

Report on Government mandate to Formas and VINNOVA

Research strategy for environmental technology



Research strategy for environmental technology
Report on Government mandate to Formas and VINNOVA
Report 4:2008

ISBN 978-91-540-6011-5

ISSN 1653-3003

Graphic design: Lupo Design

Translation: Lewis Gruber

Photo cover: Ulf Huett Nilsson/Johnér Bildbyrå

Photo credits: page 4 Claes Axstål/NordicPhotos; page 5 Formas, VINNOVA; page 8 Mårten Adolfson/Johnér Bildbyrå; page 14 Roine Magnusson/Johnér Bildbyrå; page 17 Bo Andersson/Opcon AB; page 18 Jan Johansson/Samlaren; page 19 Mikael Ullén/Orange produktion; page 21 Erik Karlsson/Greppa näringen; page 22 Rymdbolaget - Swedish Space Corporation; page 24 Naps Systems; page 25 Ulrika Malm/NordicPhotos; page 26 Lasse Hejdenberg/Tekniska Verken i Linköping AB; page 27 Svensk Biogas bildarkiv; page 28 Rymdbolaget - Swedish Space Corporation; page 30 Nonstock/Johnér Bildbyrå; page 31 Thermænius Arkitektkontor; page 32 Arno Rosemarin, SEI; page 34 Kalle Haikonen/Centrum för förnybar elenergiomvandling, Uppsala Universitet; page 36 Sveriges Tekniska Forskningsinstitut (SP); page 37 Alfa Laval; page 38 Per Berge; page 39 Sveriges Tekniska Forskningsinstitut (SP); page 40 Rymdbolaget - Swedish Space Corporation; page 43 Switchpower; page 45 Morphic; page 46 Jonas Fejes/IVLs Oljejour; page 47 Ulf Huett Nilsson/Johnér Bildbyrå; page 48 Parans Daylight; page 49 Morphic; page 54 Holmen.

Print: March 2008, Intellecta Tryckindustri.

Research strategy for environmental technology



Foreword

In 2006, the Swedish Research Council Formas and VINNOVA received a mandate from the Government to draw up a joint research strategy for environmental technology. The mandate included consultation with the business sector and other affected actors. The strategy was submitted to the Government in February 2007.

Environmental technology has and will have, a global role of increasing importance for reducing the load on the environment and thus for sustainable development. Environmental technology may also have great significance for Sweden's economy and growth. The development of a strong and competitive environmental technology sector is therefore of national interest. In this respect, small and medium enterprises are important actors since the Swedish environmental technology sector is largely made up of such enterprises.

Within the EU also, the role of environmental technologies for sustainable development is emphasised, inter alia through the Environmental Technologies Action Plan (ETAP) which has been launched with the aim to reduce the load on the environment, effectivise the use of natural resources, improve the living environment and stimulate growth.

Sweden is in a leading position in many areas of environmental technology and can in this way create competitive advantages in global markets. The strategy has identified six areas of special Swedish expertise – sustainable built environment, sustainable transport, environmental protection technology, biological resources, lightweight and advanced materials, and energy. Sweden can mainly create advantages through a focus on system innovations and system solutions. This necessitates system oriented and interdisciplinary research. Generally, research on environmental technology must



Rolf Annerberg
Director General Formas



Lena Gustafsson
Deputy Director General VINNOVA

be given greater prominence, and the behavioural and social scientific aspects of environmental technology must receive greater attention.

However, research cannot on its own create the conditions needed for the development of the environmental technology sector. Coordination and cooperation among research funding agencies, research performers, authorities, organisations, companies and other actors is needed for such a development to be achieved. Value chains along the entire sequence from idea to market must be supported by inputs.

In the work on the strategy report, great importance has been given to eliciting the views of other actors such as the authorities, research funding agencies, the business sector and academia. Two major workshops attended by a large number of delegates were held. At the first, around fifteen focus groups were initiated among those attending to discuss research needs and to initiate research cooperation in different areas. A number of consultative meetings with research funding agencies and the authorities were also held. Commissions given to the Swedish Institute for Growth Policy Studies (ITPS), the Swedish Environmental Research Institute (IVL) and the firm of consultants inno Scandinavia produced three reports which formed the basis for the strategy.

Rolf Annerberg

Director General Formas

Lena Gustafsson

Deputy Director General VINNOVA

Contents

Summary	9
The proposals	10
Introduction	15
The mandate	15
Implementation	15
Terms of reference	17
What is environmental technology?	17
Technology for a global market	23
Global perspectives	23
EU	25
USA	28
Japan	30
Large growing economies – China, India, Brazil	31
Swedish conditions	35
Opportunities for Sweden	36
Sustainable built environment	37
Sustainable transport	37
Environmental protection technology: treatment technology, waste management	37
The use of biological natural resources	38
Lightweight and advanced materials	38
Energy	39
Threats and difficulties	39
Cooperation for environmental technology	41
Cooperation and co-funding with the business sector	42
A research strategy for environmental technology	47
Vision	47
Terms of reference for the draft research strategy	48
The proposals	49
Background reports	55
Appendix	56
Swedish actors in relation to environmental technology	
The Government	56
Authorities and other national actors	56
Research funding agencies	62
Research and education	65



Summary

The Swedish Research Research Council Formas and VINNOVA have received a mandate from the Government to draw up a joint research strategy for environmental technology. This report sets out the background, terms of reference and deliberations for the strategy. Details are also given of the proposed strategic measures and initiatives within the spheres of activity of Formas and VINNOVA, also in collaboration with other actors.

The objective of the research strategy is to make a concerted effort for research and development concerning environmental technology within the spheres of activity of Formas and VINNOVA. The intention of the strategy is to promote the development of new knowledge and to strengthen the competence in the field of environmental technology, and to enhance Swedish competitiveness in the global market for environmental technology. A common vision is formulated.

Vision

Sweden is internationally competitive in developing products, systems, processes and services which satisfy stringent demands concerning resource effectiveness and environmental performance for sustainable development and growth.

This vision demands that competence with regard to environmental aspects and resource effectiveness will have been developed. Needs and demands in the market, i.e. the choices and preferences of the users, must be considered. It is further essential that a holistic approach and system aspects will have provided the guidance for the initiatives.

Formas and VINNOVA have decided on a broad definition of environmental technology, in line with the definition in the EU environmental technologies action plan ETAP.

Definition

Environmental technology comprise products, systems, processes and services which provide clear environmental advantages in relation to existing or alternative solutions, seen in a life cycle perspective.

In view of this broad approach, the focus is shifted from products to entire systems, resource effectiveness and sustainable development. With this definition, environmental technology encompasses many areas of knowledge and technologies, and affects many actors. The proposals made here do not intend

to deal with or discuss the priorities for the programmes conducted by other research funding agencies, but they do touch upon possible cooperation with other actors.

The proposals

I. Greater focus on environmental technology in research

Environmental research is to be highlighted and more clearly set out in the spheres of activity of Formas and VINNOVA. Special attention should further be given to the needs and conditions for research by, and in cooperation with, small and medium enterprises (SME).

New initiatives regarding environmental technology must be characterised by a holistic approach, with the focus on innovations and system solutions of high environmental relevance. They must also be characterised by receptiveness to issues which are having difficulties in attracting funding within the research programmes of today. High priority must be given to a life cycle approach.

Proposal No 1

Promote research on environmental technology across academic, technological and industrial boundaries through providing finance for:

- interdisciplinary and transdisciplinary research of high scientific quality and high environmental relevance, which also includes
- social scientific research that provides knowledge on needs, markets, user preferences, regulations, control instruments etc in a European and global perspective.

Proposal No 2

Increase the opportunities for SME to cooperate in and co-finance innovative projects of high environmental relevance, by:

- creating the opportunities, in financing environmental research, for including demonstration of the technique, particularly when SME are cooperating in the project
- supporting research on further development of methods and tools for sustainable development of products, with special reference to the needs of SME
- putting research resources at the disposal of SME, through cooperation with industrial research institutes, further investment in programmes such as Forska & Väx (Research & Grow), and collaborative programmes such as Formas-BIC.

II. Investment in areas of special Swedish expertise

In the Swedish innovation system, six areas of special expertise have been identified.

- *Sustainable built environment:* more overarching areas such as sustainable buildings, sustainable renovation and sustainable cities, and more specific areas of technology such as building systems for timber, control and monitoring systems, and technology for local energy supply.
- *Sustainable transport:* vehicles, traffic systems, logistics – new engines and new technology for propulsion, new fuels, technology and systems for public transport and shipping, and new methods and systems for effective transport that is coordinated among different modes.
- *Environmental protection technology:* treatment of water and sewage, cleaning of flue gases, soil remediation, waste management and recycling – cooperation among society, research and companies provides good opportunities for promoting development and export, and not least for demonstrating good examples.
- *Use of biological natural resources:* new processes for utilising several components and/or energy in an effective way, new materials from renewable raw materials, new functional composites, surfacing and barrier materials, packaging and lubricants.
- *Lightweight and advanced materials:* many areas of application, for example in applications where weight is of importance for energy or fuel use, materials that give little waste or can be recycled, and advanced materials for e.g. electronics, medical technology, solar cells and sensors. In this respect also, new processes for more effective production are of importance.
- *Energy:* new technology for energy supply – solar electricity, wind power, district heating, biofuel technology, biorefineries for fuel production – and technology for more effective use of energy, such as effective industrial processes, effective construction techniques and lighting technology, and so on. Research in this area is the responsibility of the Swedish Energy Agency, but co-operation should be aimed for.

Proposal No 3

Draw up concrete research and development initiatives for each and every one of these areas of special expertise with respect, inter alia, to prioritised areas, system aspects and interdisciplinary science.

The initiatives must be based on a broadly established vision and development strategy for each area, which should result in prioritisation and focusing of the overall national initiative.

Renewal and innovation potential, research potential and business potential, as well as environmental values, are essential parameters in this context. Take also into account the recently produced industrial programmes which concern several areas of expertise.

- Identify the possibilities of finance from the EU framework programmes within the ambit of each development strategy. Investigate the issue of co-finance for each area. The EU strategy recently presented by VINNOVA may be a tool for strengthening Sweden's position.
- Identify products and services in the area which are suitable for procurement of innovation. This implies public purchasing of goods or services that do not yet exist or need to be improved, and thus necessitate research and innovation for the specifications to be satisfied.
- Identify issues concerning regulations, standards, environmental codes, building codes, taxation rules etc which are of importance for development in the area concerned and submit them to the responsible body.

III. Cooperation for research on environmental technology

Several activities and projects with respect to environmental technology and associated areas are at present being conducted by various actors who have been mandated to work for sustainable development. Increased cooperation among these authorities, research funding agencies, business and other actors is therefore of great value.

Proposal No 4

Together with the affected authorities, research funding agencies and other actors should:

- develop research and development activities with respect to the areas of special expertise according to Proposal No 3
- develop cooperation among the actors concerned, for example by generating joint interdisciplinary research activities
- draw up vision and development strategy for the entire value chain for environmental technologies according to Proposal No 3
- promote international research cooperation in the Nordic area, with countries in the Baltic area and in the EU, and also globally with countries that have large or potentially large markets
- make sure that the boundaries among authorities are if necessary modified so that all the important sections of the area covered by environmental technology are included.

Energy system with wind, solar and
hydrogen power/Karlskoga





Introduction

The Swedish Research Council Formas and VINNOVA have received a mandate from the Government to draw up a joint research strategy for environmental technology. This strategy shall form the basis for the identification of areas of cooperation between Formas and VINNOVA.

This report sets out the background, terms of reference and deliberations for the strategy. Details are also given of the proposed strategic measures and initiatives within the spheres of activity of Formas and VINNOVA, also in collaboration with other actors. The proposals focus on environmental technology areas with a large growth potential.

The mandate

In their appropriation documents for 2006, Formas and VINNOVA were mandated to

“together draw up a research strategy for environmental technology in consultation with the business sector and other affected actors. The conditions for research jointly financed by the State and the business sector shall be elucidated, as well as the way in which cooperation by small and medium enterprises can be facilitated. The strategy shall take account of the priorities in ETAP and the opportunities for cooperation with the environmental technology councils in Sweden – Swentec and Nutek’s programme for environment-motivated business development. The research strategy shall be submitted to the Government no later than 1 November 2006.”

The date of submission was later altered to 1 February 2007. In the Research Bill *Research for a better life*, 2004/5:80, it is stated that special funds will be allocated for joint research initiatives, totalling MSEK 45 for the years 2007 and 2008.

Implementation

The work was assisted by a steering/coordination group comprising representatives from Formas (Hans-Örjan Nohrstedt and Conny Rolén) and VINNOVA (Lars Wärngård and Anna Hallgren). A working group comprising Anna

Hallgren, Conny Rolén and Leif Magnusson, Energia AB, had the operational responsibility for developing the strategy.

Two major workshops/seminars were held, attended by representatives from research, the business sector, authorities and organisations. The aim of these meetings was to obtain the views of the actors concerned as to the areas in which the need for research is greatest, and the forms in which research should be carried out. In connection with the first workshop, around 15 focus groups were initiated with the task of discussing research needs and commencing research cooperation in various areas. The focus groups comprised both researchers from universities and university colleges and representatives from companies and organisations. The working group of Formas and VINNOVA also had other meetings on several occasions with the authorities, research funding agencies, researchers, companies and other interested parties. A joint meeting with the authorities and research funding agencies was also arranged.

A number of assignments were also given to provide data for work on the strategy. The Swedish Institute for Growth Policy Studies (ITPS), within the framework of one assignment, described the Japanese research strategy in the area of environmental technology. A review made by ITPS of the situation of environmental technology in the US was also used in the work.

The Swedish Environmental Research Institute (IVL) had the assignment to study, inter alia, the driving forces for environmental technology in large growing economies, with the focus on China, India and Brazil.

An interview survey of the views of Swedish companies on the challenges, needs and important areas for initiatives in environmental technology was made by inno Scandinavia AB.

As background and documentation for the present work on the strategy, use was made of the conclusions and proposals in the national innovation and research strategy for the area of environmentally motivated technical development, which VINNOVA drew up in 2003 in collaboration with other research funding agencies and the affected authorities (reported in VP 2003:4). Parallel with the production of VP 2003:4, Nutek drew up a strategy for environmentally motivated business development, and this was also used as a basis for the work.

Terms of reference

What is environmental technology?

In the environmental technology area, the focus has changed from an earlier focus on local emission problems towards a concentration on global problems and sustainable development. Today, measures for a better environment are concerned more with greater effectiveness in the use of resources and with a reduction in the use of substances that are environmentally harmful and a health hazard. Large parts of the western world are in this phase at present. On the other hand, many of the rapidly growing economies such as China, India and several countries in Eastern Europe, as well as the poor countries of the world, still have a great need for treatment of exhaust gases from heating, heavy industry and vehicles, and the treatment of sewage effluent, measures which, to a large extent, have already been implemented in the rich parts of the world.

Environmental technology, in the sense of technologies that purify exhaust gas emissions to air and discharges to water and sewerage, or treat or render harmless various types of residual products or waste, are established industries with a large international market, with several Swedish players. There is a need here for further development to increase performance, and it is desirable that the technology should also be put into use in developing countries.

Legislation and politics have had great importance as driving forces for the development of new technologies with better environmental properties, but the general development of technology is largely driven by the demand in various markets where several factors apart from the environment are of great importance:

- Fuel consumption is significant in the choice of vehicles, but vehicles are often chosen for appearance, performance, safety and convenience. However, there has been a great increase in the sale of environmental vehicles due to incentives.



Cogeneration plant in Eskilstuna with a “Powerbox” that converts waste heat into electricity



- Miniaturisation and requirements for increased performance provide the impetus for lower consumption of electricity by appliances and electronics, which means a reduction in the environmental burden, but the driving force in the development has been other types of performance or lower costs for development and production.
- Digital paper, communications technology, broadband internet and mobile internet provide advantages in the form of rapid access to information, and in the longer term they reduce the need of paper for newspapers, advertisements and in offices, but, on the other hand, greater welfare and increased use of computers in the growing and populous economies results in increased paper consumption.
- Remote sensing and control of equipment using computers and communications technology with the intention of reducing costs and improving operation, are at the same time lowering the need for energy and the need for staff journeys.
- Comfort, status and convenience play a great part in the design of buildings – in spite of more effective new technologies, there is a trend towards higher energy use in residential and non-residential premises as a result of increasing areas, large glazed surfaces, air conditioning and underfloor heating.

The above examples illustrate that new and advanced technology may result in both environmental advantages and greater environmental burden. Even though other performance requirements in most cases constitute the design criteria, environmental aspects are increasingly considered in all technical developments.

To define what is meant by environmental technology is not a matter of course. Technologies developed directly to reduce the impact on environment and health, such as treatment plants and renewable energy technology, are obviously environmental technology. But even technology that have been developed to meet the demand for e.g. transport or comfortable living conditions, and which at the same time result in lower use of resources or reduced emission of harmful substances can, when seen in a holistic perspective, have great importance in reducing the impact on the environment, even though other considerations had provided the impetus for the development.

The final user/consumer has an important role in greater use of environmental technology. There is a risk that the need and demand for products, services and systems will drive the development towards increased environmental impact. At the same time, increased awareness of the global environmental issues gives rise to demands for a long term sustainable society.

Betalstation

15 Kr



The choices and value judgments of people therefore have great significance. All actors in an innovation system need new competences in order to satisfy all needs – ranging from customer preferences, production factors, business logic to resource efficient system solutions.

The service sector has a great and increasing role in the Swedish economy and in all industrialised countries. Services can offer considerable business opportunities in environmentally driven markets, and they constitute an increasing proportion of Swedish systems and products, not least in the development towards a higher degree of innovation in the economy. One type of service that has for a long time been referred to in environmental discussions is the sale of integrated solutions, which means that, instead of a product, the supplier sells a function, for instance travel instead of a vehicle.

With increasingly open frontiers and interaction in the global production chains, it is not only a matter of developing products and services, but also the conditions for finding new resource efficient and environmentally friendly solutions for entire systems, in a way that suits different markets. The way this is usually referred to is that there is a need for “system innovations”, i.e. that entirely new ways of producing desired commodities or functions must be found.

Owing to the strong association among individuals and various institutions in society, there may be demands for changes in the soft systems in the form of “institutional innovations”. The introduction of new solutions in the market may demand changes in both social systems and in ways of thinking.

To sum up, it may be said that new technologies often result in considerable increases in effectiveness and in lower energy use, but they may also give rise to a new type of demand with new energy needs and new risks of environmental stress. Greater welfare results in increased consumption of journeys, goods and foods that are transported over long distances. This underlines the need for a holistic perspective and system thinking in research and the development of all new technology, and for environmental aspects to be considered at all times in such developments.

In view of the above reasoning, Formas and VINNOVA have decided to base their work in this strategy on a broad approach and a broad definition of environmental technology:

Environmental technology comprises products, systems, processes and services which provides clear environmental advantages in relation to existing or alternative solutions, seen in a life cycle perspective.

The definition covers not only technologies and technical systems as such, but also a holistic approach concerning

entire production chains including the recycling or treatment of residual products, i.e. the entire life cycle. Such a definition of environmental technology is wholly in line with the definition by the EU in *An Environmental Technologies Action Plan for the European Union* (ETAP COM (2004) 38 final):

“Environmental technologies – taken in this Action Plan to include all technologies whose use is less environmentally harmful than relevant alternatives [...] They encompass technologies and processes to manage pollution (e.g. air pollution control, waste management), less polluting and less resource intensive products and services and ways to manage resources more efficiently (e.g. water supply, energy saving technologies). Thus defined, they pervade all economic activities and sectors.”

The definition in ETAP is in turn based on the definition of “environmentally sound technologies” in Agenda 21. This states (quoted from ETAP):

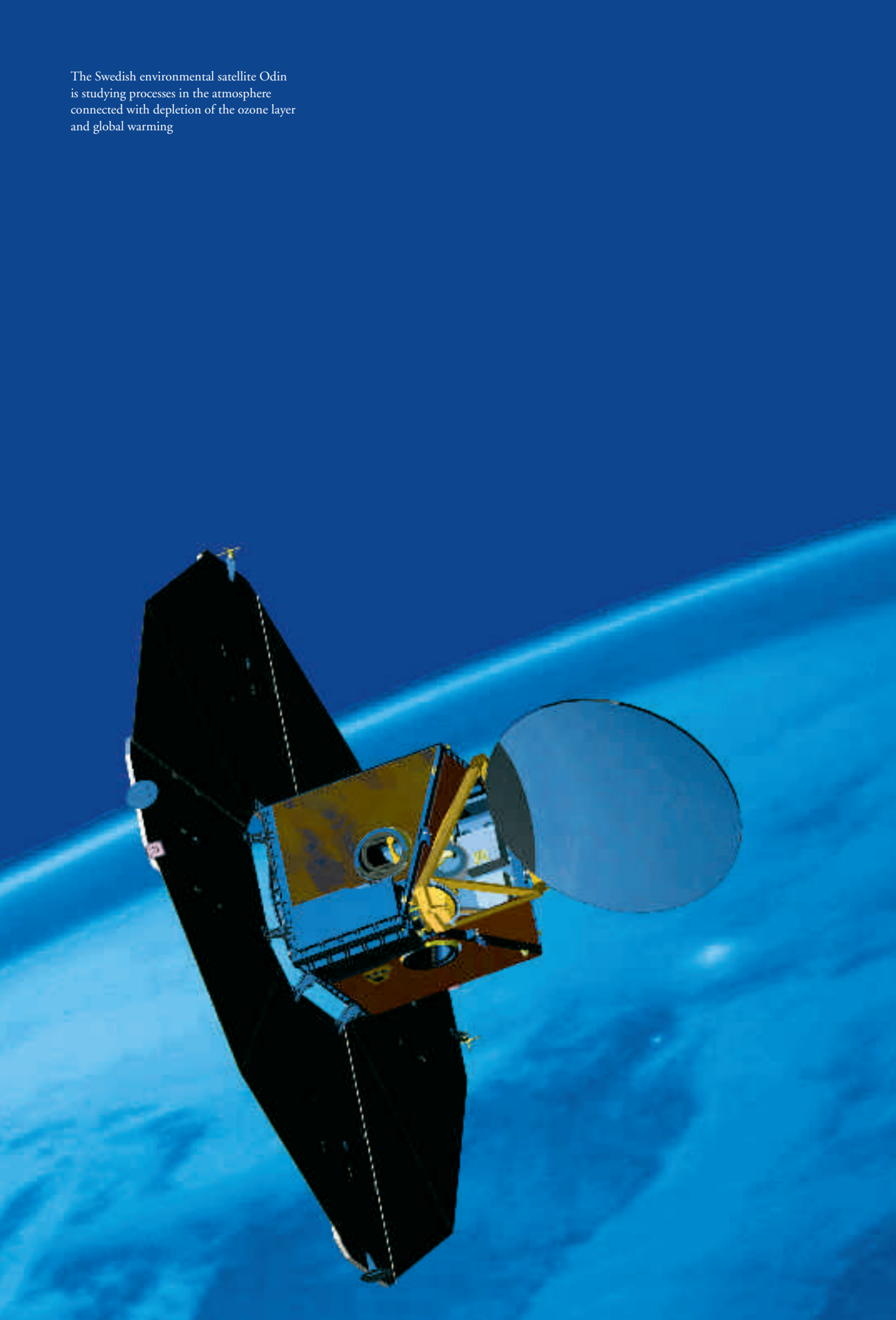
“... environmentally sound technologies protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the traditional technologies for which they were substitutes. Environmentally sound technologies may also be process and product technologies that generate low or no waste and thus prevent pollution. They also cover “end of the pipe” technologies for the treatment of pollution after it has been generated. Environmentally sound technologies are not just individual technologies, but can also be total systems which include know-how, procedures, goods and services, and equipment as well as organisational and managerial procedures.”

With the broad approach to environmental technology that is applied in this strategy, the focus is shifted from products and appliances to entire systems, resource effectiveness and sustainable development.

Urine container with roof – reduces loss of ammonia



The Swedish environmental satellite Odin
is studying processes in the atmosphere
connected with depletion of the ozone layer
and global warming



Technology for a global market

Sweden is a small player as regards markets and environmental requirements. Regulations, control instruments and market requirements are largely formulated by the EU and by a global market, and through international cooperation. However, Sweden is regarded to be an internationally important nation with regard to environmental policy.

The guiding principle in drawing up this draft strategy is that it is primarily environmental technology for a global market that should be in focus. The Swedish market is small, but Sweden can increase its market share internationally through forward-looking national initiatives, through legislation/regulations, incentives, control instruments, public procurement with respect to environmental performance, and through support for research and development. The domestic market provides an important opportunity for small and medium enterprises to become established and to consolidate their technologies before taking major international initiatives. An interaction among players in Sweden on a national arena may provide opportunities for testing, evaluating and introducing technologies before they are introduced in other markets.

Development of innovations for an international market demands knowledge of conditions in other markets regarding the attitudes and preferences of customers and users in different countries and cultures, national regulations and control instruments and the way they function. Knowledge of the interaction between individual and public driving forces, and between different players in the whole chain from natural resource to the final use, is also necessary.

Global perspectives

In the international market there is a strong increase in demand for environmental technology. This applies both to the broad meaning of environmental technology and to the more limited



Solar electricity



Refrigerator in the desert

applications such as treatment technologies, waste management and recycling. The large issues in a global perspective are climate, eutrophication and toxic compounds in effluents, emissions to air by traffic/heat and electricity production, lack of clean water, loss of biodiversity and loss of cultivable land (due to erosion, salinisation and desert encroachment) as well as environmental pollutants used in agriculture and in products.

There are several strong driving forces involved in the increasing growth of environmental technology:

- The issue of climate which is a global problem is attracting great attention at present, especially politically. In the Kyoto Protocol, many countries have undertaken to take various measures to reduce the emission of greenhouse gases.
- Another issue that has attracted great attention is secure supply of energy. In order to reduce the risks, and to reduce emissions of greenhouse gases, the energy policies of the EU, USA and Japan contain powerful initiatives for renewable and sustainable energy supply – from the sun, wind, waves and bioenergy – and also initiatives to increase the efficiency of energy use.
- In many regions, rapid economic expansion, population growth and urbanisation create acute problems regarding air pollution, discharges to water and eutrophication. There is therefore a very great need for investments in treatment plants, waste handling, etc.
- Agenda 21 also highlights other very serious global problems – inter alia, poverty as an obstacle to development and the lack of clean water in large parts of the world. There are a lot of indications that radical changes are needed to meet these challenges.
- Environmental pollutants such as heavy metals, chlorinated compounds, medication residues and so on are still posing great dangers even though successful action in industrialised countries has reduced the exposure to many compounds in e.g. consumer goods and food. There is also a need all over the world for very comprehensive action for soil remediation to clear the pollution left behind by environmentally hazardous industries.
- New technologies open the way to entirely new solutions in many areas. Miniaturisation can provide opportunities for reductions in energy use, and IT and communications technology provide tools for greater efficiency in many stages of production and in the use of technologies.

Challenges exist on many levels, not only in relation to environment and sustainability. For the Swedish economy and Swedish society, globalisation of markets and production systems also poses great challenges. Laws and regulations

in many important respects are formulated by the EU, and Swedish scope for action has therefore been curtailed. Production systems have become more global, with specialisation and mass production in countries with favourable conditions. Many traditional Swedish companies now belong to international groups.

The insight concerning environmental problems and the great challenges has provided the impetus for public action on an international, national and local level, such as in the Kyoto Protocol, through requirements for reduction of exhausts from vehicles, through European initiatives in various directives and regulations, and through national requirements. There are also many other control instruments such as those which exert an influence through codes and standards, through changing relative prices or through facilitating market introduction of products.

The concern that people have for the state of nature, the climate and the environment is also a strong driving force that induces individuals to make their choices with reference to the environment and sustainability. This is manifested in their roles as purchasers and users of products and systems, in companies and authorities. Both public measures and the choices made by individuals/companies/authorities create the demand for environmental performance.

EU

General

The EU has a common environmental policy in the present sixth environmental action programme which contains framework directives and which highlights areas, guidelines and overarching projects. Areas which are accorded priority are climate change, nature and biodiversity, environment and health, as well as the use of resources and waste management. However, there are as yet no common rules regarding environmental taxes and charges.

The environmental action programme lists seven thematic strategies which will play an important part in the implementation of the programme. Two of these are “sustainable production patterns” and “sustainable use and management of natural resources and recycling”. These two, in particular, will be important for the development of Swedish technology. With regard to sustainable production patterns, the intention is to improve cooperation with companies and encourage the innovation of products. The Integrated Product Policy (IPP) is part of this area. IPP is based on a life cycle perspective, and will encompass many areas such as production methods, transport, commercial rules and environmental control.

Sustainable use and management of natural resources and waste comprises the promotion of recycling and production





Biogas train Amanda on the Linköping-Västerås line

methods and technologies in order to support eco-effectiveness, through e.g. research and technology transfer. In order to prevent waste, an investment will be made in environmentally friendly and sustainable product design.

Environmental technologies are also referred to in the directive on chemicals and electrical and electronic products, which deals with issues concerning the use of various chemicals and substances and the responsibility of producers regarding environment, health and the disposal of waste.

In order to reduce emissions of greenhouse gases in energy production and transport, EU is endeavouring to encourage the use of renewable fuels and fossil fuels with a lower carbon content. One mechanism to speed up this development is the common system which puts a ceiling on the emission of carbon dioxide and involves a system for trade with emission rights. Goals have also been set up for greater use of renewable electricity production and the use of biofuels. Energy effectiveness in buildings is also an area that is highlighted.

Environmental Technologies Action Plan (ETAP)

The aim of ETAP, the common action plan for environmental technologies, is to make use of the possibilities of technology to reduce the pressure on natural resources, to improve the living environment and to stimulate growth. The goal is to remove obstacles, to make EU take a leading role in the development of environmental technologies, and to unite all actors. One basis for this plan is the sixth environmental action programme and a broad definition of the term environmental technologies; see Chapter 2.

ETAP comprises 28 actions to be taken by the Commission, member countries and a number of other actors and common organisations on EU level. These are grouped in three principal areas:

- to progress from research to market
- to improve market conditions
- to act globally

Most of the actions concern the promotion of environmental technologies, while research and development are primarily dealt with in the first three: greater and focused research, demonstration and dissemination of technology and coordination of initiatives; establishment of technology platforms in the seventh framework programme, and the development of common standards and codes.

Research in the seventh framework programme

Environmental technology and environmental issues are touched upon in many of the programmes contained in the seventh framework programme for research, technical development and demonstration over the period 2007 – 2011. Environmental technology are dealt with in the clearest terms in one



Biogas plant/Linköping

of the programmes, *Environment (including Climate Change)*, but primarily in the form of the direct environmental technology such as treatment technology. However, issues concerning the environment and sustainability have a major role in the motives for several programmes. This applies in particular to the energy programme, but also programmes dealing with transport technology, new production technology, biosciences and the use of raw materials from forestry and agriculture, and so on. The initiatives in information technology and communications technology, and in nano-technology, also provide new tools and enabling technologies which can be instrumental in increasing efficiency in all stages of the production and use of new technologies.

Opportunities for Sweden – but a need for co-funding and national cooperation

One obvious consequence of the expansion of the EU is that the single market has greatly increased in all areas. This is especially true for the direct environmental technology and energy supply since there is a great need for the expansion of infrastructure in the countries around the Baltic Sea and in Eastern Europe. Seen from an R&D perspective, expansion provides new opportunities for cooperation, both for research and Swedish companies.

At the same time, this focuses attention on the need to co-fund EU support with Swedish research money. This requires coordination of Swedish inputs, so that it may be possible for Swedish researchers to participate in research cooperation and in development projects. This applies, for example, in treatment technology and bioenergy where, in many cases, Swedish companies are too small to take part in international R&D projects or in international civil engineering projects. Several of these areas may be encompassed by the EU strategy recently presented by VINNOVA.

USA

According to an overview performed by ITPS, there is strong growth today within Clean Tech, inter alia in energy technology, materials technology, process engineering, and in established mature industry in the direct environmental technology. Clean Tech encompasses both direct treatment technologies and new technologies of high environmental performance in e.g. energy technology. The US is also in a leading position in many fundamental scientific areas of key importance for the development of environmental technology.

Security of supply is still given great importance in initiatives in energy technology, even though the climate, especially on State level, has received increased attention. In line with this, there is strong investment in the field of transport, reduced dependence on fossil fuels and increased efficiency.



Some conclusions from the report:

- there is a development towards services in resource management rather than technical services, in e.g. waste and the direct environmental technology
- market based mechanisms are assuming a greater role
- one strong driving force is that new technologies provide new opportunities for technology with lower resource use, renewable electricity production or reduced emissions
- there is increased awareness on the part of companies and individuals which provides the impetus towards the development of environmental technology in a broad sense

A general description of conditions regarding environmental technology in the US was given in an appendix to VP 2003:4, compiled by ITPS in Los Angeles. The driving forces in the field of the environment, from Federal level in the US, can be largely associated with endeavours towards lower oil dependence and greater economic growth. At the same time, it is stated that environmental policy on Federal level does not have as high a priority as in Sweden, and that investments are primarily motivated by the wish to secure energy supplies.

On both Federal and State level there are however many examples of programmes which, in various ways, support investments in environmentally friendly technologies, especially solutions which promote energy efficiency or the application of renewable energy sources, wind power, solar energy, biofuels.

In the judgment of the report, Swedish companies have great opportunities to export environmental technology and experiences to the US in areas such as:

- energy efficient products, e.g. white goods
- renewable fuels for transport and energy production
- environmental design (general Swedish design, IKEA and HM, for example, have great success)
- environmentally friendly materials (e.g. wood – in this respect also IKEA is a good example)
- resource efficiency, recycling and closed cycles in the heavy process industry
- recycling, combined services in waste management and soil remediation
- safety, working environment and health



Japan

On behalf of Formas and VINNOVA, ITPS has described the strategies for research in environmental technology in Japan.

The report gives a thorough description of state financed environment related research that is conducted for different ministries. Environmental research has greatly increased over the past few years. *Environmental science* is one of the four prioritised areas in the new five year plan for research in science and technology. The area includes, inter alia, 3R (Reduce, Reuse and Recycle), the use of biomass, climate research and the risks and safety associated with chemicals.

The report also describes the initiatives taken to promote application of technology, for example in industrial cluster initiatives, *Eco-Towns*, and an initiative for quality assurance of the information on environmental technology as support for implementation and commercialisation.

The conclusions drawn in the report are:

- the environmental market is undergoing rapid expansion
- new environmental technologies such as hybrid vehicles and solar cells are very successful internationally
- great importance is given to pioneering technologies such as nanotechnology
- there is focus on 3R and technologies for reduced climatic impact
- there is greater awareness of international dependence and that environmental problems must be solved regionally and globally
- cooperation between society and business, e.g. in Eco-Towns, is given great importance in the work on introduction and commercialisation
- Sweden could learn from Japan as regards approaches to countries in Asia, both with respect to markets and in looking for research cooperation

For Japan also, an appendix to VP 2003:4 gives a description of conditions regarding environmental technology. A high population density and great dependence on imported energy create a need for a change to more sustainable solutions such as more efficient and cleaner technology in products especially in vehicles, electricity production and industrial processes, reduced quantities of waste and recycling of waste and new technologies for energy supply. A strong export industry sees business opportunities in environmentally driven markets. The driving forces in Japan for environmental investments are in general similar to those in Sweden.

The measures taken are similar to those implemented or discussed in Europe. Some of the differences pointed out in the report are perhaps greater optimism in technology, extensive company-driven research, clearer programmes for, and monitoring of, resource efficiency in large companies.

Sweden is probably ahead of Japan with respect to recycling, but strong development is taking place in Japan. Sweden is also ahead as regards insight into consumer preferences, user behaviour and structural obstacles to sustainable development. As regards the coordination between environmental policies and R&D initiatives, however, the association appears to be stronger in Japan.

Some conclusions drawn in the report are:

- Investments in environment-related technologies are considered in Japan to be an important factor for growth. Unique solutions for a future green market are regarded as an important competitive factor.
- Environmental quality is a strong driving force in the increasing research support for institutes and universities. There is greater coordination and strategic planning for national research initiatives, with great importance accorded to climatic and environmental aspects.
- The State is actively engaged in procurement of green products and green technologies according to the new legislation concerning environmentally sound public procurement. Examples are the introduction of environmental cars and solar cells.
- Companies are also investing increasingly in green procurement and in the introduction of environmental requirements in the supply chains. Resource and material efficiency in a life cycle perspective are given great importance by many companies.
- However, consumer demand for green products is weak. Customers are not prepared to pay more; environmental performance is not a competitive factor.
- Swedish environmental policy and environmental technology are strong “trade marks” in Japan.

Large growing economies – China, India, Brazil

An interim report from IVL, *Research, Development and Demonstration Strategies on Environmental Technology*, describes current issues concerning growth and environment. The report is based on three examples of large growing economies, China, India and Brazil, and describes the situation in these countries.



Crops grown near an urban area /Japan



Toilet system with urin separation installed in Dongshen/China

It is common to these countries, and many other populous countries, that there is great movement from the countryside into towns. Giving consideration to the environment and providing reasonable living conditions for both the urban and rural population will require very great expansion of infrastructure: sewage treatment, supply of clean water, electricity, housing, and roads and communication systems.

Another common factor that places great stress on the environment is the rapidly growing middle class with increasing welfare. The increasing consumption of goods, new consumption patterns and the increased car ownership will put the environment and natural resources under very great stress. This can already be noted in increased Chinese activity to secure oil supplies and an increased demand for metals which has been evident, for example, through increased steel prices in world markets. For the three countries, some of the findings of the report are as follows:

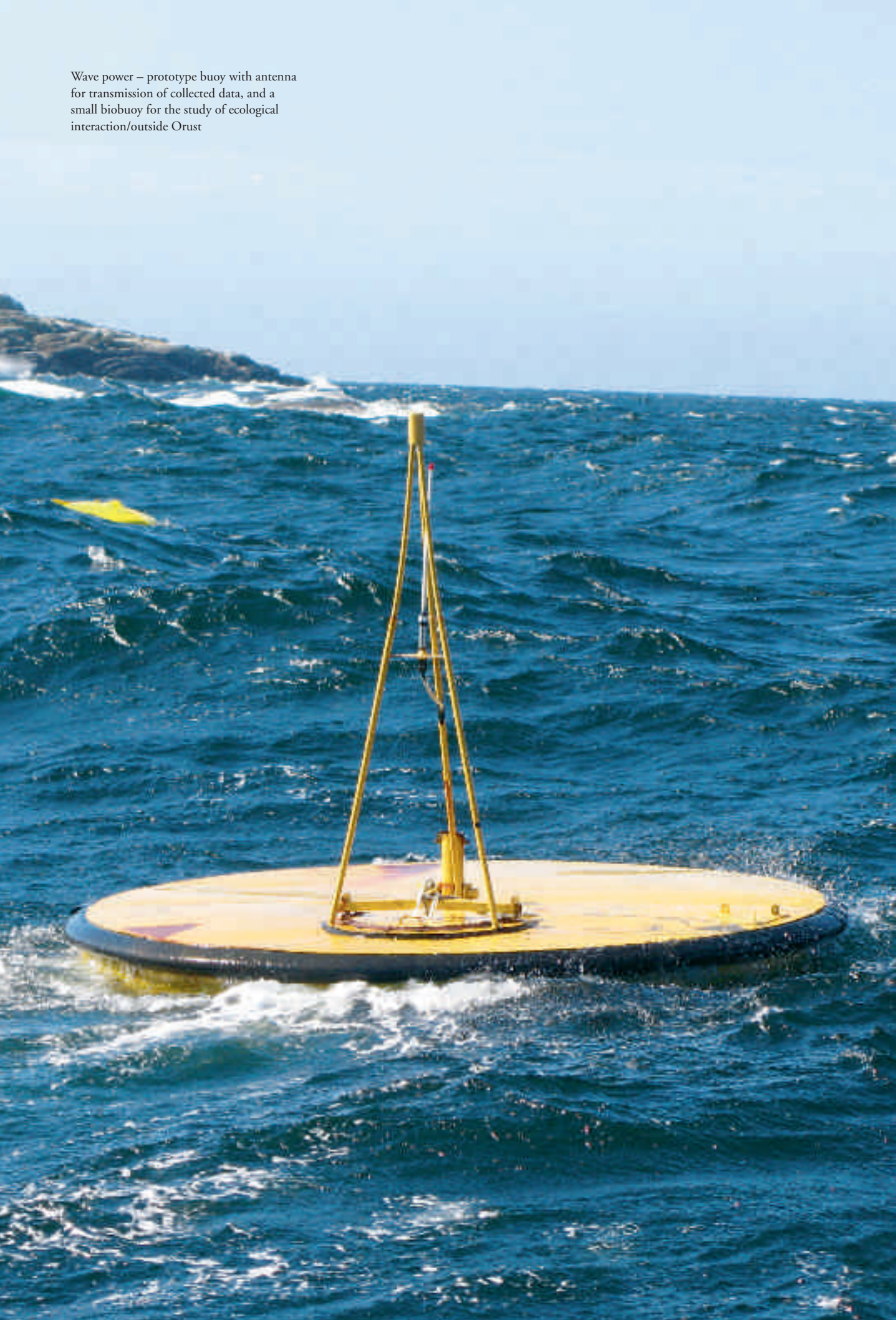
China	Strong investment in research and industrial growth
	Large ongoing expansion of the infrastructure
	Rapidly growing middle class
	Many companies are ineffective, shortcomings with respect to the environment
	Simultaneous increase in environmental awareness, stricter legislation
	Barriers for foreign companies through standards and laws
India	Scarcity of resources, great pressure on markets for oil, metals (but good supplies of coal as an alternative for electricity and fuel production)
	Strong pressure on the land, salinisation of irrigated land, plant poisons, eutrophication of waters
	Lack of clean drinking water, sewage treatment underdeveloped
	Rapidly increasing middle class and consumption

Brazil

Problems similar to those in India, with high pressure on land, underdeveloped sewage treatment, and lack of clean water

Great differences, with both modern industry and riches, and very many poor people

Wave power – prototype buoy with antenna for transmission of collected data, and a small biobuoy for the study of ecological interaction/outside Orust



Swedish conditions

In many respects, Sweden has favourable conditions for development and growth in environmental technology. There is strong awareness and great interest among individuals, in politics, and in legislation and among the authorities. Sweden has been one of the countries that has been in the forefront as regards various measures to deal with discharges and emissions and with noxious substances in products and industrial processes. Sweden has provided the impetus in the international work.

Other strong points are that Sweden has:

- an established industry that directly focuses on environmental technology in the treatment of air/exhaust gases, water/sewage, and renewable production of electricity and heat
- high standard of knowledge and competence, in research, education, the authorities and companies

As regards environmental technology in the broad sense of the term, Sweden is in a strong position in several areas, with an established industry, research and education. One example is sustainable transport. We have a strong automotive industry and are in a leading position with respect to the development and introduction of renewable fuels. Other examples are material technology in a broad sense, where we have both the forestry industry and the steel industry with a high degree of refinement and a strong position in the world market, energy technology where we have a long industrial tradition and also successful research in new energy technology, and construction where Sweden has great knowledge, not least regarding construction in a cold climate, and in district heating technology.

But there are also shortcomings and weaknesses in the Swedish innovation system, from both the environmental and economic perspectives. Globally, the Swedish domestic market is small, and many of the companies in treatment technology, waste handling technology and renewable energy are small in the world market. Many areas in Sweden are dominated by a few large companies which have their own research resources and

sufficient resources for cooperation with academic research. Another weakness is that the industry that develops process technology for heavy industry has largely been sold, moved to other countries or been closed down.

Opportunities for Sweden

What are then the opportunities for the Swedish business sector in the international market as regards environmental technology?

A natural starting point in a discussion are the increasing needs and the markets which follow a strong growth in populous countries, and the consequent threats to the environment and climate. It concerns the need for infrastructure and equipment for environmental technology for the treatment of sewage, water and exhaust gases, and also technology that is resource and energy efficient in general, including the supply of renewable energy.

What are the areas in which investments should be made in Sweden has been discussed in several contexts. Examples of areas which are mentioned apart from the direct treatment and environmental protection technologies are renewable electricity production and production of heat from biofuels and refuse, as well as renewable fuels and the vehicle technology for these.

In *Technical Foresight*, both the original project in 1999 and the second stage in 2004, there is a discussion of the areas of special Swedish expertise. In the synthesis report of 2004 and in the interim report *Inspiration to innovation*, reference is made to environmental and life cycle technology and a number of areas in energy and material technology as areas where Sweden has good prospects. Environmental and life cycle technology encompass an LCA approach, design for the users and production, production, technology for environmental remediation, as well as air pollution control/water purification.

These issues are dealt with in the ongoing IVA project *The new arena of environmental work* which is financed by Mistra and the Swedish Environment Protection Agency. The aim of the project is “to highlight resource and environment issues and place them into a broad and forward looking perspective that comprises both global and Swedish environmental challenges. This is done by describing the present and future global resource fluxes and analysing the way these affect Sweden, with regard to both the environment and the economy. Charting of Sweden’s comparative advantages within innovation systems and R&D shall be instrumental in providing an answer to where and how environmental entrepreneurship can be developed.”



Composite material

Among Swedish areas of special expertise, VINNOVA VP 2003:4 lists green materials and bioenergy, sustainable transport, lightweight and advanced materials and sustainable built environment based on a discussion of Swedish competitive advantages.

With reference to this and other studies, and the background material accumulated in the strategy work that has now been completed, in interim reports and in meetings, a description is given in the following of the areas which may be judged to provide good opportunities for Swedish development and continued growth.

Sustainable built environment

There is a large domestic and global market for sustainable built environment, with energy effective, resource efficient and sound housing environments and workplaces. Sweden is in the forefront and has good knowledge of systems and components for energy effective buildings. We have also, by virtue of our climate, users who are aware of environment and energy, tradition and regulations, a well informed domestic market and good conditions for the introduction of new technologies of good environmental performance. Examples of areas of international interest, with sound Swedish expertise, are system oriented areas such as sustainable buildings, sustainable renovation and sustainable cities, as well as more specific areas of technology such as construction systems for timber, control and monitoring systems, technology for energy effectiveness, and technologies for local energy supply, for example biofuel boilers, pellet technology, solar heating technology, fuel cells, and small cogeneration plants.

Sustainable transport

With regard to sustainable transport - vehicles, traffic systems, logistics – in Sweden there is a long tradition of developing and making cars, lorries, aircraft and trains, and also of a large number of subcontractors. Examples of areas where sustainability may be a competitive weapon are the development of new engines and new technologies for propulsion, new fuels, technologies and systems for public transport and navigation, and new methods and systems for effective transport that is coordinated among different modes.

Environmental protection technology: treatment technology, waste management

As has already been pointed out, there is a very strong and rapidly growing market for environmental protection technology in e.g. Eastern Europe and the rapidly growing economies in Asia and South America. Sweden has a well developed infrastructure and a high standard in areas such as the treatment of water and sewage, flue gas treatment, soil remediation, waste management, recycling and environmental improvement methods in agriculture. Sweden has an established industry,



Separator for water-free purification of biodiesel in arid climate

even though it has, in an international perspective, a relatively large number of small companies. One special strength that is highlighted in the IVA project *The new arena of environmental work* is the knowledge and experiences present in the public sector, for instance in the municipal enterprises that operate installations and systems. Through cooperation among society, research and companies, there are good opportunities for promoting development and, especially, for demonstrating good examples.

The use of biological natural resources

In the areas green materials and bioenergy, there is increased international interest in using cultivated plants and trees more effectively and better than today, inter alia in biorefineries. Sweden has good prospects to develop knowledge and new resource efficient technologies, through strong research and good knowledge in biology, physics, chemistry and materials technology, and a strong industrial base. Examples of applications that have a growth potential are:

- new processes to utilise several components and/or energy in an effective way (biorefineries/bioindustry clusters, associated with the forestry industry, fuel production or district heating)
- new materials such as fibres and composites with plant fibres and biopolymers/polymers from renewable raw material
- development of new functional materials and packaging, with new properties or as replacement for petroleum-derived raw materials



House built from recycled empty bottles and crushed windscreens/Njurunda outside Sundsvall

Lightweight and advanced materials

Lightweight and advanced materials can offer great environmental gains in several respects:

- Light weight and high strength are important competitive factors for materials, and benefit the environment through reduced transport needs, lower consumption of raw materials and less fuel consumption in vehicles.
- Materials that produce little waste and can be recycled, or are easily degraded, can provide environmental gains at many stages in their life cycles.
- Nanotechnology and chemistry/physics/biology promise great opportunities for new resource efficient technology in e.g. electronics, medical technology, solar cells and sensors.

Sweden has a strong industrial tradition and research with a high degree of expertise in the metal and forest industries. There are also advanced material users and technological development in the automotive, aviation, energy, white goods and packaging industries. Examples of areas of application for new materials of high environmental relevance are

materials for vehicles, packaging and recreational equipment. Other examples are described in the previous section on the utilisation of biological natural resources and transport.

Energy

On a system level, energy is an important part of several of the above areas of special expertise. Energy efficiency and energy technology, as such, for the production of electricity and heat and for transport are also areas of special Swedish expertise. They encompass both new technology for energy supply (such as solar electricity, wind power, district heating, biofuel technology, biorefineries for fuel production) and technology for more effective use of energy such as effective industrial processes, effective lighting technology, etc. The Swedish Energy Agency is responsible for energy research, but in view of the fact that energy technology is an integral part of several of the areas designated as environmental technology, broad collaboration in the area of energy should be aimed for.

Threats and difficulties

But there are also a number of obvious threats and difficulties apart from those already referred to above. Owing to the increasingly global supply chains and the international markets, it is more difficult for individual companies that are only a link in the chain to exert an influence or to launch new technologies. Knowledge of markets and resources is required to become established, especially in the case of remote markets. One further threat that has often been discussed is that research follows when production is relocated abroad or moves closer to large markets as the companies become more global. In this respect there is competition among countries, with various forms of support for companies that establish new activities.

Passive building/Lindås park, Gothenburg



High altitude balloons for climate studies/
Esrange Space Center outside Kiruna



Cooperation for environmental technology

Environmental aspects are accorded great importance in the research supported by Formas and VINNOVA in various areas of technology and fields of application. The same applies for many other research funding agencies in Sweden, such as Swedish Foundation for Strategic Environmental Research (Mistra), the Energy Agency, the Environment Protection Agency and the Science Council.

Many of the industrial research institutes carry on research and other activities with an environmental orientation, several of them in cooperation with, and with support for, small and medium companies. Examples that can be mentioned are the Swedish Environmental Research Institute (IVL) which carries on extensive environmental research, with funding from e.g. the Environment Protection Agency, the Technical Research Institute of Sweden (SP) that has extensive projects regarding energy applications, the Industrial Research and Development Corporation (IVF) with an established network concerning environmental aspects in product development, the Forestry Research Institute of Sweden which is engaged on operating technology, raw material utilisation and logistics in the forest industries, and the Swedish Institute of Agricultural and Environmental Engineering (JTI) which has an established activity, extending over many years, in biogas technology.

It is of great importance for the breakthrough of environmental technology that the research and development results should reach the various players and users, and that the knowledge should enter education at all levels. It is not only a matter of technology but also of knowledge about markets and the choices that people make. Regulations, standards and codes, control instruments etc also obviously have great importance for the rate and extent at which environmental technology can achieve penetration and provide

improvements. In this case also there is interaction, with new technology making it possible for increased requirements to be gradually introduced in legislation or codes.

It is therefore difficult to make a clear distinction between research and development for environmental technology and other measures to promote these. There is interaction among many players, and initiatives are required along the entire value chain in order to achieve application of technologies and to promote growth. Various authorities and organisations have an important role in this respect. For instance, the Swedish Board for Industrial and Technical Development (Nutek) is engaged on initiatives in environmentally oriented product, business and economic development. As the central environmental authority, the Environment Protection Agency has an important role in regard to e.g. environmental legislation. The International Development Cooperation Agency (SIDA) is experienced in supporting environmental technology in developing countries, and in SIDA's research department SAREC there is experience in supporting environmental technology research in Asia. The task of the Small Business Partner Corporation ALMI is to promote the development of competitive small and medium companies. The task of the recently formed Swedish Environmental Technology Council (Swentec) is to strengthen the business opportunities and competitiveness of Swedish companies in environmental technology, inter alia through assisting coordination of State initiatives in this area. In this context it is therefore important to discuss the opportunities for cooperation and interaction among research funding agencies, authorities and other actors, and to find solutions for co-funding by research funding agencies and the business community.

Cooperation and co-funding with the business sector

The conditions for joint funding of research by the State and the business sector, and the way the cooperation of small and medium companies can be facilitated, has been part of the task and has also been discussed during the work in several contexts. The issue has been discussed at the two workshops that were arranged, during interviews with companies, and in the working groups that were set up at the first workshop.

Around twenty environmental technology companies were interviewed by telephone during work on the strategy by inno Scandinavia AB with regard to the companies' views concerning challenges, needs and important areas where initiatives should be taken. Background material has also been collected from other research funding agencies and authorities in connection with meetings with these. The IVA project *The new arena of environmental work* has provided further data.

One common view is that many companies and employers' organisations accord great importance to environmental aspects, as a consequence of pressure from both markets and society. Many companies have introduced environmental management systems, environmental reports are added to the economic reports, and environmental requirements and environmental statements have become an established part of the trade among companies. Many companies have taken part in various networks, initiatives and activities which have been carried out or coordinated by Nutek and the Export Council. There are also several regional initiatives where companies cooperate or take part in networks with an environmental and energy orientation, for example in Skåne, Göteborg, Stockholm and the county of Västernorrland.

Other examples of cooperation in which companies participate are the Environmental Management Council and the Bygga-Bo dialogue (cooperation among the State, municipalities and the construction industry in the form of voluntary agreements). Global cooperation among large companies with a view to promoting sustainable development is carried on in the organisation World Business Council for Sustainable Development (WBCSD). Large Swedish companies are among the 165 members.

In the joint proposal by Formas and VINNOVA for a research strategy for environmental technology it is primarily research cooperation among researchers and companies that is in focus. Established cooperation with an element of environmental technology, in various forms, is part of VINNOVA's work. *Forska & Våx* (Research and Grow) is a programme which supports R&D in cooperation among small and medium companies (SME) and research. Many of the projects concern environmental technology in a broad sense. Co-operative projects are also carried on in various competence centres in which companies take part with their own funds. In the latter case it is mainly large companies that participate, but there are many examples of participation by SME.

Formas finances research at universities, university colleges and research institutes, and has not the same extensive cooperation with companies as VINNOVA. However, in the area sustainable built environment Formas has established cooperation with the Construction Sector Innovation Centre (BIC) with the intention "to work in cooperation to ensure that Swedish construction research has a strong position nationally and internationally in the work for sustainable development and economic growth through sustainable construction".

The conclusions from the various contacts and from the documentation are that cooperation with large companies is established in research funding, in environmental technology and also in other applied and need motivated research.



Solar panels at Ullevi Stadium

There is also great interest from SME, but they also make it clear at the same time that they have serious difficulties in affording the co-funding of research projects or research oriented development projects that is normally required in the projects financed by Formas and VINNOVA. Many companies and also regional networks highlight instead the need of support and risk capital for initiatives that have a greater market orientation, such as technology development and market introduction, initiatives that are regarded by banks and risk capital as having too high an element of risk.



A research strategy for environmental technology

The intention of Formas and VINNOVA in presenting this research strategy is to make a concerted effort in research and development concerning environmental technology and to give prominence to this within the various areas of research. The proposals must also be seen as a complement to other research support with an environmental technology relevance, for example support for research that ranges over several areas and research that is system oriented.

The research strategy also examines the issue of how the results of research and development are to be transferred into practical application through action in different parts of the innovation chain, for instance in the form of demonstration projects, implementation measures and market introduction.

The intention of the proposed research strategy is to promote the development of new knowledge and to strengthen the competence in the field of environmental technology, to enhance Swedish competitiveness in the global market, and to create sustainable growth. A common vision is formulated.

Vision

Sweden is internationally competitive in developing products, systems, processes and services which satisfy stringent demands concerning resource effectiveness and environmental performance for sustainable development and growth.

This shall be achieved by:

- developing the necessary competence with respect to environmental aspects, technology and markets and the choices and preferences of users, and utilising this in the supply chain and on the part of all players, in both the public and private sectors
- making a holistic approach and system aspects the guiding principle for the initiatives



- cooperation by the actors to coordinate effective initiatives along entire value chains
- developing a high degree of competence in important enabling technologies which may be instrumental in raising efficiency in all stages of the production and use of new technologies, for example information and communication technologies (ICT), biotechnology and nanotechnology
- creating domestic markets by testing and demonstrating environmentally driven technology – in products, services and systems
- creating an active and extensive cooperation over national frontiers for sustainable development

Terms of reference for the draft research strategy

With the chosen approach, environmental technology encompasses many areas of knowledge and technology, and involves many players. Comprehensive national and international initiatives are in progress regarding fundamental science, technical research of a more applied nature, and development and demonstration of technology where environmental motives and sustainable development have a key role.

One important task for the strategy is to promote research and development of technology which satisfy both the high performance requirements of the users and stringent requirements concerning environmental performance. Greater knowledge of the interplay between technology and the behaviour and preferences of the users is therefore important.

Formas and VINNOVA have the mandate to promote sustainable development and sustainable growth, and in their ongoing activities they have several initiatives and programmes which finance research of high relevance to environmental technology. Furthermore, the energy research, vehicle research and research into the direct environmental technology (treatment technology, recycling etc) which are funded by other actors are to a high degree motivated by sustainability and environmental arguments, and, to a large extent, they come under the definition of environmental technology that has been chosen.

It is not the intention of the research strategy formulated here to review or discuss priorities in the programmes carried on by other research funding agencies, but it does examine the possibility of cooperation with other players.

The strategy has been based on the various aspects discussed in the foregoing:



Natural light through optical fibres

- The broad interpretation of environmental technology – in line with that used in ETAP – highlights the need of an increased focus on users and efficiency in the use of resources, such as effective technologies in e.g. construction, journeys/transport, the food chain and commodity supply, as a complement to technology-oriented initiatives.
- It is essential to stimulate interdisciplinary research with respect to both system innovations and innovations that cut across system boundaries and have great environmental relevance.
- Development of new technology must take account of the entire life cycle, from the extraction of the raw materials to the disposal of waste and residual products, ensuring that developers make use of ecodesign, and tools for assessing and evaluating the environmental impacts due to production, use and final disposal when the technology has come to the end of its useful life.
- There is a need for strengthened interdisciplinary and multidisciplinary research concerning the aggregate environmental impact of global supply chains.
- There is a need for social science research concerning e.g. needs, control instruments and regulations. There is also a need for knowledge of the conditions regarding the attitudes and preferences of customers and users in different countries and cultures. Knowledge is also needed concerning the interaction among individual and societal driving forces and among different actors, along the entire chain from natural resource to final use.
- Initiatives should primarily focus on Swedish areas of special expertise, areas with Swedish competitive advantages, and areas which may be considered to be in need of developing national competence.
- The research and development initiatives decided on should, to a large extent, be carried out in collaboration with, and co-funded by, the business sector.

One further general premise is that there is a great need to strengthen the prospects of SME to develop new technology, and that it is important, in cooperation with other funding agencies and SME, to find the forms that make it easier for SME to participate in R&D projects and to benefit from research, for example through initiatives that have greater market relevance.

The proposals

I. Increased focus on environmental technology in research

Research on environmental technology should be given prominence and be further clarified within the spheres of activity



Fuel cell

of Formas and VINNOVA. Furthermore, special attention should be given to the need and the conditions for research by, and in cooperation with, small and medium enterprises (SME).

New initiatives concerning environmental technology must be characterised by a holistic approach, with the focus on system innovations and system solutions of high environmental relevance. They must also be characterised by receptiveness to issues that have difficulties in attracting finance in the research programmes of today. High priority must be given to a life cycle approach.

Proposal No 1

Promote research on environmental technology across academic, technological and industrial boundaries through providing finance for:

- interdisciplinary and transdisciplinary research of high scientific quality and high environmental relevance, which also includes
- social scientific research that provides knowledge on needs, markets, user preferences, regulations, control instruments etc in a European and global perspective.

Proposal No 2

Increase the opportunities for SME to cooperate in and co-finance innovative projects of high environmental relevance, by:

- creating the opportunities, in financing environmental research, for including demonstration of the technique, particularly when SME are cooperating in the project
- supporting research on further development of methods and tools for sustainable development of products, with special reference to the needs of SME
- putting research resources at the disposal of SME, through cooperation with industrial research institutes, further investment in programmes such as Forska & Väx, and collaborative programmes such as Formas-BIC.

II. Investment in areas of special Swedish expertise

In the Swedish innovation system, six areas of special expertise have been identified.

- *Sustainable built environment:* more overarching areas such as sustainable buildings, sustainable renovation and sustainable cities, and more specific areas of technology such as building systems for timber, control and monitoring systems, and technology for local energy supply.
- *Sustainable transport:* vehicles, traffic systems, logistics – new engines and new technology for propulsion,

new fuels, technology and systems for public transport and shipping, and new methods and systems for effective transport that is coordinated among different modes.

- *Environmental protection technology:* treatment of water and sewage, cleaning of flue gases, soil remediation, waste management and recycling – through cooperation among society, research and companies there are good opportunities for promoting development and export, and not least for demonstrating good examples.
- *Use of biological natural resources:* new processes for utilising several components and/or energy in an effective way, new materials from renewable raw materials, new functional composites, surfacing and barrier materials, packaging and lubricants.
- *Lightweight and advanced materials:* many areas of application, for example in applications where weight is of importance for energy or fuel use, materials that give little waste or can be recycled, and advanced materials for e.g. electronics, medical technology, solar cells and sensors. In this respect also, new processes for more effective production are of importance.
- *Energy:* new technology for energy supply – solar electricity, wind power, district heating, biofuel technology, biorefineries for fuel production – and technology for more effective use of energy, such as effective industrial processes, effective construction techniques and lighting technology, and so on. Research in this area is the responsibility of the Swedish Energy Agency, but cooperation should be aimed for.

Proposal No 3

Draw up concrete research and development initiatives for each and every one of these areas of special expertise with respect, inter alia, to prioritised areas, system aspects and interdisciplinary science.

The initiatives must be based on a broadly established vision and development strategy for each area, which should result in prioritisation and focusing of the overall national initiative. Renewal and innovation potential, research potential and business potential, as well as environmental values, are essential parameters in this context. Take also into account the recently produced industrial programmes which concern several areas of expertise.

- Identify the possibilities of finance from the EU framework programmes within the ambit of each development strategy. Investigate the issue of co-finance for each area. The EU strategy recently presented by VINNOVA may be a tool for strengthening Sweden's position.

- Identify products and services in the area which are suitable for procurement of innovation. This implies public purchasing of goods or services that do not yet exist or need to be improved, and thus necessitate research and innovation for the specifications to be satisfied.
- Identify issues concerning regulations, standards, environmental codes, building codes, taxation rules etc which are of importance for development in the area concerned and submit them to the responsible body.

III. Cooperation for research on environmental technology

Several activities and projects with respect to environmental technology and associated areas are at present being conducted by various actors who have been mandated to work for sustainable development. Increased cooperation among these authorities, research funding agencies, business and other actors is therefore of great value.

Proposal No 4

Together with the affected authorities, research funding agencies and other actors should:

- develop research and development initiatives with respect to the areas of special expertise according to Proposal No 3
- develop cooperation among the actors concerned, for example by generating joint interdisciplinary research activities
- draw up vision and development strategy for the entire value chain for environmental technologies according to Proposal No 3
- promote international research cooperation in the Nordic area, with countries in the Baltic area and in the EU, and also globally with countries that have large or potentially large markets
- make sure that the boundaries among authorities are if necessary modified so that all the important sections of the area covered by environmental technology are included.



Background reports

Åsa Andersson, Izumi Tanaka. 2006. Research strategies on environmental technology in Japan – A close-up study commissioned by Formas and VINNOVA. ITPS. ISSN 0652-0483.

Pontus Cerin, Ulrik Axelsson. Östen Ekengren. 2006. Strategies on Environmental Technology – Suggested foundations for a Formas-VINNOVA policy – Definitions of environmental technology, Development trends in the world's vast latecoming economies and Comparative study on environmental policy-making processes for environmentally adapted solutions and technology transformation. IVL. Swedish Environmental Research Institute. Research, Development and Demonstration.

inno Scandinavia AB. 2006. How to strengthen the competitiveness of Swedish environmental technology companies through R&D cooperations? The views of the companies regarding challenges, needs and important areas where initiatives are necessary – A summary of interviews with Swedish environmental technology companies. (In Swedish).

Appendix

Swedish actors in relation to environmental technology

Formas and VINNOVA are parts of a system which has the task of supporting development towards a sustainable society and sustainable growth. Research and development are an important part in such a development. The following is not a complete list of all the actors at the various stages, but only an overview of the authorities, research funding agencies and other actors of the greatest importance for research on, and the commercialisation of, environmental technology.

Swedish Government

Several ministries are responsible for issues that concern the environment in various ways. It is the Ministry of the Environment and the Ministry of Industry and Commerce which have the most obvious responsibility for issues concerning regulations, the economy, and research and development in environmental technology. Other ministries which are responsible for issues to do with the environment and technology are the Ministry of Agriculture (agriculture and food) and the Ministry of Education (funding of research).

The influence of society is mainly exerted through legislation, often focused on discharges and emissions to air, water and soil. Support for research and development with a direct association with technology of sound environmental performance has mainly been given for energy systems and vehicles/fuels.

Authorities and other national actors

Several authorities have tasks and activities which, in various ways, have a bearing on sustainable development and environmental issues. They are responsible for the implementation of government resolutions, formulate regulations and carry out supervision – and in this way they influence the market and the prospects for the application of environmental technology.

Some of the authorities and actors which have a direct task regarding environmental technology, to promote environmentally-oriented development of companies and to promote e.g. the export of environmental technology, and which also play some part in funding research, are listed on the following pages.

Completed initiatives

In the wake of the Rio Declaration, it was realised how important it is to consider the entire life cycle, that the way waste is managed is of great significance for the overall use of natural resources over the whole life cycle and thus for the aggregate environmental impact. The Council for Waste Management Research (which was later changed into the Waste Research Board at the National Environment Protection Agency) was set up at the beginning of the 1990s with the task of financing research into method development (e.g. LCA), the disposal of waste and recycling/re-use of residual products.

Another initiative with the focus on all product development and the consideration of the overall picture was the programme *Environmentally Driven Product Development* (MPU) which, over the period 1998 – 2001, was performed by the then Nutek (before VINNOVA was created out of parts of Nutek). The MPU programme was carried out in networks, with mainly small companies and groups of researchers. The experiences are further utilised in the work by Nutek on environmentally driven business development.

One authority with a temporary and now completed mandate, with a direct focus on environmental technology, was the Environmental Technology Delegation (1997 – 2000). Its prioritised areas were the export of environmentally sound goods and services, transport, the construction sector, foods/agriculture, and ecological reinstatement of land.

Swedish Agency for Economic and Regional Growth (Nutek)

The task of Nutek is to promote sustainable economic growth and welfare over the whole country by creating new enterprises, increasing the number of growing enterprises and increasing the number of strong regions.

The work of Nutek on *Environmental management in small enterprises and Methods for environmentally sound product development* has increased knowledge of what business opportunities a more environmentally aware market offers. One experience is that when a company focuses its efforts on sustainability, the entire business strategy is often modified. The programme *Environmentally driven business development* has built on these experiences and has endeavoured to strengthen the competitiveness of small and medium enterprises by stimulating development of activities and products from a sustainability perspective.

In the area *Environmentally driven business development*, Nutek has financed over 40 pilot projects in order to carry forward development within the strategic ideas developed in

the government mandate of 2003, and has made preparations for the strategic work by Swentec. The project has been mainly carried on in cooperation with ALMI, the Swedish Energy Agency, VINNOVA, National Environment Protection Agency, Export Council, ISA, industrial organisations, universities, industrial research institutes, consultants and regional nodes for environmentally driven business development.

Nutek is planning to place special focus on environmentally driven product and business development and the conditions in the national market. Another priority area is the integration of environment and sustainability issues in regional business development.

Swentec

Swentec is the new Swedish environmental technology council which has been mandated by the Government to strengthen the business opportunities and competitiveness of Swedish companies in the fields of environmental technology, environmentally sound products, production processes and services in the Swedish and international markets.

This is to be done by:

- strengthening coordination of State inputs in this area
- working to ensure that the aggregate State inputs better satisfy the needs of companies
- promoting cooperation among the actors in the field of environmental technology – creating networks so that development and marketing of Swedish environmental technology are strengthened
- identifying and communicating Swedish competitive advantages in this area
- collecting, analysing and disseminating essential information and knowledge in this area

A Board comprising ten persons has been appointed by the Government to manage the work of Swentec.

Swedish Environmental Protection Agency

The National Environment Protection Agency is the central environmental authority of the Government. Its principal tasks are to:

- disseminate information on, and ensure the observance of, environmental laws and to provide environmental knowledge
- formulate the background documentation which the Government needs for environmental policy
- provide guidance for other central, regional and local

authorities in issues to do with the environment and monitoring of observance of environmental legislation

- explain how laws are to be interpreted, produce specifications, general advisory notes and manuals
- represent judicial and extra-judicial processes in courts and propose necessary amendments to legislation

The National Environment Protection Agency also finances environmental research in support of the work of the Agency, for example with regard to environmental objectives and the Environmental Code, and in producing documentation for international negotiations. One ongoing programme that is associated with environmental technology is *Conditions for life cycle considerations in integrated product policy* (FLIPP). The aim of the programme is to show what impact laws, taxes and environmental labelling have on different groups of people. The researchers are also to produce sustainable systems for the production and consumption of goods that benefit both the companies and the environment.

Other activities that in various ways touch upon environmentally driven technological development are the work on environmental objectives, work on integrated product policy (IPP) and the administration of the climate investment programme (KLIMP).

Swedish Road Administration

Work is in progress at the National Road Administration on producing a strategic plan for the period 2007-2016. As the basis for this work, a number of strategies for “specialist areas” are being drawn up. Strategies that concern the environment are Climate, Fresh Air, Less Noise, Landscape – Nature, Cultural Heritage and Design, and Water and Materials.

The Administration is responsible for the *Emission research programme* (EMFO). This programme deals with air pollution and noise that are caused by vehicular traffic on public roads, and emissions from tractors and large construction plant. One important task of the programme is to co-ordinate activities within the programme, with both national and international research. The programme is financed in a cooperation among the partners in Programme Council for Automotive Research (PFF) in which the Swedish automotive industry and authorities work together. Those taking part are Saab Automobile AB, Scania CV AB, AB Volvo, Volvo Personvagnar AB, Fordons Komponent Gruppen AB (FKG), the Swedish Energy Agency, National Environment Protection Agency, VINNOVA and the National Road Administration.

Swedish Board of Agriculture

The Swedish Board of Agriculture annually allocates ca MSEK 17 for projects that will produce applied knowledge in the following areas: reducing the risks associated with pesticides, the environmental effects of plant nutrients, organic production and biodiversity in the cultivated landscape. The funds are used for trials with the aim to increase the environmental and economic sustainability of agricultural and horticultural production. The trials mainly comprise farming techniques and technical development. It must be possible for new knowledge to be applied in practice over a short period (3–5 years). These funds therefore supplement the support given by other authorities and foundations for research over a longer perspective.

National Board of Housing, Building and Planning

The Board is the national authority for issues concerning spatial planning, urban development and the built environment, construction and management, and housing issues.

The Board is engaged on a large number of environmental issues which can be roughly broken down into four areas:

- The environmental quality objective Good built environment
- The environmental objective Physical planning and economic management of land and water and buildings, inclusive of the project SAMS – planning with environmental objectives
- Responsibility for the construction sector in regard to ecologically sustainable development
- Internal environmental work.

The Sustainability Council, with its office in Umeå, is part of the National Board of Housing, Building and Planning. The task of the Council is to encourage local and regional work on sustainable development.

Swedish Rail Administration

The National Rail Administration is the authority responsible for railways in Sweden. This entails monitoring and promoting development in the rail sector, assisting the Riksdag and Government in matters concerning railway issues, responsibility for operation and management of the State owned track installations, coordination of local, regional and interregional rail traffic, and support for research and development in the rail sector.

The sectorial responsibility of the Administration comprises, inter alia, initiating planning and supporting applied socially

motivated research in the railway sector. R&D area No 4 deals with the safety and environmental adaptation of the rail transport system.

Swedish Forest Agency

The National Board of Forestry is the authority for issues concerning forests. Its duty is to ensure that the forests in Sweden are protected and managed in such a way that the forests provide a sustainable good yield with the simultaneous preservation of biodiversity. As far as the forestry industry is concerned, this entails sectorial responsibility to ensure that the objectives of full employment, economic growth, regional balance and balance in foreign trade (production objective) are satisfied, and that the objectives of environmental and nature conservancy policy (environmental objective) are also satisfied.

Swedish Trade Council

The Export Council was set up in 1972 and is jointly financed by the State and the business sector. The Export Council helps Swedish companies to grow internationally by providing free information, strategic advice and local assistance.

By commission of the Swedish Government, the Export Council, through the programme Swedish Environmental Technology Export, is working to enhance the prospects of Swedish exports of environmental technology in the areas: air, water and sewage treatment, waste management, recycling and renewable energy.

Swedish Environmental Technology Export is a network of almost 700 companies. Through united effort, the services and products of the network companies are marketed internationally. The network is also a platform for the sharing of information and experience among the companies in the network, and between these and organisations and authorities. Participation in the network is free of charge.

Sida

Sida, Swedish International Development Cooperation Agency, is a national authority that has the objective to create opportunities for poor people to improve their living conditions. The task of Sida's department for research cooperation (SAREC) is to provide support for research in developing countries and for research that is important for their development. This is done by support for research councils, universities and research institutions in the countries, for regional research networks, and by support for international research programmes. The department is also responsible for support for Swedish research that is of importance for developing

countries. Areas associated with the environment are sustainable environmental technology, renewable energy, water and sanitation, chemicals and the establishment of environmental institutions.

ALMI

The task of ALMI is to promote development of competitive small and medium enterprises and to stimulate the establishment of new businesses, with the aim of creating growth and renewal in the Swedish economy. Its work encompasses the entire process from concept to profitable company. The objective is that more innovative ideas should be successfully commercialised, more viable companies should be started and developed, and that the competitiveness and profitability of companies should increase.

ALMI Företagspartner AB is owned by the State and is the parent company in a group with 21 subsidiaries in which the parent company has 51% ownership. Other owners are the county councils, regional boards and municipal cooperative agencies.

Research funding agencies

The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas)

Research Council Formas supports basic and need related research in the areas environment, agricultural sciences and spatial planning. These principal areas are subdivided into smaller areas. Formas promotes ecologically sustainable growth and development in society, multidisciplinary and interdisciplinary research, and international research cooperation. Formas is further responsible for information on research and research results. In the Formas programme Sustainable Buildings there is also provision for financing development work and experimental construction. The priority areas of Formas are environmental research, agriculture and horticulture, fishing and reindeer husbandry, forests and forestry, built environment and spatial planning. Formas is also engaged on transdisciplinary research in the principal areas.

The priorities of Formas are reflected in both research strategies and research programmes. The strategic initiatives of Formas range over several areas of R&D and are characterised by a holistic approach, high relevance and timeliness. The objective is to generate results of practical applicability within a limited period.

It is important that the social sciences and the humanities should also be represented in research in order to elucidate the relationships among the function and condition of ecosystems and a sustainable societal development. The concept of sustainability encompasses three dimensions – ecological,

economical and socio-cultural. Getting these three dimensions to function together necessitates system thinking and transdisciplinary research. Formas has the task of coordinating social scientific environmental research.

In all Formas' spheres of responsibility, there is great environmental relevance. There is also significant coupling to environmental technology in all areas.

Swedish Agency for Innovation Systems (VINNOVA)

VINNOVA is a national authority with the task of promoting sustainable growth. The task of VINNOVA is to finance need related research and development from an economic perspective. Environmental and sustainability motives are included among other motives in many of the initiatives comprised in the work of VINNOVA. The areas concerned are:

- *Biotechnology:* Food
- *Manufacture:* Effective development of products, Wood product manufacture, and Intelligent and functional packaging
- *Materials:* Lightweight materials and lightweight structures, and Green materials from renewable raw materials
- *Transport:* Innovative vehicles, ships and systems, and Innovative logistics systems and transport

Health and sustainability from a social perspective are also the objective in several growth areas, in the subject areas biotechnology and manufacture.

Initiatives in information and communication technology (ICT) have principal motives other than environmental aspects, but are of significance as enabling technologies of great importance for all technical development and effectiveness in society and business. The growth area IT in health care in the home, however, is directly related to services in health and health care.

VINNOVA is investing in some R&D programmes which specially focus on small and medium enterprises in order to assist these enterprises to increase the range of new products/services/processes and thus strengthen their competitiveness and growth and provide new work opportunities. In the programme Forska & Våx (Research and Grow), for example, some companies have received support for the development of ideas with a clear environmental relevance.

Swedish Energy Agency

The Swedish Energy Agency is engaged in several areas on the effective and sustainable use of energy and on making Swedish energy supply cost effective.

The *Energy Market Inspectorate* oversees legislation, the development of the electricity, natural gas and heat markets, and the associated competition and consumer issues.

The task of the Agency in *Sustainable use of energy* is to promote the effectivisation of energy use in society.

Development and management of control instruments provides assistance in the transformation of the Swedish and European energy system. Internationally, cooperation is taking place in several forums, not least within the EU. Climate related action motivated by energy policy is taken, for example through cooperation in the Baltic countries and Russia.

The Agency has a comprehensive programme for providing support for research and technological development, inter alia for the development of renewable electricity and heat production technology and the development of the transport system towards greater sustainability.

Utilisation and commercialisation of results are issues of the highest priority for the Agency.

Swedish Foundation for Strategic Environmental Research (Mistra)

Mistra is a foundation which has the objective “to support research of strategic importance for a good living environment”. Mistra finances research that has the aim to solve strategic environmental problems, and is instrumental in the environmentally sound development of society. The research must have practical application in companies, the authorities or in various organisations.

Several completed and ongoing programmes are in different ways related to research on environmental technology. Examples of issues and technologies that have been involved are fuel cell technology, metal reclamation, environmental antifouling paints for boats, solar cell technology, ecocyclic construction, ecocyclic pulp manufacture and soil remediation. One ongoing initiative is funding of a new interdisciplinary centre for research and policy dialogue regarding sustainable development.

Other research funding agencies

The task of the *Knowledge Foundation* is to strengthen Swedish competitiveness through supporting research and researcher training, advanced training for the business sector, as well as school improvement and IT. The foundation has no specific objective regarding the environment and sustainability. However, its work includes projects and programmes with an element of environmental issues, for example at Kalmar University College and at Örebro University.

The *Swedish Building Industry Development Fund (SBUF)* is the organisation of the building industry for research and development, with almost 5000 member companies. SBUF is working to develop the construction process so that better business conditions are created for entrepreneurs and installation contractors, so that they can make use of research and carry on development work. SBUF is supported by Federation of Swedish Building Industry Employers, Federation of Building Services Installation Firms, Swedish Organisation for Managers, Swedish Building Workers' Union, and Swedish Union for Service and Telecommunications Employees (SEKO). SBUF does not specify environmental aspects among its key criteria for support, apart from the working environment.

Swedish Farmers' Foundation for Agricultural Research (SLF) is the organisation of the agricultural industries for funding research related to agriculture. The finance is mainly obtained from agricultural producers. Research is mainly focused on the various production branches, and in many cases it has environmental relevance. One initiative with a direct environmental association is a new RDD programme Bioenergy, with the Swedish Energy Agency providing part of the funding.

The aim of *Swedish Foundation for Strategic Research (SSF)* is to support research associated with the natural sciences, technology and medicine. According to its bylaws, the Foundation must promote the development of strong research environments of the highest international standard which are important for the development of future Swedish competitiveness. The bylaws comprise no specific objectives that the research supported should relate to the environment and sustainability.

Research and education

The strategy's definition of environmental technology encompasses a large proportion of Swedish research and education. This document contains no detailed overview of research environments and areas, since that would result in an extensive catalogue.

Research with a clear focus on environmental issues and sustainable development is carried on at most universities and university colleges, often associated with applied technical research and in a number of cases also with an element of social sciences research. In various ways, environmental technology form a large part of the basic and further education at university colleges and universities. There are also several researcher training schools with a clear environmental orientation.

Many of the industrial research institutes conduct research and other activities with an environmental orientation, several in cooperation with, and support for, small and medium enterprises.

Overall, extensive research and education is taking place, with a direct or indirect environmental association, mainly at technical universities and the natural science or similar faculties at universities. At the same time it can be noted that there are relatively few broad interdisciplinary programmes with a holistic and life cycle perspective that are associated with e.g. users and regulations, and the way other driving forces influence conditions for a sustainable development.

Formas, the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, is a governmental research-funding agency. Formas encourages and supports scientifically significant research related to sustainable development.

VINNOVA, the Swedish Governmental Agency for Innovation Systems, integrates research, development and innovation. VINNOVA's mission is to promote sustainable growth by funding needsdriven research and developing effective innovation systems.



VINNOVA
Swedish Governmental Agency for Innovation Systems
 SE-101 58 Stockholm, Sweden. Visitors: Mäster Samuelsgatan 56
 Phone: +46 (8) 473 30 00. Fax: +46 (0)8 473 30 05
 E-mail: VINNOVA@VINNOVA.se, www.VINNOVA.se



Forskningsrådet för miljö, areella näringar och samhällsbyggande, Formas
The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning
 Box 1206, SE-111 82 Stockholm, Sweden. Visitors: Kungsbron 21
 Phone: +46 (0)8 775 40 00, Fax: +46 (0)8 775 40 10
 E-mail: info@formas.se, www.formas.se