 Supplementary/subsequent funding of research activities

Conclusion: *NABIIT-funded projects have given rise to a number of follow-on projects and activities.*

Recommendation: *The Council should give priority to stimulating and supporting spin-off projects from NABIIT projects, as this is likely to increase the ultimate value created by the initial grant. In the experience of the panel, and based on the insights gained from particularly the self-assessment survey and the interviews, the Council could achieve this for example by giving projects the possibility of applying for a follow-up grant to pursue novel research projects that spring from the original project.*

NABIIT-funded projects have given rise to a number of follow-on projects and activities. For example, as illustrated in figure 10.2, 49 percent of academic respondents have developed spin-off projects as a result of their NABIIT-funded activities.

Figure 10.2. Spin-off projects

Source: DAMVAD 2012 based on the self-assessment survey.
N (academic participants) = 77

According to the panel, follow-on funding for a few very successful and relevant NABIIT projects once they are completed, i.e. a renewal process, is desirable. As proposed in another section, this could provide a very competitive environment for qualifying centres or more focused larger-scale projects where the potential commercial or societal benefits have also been documented to be high.

International grants

Individuals associated with the projects that the panel met with seemed to be very successful in attracting grants from the European Research Council; this is a strong indication of the quality of the research groups.

Since these projects involve several institutions and companies, it is important to be careful in setting up too many requirements for the legal agreements with international partners. How international partners should be brought in, should be up to the nature of the project and the contributions to be made by the international partner(s).

10.3 Characteristics and outcomes of collaboration

Conclusion: *It is the impression of the panel that the overall level of interaction in the projects, national as well as international, is acceptable and similar to what is found in comparable programmes in other countries. The panel also observed a high degree of variation in the level of and approaches to collaboration among project partners.*

In-depth analysis of the projects interviewed indicated that there is an unrealised potential to strengthen the degree of collaboration among participants in

projects. For example, there were few projects which involved co-authorship among several/all of the participating research groups. In the experience of the panel, this indicates that such collaboration was lacking; this conclusion was moreover substantiated in several interviews.

Recommendation: *The panel recommends that projects become more aware of the need and benefits from close collaboration when conducting true interdisciplinary research*.

According to responses in the self-assessment survey, key channels for interaction among project participants include joint research activities, informal exchanges of information and ideas, and provision of access to research tools and infrastructure. Academic participants in NABIIT projects also collaborate through e.g. co-authorship of scientific publications and training of young researchers. In comparison, company participants often collaborate by providing access to insights or data in industry (cf. figure 10.3).
During the interviews and based on the publications from the projects, the panel noticed that with some notable exceptions, there were few projects where key publications involved all project partners.

Of the nine projects interviewed, most were not heavily dependent on close and daily interaction among project participants, although there were also exceptions to this. Had the projects had a higher degree of interdisciplinarity, they would have required a higher level of close and daily interaction.

Both academic and company respondents benefited from collaboration in the NABIIT-funded projects. Notably, participants improved their network to research institutions in Denmark or abroad, and strengthened their ability and motivation to participate in interdisciplinary research collaboration.

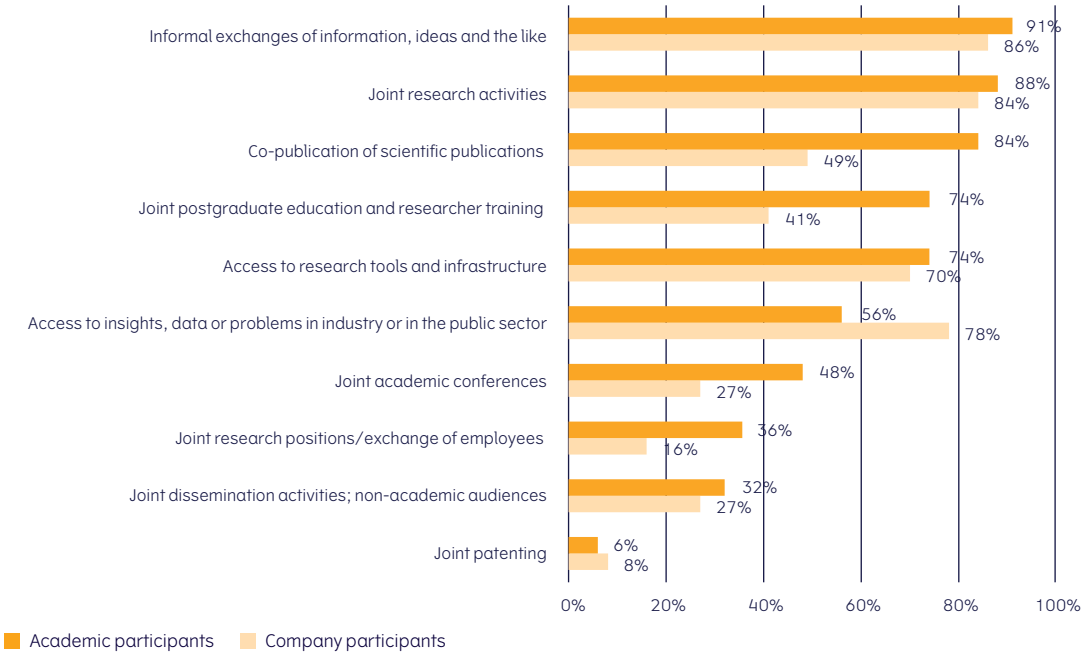
Projects are employing a combination of informal and formal approaches to research and collaboration management, e.g. frequent meetings, establishing of a steering group, or joint attendance of conferences.

Responses to the self-assessment survey from academic scientists provided by the scientists indicate that there are numerous different approaches to contact, collaboration and communication in NABIIT-funded projects.

Most scientists indicated that they met on a regular basis, supplemented by larger meetings a few times a year, and with occasional ad hoc meetings where all participants were present. The second most common model of interaction was bi-annual meetings supplemented by frequent communication through e-mail or phone. A smaller group of scientists engaged in frequent meetings (e.g. every month) as their means of interacting with partners.

A few scientists indicated that Ph.D. and post.docs lead the day-to-day interaction and collaboration in connection with the project, whereas other participants met less frequently.

Figure 10.3. Types of interaction with partners in the project



Source: DAMVAD 2012.N = (academic participants) = 77, N (company participants) = 38, Multiple answers were possible.

International collaboration
12 international participants (including both academic research groups and companies) were formally involved in the 36 projects funded by NABIIT. According to the survey responses provided by ten of these participants, their role in the projects was primarily related to participating in core research activities (e.g. performing tests), development of new methods or models, and optimisation, fabrication, and delivery of specific materials. A few international participants also acted as Ph.D. supervisors, while others mentioned that they participated in the preparation of joint articles and presentations with other project partners.

All ten international participants described the academic level in the project that they participated in, as "very good", "top level", "of high international standard" or "the leading edge of international research in the field".

10.4 Researcher mobility

Conclusion: *There are obstacles in Denmark, as in several other countries, for mobility between academia and the public or private sector.*

The analysis of researcher mobility undertaken in connection with this evaluation showed that among the total of 393 individual participants in NABIIT projects that constituted the base population in the analysis, just 58 individuals (15 percent) immigrated to Denmark and 31 individuals (8 percent) emigrated from Denmark in the period from two months prior to the start of the project period to two months after the end of the project period (though not beyond the end of 2011). Of the 58 individuals who immigrated, 16 subsequently emigrated within the survey period.

The highest level of international mobility, whether it be immigration to or emigration from Denmark, is found among project participants whose highest appointment level during the project period was assistant professor/post.doc: among these individuals, 29 percent had immigrated while 17 percent had emigrated. The second-highest proportion is seen among Ph.D. students. In this group, 22 percent had immigrated while 16 percent had emigrated. At the professor and associate professor level, international mobility (both immigration and emigration) was insignificant.

Finally, it is interesting to note that mobility from abroad to Denmark among NABIIT project participants in the university sector was lower overall than at Danish universities in general. However, among project participants at both Ph.D. and assistant professor/post.doc level, the percentage that immigrated to Denmark from abroad matches the corresponding percentage at all Danish universities.

10.5 Acquisition and efficient use of research infrastructure

Conclusion: *There were examples of investments in expensive hardware and research infrastructure that seemed to be clearly influenced by funding of projects within the NABIIT programme.*

Recommendation: *The Council should take steps to ensure that future programmes through highly application specific objectives stimulate the integration of other disciplines at the centres where large infrastructure investments in specific areas have been made.*

The self-assessment surveys did not provide a clear picture of NABIIT's contribution to establishing new infrastructures for work within the defined focus areas. Such infrastructure can be relevant in order to conduct competitive research and to attract the best researchers to the same physical environment.

The panel saw clear indications that the NABITT programme had contributed to the establishment of new infrastructure at three universities, namely University of Copenhagen, Technical University of Denmark and University of Aarhus. It has not been possible for the panel to determine the exact extent to which NABIIT funding has contributed to the infrastructure.

It is the opinion of the panel that care must be taken in future programmes that other fields, like IT and/or biotechnology are stimulated to be integrated in such centres in order to promote true interdisciplinary research.

11 Appendices

11.1 The evaluation panel

The evaluation panel behind this evaluation is:

- Søren Isaksen (chairman), Group Executive Director, CTO, NKT
- Gabriel Aeppli, Professor and Director of the London Centre for Nanotechnology
- Fredrik Höök, Professor in Biological Physics, Chalmers University of Technology.

This section contains a short presentation of the three panel members.

Søren Isaksen
Group Executive Director, CTO, NKT
He holds a Ph.D and MSc in Physics and Maths

Other positions include:

- Chairman of the Board of Directors of the Photonic Group companies.
- Board member of NKT Cables.
- Member of the Confederation of Danish Industry's Committee on Energy and Climate Policy.
- Member of the Tuborg Foundation Board.

Additionally, Søren Isaksen has held a number of research-oriented honorary positions, including chairmanship of the Danish Research Council, the Danish Technical Research Council, the Technology Foresight on Danish Nanoscience and Nanotechnology, as well as the Comittee Responsible for Assessing the Danish Research Council System.

Gabriel Aeppli
Professor and Director of the London Centre for Nanotechnology
He holds a B.Sc. in Mathematics and PhD, M.Sc. & B.Sc in Electrical Engineering from MIT.

Prior to his position at London Centre for Nanotechnology, he was a Senior Research Scientist for NEC (Princeton), a Distinguished Member of Technical Staff at Bell Laboratories, a Research Assistant at MIT, and an industrial co-op student at IBM.

Honours include:
Fellowship of the Royal Society (FRS) (2010), the IOP (Institute of Physics) Mott Prize (2008), the APS Oliver Buckley Prize (2005), the IUPAP Magnetism Prize/Neel Medal (2003), Riso National Laboratory Fellow (2002), Royal Society Wolfson Research Merit Award (2002), Mildner Lecturer, Department of Electronic & Electrical Engineering, UCL (2002), Fellow of the American Physical Society (1997), Fellow of the Japan Society for the Promotion of Science (1996).

Fredrik Höök
Professor in Biological Physics, Chalmers University of Technology.
He holds a Ph.D. in Physics, and a M.Sc. in Engineering Physics, 1992
Prior to his current position, he was a Professor of Physics (Nanoscience for Biophysics) at Lund University, Sweden and Assistant Professor of Physics/Biological Physics at Chalmers and University of Gothenburg, Sweden.

Distinctions, scholarships and awards:

- Winner of AkzoNobel's Nordic Research award 2002
- Awarded the SSF INGVAR (Individual Grant for the Avancement of Research Leaders) grant 2006
- Nominated (through Q-Sense AB) to Stora teknikpriset, Sweden, 2007

Additionally, Fredrik is one of the co-founders (two patents) of Q-Sense AB (www.q-sense.com), who has commercialized the QCM-D technology (2 pending granted patents) and the key inventor (one granted patent and three patent applications) behind LayerLab AB (www.layerlab.se) which was initiated together with Chalmers School of Entrepreneurship in spring 2003.

11.2 List of interview respondents

This section presents the nine projects that were selected to be interviewed by the panel and the different respondents from each project.

GRANT HOLDER AFFILIATED WITH THE UNIVERSITY OF COPENHAGEN

Arrays of Nanoscopic Biosensors on Surfaces
Grant size and period: 11.9 million kr.; 2005-2011
Grant holder: Professor Thomas Bjørnholm, University of Copenhagen (note: Thomas Bjørnholm was the grant holder, while Dimitrios Stamou administered the grant on a daily basis.) *Partners*: University of Copenhagen, IBM Zürich, Semasopht, Sophion BioScience, 7TM Pharma, Radiometer, AQUAPorin , Novozymes
Interview respondents:

- Senior researchers: Prof. Dimitrios Stamou, Assoc. Prof. Karen Martinez.

— Junior researchers: Nicky Ehrlich, Lars Iversen, Nikos Hatzakis, Andreas Lauge Christensen, Christina Lohr, Achebe Nzulumike, Vadym Tkach.

Centre for Antimicrobial Research CAR
Grant size and period: 27.5 miliion kr.; 2008-2014
Grant holder: Professor Michael Givskov, University of Copenhagen
Partners: University of Copenhagen, Technical University of Denmark, Universität Zürich, Teknologisk Institut, LEO Pharma.
Interview respondents:
— Prof. and grant holder Michael Givskov.
— Senior researchers: Thomas E. Nielsen, Tim Tolker Nielsen
— Junior researchers:
— Company respondents: Anne-Lise Høg Lejre and Anna Svensson

Centre for Pharmaceutical Nanotechnology and Nanotoxicology
Grant size and period: 28 million kr.; 2008-2014
Grant holder: Professor Seyed Moein Moghimi, University of Copenhagen
Partners: University of Copenhagen; Technical University of Denmark; H. Lundbeck; Nordic Vaccine Technology; LiPlasome Pharma
Interview respondents:
— Prof. Steffen Loft; Prof. Dimitrios Stamou; Assoc. Prof. Thomas L. Andresen

GRANT HOLDER AFFILIATED WITH THE TECHNICAL UNIVERSITY OF DENMARK

A Nanotechnological Approach to Studying Interactions of Biological Macromolecules - An interdisciplinary project
Grant size and period: 6.7 million kr.; 2005-2011
Grant holder: Professor Jörg P. Kutter, Technical University of Denmark
Partners: Technical University of Denmark, University of Copenhagen, Novo Nordisk
Interview respondents:
— Senior researchers: Prof. Jörg P. Kutter

Nano-technology for ultra high-speed optical communications (Nano-Com)
Grant size and period: 5.9 million kr.; 2006-2011
Grant holder: Professor Palle Jeppesen, Technical University of Denmark
Partners: Technical University of Denmark, OFS Fitel Denmark
Interview respondents.
— Senior researchers: Prof. Leif Oxenløven
— Junior researchers: Postdoc Michael Gallili
— Company respondents: Lars Grüner-Nielsen (OFS)

Metalloprotease sensitive drug delivery systems for treating cancer and inflammatory diseases
Grant size and period: 7.8 million kr.; 2007-2012.
Grant holder: Senior Researchers Thomas L. Andresen, Technical University of Denmark
Partners: Technical University of Denmark, Bioneer
Interview respondents:
— Senior researchers: Assoc. Prof. Thomas Andresen, Prof. Rolf Berg
— Junior researchers: Postdoc Jonas Henriksen, Ph.D. Rasmus Jølck
— Company respondents: Simon Jensen (Bioneer)

GRANT HOLDER AFFILIATED WITH AARHUS UNIVERSITY

Computational models and tools for drug discovery (COMODO)
Grant size and period: 7.8 million kr.; 2006-2011
Grant holder: Grant holder: Associate Professor Christian Nørgaard Storm Pedersen, Aarhus University
Partners: Aarhus University, University of Copenhagen, Molegro, Nuevolution
Interview respondents:
— Senior researchers: Assoc. prof. and grant holder Christian Nørgaard Storm Pedersen, Prof. Birgit Schiøtt, Prof. Brian Vinter
— Junior researchers: Postdoc Mette Alstrup Lei, Ph.D. Rune Friborg Møller
— Company respondents: Rene Thomsen and Mikael Hvidtfeldt Christensen (Molegro)

Development of new metal-oxide and -sulphide catalysts
Grant size and period: 8 million kr.; 2006-2012
Grant holder: Professor Flemming Besenbacher, Aarhus University
Partners: Aarhus University, Haldor Topsøe, Image Metrology, SCF Technology
Interview respondents:
— Senior researchers: Prof. and grant holder Flemming Besenbacher, Assoc. Prof. Jeppe Lauritsen, Peter Thostrup
— Junior researchers: Postdoc Stefan Wendt
— Company respondents: Poul Hansen and Stig Helveg (Haldor Topsøe), Jan Friis Jorgensen (Image Metrology)

Nano- and Bio-functionalised Surfaces for Biofilm Prevention
Grant size and period: 8 million kr.; 2007-2012
Grant holder: Professor Niels Peter Revsbech, Aarhus University
Partners: Aarhus University, Teknologisk Institut *Interview respondents:*
— Senior researchers: Prof. and grant holder Niels Peter Revsbech, Assoc. Prof. Rikke Louise Meyer
— Company respondents: Helmer Søhoel and Allan Poulsen (Danish Technological Institute), Jonas Agenhammer (Alfa Laval)

11.3 Overview of the evaluation process

As stated in the terms of reference, the purpose of the evaluation was to assess if *the objectives of NABIIT* have been fulfilled and to assess the extent to which the programme has contributed to fulfilling *the general objectives for strategic research, a*s specified in by the Danish Council for Strategic Research. 2012.

In order to fulfil this purpose, the evaluation of NABIIT has been based on an overall evaluation design. Figure 11.1 provides an overview of key elements in the evaluation design, i.e. the areas that the evaluation method collected data on:

- *Policy rationale for NABIIT and overall goals for strategic research.* This includes the underlying rationale and political motivation for the allocation of funds to NABIIT and the establishment of the programme; it also includes the overall goals for strategic research that NABIIT should contribute to, but is not evaluated upon.
- Thus, these are the overriding intentions and goals that the programme is expected to live up to in order to catalyse the intended outcomes and effects.
- *Immediate outcomes and long-term effects of the programme*. These are the short-term and long-term effects of the activities funded by NABIIT, as described previously in this chapter. These effects can only to a very limited extent be assessed at this point in time.
- *Objectives of NABIIT.* These are strategic and operational objectives of the programme; its results (i.e. outputs and immediate outcomes) must be evaluated against these objectives.
- *Design and implementation* refer to how the programme is organised and the intervention logic that it is based on. This is for example reflected in the selection and use of policy instruments and in the criteria and focus areas described in calls for applications.
- *Inputs* refer to the resources that have been invested in NABIIT-supported activities by NABIIT but also from other sources. Thus, inputs include NABIIT grants and additional funding (either provided by the participants or by other external sources of financing).
- *Activities* refer to the actual behaviour and activities that occur and create value in the projects supported by NABIIT. This includes understanding how project participants interact and collaborate and how they approach the combination of technologies.
- *Outputs* refer to the measurable results of investments under the NABIIT. It includes concrete results from projects funded by NABIIT (e.g. new knowledge, scientific publications, doctoral graduates, etc.).

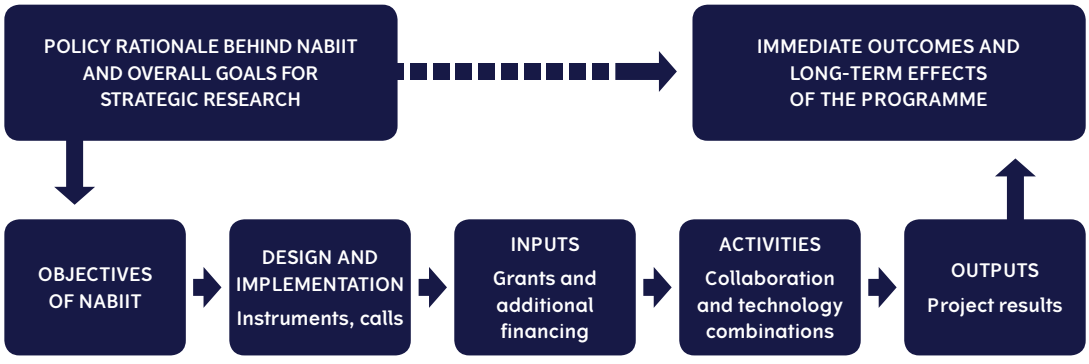
The evaluation consisted of six different methodological elements each resulting in individual sub-report. Elements from these sub-reports have been included in this evaluation report.

Methodological elements in the evaluation

Desk study of aims and activities	Self-assessment survey among project participants
Interviews with selected projects	Analysis of researcher mobility
Bibliometric analysis of publications	Case studies of selected projects and profiles

According to the terms of reference for this evaluation, case studies of two NABIIT-funded projects were to be undertaken with the aim of communicating examples of projects that promote public sector innovation, an important topic in Danish innovation policy. Additionally, the terms of reference also re-

Figure 11.1. Key elements in the evaluation



Source: DAMVAD 2012. Inspired by DG Budget. 2004. Evaluating EU Activities: A practical guide for the Commission services

quested the development of five "profiles" delving into selected themes in the NABIIT programme. Because the aim of both the case studies and the profiles was to highlight and communicate selected themes in the NABIIT programme, they do not form part of the documentation for the evaluation. The evaluation panel has not in any way been involved in these activities, which have been undertaken by DAMVAD.

The following briefly describes the different elements in the evaluation.

Desk study of aims and activities
The desk study comprised three elements:
— **Review of background documents** that describe the policy rationale behind NABIIT as well as the stated objectives of the programme.
— **Analysis of calls for applications** that shed light on the requirements that applicants to NABIIT had to fulfil. It also identified themes and criteria that were especially emphasized in calls (for example doctoral training or collaboration with industry).
— **Analysis of the project** portfolio that provided an overview of the contents of the programme's project portfolio.

The results of this study are described in the separate report, *Evaluation of the strategic research programme NABIIT - Report no. 1: A desk study of aims, instruments and grants under NABIIT.*

Self-assessment survey among project participants
The overall purpose of the survey was to collect data on activities and results in the funded projects. The survey was based on the evaluation themes. The survey was undertaken by DAMVAD, but the evaluation panel played an instrumental role in the development of the self-assessment survey questionnaire

The self-assessment survey was distributed to all project partners through three separate surveys:
— An extended self-assessment was conducted among academic participants, i.e. university research departments or centres at Danish universities. This group of respondents also included two university hospitals in Denmark.
— A shorter self-assessment questionnaire was sent to company participants in companies in Denmark (including authorised technological services institutes, also known as GTS institutes).
— A short list of questions was sent to international participants including both academic and company participants.

Table 11.1 presents the number of invited participants, how many completed the survey and the response rate. The total response rate was 81 percent.

The results of this study are described in the separate report, *Evaluation of the strategic research programme NABIIT - Report no. 2: Self- assessment by project participants.* This report also describes the results of an analysis of additional funding applications from and grants to participants in NABIIT funded projects.

Interviews with selected projects
Nine projects were selected for interviews by the panel. These included the two strategic research centres that have been financed by NABIIT and seven selected interviews distributed across grant holders at three Danish universities: University of Copenhagen, the Technical University of Denmark, and University of Aarhus. The projects were selected based on their distribution across grant holders at three Danish universities: University of Copenhagen, the Technical University of Denmark, and University of Aarhus. Additionally, the selection criteria comprised the size of the grant, whether the projects were completed (with emphasis on terminated projects), the degree of public-private collaboration and representation of both SMEs and MNEs among the company representatives.

For each project, separate interviews were conducted (on site at the universities) with multiple participants, including the grant holder and other senior scientists, young researchers (Ph.D.s, post.docs.)

Table 11.1. Response rate on the self-assessment survey

Survey	No. of invitations	No. of respondents	Response rate
Academic participants *	96	77	80%
Company participants **	46	38	83%
International participants	12	10	83%
Total	**154**	**125**	**81%**

Source: DAMVAD 2012. * Includes two university hospitals. ** Includes eight GTS institutes.

and, whenever possible, company participants. See the interview programme in the Appendix.

The results of this study are reported in this evaluation report.

Analysis of researcher mobility

This study was undertaken by the Ministry of Science, Innovation and Higher Education. The analysis carried out an outline statistical impression of the volume, composition and vertical and horizontal mobility of NABIIT project participants, based on a registry analysis. The analysis comprised just under 400 individuals, who at one time or another participated in the NABIIT projects.

The results of this study are described in the separate report *Evaluation of the strategic research programme NABIIT - Report no. 4: Analysis of researcher mobility.*

Bibliometric analysis of publications

The bibliometric analysis was based on publication lists provided by grant holders from each of the 36 grants.

Bibliometric data like publication source, author affiliation, citations and Journal Impact Factor (JIF) scores were obtained through individual searches for each publication in the leading international bibliometric database Web of Science from Thom-son Reuters.

Assessments of the scientific quality of publications were based on the Danish authority list developed.

The publications were analysed separately for completed and ongoing projects along the dimensions described below.

(1) Scientific productivity
(2) Scientific quality
(3) Scientific impact
(4) Interdisciplinarity
(5) National co-publication.
(6) Internationalisation of research

The results of this study are described in the separate report, *Evaluation of the strategic research programme NABIIT - Report no. 3: A bibliometric analysis of publications from NABIIT projects.*

11.4 Overview of the 36 projects

Grant holder*	Project title
Professor Flemming Besenbacher, iNANO, Aarhus University	Bioimaging in nanoparticles
Professor John Erland Østergaard, University of Southern Denmark	Plasmonic optical chips for medical diagnostics and chemical sensing
Senior researcher Jørgen Schou; RISØ, Technical University of Denmark	Wear control of tribological hard coatings with embedded optical nanolayers
Professor Thomas Bjørnholm, Nano-science Center, University of Copenhagen	Arrays of Nanoscopic Biosensors on Surfaces
Professor Anja Boisen, Department of micro- and nanotechnology, Technical University of Denmark	Nano Systems Engineering: NanoNose
Senior researcher Søren Højsgaard, Faculty of Agricultural sciences, Aarhus University	Automated monitoring of health and welfare of dairy cows in loose housing systems
Professor Jörg P. Kutter, MIC, Technical University of Denmark	A nanotechnological Approach to Studying Interactions of Biological Macromolecules - An interdisciplinary project
Professor Jens Ulstrup, Faculty of chemistry, Technical University of Denmark	Nanoscale Investigations of Biological Surfaces and Biofilm by Scanning Probe Microscopy
Professor Anders Stærmose Krogh, Bioinformatics Center, University of Copenhagen	Simulating proteins on a millisecond time-scale
Lektor Marleen de Bruijne, Department of computer sciences, University of Copenhagen	Computer-Aided Assessment of COPD from CT Images
Professor Herman Autrup, Aarhus University	SUNANO - Risk assessment of free nanoparticlesl
Professor Flemming Besenbacher, iNANO, Aarhus University	Development of new metal-oxide and- sulphide catalysts
Associate Professor , Troels Andreasen, Department of Communication, Business and Information Technologies, Roskilde University	SIABO - Semanic Information Access through Biomedical Ontologies
Professor Henning Christiansen, Department of Communication, Business and Information Technologies, Roskilde University	Logic-statistic modelling and analyses of biological sequence data
Professor Ivan Bjerre Damgård, Department of computer science, Aarhus University	Mobile Quantum Security

Professor Jakob E. Bardram, IT University of Copenhagen	PC Mini-Grids for Prediction of Viral RNA Structure and Evolution
Professor Robert Madsen, Faculty of chemistry, Technical University of Denmark	Cancer Treatment by Drug Delivery with Lipid-Based Nano-Particles
Professor Palle Jeppesen, TU Fotonik, Department of Photonics Engineering, Technical University of Denmark	Nano-technology for ultra high-speed optical communications (Nano-Com).
Professor Eva Bjørn Vedel Jensen, Department of mathematical sciences, Aarhus University	High-Speed Histomorphometry
Associate Professor, Christian Nørgaard Storm Pedersen, Department of computer science, Aarhus University	Computational models and tools for drug discovery (COMODO)
Senior researcher, David Plackett, Danish Polymer Center, Risø, Technical University of Denmark	Biopolymer nanocomposite films for use in food packaging applications (NanoPack)
Professor Bjørk Hammer, Department of physics and astronomy, Aarhus University	Hybrid functionals for metal oxide surfaces and nano-particles
Professor Niels Peter Revsbech, Department of biology, Aarhus University	Nano- and Bio-functionalised Surfaces for Biofilm Prevention
Professor Knud Jørgen Jensen, Department of basic sciences and environment, University of Copenhagen	Nano-scale properties of proteins for biopharmaceutical applications
Professor Bodil Jørgensen, Faculty of science, University of Copenhagen	Pectic polysaccharides for coating of bone implants
Associate Professor, Kristian Thygesen, Department of physics, Technical University of Denmark	Large-scale quantum simulations and informatics in nanocatalysis
Professor Jan Halborg Jensen, Department of chemistry, University of Copenhagen	Computational Design of Stable Enzymes
Professor Anja Boisen, Department of micro- and nanotechnology, Technical University of Denmark	Miniaturised sensors for explosives detection in air XSENSE
Professor Anders Kristensen, Department of micro- and nanotechnology, Technical University of Denmark	Liquid Core Waveguide Technology for Diagnositics - LiCorT
Associate Professor Thomas L. Andresen, Danish Polymer Center, Risø, Technical University of Denmark	Metalloprotease sensitive drug delivery systems for treating cancer and inflammatory diseases
Professor André Chwalibog, Department of Basic Animal and Veterinary sciences, University of Copenhagen	Nanotechnology in poultry production. Can silver nanoparticles promote health and growth of chickens?
Professor Michael Givskov, Department of Internantional Health, Immunology and Micro biology, University of Copenhagen	Center for Antimicrobial Research CAR
Associate Professor, Jesper Nygård, NanoScience Center, University of Copenhagen	Constructing Local Intracellular Probe Systems
Professor Kurt Vesterager Gothelf. Department of chemistry, Aarhus University	Electrochemical sensors for specific monitoring of neurotransmitters in the brain
Professor Seyed Moein Moghimi, Faculty of Pharmaceutical Sciences, University of Copenhagen	Centre for Pharmaceutical Nanotechnology and Nanotoxicology
Lektor Kim Lefmann, Niels Borh Institute, University of Copenhagen	MC-Xtrace, a simulation tool for X-ray investigations of nanostructures

*The listed grant holders are from the time the grant was awarded. In some projects, however, changes have been made during the course of the project. This has been taken into account based on information from the Danish Council for Strategic Research.

11.5 The Terms of Reference

Terms of reference for evaluation of the strategic research theme "Interdisciplinary Use of Nanotechnology, Biotechnology and Information and Communication Technology" (NABIIT)

Background

The strategic research theme "Interdisciplinary Use of Nanotechnology, Biotechnology and Information and Communication Technology" (NABIIT) was allocating research grants from 2005 to 2008. There were a total of 36 grants amounting to almost DKK 320 million.

The political ambition behind the research theme was to realise and utilise the expected research potentials of each of the technologies and especially the research potentials of the technologies by combining them. In launching the research theme, there was an expectation to attain breakthroughs and discover innovative uses by combining two or all three technologies which might contribute to overcoming the challenges, for example, within the areas of health, environment and energy. Furthermore, it was expected that the development within the three technologies would affect the technological development within a number of industries considered to be Danish positions of strength, e.g. the biotechnology industry. Thus, the research theme was launched in order to encourage a combined use of nanotechnology, biotechnology and ICT.

The funded research projects have been evaluated ex ante when it was decided which applications should be funded. Parts of the funded research projects have also been exposed to interim and ex post evaluations as part of the follow-up on the projects. However, the overall results within the research theme have not been settled and it has not been assessed whether the aims of the research theme have been attained. On this basis, the Danish Council for Strategic Research together with the Ministry of Science, Innovation and Higher Education have decided to evaluate NABIIT.

Purpose, target groups and use of the evaluation

The purpose of evaluating NABIIT is to assess if the objectives of the research theme have been fulfilled and if the research theme has contributed to fulfilling the general objectives of strategic research. Besides assessing the achievement of goals regarding the research theme and strategic research in general, the purpose of the evaluation is to create awareness of the results of the research investments.

Specifically, the evaluation will assess,

- to which extent and how the research activities within the research theme have helped to identify and develop future opportunities for commercial innovation and solutions to societal problems by combining nanotechnology, biotechnology and ICT and thus create synergy between the areas.
- to which extent and how the research activities within the research theme have helped to fulfil the objectives of strategic research, including
  - advance research of high international standing
  - increased interaction between public and private research
  - cross-cutting (interdisciplinary) research initiatives
  - internationalisation of Danish research
  - postgraduate education and research training
  - strengthening Danish research environments

The evaluation will particularly emphasise the impact of research results in the private sector and on users in the public sector. Conclusions will be drawn on basis of the overall results within the research theme and not the individual research projects.

The evaluation has two target groups. One target group is the political system and the general public who will be informed about the results of investments made in the research theme. The other target group of the evaluation is the board of the Danish Council for Strategic Research and the Programme Commission on Strategic Growth Technologies which can use the results to develop future priorities and for the future implementation of research funding.

Scope

The scope of evaluation is the research funds which were allocated between 2005 and 2008 as part of the strategic research theme NABIIT – a total of 36 grants amounting to DKK 317.8 million.

Table 1 contains a number of key funding figures within NABIIT. The table shows that the funds have grown over time. Thus, the average grant amount has risen from DKK 7.9 million in 2005 to DKK 14.5 million in 2008. The average grant during the period was DKK 8.8 million. The smallest grant was given in 2005 and amounted to DKK 3.4 million while the largest grant was given in 2008 and amounted to DKK 28 million. On average, each grant has DKK 7.1 million of co-financing and the total budget of the research projects is DKK 15.9 million on average.

18 out of 36 grants have been completed at the end of 2011. Three were completed in 2010 and 14 were completed in 2011. Six out of 18 grants which were completed at the end of 2011 ran for four years, 11 grants have lasted for five years and one grant lasted for six years. The remaining grants are expected to end in 2012 (nine grants), 2013 (eight grants) and 2014 (two grants).

Table 11.2. Key funding figures within NABIIT

	2005	2006	2007	2008	Grand total
Number of grants	7	14	9	6	36
Total grant amount (current prices)	55	99.7	76	87	317.8
Average grant amount (current prices)	7.9	7.1	8.4	14.5	8.8
Minimum grant amount (current prices)	3.4	4.6	5.5	5.9	3.4
Maximum grant amount (current prices)	11.9	8	15	28	28
Average amount of co-financing (current prices)*	7.2	6.5	4.9	11.7	7.1
Average total budget (current prices)*	15.1	13.6	13.3	26.2	15.9

Source: The Danish Council for Strategic Research Note: The amounts of co-financing are subject to uncertainty.

According to the calls for applications, funding was awarded to research activities which pursued an interdisciplinary approach to established knowledge areas and included collaboration between public research institutions and private companies. There are between two and eight project partners in the research projects and the average number is almost four. Universities as well as private companies generally participate in the projects. Hospitals and approved technology institutes participate in some projects. Universities are the dominant party, with up to five departments participating in one project. There are examples of partnerships between departments at the same university and between departments at different universities.

All of the research projects combine at least two of the three areas nanotechnology, biotechnology and ICT. The subjects of the projects are broad and encompass e.g. cancer treatment by drug delivery with nano-particles, use of nanotechnology in food packaging applications, computational models and tools for drug discovery and risk assessment of free nano-particles.

Basis of evaluation

The evaluation will assess to which extent and how the objectives of the research theme have been fulfilled and to which extent and how the research activities within the research theme have helped to fulfil the general objectives of strategic research, cf. the purpose. The basis for the assessment will be a comparison of the overall results within the research theme with the objectives of the research theme and the objectives of strategic research, respectively.

The assessment of the achievement of goals will be made by an independent international peer review panel on the basis of all the different documentation gathered as part of the evaluation. In assessing the achievement of goals, the panel shall take into consideration that not all of the research projects have been completed while some research projects have only just been completed. The panel shall also take into consideration that some of the requirements in the calls for applications have changed over time.

Table 2 presents a number of indicators and benchmarks which the peer review panel may use in its assessment. The indicators and benchmarks apply to the objectives of the research theme as well as the objectives of strategic research. The indicators and benchmarks are derived from the political agreement, the calls for applications and the quality concept of the Danish Council for Strategic Research which the council uses when assessing the quality of applications. The concept of quality is made up of three equivalent criteria: the relevance, potential impact and quality of research, e.g. “Strategic research – Principles and instruments” from 1 January 2011. In the evaluation report, the panel is requested to account for the criteria used in its assessments and how the criteria have been employed.

Table 11.3. Indicators and benchmarks applicable to the assessment of the achievement of goals

Indicator	Benchmark
Purpose of research	Share basic research/applied research
Interdisciplinarity (cross-cutting research)	Participants Examples of interdisciplinarity Organisation (distribution of roles and tasks, forms of collaboration, organisation models, invested resources) Publications (joint publication)
Combined use of nanotechnology, biotechnology and ICT	Participants and forms of collaboration Examples of the combined use of technologies New or improved products, technologies, methods, processes or equipment Publications (joint publication)
Collaboration and synergies	Organisation (distribution of roles and tasks, forms of collaboration, invested resources) Collaboration with partners who are not formally part of the project Research management Publications (joint publication)
Scientific output (process and product)	Seminar and conference activity Keynote addresses given Publications (publication channels) Data set

Indicator	Benchmark
Quality of the research	CV's
	Seminar and conference activity
	Keynote addresses given
	Publications (publication channels)
	Data set
Development of research environments in Denmark	Continuation of the research activities in the projects, for example new funding
	Examples of increasing R & D activities among the participants
	Recruitment of researchers (nationally and internationally)
	Research training for PhDs and postdocs
	Training of research managers
Postgraduate education and education generally	Development of new lesson plans, including courses and conference activities
	Participants PhD scholars
	Participants postdoc scholars
	Publications (PhD thesis)
Internationalisation	International seminar and conference activity
	International visiting research fellows
	Collaboration with international research institutions (for example as part of the project or an advisory board)
	Recruitment of international researchers
	Research stays abroad
	Applications for EU framework participation and others
	Publications (joint publication and national/international publication channels)
Commercialisation of research-generated intellectual property	Patents, patent applications
	Licensing agreements
	Spin out companies
	New or improved products, technologies, methods, processes or equipment
	Public and private-sector collaboration on new or improved products, technologies, methods, processes or equipment
Public outreach (dissemination of results to the general public and companies which are not part of the project)	Media appearances (newspapers, radio and television)
	Workshops and conference activity
	Publications (publication channels)
Use and potential use in the public sector	Innovation in the public sector (new or improved products, technologies, methods, processes or equipment)
	Changes in legislation/control

Organisation

The board of the Danish Council for Strategic Research appoints an independent international peer review panel to carry out the evaluation. The panel is responsible for the overall assessment of the documentation gathered as part of the evaluation and for an evaluation report being drawn up. The panel is also to conduct qualitative interviews with representatives from the projects and to help improve the other parts of the evaluation documentation.

The panel shall be comprised of a chairman and up to five members. All members shall be internationally acknowledged researchers and have experience with broad research areas in relation to nanotechnology, biotechnology and ICT.

Furthermore, the panel shall have experience and knowledge of:

— Management of/participation in large research projects
— Collaboration between public research institutions, private companies and public users of research
— Utilisation and commercialisation of research
— International research collaboration
— Evaluation methods.

An independent secretary is responsible for drawing up the evaluation report on behalf of the peer panel.

Besides the interviews with representatives from the projects conducted by the panel, the other parts of the evaluation documentation will be carried out by one or several external consultants. The consultants shall have confirmed competencies in the different methods of data collection outlined in these terms of reference. The consultants shall also have knowledge about strategic research and research policy in Denmark.

The Ministry of Science, Innovation and Higher Education is responsible for the quality assurance of the

documentation. Moreover, the ministry will, if necessary, gather one or several parts of the documentation on behalf of the panel. Furthermore, the ministry will assist the panel and the consultants with relevant information about the scope of the evaluation, including the population of project partners, and, if necessary, with practical matters such as the planning of the interviews with representatives from the projects by the panel and travel planning.

Methods of data collection

The documentation gathered as part of the evaluation shall ensure that the evaluation sheds light on the questions asked from different perspectives and with different kinds of data. Data will be collected using the following methods:

— *Self evaluation among the participants*
  The purpose of the self evaluation among universities, private companies, hospitals and approved technology institutes is to expose the qualitative judgment of the participants as regards for example the collaboration in the projects and the achieved results.
  Furthermore, the self evaluation shall produce quantifiable factual knowledge about the organisation and the results of the research activities including the scientific output, commercialisation, postgraduate education and internationalisation.
— *Qualitative interviews with selected representatives from the projects conducted by the panel*
  The purpose of the qualitative interview with selected universities, companies, hospitals and approved technology institutes is to let the panel meet representatives from the projects in order to validate and qualify the assessments made by the panels on the basis of the self evaluation.
— *Case studies of the use and potential use of research results in the public sector*
  The purpose of the case studies is to examine concrete examples of the use and potential use of research results in the public sector.
  It shall be examined to which extent the use of research results is expected to or already has contributed to innovation, improved the basis for decisions or led to changes in public control.
— *Register-based analyses*
  Three different register based analyses are to be carried out:
  — A bibliometric analysis
  — An analysis of mobility
  — An analysis of funding.

  The purpose of the bibliometric analysis is to examine the types of publications, national and international joint publication and public outreach from the projects in order to identify different publication profiles across the projects. In that regard, the publication profiles shall, if possible, be compared with regard to networking and quality of the research.

  The purpose of the analysis of mobility is to examine to which extent the research projects have contributed to national and international mobility, including mobility between different research institutions and between the public and the private sector.

  The purpose of the analysis of funding is to examine to which extent researchers who are participating in the projects simultaneously or subsequently plan to apply, have applied or have obtained further national or international funding for the research activities in the projects.

Reporting

The evaluation will result in a written report. The report is to contain a description and analysis of the different parts of documentation, the conclusions and assessments made by the panel and an executive summary and at least five portraits of different projects suitable for publication.

The evaluation report is expected to be published in the first quarter of 2013. In continuation of the publication of the report, the panel is expected to participate in a meeting with the Danish Council for Strategic Research in order to discuss the evaluation report.

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