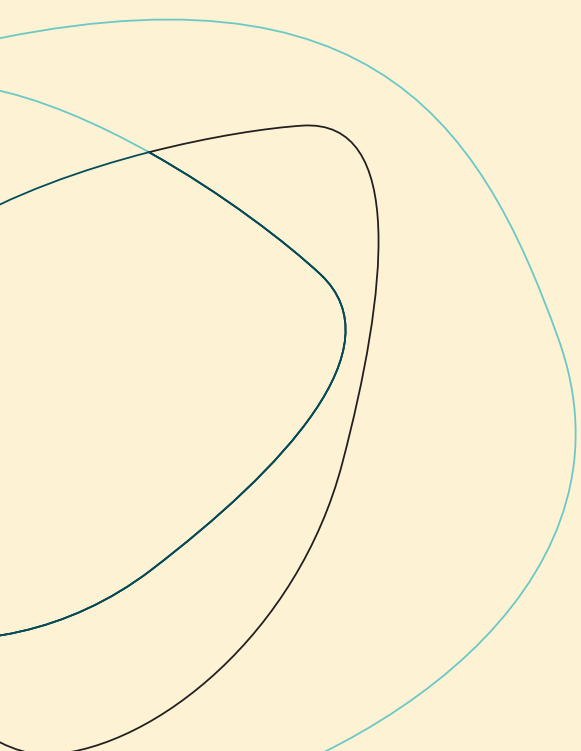


Danish Council for Strategic Research

# Research that Counts



**The Danish Research Agency**

Ministry of Science  
Technology and Innovation

September 2004

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### **Danish Council for Strategic Research**

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# Contents

Preface .....	5
Summary .....	6
Strategic Research .....	8
The Position of the Danish Council for Strategic Research .....	11
Initiatives .....	13
Innovation Accelerating Research Platforms .....	20
Level of Innovation in Danish Society .....	22
Relation-driven Research .....	24
Consolidation of Effects and Results .....	28
Here and Now .....	29
- Food & Health .....	30
- Energy & Environment .....	35
- NABIIT .....	40
Danish Council for Strategic Research Board of Directors .....	45

# Preface

The Danish Council for Strategic Research commenced its activities on 1 January 2004 as an innovation in the Danish research world. Since the beginning the Council, therefore, has worked intensively to define its role and to organise its statutory obligations. Its primary task is to seek out new research trends and implement initiatives that contribute to increasing interaction between public and private research. The Council hereby explains its view on what is understood by strategic research and presents the initiatives it wants to take, provided this is financially feasible.

It should be noted that this report is not the outcome of a process now concluded. On the contrary, the Council has only taken the first steps in an interactive process that aims to help organise strategic research in Denmark so that it addresses, as thoroughly as possible, the challenges facing Danish society. Our ambition is to help ensure Denmark's position in the long term as a global front runner with regard to welfare, economy and science.

Peter Elvekjær  
Chairman

## Summary

There is a need for increased understanding between the research world and society, and for both sides to invest more in each other. The Danish Council for Strategic Research wants to promote this trend. With this report, the Council presents a number of topical initiatives and describes the signposts for the more long-term efforts. The Danish Council for Strategic Research will:

- identify research that can lead to value-generating innovation for Danish society in order to ensure that Denmark has the necessary knowledge mass and innovative power in the short and long term.
- recommend that research funding be earmarked for Innovation Accelerating Research Platforms, i.e. areas where a) Denmark has internationally recognised research environments, b) Denmark has internationally competitive business clusters, c) there is a clear need for research-based solutions, and where new technology can provide innovative breakthroughs.
- in its initiatives build up Centres for Strategic Research that focus on collaboration between public research institutions and society in general.
- take the initiative to hold conferences and meetings throughout Denmark to establish the necessary dialogue in collaboration with relevant players.
- assure the quality of the research programmes under the auspices of the other ministries while working to coordinate them with its own research initiatives and their principles.
- map Danish research institutions' use of and need for research infrastructure, and submit proposals for a strategy of collaboration on and prioritisation of research infrastructure, both nationally and internationally.

- work for a prompt and significant expansion of funding in the areas of food & health, energy & environment and nanotechnology, biotechnology and IT, and in the cross fields between the disciplines in these three action areas in addition to allocating funding to Centres for Strategic Research with no special themes.

The Danish Council for Strategic Research will operate with a triple bottom line. Knowledge, growth and sustainability are equal goals for the Council's work.

## Strategic Research

Research has been put on society's agenda - and with good cause. There is increasing focus on Denmark's position in the knowledge-based society and the innovation-based competitive situation which has become more and more pronounced, both in Europe and globally.

Research is no longer considered an expense but rather an investment, and strategic research must be the means to ensuring the societal yield of this investment. Since World War II, the USA has targeted its efforts to seek out opportunities within strategic research, and today it is widely held that this is one of the main reasons why the USA is an economic, technological and scientific global leader.

In Europe, countries such as Ireland and Finland have quickly and consistently followed national action plans for strategic research, while in Sweden and the Netherlands work with publicly-financed strategic research was initiated many years ago. Every year they spend billions on strategic research. The demand for research that is useful is still seen in many countries as the key to competitiveness in the innovation-driven knowledge economy.

In Denmark, we have previously carried out a number of strategic research programmes. One example is the two major biotech programmes initiated at the end of the 1980s and beginning of the 1990s, which have resulted in the establishment of a large number of small biotech companies. The wind energy initiative, the research and development programmes for food technology FØTEK 1-3 and materials research programmes are three other manifestations of strategic-oriented research policy that have led to innovation and technological development in Danish companies. But public strategic research in Denmark did not have a common face until the establishment of the Danish Council for Strategic Research on 1 January 2004.

## Councils for Strategic Research in Other Countries

Swedish Foundation for Strategic Research, SSF: This foundation, established in 1994 as one of several foundations from the former so-called wage-earner funds, supports natural science, technical and medical research. The SSF allocates approximately SEK 500 million annually. The strategic research is placed between basic research and socially-motivated research. The investments have shifted from especially supporting graduate schools and research programmes to increasing allocations to framework funding and support for strategic centres.

National Technology Agency of Finland, Tekes: Tekes has supported, on a large scale, results-assured public and private research with annual research grants of approximately EUR 375. Tekes assesses what Finland should invest in using cluster analyses and has focused intensely on strengthened networking between the public and private sector. Tekes also supports projects that have obtained international financing.

Netherlands Organisation for Scientific Research, NWO: The Dutch Government's strategic research funding is handled by the NWO, which allocates EUR 470 million annually for strategic research. The strategic research in the Netherlands not only covers the natural sciences, but also spans broadly over a few high priority areas from cultural heritage to new technologies. Interdisciplinary approaches and talent spotting are among the primary tools in the NWO's research strategy.

The Council's overall task is to identify research that can lead to value-generating innovation for Danish society in order to ensure that Denmark has the necessary knowledge and innovative power in the short and long term.

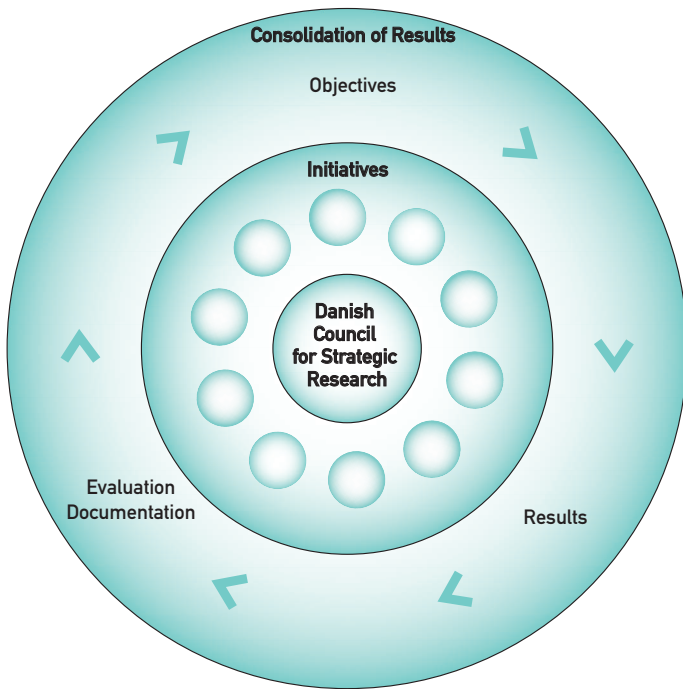
Today, Danish research is strong in terms of the number of citations in recognised scientific journals, and we have research environments of international excellence in a number of areas.

However, Denmark does not appear to be a country that has been particularly good at putting its research to use. There are too few professional environments, which are sufficiently curious about each other's expertise, regardless of the fact that the most exciting innovations come from interdisciplinary research. Nor does research appear to be a central source of innovation in the Danish business community. These patterns must be broken. In the society and the competitive situation we are facing in the future, Denmark needs to create a new synergy between university, private-sector and government

research and the overall needs of society. The Danish Council for Strategic Research is certain that the Danish research culture will prove to be a huge asset in this process, but only if someone makes it happen.

The Danish Council for Strategic Research sees itself as a catalyst for this process. Through initiatives, objectives, evaluation and documentation, the Council will help establish a new research culture and new areas of collaboration between research and society.

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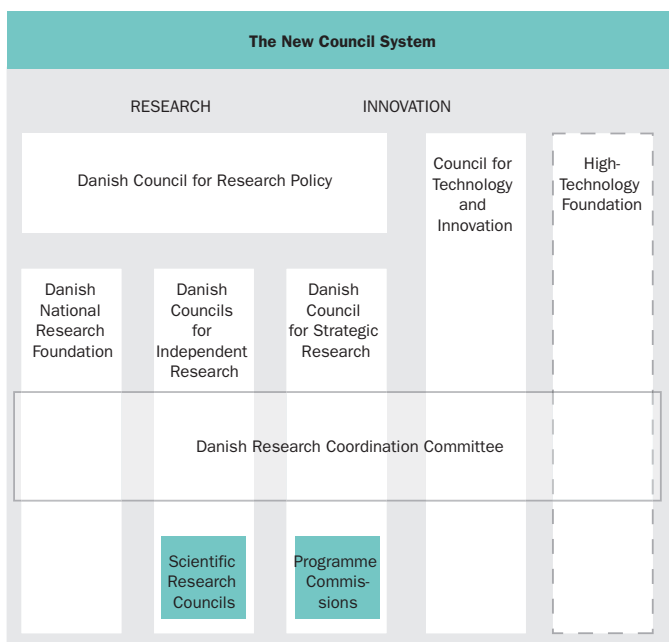
This is how the Danish Council for Strategic Research sees its role as the initiator - but also with regard to follow-up - of a variety of initiatives that will be implemented and renewed over time. The Danish Council for Strategic Research is furthermore committed to consolidate results of individual initiatives as well as to the Council's general initiating role for strategic thinking in the Danish research world.

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## The Position of the Danish Council for Strategic Research

As a visible manifestation of the new importance of research, 2004 saw a number of new creations in the research council and innovation promotion system. A key objective is to ensure a high level of innovation in research.

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The Danish Council for Strategic Research is to help communicate the perspectives of the research world to politicians and society and vice versa. Society expects research to help create a future with growth and prosperity for Danish society. The Council's ambition is for research to be considered a natural investment for policy-makers, while ensuring that the research world shows greater respect for politically prioritised initiatives. And a cultural

## Regulatory Framework for the Danish Council for Strategic Research

### *Funding Function*

- Fund: The Council allocates politically prioritised and thematically defined research funding to research teams, research infrastructure and equipment, networks of researchers, international collaboration, research training and research consortia.
- Communication: The Council helps disseminate the results of the research.
- Public-private collaboration and co-financing: The Council establishes increased interaction between public and private research and attracts resources from funds and companies for the co-financing of research projects.
- Research trends: The Council seeks out new trends in research and launches initiatives if there is funding from the Danish Parliament or other partners.
- Advising applicants and stakeholders: The Council provides professional research-related advice to applicants and stakeholders.

### *Advisory Function*

- Political advice: The Danish Council for Strategic Research gives the Danish Minister of Science, Technology and Innovation professional research-related advice in the politically prioritised and thematically defined research areas. The Danish Parliament and any minister can obtain similar professional research-related advice from the Council.
- Sector ministries: The Council approves allocation procedures and conducts professional assessments of applications submitted to the individual ministries' research programmes.
- Public and private institutions: The Council provides strategic professional research-related advice to public and private institutions.

change is needed towards making it motivational and meritable to conduct research that is applicable.

This will often mean interaction between university environments, institutions and companies, but it can also mean interaction between researchers and patient associations, public authorities or similar groups.

The objective of the Danish Council for Strategic Research, in this light, is to establish research that takes place across public and private institutions and across disciplines and professional boundaries. For instance, it is not possible to imagine a real high-tech society without including humanistic and social expertise as well as the traditions of natural science and technology. It is vital

that advances in IT take place in close collaboration with the users. Another example is the development of healthier foods by way of biological insight that incorporates an understanding of diet and eating habits, lifestyle, values and ethics. The idea of cross fields forms the foundation for the present combination of traditionally separate research areas into programme commissions that invites collaboration across disciplines.

## Initiatives

The funding from the Danish Council for Strategic Research will be used in such a way as to expand, but also take advantage of the vast amount of basic knowledge that is rooted in the Danish research environments. By forming collaborations across professions and sectors, the Danish Council for Strategic Research will contribute to releasing the tremendous potential research has for social progress and welfare.

On this background, the Danish Council for Strategic Research proposes the following initiatives:

**Innovation Accelerating Research Platforms:** There is a need for the establishment of fields within the broad research effort in Denmark in which the research effort stands out in a visible and significant way as a research effort that underpins innovation. Such initiatives must reinforce the correlation between society's strategic needs and the areas targeted by publicly-financed research. It is therefore necessary to earmark research funding for areas where a) Denmark has internationally recognised research environments, b) Denmark has internationally competitive business clusters, c) there is a clear need for research-based solutions in areas where new technology can provide innovative breakthroughs. The Council sees it as a key task to identify and define these Innovation Accelerating Research Platforms and, by way of massive and persistent initiatives, to improve research performance in these areas. The Danish Council for Strategic Research will take the initiative to establish an overview of the possibilities for strategic research initiatives.

**Action Areas:** The Danish Council for Strategic Research has chosen here and now to support strategic research within three areas, which were identified even before the formation of the Council as key areas of decisive importance for the innovative power of Danish society in coming years. The three areas are Energy & Environment, Food & Health and Nanotechnology, Biotechnology and IT (NABIIT). Today, Denmark has world-class in research as well as in business in the cross field between energy and environment. In the area of food and health, Denmark is also strong, and now, where the two branches converge, we have a historic opportunity to place Denmark centrally. Nanotechnology, biotechnology and IT will probably be the three most important technological forces in companies' and society's innovation over the next decade. Denmark will not become a world leader in the development of these three areas, but Danish society and Danish companies are well qualified for becoming world leaders in the utilisation of them. Within Environment & Energy, Food & Health and NABIIT, the Danish Council for Strategic Research will ensure that the research conducted in these areas is useful and that research in the interaction between these areas is emphasised.

**Centres for Strategic Research:** It is the ambition of the Danish Council for Strategic Research that the Danish public research environments - from universities to health services to government research institutes - consider the needs of society and the business community and actively seek out opportunities to utilise the research conducted. The dedicated souls who want this progress should have the opportunity to influence the research culture to a much greater extent than is the case today. Therefore, the Danish Council for Strategic Research recommends that the 2005 National Budget contains funding earmarked for Centres for Strategic Research. In the same way that centres for basic research today are established through the Danish National Research Foundation with funding to achieve international excellence, it should be possible to establish Centres for Strategic Research, which focus on the collaboration between public research institutions and society in general. The Council recommends that five Centres for Strategic Research be established already in 2005, each of which to be funded over a five-year period. The centres are to be selected based on applications. The initiative is to form

the basis for a more comprehensive investment in Centres for Strategic Research built up as collaborations between public research institutions and the business community/organisations/public administration/patient associations, etc.

**Dialogue:** It is of decisive importance that a better understanding between the research world and society in general be established. In a Danish context, it is particularly important to find models to establish dialogue between, on the one hand, the university and government research institutes and, on the other, small and medium-sized enterprises, where the majority of the jobs are, and where job growth takes place. At the same time, the new research will confront society with a number of ethical choices. Certain aspects of nanotechnology, for instance, not only have great potential, but also have unclarified risks with regard to the human organism. It is vital that these debates take place in an unbiased and qualified manner in the public arena and that viewpoints are developed at an early stage. Experience shows that if public opinion comes out against a new technology at a late stage, this technology will not be able to achieve growth in Denmark. The Danish Council for Strategic Research will take the initiative to establish dialogues as well as hold conferences and meetings throughout Denmark to establish the necessary dialogue in collaboration with relevant players.

**Graduate Schools:** There is a need to educate far more researchers. PhDs and Post-docs are the best agents for improving the quality of research and increasing the level of innovation in Denmark. Within five years, Denmark should double the number of PhDs - especially in the areas of science, technology and medicine. In the long term, an increase in the number of PhDs in the private sector will create entirely different opportunities for companies to collaborate with universities. Research depends on people and it is, therefore, vital to educate people who can function in both worlds. Graduate schools geared towards business and industry and co-financed PhD scholarships have proven to be an attractive opportunity to establish a more continuous contact between universities and the business community. The Industrial PhD scheme and co-financed scholarships at Graduate schools can be seen as a mecha-

nism to strengthen the exchange between the private and the public sectors - an opportunity to bring research into the business community. In line with the recommendations of the Danish Research Commission, the Danish Council for Strategic Research emphasises that 25 per cent of the growth in the number of PhD students must be international students. In part, this is a good way to measure quality as environments of international excellence attract international students and, in part, this promotes international perspectives in the Danish research world.

**Criteria for Research Projects:** The Council does not have any rigid requirements as to what research is eligible for support, as the situation differs from area to area. But there are some criteria for what the Council seeks to promote. Applications involving new PhD scholarships will have an advantage in the programmes, which the Danish Council for Strategic Research can influence. Participation of both university researchers and private companies or other users is an important criterion, as is co-funding by companies and universities. Applicants should account for why the area is strategic for Denmark, including which Danish positions of strength it builds on. Furthermore, the Danish Council for Strategic Research attaches great importance to clear and visible management in programmes and projects.

**Collaboration with the Ministries:** The Danish Council for Strategic Research must, from a professional research standpoint, evaluate the applications submitted to the research programmes under the individual ministries. Just as calls for applications and other allocation procedures must be approved by the Council. Furthermore, from 1 January 2005, the Danish Council for Strategic Research must nominate one-fourth of the Board Members at every government research institute, i.e. the portion of the Board that must be recognised researchers. The Council emphasises the importance of incorporating research into all of Denmark's strategic needs, while considering, at the same time, the targets for increasing the number of PhDs and the areas of collaboration between the research and business communities. That is why the Council also considers it important that the ministries' programmes and those of the Council are coordinated nationally and in relation to EU

research programmes. To ensure a flexible handling of the shared responsibility for the research conducted under the ministries, the Danish Council for Strategic Research has initiated dialogues with the individual ministries.

**The International Dimension:** A central parameter in our strategic research efforts is to maintain continuous international contact and to keep our finger on the pulse with regard to how Danish research is doing internationally. Danish society benefits from contributions to our research programmes by means of more PhD and Post-doc sojourns for Danish researchers in the USA and Japan as leading nations when it comes to technology. The Danish Council for Strategic Research will include tools that underpin the establishment of international collaborations and smooth the path for Danish researchers to have the opportunity to work at the best laboratories in the USA and Japan during their studies. Finland is one step ahead with its research policy and, therefore, has a good deal of influence on what happens in the EU. Denmark should have this same influence, and Danish researchers should be better at obtaining funding from the EU. Countries such as Brazil, Russia, India, China, Taiwan and South Korea are among the areas in the world that have, and are expected to have in future, the largest share of global growth. The Danish Council for Strategic Research wants to promote specific alliances between Danish researchers and the best researchers in the new growth countries based on the motto: research collaboration today, trading cooperation tomorrow.

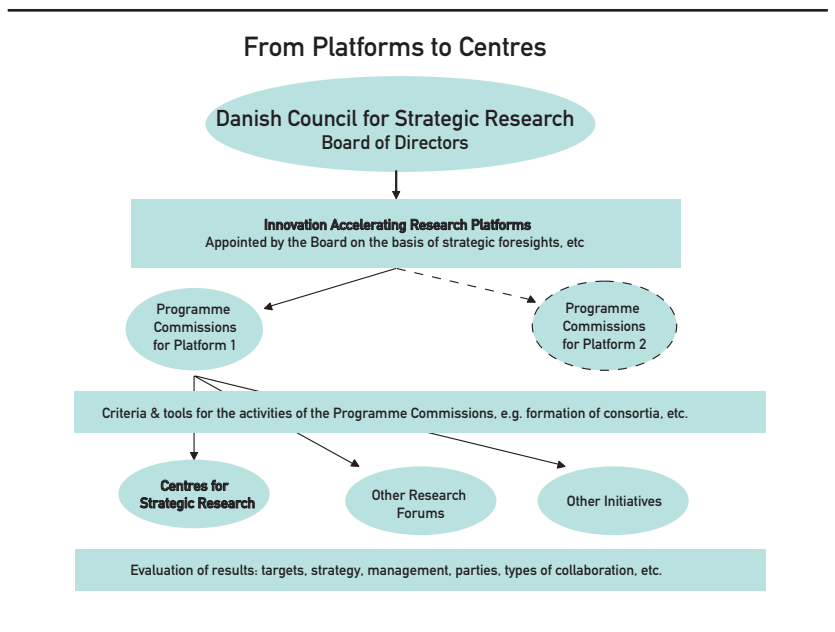
**Research Infrastructure:** The Danish Council for Strategic Research will carry out a mapping of Danish researchers' use of and need for a better research infrastructure, i.e. equipment, collections, databases, etc. Based on this, the Council will submit in mid-2005 a proposal for a collaboration and prioritisation strategy with regard to the Danish utilisation of national and international research infrastructures. The Danish Council for Strategic Research finds this task particularly important as Danish researchers' access to and use of state-of-the-art infrastructure is crucial for basic research, technological progress and research education programmes, and thus for Denmark's future socio-economic growth. Thus, it is vital for the future

research-related progress that Danish researchers have access to the best and most advanced research infrastructures. This mapping should lead to the formulation of a strategy for Danish researchers' utilisation of major national and international infrastructures, which should help secure the future of Danish research by improving and developing our international collaboration prospects. That way we will ensure that when it comes to infrastructure, Denmark is well-prepared for participating in international initiatives. Denmark must also have an adequate research infrastructure and the associated human resources to ensure, among other things, that we can take advantage of the international collaboration opportunities and research facilities. This depends on cooperation and strategic prioritisation at a national level, where the needs of the individual institutions should be seen in a national perspective with a strong eye to the international dimension.

**Small and Medium-sized Enterprises:** In general, there are special barriers linked to the collaboration of smaller companies with university researchers. The Danish Council for Strategic Research is aware of the special problems many smaller companies have concerning active participation in research and innovation collaborations, however, small organisations also have potential in that they are often much faster to act on specific opportunities. The Danish Council for Strategic Research would like to see more focus on minimising the barriers for smaller companies to participate in research projects and collaborations. Thus, the Danish Council for Strategic Research recommends that the management and collaboration capacity of smaller companies be developed through individual experiments and innovation projects. The Danish Council for Strategic Research will increase awareness of the barriers and opportunities that exist in order to strengthen researcher-based innovation in smaller companies. Minimising bureaucracy is, to a great extent, an effort geared towards incorporating more research into smaller companies. In order to ensure the professional development of smaller companies, it should be possible for them to station their academic workers for brief periods of time in public research environments and, thus, achieve a valuable updating of their competencies.

**Triple Bottom Line:** The Danish Council for Strategic Research operates with a triple bottom line in which knowledge, growth and sustainability are equal goals. The Council's analyses, proposals and efficiency measurements will, therefore, be designed to relate specifically to these dimensions. A given project must, thus, be assessed and evaluated based on three factors: the research findings produced, the growth it can produce and the ethical and environmental consequences that may be inherent in the actual technology, processes and products.

The way strategic research works is that funds, which are used correctly, can sow the seeds which then create world-class prosperity, welfare and knowledge. However, funds, which are spread too thinly and without the right idea, the right insight from the provider, the right understanding from the recipient, the right composition of the recipient consortium, the right ground rules between the parties and the right follow-up, can quickly be squandered.



At the same time, more targeted efforts in research policy will contribute to creating the necessary increased mutual understanding between the research world and the political system.

The above figure illustrates the interaction between Innovation Accelerating Research Platforms and Centres for Strategic Research.

## **Innovation Accelerating Research Platforms**

The Danish Council for Strategic Research sees it as its responsibility to strengthen the contribution of research to accelerating innovative activity in Denmark. That is why relations between the research world and the innovative environments in Denmark must be improved. In this context, the Council is working with a new concept, namely Innovation Accelerating Research Platforms. Such platforms act as driving forces for accelerated innovation, building on highly qualified, interdisciplinary and cross-institutional research efforts. This will help bring hitherto separate competencies and knowledge areas together - within the public research system and between the public and private sectors. Thus, various stakeholders will be gathered within both knowledge development and innovation.

Even though there are, as mentioned earlier, several good examples of how Denmark has managed, with strategic investments, to build up business clusters or in other ways promoted the progress of society and the citizens of Denmark, this can be done even better with a targeted effort.

The Innovation Accelerating Research Platforms are to ensure the identification of focused research areas where a higher level of research would also be more likely to be converted into a higher level of innovation in an international context. For this purpose, a framework must be created for relation-driven research activity and for consolidation of results, which stimulates results-oriented behaviour in the research environments at universities, companies and anywhere else research is conducted.

It is, therefore, vital that the Danish Council for Strategic Research counteracts the inertia in those research environments, which seem to have learned to survive by attracting funding from special programmes and then doing just about what they would have done anyway. Similarly, research teams, which

## 10 Requirements for Innovation Accelerating Research Platforms

### *International Position of Strength*

1. The research platform must comprise considerable international positions of strengths in Denmark.

### *High Level of Research*

2. The research platform is characterised by users and consumers who, in an international context, make advanced requirements with respect to services and products.
3. The research platform is characterised by profession cultures which, in an international context, make advanced requirements with respect to the services and products produced.

### *Growth Potential*

4. The research platform is an area with considerable growth potential.

### *Need for New Solutions*

5. The research platform focuses on obvious problems that call for new solutions, as such it will be able to address a need to which research can contribute with solutions.
6. The research platform is characterised by obvious needs for new research and innovative contributions in the long term.

### *Public Interest*

7. The research platform has strong public appeal and interest - among policy-makers and citizens as well as in the media.

### *Integration, Dialogue and Collaboration*

8. The research platform brings stakeholders together who ensure that barriers to innovation are dismantled and that research findings are disseminated as quickly as possible. It must be possible to identify key players who will be able to play a decisive role in coordination and implementation.
9. Basic research can be merged with strong application perspectives - strengthen interaction and dialogue between researchers and other stakeholders.
10. Traditionally separate fields of research can be brought into mutually beneficial interaction.

have obtained external funding, often find that their own university managements have re-allocated their basic funding. Thus, what was intended by the policy-makers to be a strategic investment, is actually used as a stopgap.

Breaking this pattern requires clear choices for what is to receive support, how it is supported and how we follow-up on that support. Innovation Accelerating Research Platforms are the Council's proposal for the criteria that should be considered before an area can be identified as a focus for a far-sighted strategic investment. If research is to benefit Denmark, and perhaps, in some cases, give rise to business-related positions of strength in future, then a number of conditions must be in place.

In order to invest strategic research funding appropriately, the Danish Council for Strategic Research makes its assessments based on ten criteria. The Danish research-related positions of strength must be clear. A high level of research must be in place. The areas must have growth potential and must cover the needs of society. There must be public appeal. And within the areas, the right groups of players must be brought together, which press for the same development across disciplines and sectors.

Thus, a key process in the work of the Danish Council for Strategic Research will be to identify, after thorough analysis, the Innovation Accelerating Research Platforms that can contribute to value creation for society.

## **Level of Innovation in Danish Society**

The research activity in Denmark is not an adequate source of innovation in Danish society today. It is crucial that this be changed. The Danish Council for Strategic Research must, therefore, contribute to increasing the level of innovation in Danish society.

Contrary to the general picture, Danish companies have shown that they can, by focusing on commercialisation of research and development-based inno-

vation products, assert themselves quite well, even on a global scale. Take, for example, insulin, ingredients, enzymes, wind turbines, brewing, film, catalysis, software, hydraulics, acoustics and valves, to name a few. The activities of the Danish Council for Strategic Research are to ensure us a new generation of such companies for the value generation and workplace creation in the Danish society of tomorrow. This should be the result of creating synergy with the coming so-called High-Technology Foundation, the Danish Council for Technology and Innovation and, especially, the research basis formed by the universities, the Danish National Research Foundation and the Danish Councils for Independent Research.

The many small and medium-sized enterprises form the backbone of Danish society. Their growth is a key factor for the creation of more workplaces and value in Danish society. Thus, a special effort is needed to increase the level of innovation within these companies. The Danish Council for Strategic Research recognises that such an effort will encounter a number of barriers within these companies as well as within the research support system. The Danish Council for Strategic Research will, therefore, work together with relevant players to develop programmes and pilot projects that will dismantle these barriers.

Some of the key tools for increasing the level of innovation in society are:

- *Critical mass*: Our research environments are too small and too spread out. The Danish Council for Strategic Research will support knowledge environments that can handle such an investment and, at the same time, help ensure that, where relevant, very small research environments become associated with stronger environments.
- *Support the best*: The Danish Council for Strategic Research will gather excellent researchers and research environments cultivated through the growth layers in the Danish National Research Foundation and the Danish Councils for Independent Research in order to improve the applicability of basic research.
- *Innovative alliances*: The Danish Council for Strategic Research will strengthen the formation of alliances among R&D environments in uni-

versities, government research institutes and companies. The goal is to strengthen, through the formation of alliances, mutual insight and learning circles among stakeholders with different roles in the research process.

- *New initiatives*: The Danish Council for Strategic Research will support new players and research environments that develop enterprising ways to strengthen the interaction between research and innovation.

The world of research has always been highly internationally-oriented. However, a central objective for the Danish Council for Strategic Research is to bring this international orientation out of the relatively closed circle of the research world. In coming years, Danish companies can expect to locate R&D departments internationally. This process requires considerable awareness. The Danish Council for Strategic Research will consider how Danish research can strengthen its interaction with research environments and businesses in countries where this phenomenon is becoming more common. It is important to seek out new growth alliances.

## Relation-driven Research

The public-private research collaboration needs new ways of thinking and new tools. The Danish Government's action plan *Fra tanke til faktura* (From thought to invoice) calls for greater utilisation of research to strengthen the Danish business community. The Danish Council for Strategic Research requires collaboration with the business community and other users. Companies are not just users, but also sources of knowledge for the public research system. It is vital that the expertise of the business community in identifying areas with innovation potential be brought into play. PhDs and Post-docs are key elements in the collaboration between public research institutions, industry, Authorised Technological Service Institutes and small and medium-sized enterprises.

## Funding for Relation-driven Research

*Centres for Strategic Research:* It is not enough to require collaboration between research environments and the business community or other users. There must be someone to hold the collaboration together. The Alexandra Institute at the University of Aarhus is an example of a sustainable model in which a specialised staff, with knowledge of both the research conducted at universities and the development plans of companies, actively brings companies and researchers together. The Danish Council for Strategic Research wishes to implement similar initiatives at research institutes throughout Denmark.

*Joint Financing - Research-stimulating Funding:* In order to get companies and other stakeholders to participate more actively in research, the Danish Council for Strategic Research will work with the concept of research-stimulating funding. The only way to guarantee a real interest in a research project is if the stakeholders actually contribute to financing that research. This is why funding from the Danish Council for Strategic Research must be allocated, whenever possible, so that the Danish Council for Strategic Research, research institutions and companies each stand for one-third of the funding. However, special consideration must be taken for small and medium-sized enterprises.

*Combination Positions - a Third Career Path:* The Danish Council for Strategic Research will be aware of the fact that the focus area opens up the possibility for new types of jobs. Those who form collaborations between research environments and the business community are typically people who understand both worlds. They have moved around and have personal connections they can draw on in both camps. Today, the problem is that there are too few people with knowledge of both worlds. One important tool is combination positions - i.e. jobs in which a person is employed 30 per cent of the time at a university and the remainder of the time at a company, hospital or the like. Combination positions should not replace the main career paths in either the business or university communities, but they will establish a third career path.

*Dialogue with Citizens and Users:* Compared to other countries, the interest in research is substantial in Denmark - and this interest is increasing. The needs of the population must be met. This is why the Danish Council for Strategic Research emphasises that applications incorporate communication aspects, which ensure that the purpose and results of the research are made public.

At the same time, there is essential inspiration to be gained from the Finnish method of organising research collaborations. Finland is proactive and has designed a system that is proactive. Tekes has a staff of 350, the majority of whom work in the cross field between, on the one hand, universities and similar public research environments and, on the other, high-tech-oriented companies with research potential. These bridge builders with scientific back-

grounds and detailed insight into the production and development perspectives of relevant companies are spread throughout Finland. They are the engine room of the technological development process which Finland is currently undergoing.

The Danish Council for Strategic Research does not want to copy the Finnish model as such. The Danish business structure is essentially different with fewer large technology-intensive companies. In a Danish context, models need to be developed that especially take into account the possibilities and limitations of small and medium-sized enterprises. Similarly, it is important to focus on start-up companies that emerge directly out of research environments or as spin offs from knowledge-intensive businesses.

Nonetheless, there is also a need here in Denmark for a special focus and an apparatus to make things happen. All experience shows that strategic research, driven solely by means of the evaluation of applications for funding, does not have the necessary impact. An outreaching, proactive force is needed - people who understand the technology and who understand how to bring people from different worlds together.

However, there are examples of environments which systematically cultivate common interests among research environments and businesses, as well as the needs of society in general. The Danish Council for Strategic Research wants to strengthen the researchers and the environments that are enthusiastic about this connection. They can become bearers of a new culture at institutions of higher education and other research institutes - a culture that promotes knowledge, growth and sustainability.

The Council, therefore, recommends the establishment of Centres for Strategic Research in connection with research institutions and the like. For application-oriented research, the Centres for Strategic Research are the equivalent of centres of excellence for basic research. In the area of basic research, Denmark has a tradition for free research, but also for moderate funding of the individual researcher. In order to promote very outstanding

basic research, the Danish National Research Foundation has made it possible for exceptional researchers with obvious leadership talents to have ample resources at their disposal for an extended period of time so that they can establish interconnected centres of excellence for world-class basic research. This is a good programme, one where the long-standing support of basic research now in some cases can be traced as a catalyst for emerging business clusters around the oldest of the centres for basic research.

But Denmark also needs for highly qualified researchers, who are enthusiastic about application-oriented research, to have the opportunity to establish centres. Initially, the Council recommends that DKK 75 million be earmarked in the 2005 National Budget for the establishment of five Centres for Strategic Research. Based on submitted applications, the Council can then identify the players and key persons to establish and run the centres. There is no single model of success to be followed, and dedicated people with leadership talents often tend to create original models and collaboration constellations. Thus, the Council will not initially preclude itself from untraditional solutions. If policy-makers decide to establish Centres for Strategic Research, the Council will place particular emphasis on the leader's experience in application-oriented research and in research management, the strategic aims of the centre and the support in the form of commitment and financing from the private sector, in the region's political layers, at the research institutions, etc.

The establishment of Centres for Strategic Research can be a key element in turning the research culture in Denmark towards much closer collaboration between research institutions and society in general. In addition, there are a number of other tools to ensure relation-driven research, from model contracts to combination positions to research-stimulating funding, as well as dialogue with citizens and users in general.

## Consolidation of Effects and Results

Research is an investment, the outcome of which is not apparent until after the work has been done. The Danish Council for Strategic Research's consolidation of results must therefore contribute to documenting the critical factors for the level of both research and innovation before and during the funding period. This is why the Council require an account of what the benefits, in the form of research findings and innovation, are expected to be. But the tools used for consolidation of effects and results by the Danish Council for Strategic Research also take as their point of departure documentation of how partners will ensure, in advance, that the findings will benefit various stakeholder groups. At the same time, it will also be emphasised that research management and cooperation processes underpin the research process.

The tools are:

- **Strengthened research management:** The academic world is undergoing a period of change. For decades, research management has been non-existent. Today, management discipline is gaining acceptance, but there is a lot to be done, and the Danish Council for Strategic Research will greatly emphasise the management dimension in connection with major investments. The head of research must show the Danish Council for Strategic Research a plan for how the management dimension will be handled.
- **Research plans:** Applicants must submit a research plan. What clear success criteria will they achieve within the next five years? What barriers are there - and how will they be overcome? The researchers must define milestones, against which they can be measured.
- **Research project requirements:**
  1. Account for how many PhDs and Post-docs a project will train.
  2. Both research institutions and business partners must generate and exploit synergies.

3. There must be co-financing by companies and research institutions.
4. Account for why Denmark is competitive in this field.
5. Contracts between the parties must delegate areas of responsibility, and there must be clear agreements on intellectual rights.

In assessing the Innovation Accelerating Research Platforms, ethics, social benefits and stakeholders are to be considered, and the terms for identifying the platforms must be well-documented and transparent. At the same time, the formulated targets of the projects which have been allocated funding will be followed up on.

## Here and Now

Upon its establishment, the Danish Council for Strategic Research was assigned the task of carrying out research programmes in renewable energy, food, nanotechnology and IT. Rather than, as had been done previously, appoint a programme commission to distribute each of the four programmes, the Council decided to appoint three programme commissions, one for food & health, one for energy & environment and one for nanotechnology, biotechnology and IT. With these programme commissions the Council makes a clear statement that it is crucial that we focus on these three areas and on the cross fields between the disciplines they incorporate. In 2004, the Council has had DKK 140 million to allocate within the three action areas, which is very little compared to the challenges we are facing. There is a need for an immediate and significant expansion of this effort in addition to the allocation of funds for Centres for Strategic Research with no special themes. The following is a presentation of the three action areas and their enormous potential for Danish society.

## Food & Health

Nestlé once called itself "the world's biggest food company". But three years ago, the conglomerate changed its strategy, and ever since, Nestlé has called itself the world's biggest health and well-being company. Nestlé's new strategy is part of a large-scale trend. Food and health are now thought of in an entirely new way. Some go so far as to say that health for healthy people means food. For us, we can see a trend in which special diets, for instance, are becoming common methods of treatment within the health-care system, at nursing homes and the like. We will see intense research in the correlation between genes, diet and diseases, research in healthy lifestyles and manufacturers who produce foods specifically aimed at improving the health of the individual and preventing a variety of lifestyle diseases.

For Denmark, this represents a unique opportunity. The cross field between food and health is of obvious strategic interest - both with regard to the general health of the population and in a business-related perspective.

Within both food and health, Denmark is specialised with strong business competencies, large exports, strong public support systems and research of international excellence - as well as an efficient documentation and control system for medicines and foods. One-fourth of all Danish research is conducted within the field of health, while within food research we have a tradition for strategic research promoted by, among others, the FØTEK programmes. Denmark is a global leader in the enzyme and ingredients market. At the same time, Denmark has some of Europe's strongest companies in the food industry, clusters of pharmaceutical and biotech companies located in "Medicon Valley" in the Greater Copenhagen Area, and a hospital system that can spearhead the development of new methods of treatment in the cross field between food and health.

Thus, there are powerful industrial interests in building up Danish knowledge environments in the cross field between food and health. At the same time, there is a chance that Danish agriculture, with such an investment, might

become truly high-tech for the first time. Today, the food sector is high-tech in its processes, focusing primarily on efficiency in the manufacturing of foods. However, the knowledge content of the products is moderate. Pork half carcasses continue to be the largest export product. The number of new farming nations who have now joined the EU has increased the challenge faced by the Danish food sector. Denmark, as a farming nation, must become truly high-tech. The highly automated production plants can, through intelligent use of IT and nanotechnology, be given the ability to handle more specialised niche manufacturing. At the same time, there are promising perspectives in targeted research-related and industrial investments in the cross field between food and health.

The opportunity is there. The combination of solid experience in the area, good researchers and large knowledge-intensive companies gives Denmark the potential to create a high-tech, knowledge-based food sector based on stronger research in genetics/genomics, molecular nutrition and immunology, microbiology and functional foods. By combining food research with

### **Example: Denmark Leads the World in Genetically-determined Nutrition - Nutrigenomics**

Nutrigenomics is a new research area that clearly has potential for making Denmark a global leader in this field. Nutrigenomics deals with the interaction between genes and diet - mapping what we each need and how we get this into our diets. Nutrigenomics is based on a holistic approach to nutrition as opposed to the classic in-depth studies of individual factors under certain conditions. Research in nutrigenomics will, in part, lead to better dietary recommendations - which today tend to change concurrently with new "narrow" research findings - and, in part, give us a better understanding of the factors that are crucial for health and disease and the related biomarkers. The first world congress in this field was held just two years ago. Thus, this field of research is young, and although the research performance in Denmark today seems weak, a large-scale unifying commitment can bring Denmark to the forefront and open the doors for industrial applications.

The fact that we, in Denmark, have some of the largest food and ingredients companies in Europe combined with food research of international excellence makes nutrigenomics a strategically intelligent focus area for biotechnology research.

research in the field of health, the framework is laid for a powerful industrial cluster, which Denmark can profit from for many years to come.

There has been a tendency for biotechnology and new technology to be used to make industrial processes more efficient. But the real potential in foods is achieving better quality, better taste, better utilisation of good raw materials and new, exciting products by building on insight and biological understanding.

Our vision is to unite the organic mentality, with respect for good raw materials, with high-tech and biotechnological possibilities to produce real progress for the consumer and the environment, and to use this to strengthen the industry's competitive edge. A Danish food sector that differentiates products based on knowledge of the food's influence on health would become significantly stronger in the competition of tomorrow.

## **Action**

The Danish Council for Strategic Research has appointed the Programme Commission for Food and Health in order to strengthen Denmark's strategic investment in this area. We need to invest extensively and quickly if Denmark is to embrace this opportunity. Existing institutions and professional value sets need to adopt new thoughts and action. New research funding dedicated to this process of change can act as a catalyst for a process that, there is reason to fear, would otherwise be too slow. With a strengthened effort, the Danish Council for Strategic Research will create the necessary incentives for this to happen, and we will focus on it in connection with applications for specific projects.

At the same time, the Danish Council for Strategic Research will emphasise the incorporation of humanistic and social viewpoints into the work as well. It takes more than just technical viewpoints to understand modern consumers in our vision of Denmark as a high-tech society.

## Example: From Classic to Molecular Biotechnology

In the field of microbiology, Denmark has a long classical biotechnology tradition based on fermented products - bread, beer, yeast, alcohol, cheese and yoghurt. Biotechnology research and microbial production is a Danish position of strength.

Denmark currently occupies a strong industrial position in the microbial manufacturing of pharmaceutical products, enzymes and other metabolites as well as microbial cultures for feed supplements and probiotic nutritional supplements. These industries are highly dependent on gathering results from the latest research for use in continuous improvements in production efficiency and product innovation. It is, therefore, strategically crucial for Denmark that research efforts are at the cutting edge in molecular biotechnology.

Potential: New biotechnological research is expected to lead to dramatic product innovations within such areas as probiotic cultures and prebiotic biologically active substances to regulate the intestinal flora of humans and animals, which will play a major role in the prevention of diseases and in food safety.

Similarly, the microbial biotechnological manufacturing of enzymes and bioactive substances will lead to entirely new possibilities for precise regulation of the metabolism in animals and humans, which can prevent lifestyle diseases, including obesity, and reduce the environmental impact of non-metabolised nutrients, minerals, etc. In addition, there are a large variety of functional food ingredients which are currently produced using chemical process technology, but which could be produced, in future, by means of more sustainable microbial fermentation - e.g. colorants, flavourings and stabilisers.

First, we need increased knowledge of the driving forces and wishes behind the composition of food consumption of various groups of consumers, including:

- The correlation between their concept of health and environment, their understanding of risks and their behaviour, shopping habits, finances, lifestyles and consumption of foods.
- The importance of health information, advertisements, labelling and similar health-promotional communication efforts.
- Biological, psychological, cultural and social factors behind the growing prevalence of food-related diseases.
- Food and socialisation, including how children learn to eat, make food and choose foods.

Second, it is essential that research in the disease-preventive and health-promoting aspects of foods for the individual and society be conducted. We need to investigate the health-related aspects of manufacturing foods that can be used by well-defined segments of the population. In this area, new functional foods, including genetically modified components with special, well-documented properties, will be a natural aspect of the considerations:

- Characterising the food needs of special population groups, e.g. pregnant women, children being weaned from breast milk, elderly with low physical activity and people at institutions such as hospitals, nursing homes and schools.
- Studies of the chemical/biochemical implications of combining specific ingredients and raw materials. This covers both preservation of technical and health-related functionalities and modelling of the effectiveness of active ingredients under various conditions.
- Understanding and documentation of how functional foods have improved quality and nutrition-related attributes regardless of whether the products are developed and manufactured using traditional, biological or gene technological methods.

Third, the sustainability of foods is a key challenge, and in that context there are considerable opportunities to utilise high technology. For example:

- Use of sensors in all segments of production. Technology makes it possible to measure environmental pressure much more precisely and to target the dosage of feed, medicine, etc.
- Development and optimisation of conventional and organic modes of production can transform Danish agriculture into a pioneer in the area of monitoring the nutrient cycle, thus creating the basis for a new support industry with the prerequisites for international expansion concurrent with the probable growth in this market.
- By using e.g. bioinformatics, agriculture can achieve a better understanding of the treatment of animals and far more often prevent and treat diseases with programmes adjusted to suit the individual animal.

Fourth, a dedicated effort to utilise nano, bio and information technology in the food industry would increase competitiveness:

- IT can contribute to food safety, including tracing a food product through every segment of the manufacturing process.
- Nanotechnology can contribute to documentation and modelling of the biological data of foods.
- Development and testing costs can be reduced with the use of nano-models.
- Biotechnological methods can be used to improve the nutritional composition of foods and risk assessments.

These four dimensions require a multifaceted research performance. We need more research in social and behavioural causes for unhealthy lifestyles. Similarly, we need research in and manufacturing of differentiated foods that manage to satisfy the health, taste, social and practical needs of the consumer all at the same time. Finally, we need a targeted incorporation of high technology into all manufacturing segments in the food sector. This can result in improved quality of life for the individual, lower health costs for society, better products for companies and a significant improvement of the existing Danish business clusters in the area of health and food.

## Energy & Environment

Denmark has strong traditions in both energy and environment, with unique traditions in the cross field between energy and environment. Today, Denmark capitalises on the public and political focus on the energy and environment sectors in the form of a number of research and business-related positions of strength.

With regard to the environment, Denmark has strengths in such diverse areas as water, environmental software and process technologies.

Clean water is the most important resource problem in the world - and in the long term also in Denmark. It is an area of key political importance and will encompass significant economic dynamics in coming decades. There is money in knowledge about water, as well as jobs and social benefits, and there are a lot of people and companies in Denmark who possess this knowledge. We have strong research environments, several of our major engineering companies have built up expertise, and in the area of software, Danish companies provide world-class systems for mapping the environmental impact of water currents.

Danish companies are among the most advanced users of environmentally sound processes in manufacturing. Similarly, the large Danish industrial companies are far ahead when it comes to cradle-to-grave approaches that map and minimise, over a life cycle, the environmental impact of products and their energy consumption.

In the field of energy, Denmark possesses key competencies in the areas of wind power, solar cells, bioenergy, fuel cells and energy-conserving technologies. The Danish energy system is studied all over the world, and the ability to handle flexible energy systems with decentralised power sources on a large scale is seen as one of the keys to the construction of energy systems that can handle the shift away from today's coal and oil economies. The world demands more and cleaner energy. This demand will grow in the future, and Denmark has a good deal to offer with regard to both research and industry.

The environmental impact of traditional energy products makes it essential that we strengthen our research in alternative sources of energy. The traditional production of energy in power plants, oil-fired furnaces and motors consists of burning fossil fuels like oil, coal and natural gas. This type of energy consumption impacts the environment by producing carbon dioxide, sulphur dioxide, nitrogen oxides, heavy metals and the like. In recent years, the production of carbon dioxide in the Western World has fallen slightly, but the contribution by growth economies in Asia has increased. Combined, the latest measurements of carbon dioxide show the largest quantities ever.

The prospects of increasing oil prices make alternative energy even more strategically promising. With increasing prices, it will be more economical to utilise energy better and to cultivate new sources of energy. At the same time, Denmark spends less public funding on research in energy compared to the other countries we normally compare ourselves with. When measured in terms of the share of GDP, publicly-financed energy research in Denmark is less than in Sweden and Norway, and countries such as Finland and the Netherlands spend twice as much or more.

## **Action**

The Danish Council for Strategic Research will focus on the environment and on sustainable development, energy, processes and production. There are clear business-related and societal interests in investing in each area, and the Council intends to seek out the most promising. At the same time, the Council will be specifically interested in the interaction between these areas, as there are many examples in this field of Danish world-class knowledge.

For instance, Denmark has strong knowledge environments and trend-setting companies in a variety of alternative energy types. In the field of wind energy, Denmark has succeeded in attracting large international companies thanks to an interesting competency environment.

Thus, it is logical to support and strengthen the knowledge base even more within these areas, especially in fields that attract the attention of the research world, business community and policy-makers. The Danish Council for Strategic Research will focus on areas where it is obvious that Denmark can play a special role.

Today, Denmark is especially strong in wind power, bioenergy and fuel cells. At the same time, there is a vast undergrowth of private research in many other types of alternative energy production. In many cases, it should be pos-

## Example: Fuel Cells and Hydrogen

Many consider motors based on fuel cells to be the future alternative to petrol and diesel internal-combustion engines. The most common fuel cells use hydrogen as fuel. This is something that many talk about, but very few people actually know how to make fuel cells. Denmark knows how. Several Danish companies and knowledge centres have a very strong position internationally when it comes to research and innovation into fuel cells.

The technology is still so young that we are talking rather of a potential than of a fully developed industry. But the potential is there – and it is stronger in Denmark than in most other places. If they take the lead, policy-makers can seek out, with research funding and public demand, the same types of opportunities that came with the growth of wind energy.

If Denmark succeeds in achieving a significant lead in fuel cells, then we will have a share in an even stronger development. Fuel cells are a sub-component in hydrogen energy, which is a major focus area in many countries. The USA, EU and Japan have initiated comprehensive research programmes in hydrogen energy, and some actually talk about a "hydrogen society" as the alternative to the oil-based economy of today.

The Danish Council for Strategic Research assesses that generally Denmark does not have the necessary critical mass in research and the business community within the entire spectrum of hydrogen energy. But in one sub-component, such as fuel cells, we have the opportunity to lead the way in a strategically important field.

sible to achieve synergies and to intensify knowledge development in these areas through closer collaboration between the parties.

Today, wind power has grown into a key industry with a turnover of DKK 22 billion, of which exports account for 88 per cent. In 2003, wind energy covered more than 16 per cent of the domestic supply of electricity. According to the Danish energy action plan, *Energy 21*, half of Denmark's electrical energy consumption must come from wind power by 2030. This is certainly realistic, especially in light of the continuous product development taking place in the field. From 1989 to 1999, the energy production per square metre of rotor area, thus, increased by 44 per cent. Nanotechnology will make it possible to produce even larger, stronger and lighter blades in the future.

The growth of the wind turbine industry is a textbook example of how far Denmark can go with strategic research if we consider our strengths. Denmark focused on research in wind energy at an early stage, and it was a necessary, though far from sufficient explanation of the industrial fairy tale that stands in all its glory today. For in terms of research funding, the USA spent more than 100 times as much. And yet, the companies emerged in Denmark, and today the Danes hold 40 per cent of the global market. There are most likely two reasons for this. One, the political system actively supported the demand for wind turbines. Policy-makers created a market, from which the companies emerged. Second, there was a distinctly public breeding ground for wind energy. The revolt against nuclear energy had created a public opinion in favour of wind energy and engaging the active commitment of grass-roots environments. It was the combination of research, a well-timed political focus on stimulating demand, a general public acceptance and a group of dedicated people, which promoted the early industrial development and created the platform that is now a key industry in Denmark.

This understanding of the dynamics between research, the business community, politically established demand and public commitment is vital for the development of the billion-kroner industries of the future. For the Danish Council for Strategic Research, the task is not limited to identifying promising technologies where Denmark has both business and research-related key competencies. The public dimension must also be considered, just as the Council will also indicate the political initiatives that can act as catalysts for new industries.

Today, Denmark has world-class knowledge environments in the field of wind energy at the Risø National Laboratory, the Technical University of Denmark and Aalborg University. But even though Denmark dominates the global wind turbine market with its 40 per cent market share, there has actually been a decline compared to previous years when Denmark occupied about half the market. And therein lies another lesson. A world-class position is easier to defend than to build up from scratch, but it must be defended. In the past three years, giant conglomerates such as General Electric and

Mitsubishi have focused massively on wind energy, and Denmark was passed up when the companies decided to locate their development departments in, among other places, Shanghai, Munich, India and the USA. While Denmark has cut back on research in wind power, the large conglomerates have increased theirs. Strategic investments for the future are not something that has been done, but something that must be done every single year and every single day.

## NABIIT

Nanotechnology, biotechnology and IT are all technologies with enormous research potential, both separately in interaction and as a basis for research and innovation within a large variety of other research areas. They are technologies whose applications will have enormous influence on future growth and welfare, and many countries are committed to achieving leading position in these areas. The USA, the UK, France, Germany and Japan are among the countries in the world that have invested the most in nanotechnology and nanoscience. However, considerable funding has also been allocated under the auspices of the EU's 6th framework programme. The National Technology Agency of Finland, Tekes, has highlighted IT, biotechnology and nanotechnology as the driving technologies for development, while countries such as Taiwan have invested DKK 10 billion in establishing research into nanotechnology.

In other words, these are areas in which global investments are so great that it does not make sense to imagine Denmark as a leader within all three fields - or even as dominant in just one. Thus, there are basically two very different strategic reasons to invest in nanotechnology, biotechnology and IT. One type of investment comes from an ambition of becoming a world leader, and in selected areas the environments are in place for that. The other type of investment, however, focuses on keeping up with the rest. Danish research must keep pace in order to ensure that there is a system to capture and bring the advances of the technology back to the blades of the wind turbine industry,

the weight-bearing constructions of the building industry or the medicines of the pharmaceutical industry. The prerequisite for achieving a position as a high-tech society is that Denmark possesses the latest knowledge in these areas.

## Action

The Danish Council for Strategic Research has shifted its focus to the possibilities inherent in the three technologies and in the interaction between them. The Council's responsibility is to promote research based on the needs of society.

### What is it About?

For decades, information technology has had a fundamental influence on our society, business community and daily lives. Computer chips are becoming increasingly smaller, faster and cheaper and, thus, applicable in still more contexts. This forms the point of departure for expecting IT in everything, or "pervasive computing". This also opens up for entirely new opportunities to integrate the technology into other areas of research.

Modern biotechnology can be divided into three segments: health care (red biotechnology); genetically modified or GM plants (green biotechnology); and biological solutions for industrial processes (white biotechnology). There is an enormous unexploited potential within all three segments, which can create value for both humans and the environment in the form of environmentally-friendly products, better food quality and improved health and welfare.

Nanotechnology can be described as a molecular science on the borderline between physics, chemistry and biology. With nanotechnology it is possible to manipulate with the properties of materials. This refers to all technology that has a scale in nanometres (1 nm = 1 billionth of a metre), e.g. on the molecular scale. There are roughly three types of nanotechnology:

- " Nanomaterials: artificial materials with nano-sized structures
- " Nanoelectronics: electronic circuits with nano-sized components
- " Nanomachines: Tiny, multifunctional systems

As nanotechnology becomes less expensive, there are high expectations to its dissemination and applicability in connection with research and industry. This makes it one of the technological driving forces of the future and, thus, an area in which Denmark must invest strategically.

The ability of IT to handle enormous amounts of information along with the increasing complexity of biotechnology makes it even more necessary that the two technologies be combined.

Nanotechnology may turn out to be the link between biotechnology and IT, because like biochemistry it operates at the molecular level.

With nanotechnology it is possible to develop materials that are not rejected by the human body. This opens up for entirely new possibilities within biotechnology, for instance increased possibilities for combining electronics and mechanisms with human tissue.

At the same time, it is possible that the path to functional nanomachines is actually via biotechnology. Several researchers consider it far simpler to modify existing, microscopic organisms to perform various tasks in the human body than to build nanomachines from scratch.

Nanomedicine is one example of the possibilities contained in this type of interaction. The physicist Eric Drexler, who invented the concept of nanotechnology, envisions a future in which we will be able to design microscopic

### **Example: Danish Strengths in Biotechnology**

The importance of political and public attitudes is directly reflected in the Danish biotech sector. In the 1980s and early 1990s, Denmark was a leader in plant-related biotechnology. At the end of the 1980s and beginning of the 1990s, policy-makers carried out two biotechnology programmes, which formed the core group of researchers who today are the main reason for the existence of more than 150 biotech companies in Denmark. The motive behind these programmes was, in fact, that Denmark was falling behind with regard to biotechnology and now it is clear that the strategic research effort succeeded.

Paradoxically, however, the foundation for the Danish strength in biotechnology - the great flow of new highly qualified graduates - is beginning to ebb out. Whereas biotechnology used to be the hottest field of research a few years ago, nanotechnology is now taking its place. So resources have been moved, resulting in the reduction of special programmes to train PhDs in biotechnology. Thus, the strategically successful research policy focus on biotechnology has been critically weakened at the height of its success.

## Example: Danish Strengths in IT

Within IT, the Danish Council for Strategic Research sees three immediate Danish positions of strength:

**Software products:** Microsoft's largest development department outside the USA is in Vedbæk, north of Copenhagen. This is no coincidence. Denmark is strong in the area of software products, i.e. programmes that work all over the world and on all types of systems, as opposed to individual software solutions. The development of software products, such as the original Navision accounting system, is demanding and this Danish strength is confirmed by a number of medium-sized IT companies like CCI in Aarhus, which makes software for printing houses, and Danware, which makes network logins. An increased focus on software products could pave the way for many new companies.

**IT-in-everything, or pervasive computing,** is a powerful trend where the IT village of Katrinebjerg in Aarhus has been able to position itself as one of the leading centres in Europe. The field is so new that we do not yet have any large companies, but pervasive computing is now turning up in products from Lego and B&O. For Denmark, it would make sense to build further on the expertise of Katrinebjerg and the Alexandra Institute, including investing funds that can make the centre truly nationwide and, thus, a stronger foundation for the major part of the IT industry, which is located in and around Copenhagen.

**IT communication:** Denmark has strengths in areas such as wireless and optical communication, from which Giga, among others, emerged.

In addition, there are three other areas qualified for developing into actual positions of strength, namely computer games, security and environmental software.

"robots" that are capable of building copies of themselves. The vision is that nanomachines will be able to perform a variety of specialised tasks, such as cleaning human veins of calcification and cancer cells or otherwise improving the body's performance. This function is often called *nanomedicine* and according to the National Institutes of Health (NIH) in the USA, nanomedicine may already be used in practice in ten years' time.

Internationally, a good deal of research is being conducted in nanomaterials that are not rejected by the human immune system. For instance, materials are being developed that can act as skeletal supports for the regeneration of bone tissue, skin, muscles, etc. Research is also being conducted in materials that

can act as an interface between biological tissue and artificial materials such as plastic and metal.

Strategic research in nanobiosystems is a very important field with definite potential in Denmark. With regard to research, Denmark is already among the world leaders in some aspects within this field.

It is the position of the Danish Council for Strategic Research, therefore, that research in nanobiotechnology should be strengthened with substantial research funding in order to maintain this leading position, and that this investment should take place while Denmark is still on the frontline. By maintaining the focus on the coupling with biotechnology, Denmark has the opportunity to achieve a key position in an important niche.

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