

**Government Commissioned Report**

# Analysis of Environmental Research and Strategy Proposal for 2011–2016



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# Foreword

The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas) was tasked by the government to undertake a comprehensive review of environmental research, in consultation with the stakeholders funding this research, and to subsequently propose a national research strategy for the period spanning 2011–2016.

A reference group comprising representatives of the environmental research funding bodies was affiliated to the project. This group was composed of: Lars-Erik Liljelund, Mistra, Leif Moberg, Swedish Radiation Safety Authority, Eva Smith, Swedish Environmental Protection Agency, Jonas Brändström, VINNOVA, Lars Guldbrand, Swedish Energy Agency, Maria Nilsson, Swedish National Space Board, Sven Stafström, Swedish Research Council (VR), with Malin Andersson and Anders Berndtsson from the Swedish Transport Administration.

At the beginning of the year Formas arranged a workshop where participants included members of the Formas Scientific Council as well as other key resource personnel identified by the reference group. The objective was to highlight and define future research issues from the starting point of today's major environmental challenges.

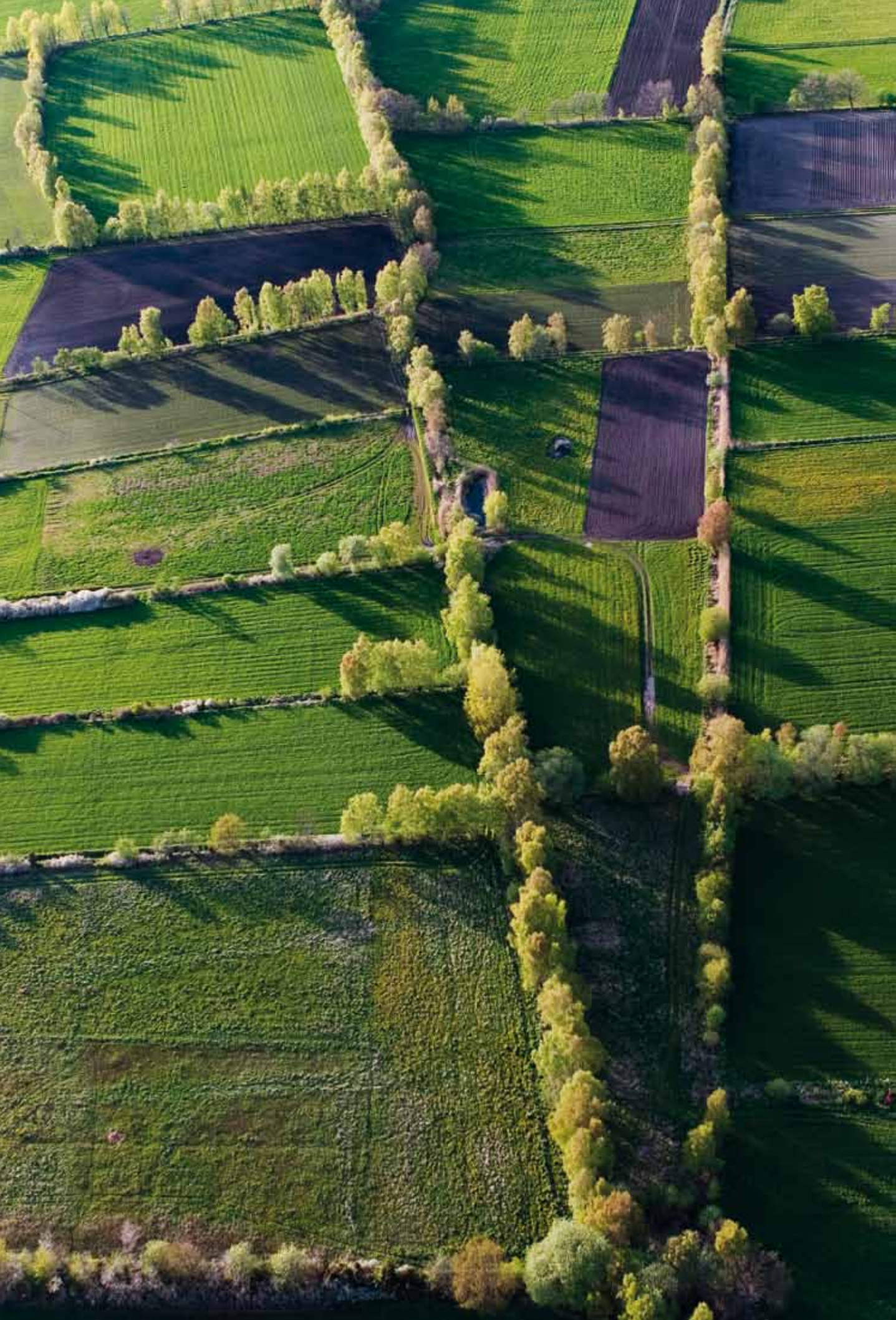
Formas would like to thank the members of the reference group as well as everyone who has contributed valuable information to the analysis and played a constructive part in strategy development.

Formas would also particularly like to thank Maria Nilsson and Kari Stange for their exemplary work within the project group.

*Rolf Annerberg*  
Director General of Formas



Rolf Annerberg  
Director General of Formas



# Summary

Formas was tasked by the Swedish Government to undertake a detailed analysis of all environmental research and to develop a national research strategy proposal for the period 2011-2016.

**This analysis revealed** that the Swedish state in 2009 invested just over SEK 2 000 million in environmental research, in addition to faculty funding. This included funding allocated by means equivalent to those of research council grant funding methods, direct funding of environmental research performed by government agencies and institutes carrying out research within the framework of their internal operations, as well as the financing of environmentally related infrastructure. Over and above this there was also financing originating from the EU framework programme that in 2009 was estimated to constitute approximately SEK 400 million within the area of environmental research. State funded environmental research is also performed to a significant extent via direct appropriations of faculty funding to universities and university colleges.

To illustrate the focus areas within environmental research the research grants were ordered in accordance with the 16 national environmental quality objectives. The analysis demonstrated that individual research funding bodies focus operations on one or more of the different environmental quality objectives, which means that several funding bodies are active within one and the same subject area. This generates flexibility and contributes to diversity, but imposes demands on good cooperation between the grant awarding bodies in Sweden.

**The analysis revealed that** the major portion of environmental research grant funding is allocated to the environmental objective category *Reduced Climate Impact. A Good Built Environment* is a major environmental research area and Formas is the major source of financing in this category. There are also major investments directed towards the environmental quality objective category of *A Rich Diversity of Plant and Animal Life*, which encompasses research oriented towards biological diversity. Other major areas are *A Non-toxic Environment*, *Sustainable Forests*, *A Balanced Marine Environment* and *A Varied Agricultural Landscape*.

The mapping of environmental research funding also demonstrates that a major portion of environmental research, around 65 percent, is performed within the framework of research programmes with a thematic focus. These programmes are utilised to direct research towards the areas where distinct needs have been identified. The users of the research, however, are seldom involved in the structuring of the programme. It is the opinion of Formas that the user value of such programmes and the benefits resulting from these would in all probability increase if the users of the research results were given a role in programme planning. Researchers should be responsible, however, for formulating the research issues to be addressed based on the knowledge requirements of society.

**Evaluations by the funding bodies** of the focus of the respective operational activities demonstrates that approximately half of all Swedish environmental research can be classified as causal research and half as intervention research. The material demonstrates distinct differences between funding bodies that is partially reflected by their different mandates. This again illustrates the need for cooperation among funding bodies.

A review of some 30 evaluations demonstrates that the research that has been evaluated in the majority of cases has been assessed to be of good quality. Within certain areas it has been noted that the number of publications has been fewer than anticipated. Many of the evaluations have taken into account the societal relevance of the research, which in general has been judged to be high. A recurring recommendation found in the evaluations has been that of encouraging increased collaboration between research groups, both nationally and internationally. In several instances the evaluation panels have recommended encouraging a higher degree of interdisciplinary research. Several of the evaluations have also highlighted the need to develop the methodology for disseminating research results to potential users in order to ensure that the research results are utilised and benefit the user community. It is also desirable to increase efforts to ensure that research results are commercialised.

Formas was also tasked as part of this commissioned review to identify strong and weak research areas in relation to the needs of society. In general it can be concluded that Sweden holds a strong position within the research disciplines that are related to environmental research. Even in these areas, however, a need to improve interdisciplinary research efforts can also be identified, which would provide environmental research with better prerequisites to meet the knowledge requirements of society.

**Formas has identified**, based on the major challenges documented in the Lund Declaration, as well as elsewhere, seven

category areas that are particularly relevant for future environmental research in Sweden, namely Biological Diversity, Efficient and Sustainable Use of Natural Resources (including water), Energy, Marine Environments, Sustainable Cities, Chemicals and Climate Change. Within these seven category areas there are a large number of research issues that should be given high priority in the future. Formas is also open for new significant research issues being identified within these areas during the coming years.

It is important to note that the potential solutions to the problems within the respective category areas are multifaceted and complex and the identification of these solutions will necessitate the performance of discipline-specific, interdisciplinary and cross-disciplinary research. This means that initiatives to strengthen interdisciplinary research, preferably from a system perspective, will be required.

**Within several of the areas** Formas judges that it is primarily intervention studies that require additional augmentation, but causal studies are also naturally required to identify and quantify new challenges. Issues relating to governance for managing these complex systems should be brought to the fore, as these are often regarded to be decisive in terms of whether new solutions are actually implemented and potential benefits are realised.

Formas does not suggest that any changes be made to how environmental research is organised. The analysis has however identified the need for users to be involved more closely in the prioritisation of knowledge gaps and new problem areas. Formas will therefore establish a user forum that will function as an advisory resource for those funding environmental research.





# 1. Introduction

On 29 April 2010 Formas was tasked by the Swedish Government to undertake a comprehensive analysis of environmental research and to develop a national research strategy proposal for the period 2011–2016. The report of this analysis was intended to comprise the analysis itself and a national research strategy proposal. The strategy proposal is presented in section 2 of this report and the analysis report is presented in section 3.

Formas has conferred with the funding bodies named by the government when commissioning this review, namely Mistra, the Swedish Radiation Safety Authority, the Swedish Environmental Protection Agency, VINNOVA, the Swedish Energy Agency, the Swedish National Space Board, the Swedish Research Council (VR) and the Swedish Transport Administration. These organisations have contributed material to the analysis and have served as a reference group for the review. The reference group has met on four occasions to discuss the review, the way the review has been carried out and the conclusions of the review.

No all-encompassing comprehensive analysis of environmental research in Sweden has been performed since 1992 when the report SOU 1992:68 (*Långsiktig miljöforskning*), a review of research concerning long-term ecological governance, presented its conclusions. A significant number of thematic evaluations of research within the area of the environment have, however, been carried out over the last decade. These form an important part of the background material for this report.

To begin with it can be concluded that the term environmental research is not an unambiguous, well defined concept. Historically, 30 to 40 years ago, the term environmental research was generally primarily associated with natural science disciplines, such as ecology or environmental chemistry. Today environmental research is carried out within many scientific areas and to an increasing extent has adopted social science and interdisciplinary perspectives. This development is reflected by the fact that the challenges faced within the area of the environment are important problems for society that necessitate extensive research within many areas for solutions

For the purpose of this review, environmental research has been defined as research of relevance to the environmental quality objectives.

to be found. For the purposes of this review, environmental research has been defined as *research of relevance to the environmental quality objectives*. In accordance with the mandate of the work commissioned, the analysis and strategy in the first instance should encompass research within the responsibility area of the Ministry of the Environment. The definition that was applied encompasses a somewhat broader area that corresponds relatively well to the responsibility areas of the bodies funding the research.

The distribution of research funding is seldom documented in ways that enable the funding awarded to environmental research to be readily distinguished. The possibilities of utilising data sources such as SCB statistics and annual management reports as background material for the review have therefore been limited. The gathering of material for analysis has therefore been carried out through direct dialogue with the stakeholders concerned. Applying the definition *research of*



*relevance to the environmental quality objectives* to the portfolios of the different funding bodies proved to be a challenge in some cases. With the exception of the Swedish Environmental Protection Agency, none of the funding bodies could easily present the subtotals that could be classed as environmental research funding from their total funding portfolios. Differentiating environmental research from total funding in these cases has been based on the searching and sorting function capabilities of the internal project databases of the funding bodies. Subjective decisions and indistinct lines of demarcation underlie such distinctions. The boundary distinguishing between research and development is also not always obvious. The mapping of the scope of environmental research has primarily focussed on the nine stakeholders named in the mandate of the work commissioned and has been directed towards research performed with state funding that has been awarded on a competitive basis equating to the forms used by research councils.





## 2. National Research Strategy Proposal

There are major challenges facing society and new knowledge is required to ensure sustainable societal development. Formas has identified seven particularly relevant categories as future areas for environmental research in Sweden.

Several international initiatives have been developed to identify the greatest challenges. The Lund Declaration, developed in conjunction with the *New World – New Solutions* conference arranged during the Swedish presidency of the EU in 2009, highlighted global warming, as well as access to energy, food and water resources as being some of the most important environmentally related challenges. Sweden's first contribution to the next generation of the EU framework programme for research etc. in December 2010 also addressed these perspectives and proposed prioritisation within the framework programme for the major challenges.

These challenges concern problems that must be solved as quickly as possible to enable our world in the future to be able to sustain a growing population and provide people and animals with reasonable living conditions. It is therefore important that problems and possibilities are placed in the spotlight and that research questions are formulated based on these. The form the research takes (basic or applied research, curiosity-driven or needs-driven research etc.) is of lesser importance. What is essential is to ensure that new knowledge is generated so that the challenges that have been identified can be addressed and so that new challenges can continue to be identified. This requires both causal research, which identifies and quantifies problems, as well as intervention research, which develops solutions. The necessity for a system perspective, as well as interdisciplinary and cross-disciplinary research in order to meet major global challenges has been pointed out, among others, by groups of experts associated with the International Council for Science (ICSU). Future efforts should include exactly these aspects. Environmental research cannot be viewed solely as a combination of natural sciences and technical disciplines, but must be performed in an interdisciplinary manner involving natural sciences, technology/engineering, social sciences and the humanities,

as well as sometimes also including medicine. In addition, environmental research must also be performed in a cross-disciplinary manner; that is to say in a way that bridges the traditional boundaries between the research community and the rest of society. The need for research concerning "governance", or the ways that society manages complex systems, should be brought to the fore, as this is often regarded to be decisive in terms of whether new solutions become implemented and realise their potential worth.

### **Priority Research Areas**

Formas has identified seven particularly relevant categories as future areas for environmental research in Sweden. These are Biological Diversity, Efficient and Sustainable Use of Natural Resources (including water), Energy, Marine Environments, Sustainable Cities, Chemicals and Climate Change. A selection of priority research issues within these seven areas is presented below. Common to all of these areas is their complexity, particularly when it comes to identifying successful solutions. It can also be concluded that all of these areas are partially integral to each other and sometimes overlap. Our aim has therefore been to state each of the individual research needs that have been identified once, despite the potential that these may be included in more than one problem area.

### **Biological Diversity**

Biological diversity is usually defined as a rich variation in all living organisms and the ecological systems of which they are a part, both on land and in the water. This diversity encompasses diversity of ecosystems, species and genes within species. This diversity provides society with ecosystem services, such as the provision of food, water or recreational activities. A rich biological diversity heightens the ability of ecosystems to withstand changes over the long-term and to develop further. This capability is often termed resilience.

Over the entire world ecosystem changes are happening rapidly: destruction of rainforest and virgin forests, the establishment of large-scale plantations, the disappearance of cultural landscapes, desertification, salinisation and drainage of wetland. Large land areas are converting from complex, species-rich environments to monocultures with only a handful of species. The continuous loss of biodiversity and the impoverishment of ecosystems are two major challenges facing science and society. Sweden has a long tradition of diversity research and is one of the leading countries behind the agreements included in the international convention treaty on biological diversity (CBD). Last year in Nagoya the treaty partners agreed on a strategic plan for the period 2011-2020, a projected vision for the year 2050, overall targets for 2020, five strategic objectives and 20 partial objectives. These targets include measures to arrest the global loss of biodiversity so



that ecosystems can become resilient and produce essential ecosystem services by 2020. The problem areas are complex and involve the natural sciences, social sciences and the humanities and the issues themselves necessitate an increased degree of interdisciplinary collaboration. Below is a list of a number of important research questions:

- *Effects on biological diversity* of changes in land use, climate changes and changes to the structure of the landscape. A long-term, sustainable change of land use means that the ecosystem can resiliently deliver ecosystem services, such as raw products for forestry, food, energy and tourist and recreational activities. The ecosystem must also be able to cope with the effects of climate change and future changes in global competition situations.
- *Ecosystem services and multi-functionality*. This is not just about the relationship between richness of species and individual ecosystem services (such as the production of biomass, for example), but also concerns the connection between biological diversity and the ability of the ecosystem to be able to generate a number of different functions and services.
- *Ecosystem management* encompasses how stewardship methods in combination with biological diversity can contribute to or damage the long-term preconditions for creating and maintaining ecosystem services. Opportunities exist also in terms of generating new, innovative products and services that are based on ecosystem services. Another issue is the integration of (regard of) ecosystem services/biological diversity in the decision-making processes of society; something that demands a combined human science and natural science research effort.
- *The dynamics of biological diversity*. This includes the study and identification of key mechanisms and factors (evolutionary, adaptable over long and short-terms, spatial structures) that impact the dynamics of biological diversity. Other research questions include modelling and scenario development for biodiversity dynamics (and general dynamics within complex systems), as well as scenarios for the development of biological diversity (using different stewardship models and strategies).
- Biological diversity as a source of new *biotechnologies* and as a support for sustainable development of business in different forms.
- *Traditional knowledge*. Among the traditional users of natural and partially impacted ecosystems (for example indigenous population groups) there is often valuable

knowledge about the long-term protection and management of natural resources. This knowledge should be documented and made available.

### **Efficient and Sustainable Use of Natural Resources (including water)**

Many natural resources are being consumed more rapidly than is sustainable in the long-term and there is therefore a risk that the depletion of natural resources poses a great threat to the environment. The challenges faced include sustainable use of raw materials, land and water, changes in the patterns of consumption and the development of sustainable production methods. Here there are links to areas such as material, processing and manufacturing technologies and therefore a strong element of innovation and utilisation in commercial activities. On a global scale the supply of water poses the greatest challenge. A list of the issues that should be prioritised is presented below.

- *Switching to a sustainable bioeconomy* (bioeconomy is here intended to mean sustainable production and conversion of biomass into different foodstuffs and health products, fibres, industrial products and energy). Expanding populations and economic growth globally confers increased demands on biomass utilisation as raw materials or finished product for foodstuffs, materials, energy and transportation. An efficient use of renewable biomass resources from raw materials to finished products, including efficient use of the waste generated, is an issue to be researched. A sustainable bioeconomy is dependent on creating biomass-based added value, minimising energy consumption and recycling nutrients and energy from end products. This requires knowledge about production factors, environmental impact, economic conditions and consumer prerequisites and behaviour. Prior to deciding to switch production systems all of the bioeconomic and environmental consequences should be envisaged based on knowledge of the economic, ecological and social effects of such measures. This necessitates an over-bridging system perspective where researchers, producers and consumers work together in interdisciplinary ways to identify optimal areas of utilisation and process flows.
- *Intensified production within agriculture and forestry – sustainable utilisation of nutrients and water.* Increased plant production can in many instances be achieved by the addition of nutrients. Addition of nutrients has an inherent cost and also can result in leakage into water systems and the atmosphere, which can have subsequent negative consequences. The intensification of sustainability, in other words an increased production through growing plants with a more efficient use of nutrients, as



well as the capability of the land to store and circulate nutrients without loss to the environment is a challenge that should be tackled to meet increased production demands. In addition to knowledge concerning the control of storage and availability of nutrients in the soil and groundwater, the efficiency of utilisation of nutrients and water can also be improved through choice of methods used for growing crops or genetic modification. This means that biological basic research is converted to applied research to benefit physiological characteristics that contribute to improved efficiency, in addition to research into the ecological effects that these crops have on the environment.

- *Multi-use – efficient land and water utilisation, competition and conflicts.* Bioeconomic efficiency is dependent on the choice of areas of use, refining and recycling of biomass materials. Areas used for biomass production can also yield other valuable commodities and services that contribute to sustainable development, such as recreation, hunting and fishing, for example, as well as supplying energy. Conflict situations, equating to competition for biomass resources from different product chains, occurs when different stakeholders desire to use the same areas. This demands a system perspective in order to find optimal solutions that maximise benefit for the user and sustainable societal development.
- *Efficient use of resources.* When there is a rapid increase in demand for natural resources it becomes increasingly important that finite resources are utilised in the most efficient manner. This may be a matter of efficient use of water by both society and industry, for example, the extraction of base metals with the best possible utilisation of resources, efficient utilisation and provision of energy or the development of bio-refining concepts. It is important to utilise biomass resources efficiently for different purposes as a replacement for fossil-based and energy-consuming raw products and materials. One route to achieving this is the use of bio-refineries, where the biomass is used to produce products such as materials, heat, electricity, bio-fuels and chemicals. This is essentially a matter of increasing the investment in highlighting optimal use of resources from a system perspective and developing better grounds for evaluating potential advances.
- *Reduction of the environmental impact of mining.* To further reduce the environmental impact of existing and new mining operations, knowledge is required concerning how waste products should be handled and how the effects on recipients can be reduced, as well as how downstream processing of existing gravel and sand reserves can be improved.

- *Sustainable consumption, reuse, recycling and designs for recycling.* Consumers play an important role in the reduction of greenhouse gas emissions, mineral and nutrient depletion to safeguard global food supply. The rich nations consume more natural resources than ever and many products are not produced in a sustainable way. When products are offered for sale at low prices, the costs of environmental pollution and social consequences in the country of production are not exported together with the goods themselves. A switch to sustainable bioeconomics requires consumer awareness and sustainable purchasing behaviours, not just with respect to economic or ecological sustainability perspectives. This necessitates consumer acceptance and consumer confidence in the new production methods and products. For these reasons transparency and knowledge transfer regarding the bioeconomic benefits and risks is important. Research can contribute knowledge of how consumer patterns can be altered, how waste amounts can be reduced and also how households can become more efficient at waste recycling. More efficient transport, resource-saving packaging and longer shelf-life times are also factors that contribute to sustainable consumption and reduced waste. Research should therefore be cross-disciplinary.
- *Reduced climate impact – within agriculture and forestry.* Even if fossil-based raw materials are being increasingly replaced with renewable biomass ones, there are further opportunities for agriculture and forestry to reduce greenhouse gas emissions into the atmosphere. In addition to reducing the dependence on fossil fuels in these sectors and the emission of greenhouse gases, carbon is bound by growing crops and the soil, at least over the short-term. A global switch to an economy free of fossil carbon takes time. Every opportunity to bind carbon from the atmosphere can be worthwhile, even if only for a short period. Research into how to best and most efficiently bind carbon in the soil and through the forestry ecosystem, as well as methods for retaining these stores for longer periods, is urgently required. Within farming, ruminant cattle contribute significantly to methane emissions. Reducing these emissions is a pressing area for research and development.

## Energy

Efforts in the energy area should be directed towards tangible contributions to the energy and climate policy targets set for 2020 and 2050. Ambitions to utilise results are high and the research should be closely coupled to development, demonstration, innovation and commercialisation efforts. Research should be focused partially towards those areas that can contribute to a sustainable energy system in Sweden and partially towards areas where Swedish research and Swedish businesses

have good opportunities to contribute to sustainable development in the energy areas of other countries and regions. Investments should be made that include links to EU initiatives in the energy area. Energy research is structured on an international basis and the results and studies performed within international collaborations should be better utilised. Some issues have a more Nordic perspective, however, as they are coupled to conditions in our relatively cold climate. Some priority issues within this area are listed below.

- *Renewable energy.* Research and development surrounding renewable energy as a complement to and replacement for fossil energy is one of the main tasks of the energy area. The introduction of such energy provision reduces the emissions of climate impacting gases, improves reliability of supply and contributes to an efficient and sustainable utilisation of natural resources. Among the different forms of renewable energy can be named bioenergy, solar energy, wind, wave and hydroelectricity. Research into all of these areas is pressing. Solar power, solar heating and wind power are becoming ever more important elements in the global energy system. Wave energy, as well utilising ocean currents, has great potential. Hydroelectricity is already of major importance today, but it is of interest to further study efficiency and environmental aspects. Geothermal energy may also come to play a significant role in contributing to renewable energy provision. Major efforts to expand the use of wind power in Sweden bring major inherent needs for research efforts coupled to development, demonstration and commercialisation.

Against the backdrop of Sweden's natural resources, industrial structure and research climate, bioenergy assumes an exceptional position. Bioenergy is of major importance in reaching the targets set in the Reduced Climate Impact quality objective. Negative environmental consequences should be avoided to the greatest extent possible, but conflicts between the expansion of bioenergy and meeting environmental targets cannot be avoided entirely. Concomitantly bioenergy offers the possibility of being able to contribute to achieving several environmental objectives in addition to climate targets. There is a pressing need for the study, development, optimisation of growth, production, refining and logistics for the reliable production of bio-fuels that meet national environmental requirements and international sustainability criteria. It is important to utilise resources in the form of the biomass efficiently, for example by bio-combinations, where the biomass is used to produce several different beneficial products, such as heating, electricity, bio-fuels, chemicals and other materials. Production of second generation bio-fuels has high priority.



- *Increased energy efficiency* is another principal focus for the development of a sustainable energy system. Many societal goals can be achieved by improved energy management and more efficient energy use. Research to promote improved energy efficiency concerns technological issues as well as social science and behavioural science aspects. An interdisciplinary approach is essential. Research concerning improved energy efficiency should focus both on the supply and distribution of energy and on its use in different sectors, such as urban areas (please also refer to the section entitled Sustainable Cities), industry and the transport system (see below).
- *Energy systems.* Issues focussed on individual systems and those impinging on other areas merit particular attention. This could, for example, be better use of generated heat that is otherwise lost, or waste energy from industry in communities, integration of electric and hybrid vehicles into the electricity grid, or the coordinated use of energy by industry for the concomitant production of energy in the form of fuel, power and heat, such as from biologically based chemicals and green materials. Efforts are not only needed in terms of technological system perspectives. Interactions between stakeholders of different types and between technology systems and the institutional frameworks these are encompassed by are important research areas. When there is a rapid increase in demand for natural resources it also becomes increasingly important from a societal perspective that finite resources are utilised in the most efficient manner. Social governance measures should be developed so that resources are used optimally, both from climate and supply/provision perspectives, taking into consideration the energy systems of today and of the future. The ambition should be to highlight optimal use of resources from a system perspective and to develop better grounds for evaluating potential advances.
- *Smart Grids.* Electricity networks need to be developed to enable these to be better at utilising a greater contribution from small-scale renewable sources and to be able to contribute to more efficient use of electricity by providing smarter energy services etc.
- *Electrification of the transport system.* Transport systems occupy a unique position, among other things because of the major increase globally in vehicles and transportation and the strong dependence on oil. There are major gains to be made in terms of energy efficiency, environmental impact and reduced oil dependency, from the use of electricity for (road) transportation. This area is also coupled to Renewable energy, Sustainable cities and Smart Grids.

- *Carbon Capture and Storage (CCS)*. The capture and storage of carbon dioxide can reduce the climate impact effects of both fuel-based energy facilities and industrial processes and may be an important over-bridging technology in reducing climate effects.

### **Marine environments**

The marine environment is extremely sensitive to different human activities, such as fishing, leakage of fertilisers from the land, release of toxins and waste, boat traffic, the introduction of non-native species and climate change. As coastal areas are becoming populated to an ever increasing extent and industrial activities in such areas are intensifying, the impact on seas and coastlines in the future will become even greater. There is also a human desire to use seas and coastal regions as areas for recreation and tourism, which imposes even more stringent demands for good stewardship of these aquatic environments and coastlines. This in turn must be based on a fundamental knowledge of both the aquatic systems themselves and the society using the oceans.

Sweden has a long tradition of marine research of high scientific quality. Marine research is carried out by many universities, university colleges and institutes, which is an advantage with regard to scientific diversity. The research performed, to a relatively large degree, focuses on causal studies. There is also however a clearly identified need for further intervention research.

The establishment by the Swedish Government in 2008 of the Swedish Institute for the Marine Environment is a step in the right direction in mustering marine environmental research. The Institute does not have the power, however, to affect the focus the research takes.

Research into and about marine environments is resource demanding, as access is needed to costly infrastructure in the form of research vessels, stations, laboratory facilities etc. To ensure accurate prognoses data of high quality is necessary, founded on well thought-out monitoring programmes with sufficient resolution in time and space. It is also important that technology development is a continuous process, so that research needs can be met with highly qualitative data. Research areas that are important and should be given priority in the future are listed below.

- *Biogeochemical cycles and eutrophication*. Biogeochemical cycles have a very important role, among other things, in the methods and rates of cyclic turnover in the oceans of nutrients and environmental toxins. Fundamental knowledge of biogeochemical cycles is a prerequisite for understanding the large-scale functions of marine environments and how problems of over-fertilisation affect and



are affected by these cycles. Eutrophication is understood by the majority of experts as the most serious environmental problem of all, especially in the Baltic Sea. The Baltic Sea Action Plan constitutes a major commitment and in all probability significant costs for both the state and the different stakeholders involved. For this reason research concerning the mechanisms of eutrophication is required. This includes clarification of how great a portion of eutrophication effects are dependent on external (actionable) stresses and how much is regulated by internal mechanisms and water turnover. The assessment of the tangible effects of intervention measures and cost-effectiveness in both planning and follow-up should also be included in this research.

- *Marine stewardship.* A knowledge-based, wise management of marine and coastal environments will be a prerequisite for future sustainable usage. Research is required in a number of areas, for example in the areas of marine and coastal zone planning, conflicts of interest and responsibilities, managing local fish stocks and other resources, socio-economic analyses of implementing and not implementing measures and the illustration of different policies (such as the water directive and the marine directive).
- *Sources and turnover of environmental toxins.* The concentrations of environmental toxins in sediment and the biota are not reducing to the extent desired. A better understanding of the sources of toxins and their turnover in marine environments is required. This also requires more research into naturally occurring toxins formed, for example, by algae and bacteria. These to a large extent can mimic anthropogenic toxins, but how do we distinguish between these and what regulates the formation of naturally occurring toxins? (Please also refer to the section entitled Chemicals).
- *Biological diversity and the introduction of non-native species into oceans.* A large fraction of the biological diversity of the oceans is still poorly understood and characterised and this is clearly coupled to conservation issues. Which species or other groups are important to protect? Is maintaining the function of an area more important than the species in that area? Biological diversity also concerns the effects that introduced or invasive species have on an ecosystem in which these become established.
- *Research to reduce negative impacts on the Baltic Sea environment.* Extensive knowledge development and the utilisation of research results are required to be able to solve the environmental problems in the Baltic Sea. This may be a matter of more efficient and safer marine transportation, solutions to reduce over-fertilisation or

the stresses imposed by hazardous substances, or may concern methods and technologies to rectify sites that have high concentrations of heavy metals or other toxic substances. A central factor is also the establishment of an environmental monitoring system that will ensure efficient and safe development.

### Sustainable cities

The year 2008 marked the turning point where for the first time the global population living in urban areas was greater than that living in rural areas. This trend is expected to continue, with major urbanisation expected in the world's poorer regions. In Sweden today approximately 80 percent of the population lives in urban areas. Metropolis areas with more than 10 million inhabitants are often a focus topic for growth debates, but the most substantial population growth is being experienced by small and medium-sized towns and cities. With regard to climate change, cities comprise both a threat and an opportunity in the achievement of a sustainable society. The residents of cities are responsible for a large fraction of global consumption and also consequently produce the majority of carbon dioxide and other types of emissions. In addition, the buildings in towns and cities are responsible for 30–40 percent of total energy consumption and around one third of CO<sub>2</sub> emissions. The construction sector is therefore very significant from an environmental perspective.

The development and problems of cities necessitates a global, multi-factorial and sector-spanning approach. There is a requirement for both long-term, cross-disciplinary general research and for in-depth investigations within individual disciplines. The interdisciplinary focuses are relatively well developed within this area. Below is listed a number of priority research issues.

- *The city as a system.* Research efforts are required to study cities as systems and to acquire clearer knowledge about the causative links between different processes in cities, for example as a basis for decision-making in whether to construct more population-dense cities, to reduce the climate effects of transport and at the same time to clarify air and lighting requirements and the need to conserve green areas. Knowledge is similarly required concerning possible systems for the economic development of cities, in keeping with aspects of organic resilience and long-term social and cultural development for those living and working in cities.
- *Urban planning.* Research into the planning of construction of cities needs to be developed with more in-depth studies into how different organisational urban planning and social and cultural groups within cities consume and produce goods and ecosystem services. One example is



the importance of parks and other green areas in and around cities. Green areas contribute to a good local climate, improved air quality and provide opportunities to save energy and manage and purify surface water. Knowledge is also required as to how urban ecosystems can be conserved and created in relation to ongoing climate change.

- *Relationships between urban and rural areas.* The increase in urbanisation leads to depopulation of the countryside. There is therefore a need for more knowledge of the mutual relationship balance between urban and rural areas and of how to support cyclical patterns involving goods and services between cities, surrounding suburban catchment areas and other parts of the country in order to achieve sustainable development throughout the entire country.
- *Sustainable and resource-efficient construction with low energy requirements.* The EU has adopted energy targets for buildings for the year 2020. By 2050 energy use by Sweden's buildings should be reduced by 50 percent. Major efforts will be required concerning existing housing and new and existing knowledge will need to be utilised to achieve the targets. Concomitantly buildings should offer a good indoor environment and functionality and this makes a system perspective important. Within the area of research into building techniques there is well developed knowledge of technical systems for individual buildings. This can be developed (for example insulation, window or ventilation systems), but improved knowledge is additionally required as to how different sub-systems and components work together in systems. This necessitates cross-disciplinary and multifactorial scientific construction research. In addition there is also a need for improved knowledge of construction and management processes with a focus on how new knowledge and technological advancements can be implemented. Issues concerning the importance of the role of IT become more pressing in planning, construction and management processes and require broad research approaches that take into account the balance between different aspects of technologies, financial and legal aspects, ecological and social conditions.
- *City infrastructures, communication and transport.* Energy, water, transport and waste management are fundamental infrastructural issues concerning cities. Access to clean water is today an international problem, but even in Sweden there are sometimes problems in the provision of drinking water supplies. In cities transport is a central aspect that impacts on air quality and noise pollution, congestion and communication possibilities. More stringent environmental requirements, rising fuel costs

and the computerisation of logistics flows have led in recent years to increased productivity, efficiency and innovation. At the same time cities are developing new strategies and policies to reduce private car traffic in favour of collective transport and the use of bicycles.

- *Practices, behaviours and the adaptation of society.* The embracing of new technologies, urban ecosystems and the role of the individual in creating a sustainable society are factors that are dependent on the structures that regulate human practices and behaviours. Ownership and administration in cities is changing. This requires research into the effects that these changes are likely to bring regarding the long-term sustainability of the city, as well as from ecological, economic and social perspectives. There is also a need for research focussing on how the ongoing social changes impact relations between politicians, civil servants and citizens. Similarly there is a need to elaborate new methods for the participation and influence of consumers and residents. There is a need for research that can obviate hierarchies and power structure relationships between, among other things, economic, ecological, social and cultural dimensions of sustainability.

## Chemicals

Both humans and the environment are continuously exposed to chemicals. There is a growing knowledge base regarding the damaging effects different chemical substances have on living organisms. Major challenges in this area concern reducing emissions and the spread of environmentally hazardous chemicals, developing alternatives to the use of particular chemicals and heightening the understanding of the dynamics concerning the spread and effects in the environment, as well as to be accurately able to determine exposure risks.

Research within the area of chemicals should be carried out in close collaboration with the relevant industrial sectors and with the regulatory government agencies and decision-makers concerned. This requires interdisciplinary research topics with contributory natural science, technology, medicine and social science elements. It is important that problems are identified not just from an ecological perspective, but also from a social and economic perspective.

Several important initiatives have been implemented in the last decade to reduce chemical emissions and therefore reduce exposure of humans and the environment to hazardous chemicals. Among the most important of these is the REACH directive governing chemicals and the two water-related directives, namely the framework programme for water and the marine directive. Meanwhile it has become clear during the implementation of both the REACH regulations



and the water directive that there are still many chemicals for which knowledge is lacking regarding their source, release and environmental distribution.

Research requires to be intensified within this area, primarily regarding intervention measures. This can be most suitably achieved by increased international collaboration. Below is listed a number of research issues of high priority.

- *Exposure and effects.* There is a major need for better knowledge of combined effects. Exposure and effects in children should be particularly considered, as the greater portion of prior research has focussed on exposure in adult males. Examples of 'chemical groups' for which knowledge is urgently required are nanomaterials and substances that interfere with hormones. Resources should also be allocated, however, to the identification of new groups of problem chemicals and routes of exposure. One example of this is risk assessment in terms of the effects pharmaceuticals may have on the environment.
- *Regulatory measures.* Research into new methods for reducing exposure for humans and the environment is required for hazardous chemicals. This is a matter of developing measures to be implemented for particular chemicals and chemical groups, such as banning and substituting chemicals, provision of information and environmental labelling, but also performing emission checks during production and recycling, as well as the management and purification of waste water and surface water. It is essential that this research is performed from a holistic perspective with regard to the entire life cycle of the chemical from the production of articles and products, through use and recycling in society and emission from point sources (such as water purification plants and leached water).
- *Costs resulting from damage.* Within many areas of environmental policy it has been demonstrated that it would have often been more cost-effective to have implemented preventive measures instead of having to attempt to repair damage retroactively. The chemical field is rich with such examples. Asbestos removal and PCB decontamination measures are just two that can be mentioned. Research regarding the costs to society as a result of damage caused by chemicals is therefore important. These may be decontamination costs, healthcare costs and costs for the payment of long-term invalidity benefits.

### **Climate change**

Future climate changes, measures to slow the effects of these and adaptation to impending conditions are some of the great global challenges. According to many studies it will cost a lot



of money to adapt society to cope with future climate changes and the longer we wait to implement measures in this area the more expensive it will become. There are many areas where there is a paucity of knowledge and further research efforts are required, but there are also areas where there is a plethora of knowledge but where this knowledge is not utilised to a sufficient extent in society. In general, interest in research concerning adaptation to climate change, as well as in measures to reduce climate change effects, has increased in recent years.

Characteristic for climate changes and the consequences of the effects of climate changes are that these encompass wide areas with distinct links to the six other category areas identified. The priority issues that are listed below are also characterised by their high relevance to society, as well as having insufficient current knowledge available or lacking sufficient validation. Climate change is an issue that must be solved over the long-term, but is an area where short-term efforts are also meaningful.

- *Implications, consequences and predictions.* Research is required into what climate changes will mean locally, regionally and from a global perspective. What will the consequences of climate change be and how certain are we?
- *The Earth as a system.* This area includes stand-alone effects, the aggregate consequences of changes, combinations, system effects etc. Until now research has been primarily directed towards single significant components, such as carbon dioxide levels in the atmosphere and the emission of greenhouse gases. The emission of particles and aerosols is an area where further knowledge is required. What are the aggregate consequences of individual changes? This is an important area which is being increasingly recognised internationally.
- *Social adaptation and important social utilities.* This area includes water supply, the management of water resources (access to fresh water in vulnerable areas, sea level fluctuations, including brackish water boundaries), groundwater fluctuations and the leakage of contaminants. Another issue is the risk of increased precipitation and thereby increases in water levels, which would result in greater erosion risks (shoreline erosion, protection of sensitive shorelines, beaches and river valleys). Studies of the risks are required (risk assessment, risk analysis) and protective measures (for example protection against contamination).
- *Design, measurement parameters and the interpretation of observations and monitoring systems.* These are essential basics to enable forecasting, climate modelling and climate

systems and are therefore important to invest in. Observations and measurements made in space, as well as paleoclimatology (studies of climate history over longer time periods) are examples of this area. Longitudinal measurement series are important, among other things to enable weather and climate to be differentiated.

- *Reduction of greenhouse gas emissions and other climate-related emissions.* Research of permafrost areas as "methane bombs" both on land and in the oceans is urgently needed. There are broad research activities ongoing in Sweden but there is a pressing need to continue, intensify and validate this research to be able to slow the effects of climate change (please also refer to the section entitled Energy).
- *Polar regions* (land, ice, sea, atmosphere and stratosphere) are the Earth's antenna and the prime indicators when observing climate changes. These are important for international climate studies and several scientific disciplines are active within the same physical environs. Polar research imposes great demands on research infrastructure.
- *Oceanic effects on climate.* The role the oceans play as climate regulators (for example in trapping carbon dioxide) is a research topic that will require investment. What role do ocean currents play? What regulates what? All of Earth's oceans are important in climate terms and these also play a significant part in food provision via fishing. Research in the Antarctic and Arctic oceans also has close links to polar research.
- *Policy development.* Strategies and policies are developed to address climate changes. A central issue is how different strategy and policy decisions influence the development and dissemination of solutions to problems to reduce the effects that humans exert on the climate or in adapting to climate changes. How is innovation stimulated? This area encompasses information, communication, decision-making processes and how human behaviour can be influenced.
- *Population mobility and tourism.* As climate changes happen it is predicted that global warming and food shortages will occur in many countries, resulting in population migrations that in turn will have major consequences. This category also includes effects on summer and winter tourism, essentially throughout the whole of Europe. This will be an important research area in the long-term.



## **Organisation of Environmental Research in Sweden**

Swedish environmental research is funded by a number of different funding bodies with different roles and mandates: research councils, government innovation agencies, government agencies with sector responsibilities and foundations. Formas regards the current division of roles and responsibility areas among these stakeholders to be distinct and to function well. It is of great worth to have diversity in funding so that good ideas and concepts can attract support. This diversity necessitates functional cooperation between funding bodies to ensure that research with broad perspectives and using several approaches can attract funding. Examples of this that can be mentioned are the necessities to fund both small projects (costing around SEK 3 million over three years) and larger programmes (with costs of around SEK 50–100 million over 5 to 10 years), in addition to funding research over the entire spectrum from basic research to applied research and implementation. There is therefore no need to introduce changes at the organisational level.

The funding bodies that have participated in this commissioned review recognise that diversity imposes demands for efficient collaboration between stakeholders. A continuous exchange of information between funding bodies in terms of initiatives, strategies and policy developments would provide opportunities to identify gaps in the environmental research system and allow for proposals to rectify such. Formas will therefore call environmental research funding bodies together a couple of times each year to exchange information and to discuss collaborations on common initiatives.

In addition Formas intends to establish a User Forum comprising representatives of consumers of research results (government agencies, companies, NGOs) and other national and international stakeholders who can contribute strategic advice for the prioritisation of research within the area of the environment. An advisory committee of this type working together with the funding bodies should facilitate collaboration and cooperation between the actors in this area and contribute to research focussed on resolving the needs of society for new knowledge.



### 3. Analysis of Swedish Environmental Research

According to SCB (Statistics Sweden) figures the total state funding of R&D activities for the year 2009 amounted to SEK 28 270 million. In charting the breakdown of funding in 2009 by category area this review has identified SEK 2 122 million as being Swedish investment in studies directed towards environmental research, of which SEK 2 096 million comprises state investment (excluding faculty funding).

#### **Mapping Swedish Environmental Research**

Table 1 shows funding in 2009 that was allocated by means equivalent to those of research council grant funding methods, direct funding of environmental research performed by government agencies and institutes carrying out research within the framework of their internal operations, as well as the financing of environmentally related infrastructure. These figures also include strategic investments totalling SEK 75 million annually allocated to Formas in accordance with the SOU 2008/09:50 government bill (*Ett lyft för forskning och innovation*) boosting research and innovation. It is too early to assess, however, the effects of this initiative on the entire research portfolio, as 2009 was the first year that this funding was awarded. The infrastructure underpinning this initiative is of major importance for environmental research and in many cases is a prerequisite for research of the highest quality. The infrastructure is operated and financed through different international and national collaborations.

In addition to the funding presented in Table 1 there is also funding from the EU framework programme, which is estimated to have awarded SEK 400 million to the environmental research area in 2009. Funding from commercial entities has not been included in this mapping. Further information concerning the mapping of research funding is available in the Appendix.

State funded environmental research is performed to a significant extent via direct grants of faculty funding to universities and university colleges. Faculty funding is a difficult area to dissect in terms of Swedish environmental research funding. To form a better picture of this a pilot study was

Table 1. Funding of Swedish environmental research in 2009.

	MSEK
<b>Funding awarded in ways equating to those employed by research councils</b>	<b>1 655</b>
Government agencies functioning as research funding bodies	1 356
Government foundations funding environmental research <sup>1</sup>	273
Private foundations funding environmental research <sup>2</sup>	26
<b>Direct state appropriations to agencies and institutes</b>	<b>122</b>
<b>Infrastructure for environmental research</b>	<b>345</b>
<b>Total</b>	<b>2 122</b>

<sup>1</sup> The Knowledge Foundation (KK Foundation) was not able to differentiate environmental research from other research funded and so is not included in this mapping.

<sup>2</sup> The Knut and Alice Wallenberg Foundation elected not to participate in this mapping.

performed on the faculty funding awarded to Stockholm University. This study demonstrated that from just over SEK 1 200 million allocated to Stockholm University in 2009 as faculty funding for R&D at university research level approximately SEK 245 million was devoted to environmental research, or in other words around 20 percent. The University of Lund estimates that around SEK 150 million of its faculty funding was used for environmental research in 2010. This information contains a great degree of uncertainty. The capacity was not available within the scope of the review to perform equivalent investigations for the other universities and university colleges carrying out environmental research. It can be concluded that the funding allocated in conjunction with the government bill SOU 2008/09:50 aimed at boosting research and innovation, to be allocated directly to universities to augment faculty funding, first came into effect in 2010 and so is not included directly in this review.

### Research focus

To illustrate the focus of the environmental research undertaken the research grants have been sub-categorised at a general level in accordance with the 16 environmental quality objectives. Certain projects of a basic research nature and studies with a social science focus have been categorised as environmental research without a specific environmental objective being able to be stated. These are to be found in the category "Other". Figure 1 shows the scope and profile of grants awarded for environmental research in 2009 by the nine funding bodies cited in the commissioning of the review. The figure shows that all of the funding bodies direct activities towards several of the areas represented by the environmental quality objectives and that many of the funding bodies are active within the same subject areas. Details about the individual funding bodies are presented in the Appendix.

Figure 2 shows the total amount of government funding allocated to environmental research in 2009, broken down by environmental quality objective, for all of the funding bodies that contributed material to the mapping. For several

## MSEK

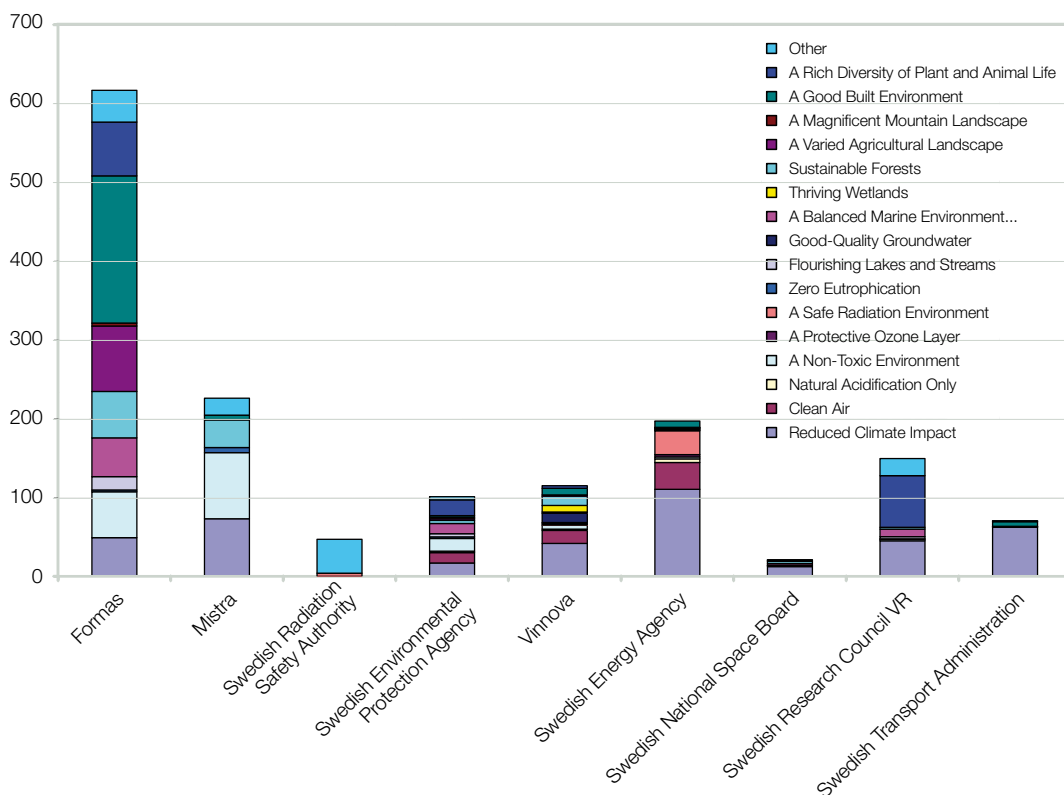


Figure 1. Grants awarded by nine state research funding agencies for environmental research in 2009.

of the foundations and for Sida and SP there was no categorisation by environmental objective and the funding from those stakeholders can therefore be found in the category “No breakdown by environmental objective”. The figure shows that the major portion of environmental research grant funding is allocated to the environmental objective category *Reduced Climate Impact*. Climate change has a high priority at national level and many of the funding bodies have announced calls in recent years targeting the climate area. This category includes research with very different focuses, for example climate models, alternative fuels, improving energy efficiency and the adaptation of species to altered climates. *A Good Built Environment* is a major environmental research area and Formas is the major source of financing in this category. There are also major investments directed towards the environmental quality objective category of *A Rich Diversity of Plant and Animal Life*, which encompasses research oriented towards biological diversity. Other major areas are *A Non-toxic Environment*, *Sustainable Forests*, *A Balanced Marine Environment* and *A Varied Agricultural Landscape*. It should be pointed out that the categorisation by environmental objective for a number of the funding bodies has been done on a general level. For this reason it may be possible that research that is relevant to the environmental quality objective *Zero Eutrophication* has been assigned to the category of *A Balanced Marine Environment* or *A Varied Agricultural Landscape*.

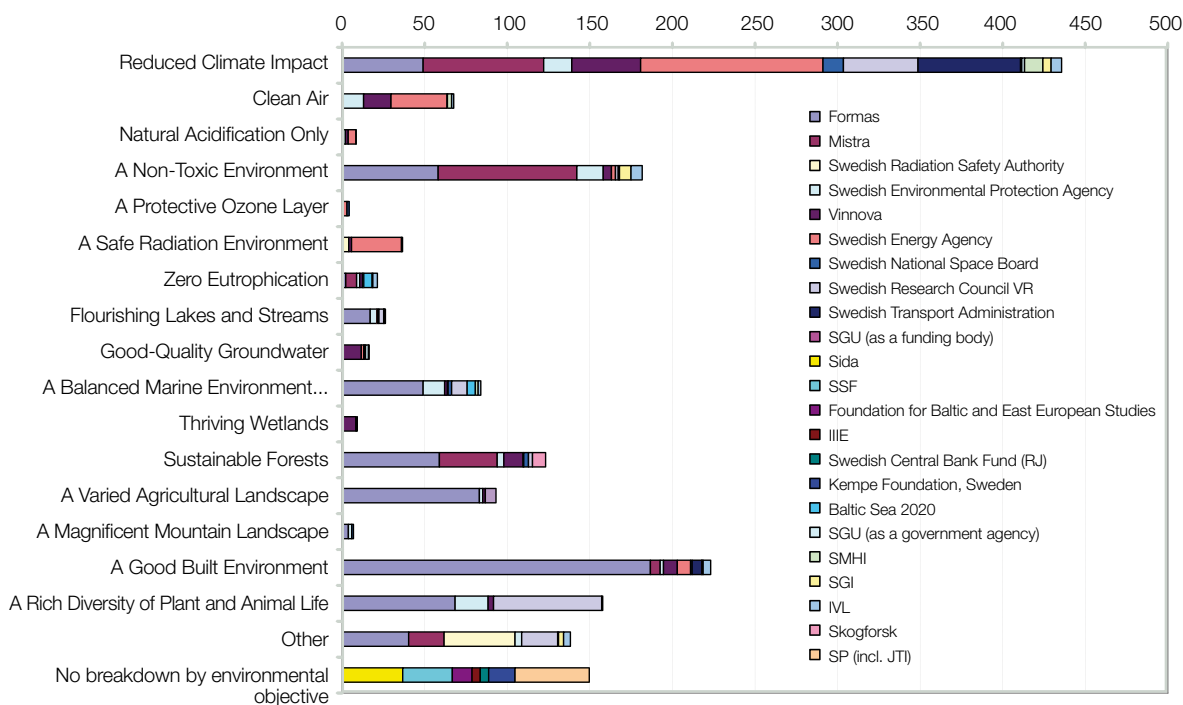


Figure 2. Funding of environmental research in 2009 divided according to the 16 environmental quality objectives.<sup>3</sup>

## Overall Conclusions

The following presents a summary of the answers to the questions this review was commissioned to investigate. The background material used in formulating these conclusions can be found in the Appendix. The review was commissioned to undertake an analysis of:

- A comparison between Swedish environmental research in terms of focus topics and scope and those of the other Nordic countries, other countries in Europe and the USA.
- An assessment of the division of responsibilities, roles and collaboration with regard to Swedish environmental research funding bodies.
- An overall evaluation of the balance between project-funded research and research programmes.
- The balance between environmental causal research and intervention research.
- An assessment of the specific national environmental research initiatives during the period 2000–2010.

<sup>3</sup> Several of the foundations, Sida and SP are included in the category “No breakdown by environmental objective”.

- An overall evaluation of the quality and relevance of environmental research, including comparisons based on other evaluations that have been performed.
- A mapping of how environmental research is organised and an assessment of the need to establish new centres for research or to introduce changes in how the research is organised.
- A description of the strong and weak research areas in relation to the needs of society.
- An assessment of how the results of environmental research are utilised and commercialised.
- An assessment of Swedish participation in the FP7 (seventh framework programme for research and technological development), as well as identification of the synergies that participation has facilitated and how participation impacts Swedish research funding.
- An analysis of the Nordic TFI Top Research Collaboration.

**A comparison of the focus topics and scope of environmental research with that of the other Nordic countries, other countries in Europe and the USA**

As has been previously stated, there is no standard definition of the term 'environmental research' and it has therefore been difficult to find comparative information concerning the investments of the different countries in environmental research areas. A comparison of the scope of environmental research in other countries has therefore not been possible to perform within the framework of this commissioned review. Information has however been gathered regarding how environmental research is funded, organised and focused. Mapping of environmental research in Denmark, Finland, Norway, the Netherlands, the UK, Germany and the USA is presented in the Appendix.

In several of the countries studied the research funding system is reminiscent of that in Sweden, but in Denmark and Finland the government appears to have a more direct influence over what research is performed within the environmental area. In Denmark research and innovation policies are synchronised and coordinated by the Danish Research Coordination Committee, which is a part of the Danish Agency for Science Technology and Innovation within the Ministry of Science. In Finland the Ministry of the Environment itself directs and funds certain environmental research efforts.

Several of the countries studied are similar to Sweden in having many stakeholders, both performing and funding research. In some countries there are examples of interesting

initiatives to improve coordination coherence between the actors involved. In the UK research funding agencies and research users work together to jointly ensure that the knowledge required by society is generated. Research institutes within the environmental sector in Finland have created a forum for cooperation. In Sweden environmental research is performed primarily by universities and in this respect Sweden differs from many of the other countries where research institutes play a larger role. Norway, Finland, the UK and the Netherlands belong to the group of nations where major fractions of environmental research is performed by government research institutes. Denmark has a more similar structure to Sweden, following a major organisational overhaul in the middle of the last decade.

As environmental research impinges into several areas this has conferred increased requirements for strategic national consideration. The UK carried out a strategic analysis of its environmental research activities in 2007. At that time a database was developed that has been kept updated and can function as a tool, for example, to identify past and current prioritised research areas, knowledge gaps and opportunities for collaborations. From 2004 onwards Denmark has had a dedicated strategic research advisory council to manage targeted, issue-driven research based on political initiatives and the major challenges faced by Danish society. Many countries recognise that there is a requirement for interdisciplinary research. Countries such as Norway and Finland have defined this as a priority area and have also chosen to introduce specific investments for expansive programmes with distinct interdisciplinary objectives.

In some countries, for example in the USA, efforts are being made to identify areas where knowledge is lacking and to prioritise research accordingly. A similar initiative has been implemented in Sweden, with Mistra and the Royal Swedish Academy of Sciences recent decision to establish an independent committee for the evaluation of environmental research with the aim of improving the basis for decision-making in environmental work.

### **Assessment of the division of responsibilities, roles and collaboration with regard to Swedish environmental research funding bodies**

The current system in Sweden, where there are many actors involved in the funding of environmental research, provides flexibility and contributes to diversity. The funding bodies that have participated in this review do not envision the need for changes to be introduced at the organisational level and believe that they complement each other well. The number of stakeholders involved does however impose demands for good cooperation between the Swedish funding bodies. Since the last government research bill there has been heightened cooperation between the different funding bodies.

Discussions held with the reference group illustrate that there is a need for further development and improved cooperation between the actors funding environmental research in order to achieve better coordination of initiatives, strategies and policy development. Some examples of this are:

- The EU framework programme is becoming an increasingly important funding source for Swedish environmental research. It will therefore be important for the funding bodies to have a common strategy in terms of how the EU framework programme will be used to generate added value.
- Certain problem topics concern the activity areas of several funding bodies. Improved cooperation would bring added value to such areas.

### **Assessment of the balance between project-funded research and research programmes**

Project-funded research has been defined in this review as research funded via open calls (bottom-up), while research programmes are defined as research funded in accordance with focussed thematic investments (top-down). There is naturally a need for both of these types of research funding based on the demands and needs of society. Research programmes funded according to focussed thematic investments can be used to direct research to the areas where clear needs have been defined. In addition, research programmes often have the possibilities to bring about much-needed interactions between different research areas and between scientists and the users of research results. At the same time, bottom-up initiatives that are made possible by project-funded research are required to stimulate and capture new ideas and new research areas.

This mapping of environmental research has demonstrated that a major portion of environmental research, around 65 percent, is performed within the framework of research programmes with a thematic focus. Programmes are used to direct research to areas where distinct needs have been defined, but the users of the results are seldom involved in the structuring of such programmes. The user value of such programmes and the benefits resulting from these would in all probability increase if the users of the research results were involved in the programme planning stages.

### **Balance between environmental causal research and intervention research**

Evaluations by the funding bodies of the focus of the respective operational activities demonstrates that approximately half of all Swedish environmental research that receives funding can be classified as causal research and half as intervention research. Causal research is defined here as research



*Casual research* is defined here as research undertaken with the objective of identifying and quantifying environmental problems as to gain an understanding of the causative factors underlying the environmental problem.

*Intervention research* is defined here as research undertaken with the objective of finding solutions to environmental problems.

undertaken with the objective of identifying and quantifying environmental problems as well as to gain an understanding of the causative factors underlying the environmental problem. Intervention research is defined here as research undertaken with the objective of finding solutions to environmental problems.

The profiles of the funding bodies with respect to a breakdown of funding by category of causal or intervention research are presented in the Appendix and it can be seen that there are distinct differences between the funding bodies. A more detailed study of Formas research funding has however demonstrated that different research fields have a trend bias in one direction or the other, and the differences are likely to be due both to the research field the funding body is active within and what the mandate of the funding body is.

### **Assessment of specific national initiatives for the period 2000–2010**

To date evaluations have only been carried out for a few of the national initiatives implemented in the environmental research area since the year 2000. Those evaluations that have been performed demonstrate that these efforts have yielded worthwhile additional knowledge in important areas. It is also clear that specific national investments can be valuable in concentrating major efforts targeting problem areas that span discipline boundaries. Initiatives of this type are judged to provide particular added value if they generate interdisciplinary collaborations between different research groups, or if they provide better opportunities to involve users of the research results in the research process itself. The evaluations have also demonstrated that national initiatives can make a major difference and give clear added value, but it can be necessary to divide funding in accordance with specific frameworks, such as a demand for an interdisciplinary approach, the involvement of users, a well developed strategy for dissemination of results, etc.

### **Assessment of the quality and relevance of environmental research**

Some 30 evaluations have been studied that have been carried out by the funding bodies named in this government commissioned review (each of these evaluations is listed and summarised in the Appendix). In summary it can be concluded that the research that has been evaluated in the majority of cases has been assessed to be of good quality. It has been observed within certain areas that the number of resultant publications has been fewer than anticipated. This applies particularly to the areas of agriculture, forestry and energy systems, as well as to some extent urban environmental development and architecture, where it has been noted that the frequency of international publication is low.

Many of the evaluations have taken into account the societal relevance of the research, which in general has been judged to be high. This applies, for example, to marine environments, agriculture, forestry, wildlife and game, as well as energy research. The dissemination of research results to potential users is however cited in several instances as an area in which there is significant scope for improvement. But there are a few exceptions. Skogforsk is cited as a very active stakeholder when it comes to dialogue between researchers and users and researchers involved in game/wildlife research has also been exemplary in disseminating results to users.

A recurring recommendation of the evaluations is to invest in encouraging increased collaboration between research groups, both nationally and internationally. This aspect is stressed in evaluations of environmental research within areas such as organic production, biological diversity, architecture, energy systems and remote sensing analyses. In several instances the evaluations have sought a higher degree of interdisciplinary research. The need for increased international collaboration has also been pointed out in reference group discussions.

### **Mapping of how environmental research is organised and an assessment of the need to establish new centres for research or introduce changes in the organisational structure**

The majority of Swedish environmental research is performed by the universities. From a starting point of the distribution of research funding by Formas, Mistra and the Swedish Environmental Protection Agency, the single largest actor in the area is SLU, followed by the universities of Lund, Stockholm, Gothenburg, Uppsala and Umeå. In recent years a number of centres with an environmental research focus have been established within the Swedish universities. Some of these have been the result of specific government initiatives and others have been established by the research funding bodies or through the initiative of the universities themselves.

Mistra has concluded that the focus of environmental research has changed from primarily being focused on the natural sciences and technology to focussing more on social science-based environmental research. The building of centres is characterised by interdisciplinary collaboration within and between educational institutions, as well as by close contact with stakeholders from outside the academic environment. The increase in the number of centres being established demonstrates distinctly how the nature of environmental problems necessitates this type of environment.

In conjunction with this review Formas has not identified a need to initiate the establishment of any new centres. It

cannot be excluded, however, that such need may arise, or that there may be a reason to concentrate particular major efforts within the universities.

### **Description of strong and weak research areas in relation to the needs of society**

A number of priority research areas were identified in section 2. There now follows a summary of the position Swedish research holds within these seven prioritised areas. In general it can be concluded that Sweden has a strong position when it comes to research within individual disciplines. A need has been identified, however, to improve interdisciplinary research efforts to provide environmental research with better prerequisites to meet the knowledge requirements of society.

Climate change is an area that Swedish research has a strong position in. Predictive modelling, atmospheric and polar research are some of the areas in which Swedish research occupies a leading position. An area that in contrast is regarded to be relatively weak is interdisciplinary implementation research.

Swedish energy research is based to a large extent on the prevailing national conditions, such as natural resources, industrial structure and climate. Areas where Swedish research occupies an advanced vanguard position include therefore bioenergy from sustainable forestry, electric and hybrid vehicles and bio-fuels, energy-intensive industry, urban energy use, etc.

Within the field of efficient and sustainable use of natural resources there are strong research groups within the areas of molecular genetics, bio-based materials, woodland ecology, environmental effects and plant diseases.

Within the biological diversity category there are strong Swedish research groups working with forestry, aquatic and agricultural ecology and there is great competence within taxonomy, evolutionary biology, population biology, conservation genetics, microbial ecology, climate and ecosystem modelling, economics and landscape ecology. Even within this area interdisciplinary research has been identified as an issue requiring larger investment.

Swedish environmental research in the chemical field has in many contexts been world-leading and has had major global significance in areas such as environmental chemistry, including analysis development, toxicology, ecotoxicology and environmental medicine. These areas have primarily focussed on exposure and effects on humans and the environment and there are strong Swedish research groups in this area. Research that is more focused on intervention is weaker. There is some research of high quality within the field of technology

development, for example in purification techniques, but this research should be augmented. One growing area that requires further strengthening is research into the sources of chemicals and their distribution in society.

There is a good knowledge base in the area of sustainable cities, where Swedish research also occupies a strong international position. There is positive development in research in this area, with focus topics being urban climate and energy issues, ecosystem services and environmental economics. Previous evaluations have assessed a number of interdisciplinary initiatives as having been particularly successful. The research environments at the Stockholm Resilience Center and at the Graduate School for Energy at KTH have been cited as role models by both international and national experts because of their conscious efforts to place an emphasis on interdisciplinary research. Sweden has traditionally been a prominent nation within construction technology, for example within areas such as material research, energy technologies and energy utilisation, as well as in indoor environments and health. These vanguard positions are not as self-evident today.

Swedish marine environmental research is in general of high scientific quality and deals with issues that are of great societal value. The research is however somewhat fragmented between educational institutions and is primarily focussed on causal studies. Intervention studies need to be augmented.

### **Assessment of how research results are utilised and commercialised**

A major portion of the environmental research performed to date is relevant for society. According to several evaluations performed previously, however, there is a need to develop the methodology for disseminating research results to potential users in order to ensure that research results really are utilised by the user community. There is also an urgent need to increase efforts to ensure that Swedish research results are commercialised. This applies in general, but is also relevant to the area of the environment.

Formas judges that there is a need for improved dialogue with the users of research results as a foundation for ensuring that researchers formulate relevant research questions to investigate.

Several of the nine funding bodies participating in this review have made major investments in innovation and development within the area of the environment and the conclusion is that there is a need for coordination among the funding bodies in order to take all aspects of basic research, applied research, product development and commercialisation into account.

## **Assessment of Swedish participation in FP7 – synergies and impact on Swedish research funding**

Swedish participants in EU projects have received funding of almost SEK 6 000 million since the programme began in 2007. FP7 (the seventh framework programme) is therefore an important source of funding for research and development in Sweden. The EU framework programme has been estimated to have contributed SEK 400 million to Swedish environmental research during 2009 (information detailing how this estimate has been calculated is presented in the Appendix). This would make this framework programme the second largest funding source for Swedish environmental research next to Formas. This demonstrates that Swedish scientists and research groups have been successful in terms of being awarded EU grants.

To be able to cope with the major challenges of the future, environmental research must be internationalised further. This will increase the likelihood that high quality and relevance will be achieved. In several of the evaluations that have been studied within the scope of this review (see Appendix) it has been concluded that Swedish environmental research in many instances has a need to increase international collaboration. The EU framework programme creates opportunities for Swedish researchers to collaborate with the best researchers within the EU, which should be encouraged.

This makes it important that funding allocated by Swedish research funding bodies contributes to establishing research groups capable of competing within the EU framework programme. This is therefore an area where cooperation between the Swedish stakeholders funding environmental research takes on major significance. This cooperation needs to be further developed and Formas will take initiative in line with this in cooperating with other funding bodies.

### **Analysis of the Nordic TFI Top Research Collaboration**

In the autumn of 2008 the Nordic countries joined forces to create a top research collaboration initiative (TFI), which is the largest Nordic research and innovation effort to date. With a budget of around SEK 500 million apportioned over five years, the initiative focuses on areas concerning climate and energy research that is of mutual interest to the Nordic countries. This is the largest research initiative that has ever existed within the framework of collaboration between the Nordic countries.

Collaboration within the TFI demonstrates that the Nordic countries have many common issues. Researchers within the Nordic countries also share common values and principles, which provides good preconditions for joint efforts.

The TFI was established in 2008 and the first call for proposals was in 2009. It can already be concluded, however, that the TFI functions as a valuable forum for Nordic researchers to work together. Within environmental research there is in general a great need to collate and map the research that already exists. Through such synthesis important research advances can be made and the TFI contributes to exactly this by affording the Nordic researchers opportunities to meet, compare data and discuss the research results emanating from other countries.

Nordic collaboration is of great value when it comes to environmental research. No decisions have been taken as to what will happen when the TFI ends. If there should be similar initiatives within the framework of examining challenges faced in the area of the environment this would be of major interest to Swedish environmental research.



# Appendix.

## Background material for the analysis

### **1. Mapping of environmental research funding**

#### **Funding awarded in ways equivalent to those employed by research councils**

To obtain an overall picture of Swedish environmental research the apportioning of funding by the funding bodies has been mapped for the year 2009. In 2009 the total sum allocated to fund environmental research that was awarded in ways similar to the distribution of research council funding, in the form of open calls or within thematic programmes amounted to SEK 1 507 million (Table 2). Formas awards the largest amount of funding for environmental research and around 75 percent of the grants awarded by Formas in 2009 were allocated to research of relevance to the environmental quality objectives. It can also be noted that all of the funding awarded by Mistra and the Swedish Environmental Protection Agency is allocated to environmental research. For the other funding bodies environmental research constitutes a portion of the grants awarded. Grants from the nine funding bodies named in this review constitute 85 percent of the total funding of environmental research that is awarded by means similar to the format employed by the research councils, i.e. faculty funding is not included. Of the other authorities and foundations Sida is a significant sponsor of environmental research, even if one only takes into account the portion of Sida's operations that are allocated to Swedish researchers by means similar to those of the research councils. The funding agencies are described in section 6 and comments regarding the figures used for mapping the funding awarded can be found in section 7.

A major portion of this funding has been allocated within thematic research programmes. Project-funded research has been defined in this review as research funded via open calls (bottom-up), while research programmes are defined as research funded in accordance with focussed thematic investments (top-down). Where the boundaries should be drawn is not always, however, entirely self-evident. The assessments of the funding bodies themselves as to how grants are apportioned between these categories are presented in Table 3.

**Table 2. Total research funding and the portion allocated to environmental research in 2009 by funding bodies awarding grants in ways equating to those of the research councils.**

Stakeholder	Research funding (SEK)	Portion allocated to environmental research (SEK)	Environmental research total (SEK)
<b>Government agencies functioning as research funding bodies</b>			<b>1 356 491 000</b>
Formas	814 865 000	616 769 000	
Swedish Radiation Safety Authority	84 500 000	47 000 000	
Swedish Environmental Protection Agency	101 000 000	101 000 000	
VINNOVA	1 107 000 000	115 000 000	
Swedish Energy Agency	197 000 000	197 000 000	
The Swedish National Space Board	62 437 000	21 180 000	
Swedish Research Council (VR)	3 220 000 000	149 431 000	
Swedish Transport Administration	865 000 000	70 622 000	
SGU (as a funder of research)	5 509 000	1 750 000	
Sida	1 000 000 000	36 700 000	
<b>Government foundations funding environmental research<sup>4</sup></b>			<b>273 000 000</b>
Mistra	226 000 000	226 000 000	
SSF	498 000 000	30 000 000	
Foundation for Baltic and East European Studies	260 000 000	12 000 000	
Swedish Central Bank Funding – Riksbankens Jubileumsfond (RJ)	317 000 000	5 000 000	
<b>Private foundations funding environmental research<sup>5</sup></b>			<b>26 000 000</b>
The Kempe Foundation, Sweden	53 000 000	16 000 000	
Baltic Sea 2020	10 000 000	10 000 000	
<b>Total</b>			<b>1 655 491 000</b>

<sup>4</sup> The Knowledge Foundation (KK Foundation) was not able to differentiate environmental research from other research funded and so is not included in this mapping.

<sup>5</sup> The Knut and Alice Wallenberg Foundation elected not to participate in this mapping.

**Table 3. Environmental research funding awarded in 2009 apportioned according to project funding and research programme funding for the nine funding bodies.**

Funding body	Project funding	Research programme
Formas	50 %	50 %
Mistra	10 %	90 %
Swedish Radiation Safety Authority	10 %	90 %
Swedish Environmental Protection Agency	0 %	100 %
VINNOVA	0 %	100 %
Swedish Energy Agency	50 %	50 %
The Swedish National Space Board	100 %	0 %
Swedish Research Council (VR)	65 %	35 %
Swedish Transport Administration	0 %	100 %
<b>Total (funding)</b>	<b>35 %</b>	<b>65 %</b>

### Direct grants for environmental research

Direct funding of environmental research by government agencies and departments amounted to SEK 122 million in 2009 (Table 4). Government agencies performing state funded environmental research within the framework of their own

**Table 4. Direct state funding of environmental research allocated to agencies and institutes in 2009.**

<b>Stakeholder</b>	<b>Environmental research funding (SEK)</b>
SGU (internal research)	4 000 000
Sgi	15 000 000
SMHI	17 000 000
IIIIEE	5 000 000
IVL	28 000 000
Skogforsk	7 900 000
SP Group (including the JTI)	45 000 000
<b>Total</b>	<b>121 900 000</b>

operations include SMHI (Swedish Meteorological and Hydrological Institute), SGI (Swedish Geotechnical Institute) and the SGU (Geological Survey of Sweden). The IIIIEE (International Institute for Industrial Environmental Economics) is partially state funded through the IIIIEE national foundation. Other research institutes carrying out environmental research with the support of state grants are the IVL (Swedish Environmental Research Institute), the foundation for forestry research institute Skogforsk and the SP Group, including the Swedish Institute of Agricultural and Environmental Engineering (JTI). These institutes have several sources of financing and the state grants for environmental research presented here are only a portion of total financing. Skogforsk and JTI receive direct financing via Formas, while IVL receives funding from both Formas and the Swedish Environmental Protection Agency. These stakeholders are described in section 6.

### **Infrastructure**

A well functioning infrastructure is crucial to the success of the research within several environmental sub-categories. Funding for this is provided in part by other stakeholders. Infrastructural initiatives that are of major importance to Swedish environmental research are listed below. Certain initiatives are run and financed nationally while others are administered through international collaborations.

*Swedish Research Council – Council for Research Infrastructure (RFI).* The Council for Research Infrastructure works to promote and support the establishment and use of infrastructure to enable Swedish researchers to have access to an infrastructure that facilitates research of the highest quality. There are many infrastructural amenities in Sweden, but to meet the infrastructural needs of researchers in all areas Sweden also has agreements with international facilities and organisations. In addition to the initiatives listed in Table 5, large amounts are also spent on facilities such as the NIC and the MAX Laboratory, which can be used for climate modelling and environmental analyses, among other things. Two new initiatives were introduced in 2010 that are not listed in Table 5: ICOS (a station for monitoring carbon dioxide cycling) and LifeWatch.

*Polar Research.* Infrastructure related to polar region expeditions is financed by the Swedish Polar Research Secretariat. The Secretariat administers two Swedish research stations in the Antarctic and the ice-breaking vessel Oden, which is leased from the Swedish Maritime Administration for research expeditions. Infrastructural support is administered jointly between the Swedish Research Council and Mistra.

*ECDS.* Environment Climate Data Sweden (ECDS), previously the SND KM, is a service organisation at SMHI for Swedish research within climate and environmental areas that facilitates researcher access to existing data, both within Sweden and externally. The ECDS focuses on collecting and disseminating data information and on developing information about standard practices and tools for documentation and data access.

*Satellites and satellite data.* The Swedish National Space Board provides financing, primarily for satellites, through the European Space Agency, ESA, where a major focus is placed on satellites studying environmental and climate issues. Satellites for research and for weather and climate applications are developed by EUMETSAT, where Swedish participation is financed by the SMHI. The Swedish National Space Board also participates in bilateral collaborations concerning satellites and instrumentation and has also in the past funded national research satellites. The Swedish research satellite Odin is currently supplying data for studies of the atmosphere. ESRANGE is an important research facility for weather balloons and rocket probes used in climate and environmental research. This is paid for partially by the Swedish National Space Board in collaboration with other countries. A national satellite database, SACCESS, is financed by the Swedish National Land Survey (Lantmäteriet).

**Table 5. Swedish contributions to environmental research infrastructure in 2009.**

Infrastructure	Responsible stakeholder	Costs (MSEK)
ESA – satellites monitoring the environment and climate	The Swedish National Space Board	98
Larger Swedish research stations	Several different principal stakeholders	70
EUMETSAT – satellites monitoring weather and climate	SMHI	47
Satellites and satellite data plus ESRANGE	Swedish National Space Board/National Land Survey	34
Swedish Species Information Centre	SLU	32
Infrastructure for polar research	Swedish Polar Research Secretariat/VR	25
Expensive scientific equipment	VR	10
ECDS – climate and environmental data	VR/SMHI	6
EISCAT – radar stations for atmospheric studies	VR	6
IODP/ECORD, NEM, ICDP – scientific drilling	VR	6
Facilitating access to databases/systems	VR	5
GBIF Data on biological diversity	VR/Swedish Museum of Natural History	4
Operation of NORDSIM - second	VR/Swedish Museum of Natural History	2
<b>Total</b>		<b>345</b>

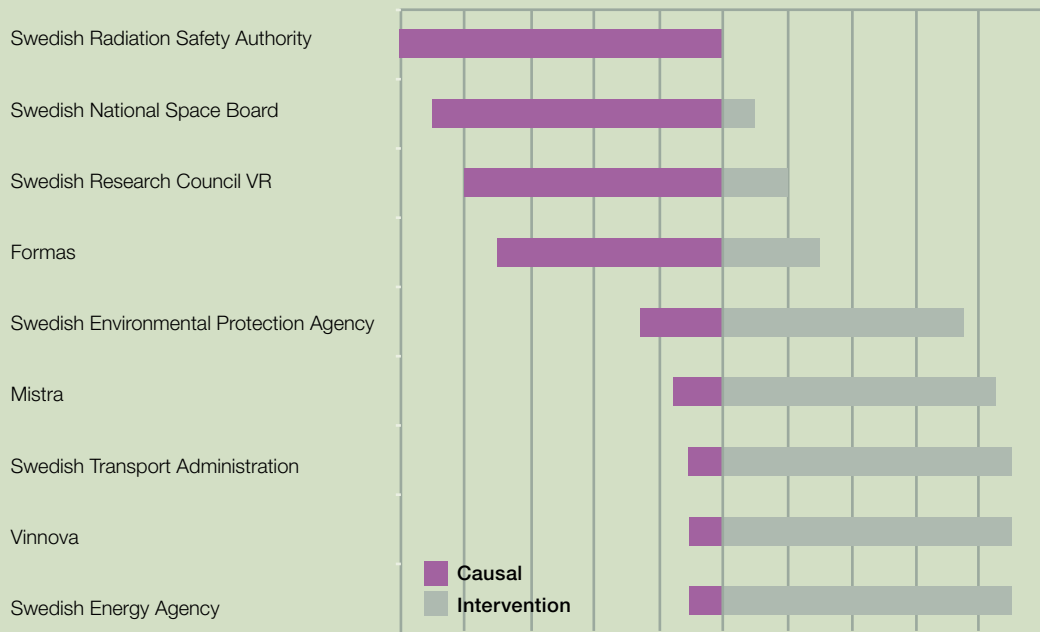
*Research stations.* Research stations comprise a significant infrastructural aspect for terrestrial research. Swedish terrestrial research stations are run by different principal stakeholders and to date have limited synchronised cooperation. There is currently no overview that delineates which stations are of international, national or exclusively local interest. Better coordination of Swedish research stations would improve both the access of Swedish researchers to important infrastructural resources and would increase the potential for Swedish stations to be involved in EU projects, among other things. The RFI has initiated a review with the objective of developing a background for decision-making concerning research stations and other infrastructural facilities for terrestrial research field studies (including limnology).

*Vessels and marine stations.* On the marine environment side there is comprehensive infrastructure in terms of research vessels and marine stations (UMF Norrbyn, the Askö Laboratory, Klubbans Biological Station, the Sven Lovén Centre for Marine Science, as well as the research station at Ar). The costs for these have not been calculated within the framework of this review, but these in all probability constitute a substantial fraction of the funding allocated for environmental research infrastructure.

### **Research on environmental causative effects and intervention measures**

Causal research is defined here as research undertaken with the objective of quantifying environmental problems as well as gaining understanding of the causative factors underlying the environmental problems. Intervention research is intended to mean research undertaken with the objective of finding solutions to environmental problems. Collectively around half of the environmental research funded can be viewed as causal research and half as intervention research. Figure 3 shows that the funding bodies have different respective focuses and different roles in the funding of causal and intervention research.

The Swedish Radiation Safety Authority and the Swedish National Space Board operations focus on causal research while VINNOVA's and the Swedish Energy Agency's research funding is focussed towards intervention research. Formas, the Swedish Environmental Protection Agency and the Swedish Transport Administration fund both aspects. The fulcrum of funding awarded by Formas tends to be shifted towards causal research, while the Swedish Environmental Protection Agency, the Swedish Transport Administration and Mistra's funding more concerns intervention research. Variation is however great within the portfolios of each of the stakeholders involved. Within the operations of Formas there is a tendency, for example, for construction-related research to be more focused towards intervention research, while



**Figure 3. Percentage estimated apportioning of funding between causal environmental research and intervention research for each funding body (20 percent per scale division).**

projects with areas such as ecology are more causally related. It should be pointed out that all environmental research does not lend itself to classification in this manner.

## 2. Specific national initiatives

During the last decade the Swedish Government has initiated nine specific thematic initiatives related to the area of environmental research. These are:

- Environmental and sustainable development, Parliamentary Bill 2000/1:3, SEK 20 million, 2001–2003
- Biological diversity and sustainable ecological development, Parliamentary Bill 2001/01:130, SEK 630 million, 2002–2009
- Strengthening research environments, Parliamentary Bill 2004/05:80, SEK 300 million, 2006–2008
- Sustainable development, Parliamentary Bill 2004/05:80, SEK 210 million, 2005–2008
- Energy, Parliamentary Bill 2008/09:50, SEK 310 million, 2009–2012
- Sustainable use of natural resources, Parliamentary Bill 2008/09:50, SEK 70 million, 2009–2012
- Impacts on natural resources, ecosystem services and biological diversity, Parliamentary Bill 2008/09:50, SEK 75 million, 2009–2012
- Climate models, Parliamentary Bill 2008/09:50, SEK 40 million, 2009–2012
- Marine research, Parliamentary Bill 2008/09:50, SEK 40 million, 2009–2012

Evaluations have been carried out of sustainable development, biological diversity and Linnaeus environments (see section 8).

In the evaluation of the social science research aspects within sustainable development it was judged that there had been positive development in the area due to the increased funding and an increased number of doctors. The initiative had also led to positive development towards more interdisciplinary research. On the other hand, however, a lack of communication was identified between users of the research results and the researchers.

In the evaluation of the biological diversity initiative it was stated that a number of strong research groups had developed within certain disciplines. Lack of collaboration was identified, however, between both research groups nationally and with international research environments, as well as between the researchers and users of research results. This is likely to be due to the fact that a large portion of the funding was awarded to research within already established research fields and to a lesser degree to interdisciplinary efforts within new areas.

The Swedish Research Council and Formas have performed an initial evaluation of Linnaeus environments, which is one aspect of the initiative to strengthen research environments. These efforts have not come very far as yet and it is therefore difficult to draw any finite conclusions. It can however be determined that the majority of these environments have a fundamental organisational structure in place and can demonstrate collaborations. Variation between research environments is great, including the extent to which the Linnaeus environments have developed their own identity and profile.

### **Strategic Research (SFO)**

In the most recent government research bill (2008/09:50 "Ett lyft för forskning och innovation") aimed at boosting research and innovation, the five government agencies comprising the Swedish Research Council (VR), FAS, Formas, VINNOVA and the Swedish Energy Agency were tasked with announcing calls and evaluating applications for funding within twenty strategic research areas. These bodies submitted their recommendations to the government during the spring of 2009. The Swedish Government decided to award support for a total of 43 research environments within the 20 areas for the period 2010–2014. This funding means raising levels over a five year period, which following an initial escalation in 2012 will amount to SEK 1 350 million annually. Investment of SEK 748 million is also earmarked for infrastructure over the same time period, within the framework of the strategic initiatives. As these increases concern funding directly

to universities from 2010 onwards, they have not been included in the summary presented in the above mapping of Swedish environmental research funding.

The government agencies were however tasked as part of their mandate to perform annual follow-up reviews. The first of these annual follow-ups was delivered to the Swedish Parliament on 30 March 2011. The main conclusions are summarised in the following points:

- It is the collective assessment of the government agencies that the educational institutions demonstrate high ambitions to fulfil the objectives of the initiatives and on the whole in the first year have been positive towards developing SFO environments.
- SFO funding has made it possible for the educational institutions to implement measures that would not have been possible with normal faculty funding. For example, they have been able to create broader research themes that are better aligned to the needs of society and commerce. Many of the environments have utilised the possibilities to buy equipment to augment the local infrastructure.
- Activities over the first year have primarily focused on structural aspects of environments, as well as management and organisational issues in addition to research. International recruitment has taken place in many cases.
- Each SFO environment consists in general of four research groups with strong scientific profiles. Many of the environments are partially based in existing centre initiatives that are funded by research councils, government agencies, strategic foundations or the EU.
- In replies to questionnaires the SFO environments describe the relevance of the area to industry and society in varying degrees. Companies or public sector parties have often been involved in the formulation of the problem to be addressed by the research. Many of the environments include skilled parties from the surrounding community.
- One impression is that many SFO environments in the coming years will improve their possibilities of contributing to sustainable growth and renewal in the commercial and public sector if they involve commerce and public sector operations in their research to an even greater extent. Therefore the innovation potential is difficult to judge. This will need to be followed up.

- The funding provided by the government in the total funding for the environments comprises in total an average of 15 percent. The variation between environments is however great.
- In total around two thirds of the government funding has already been spent, or in other words around SEK 291 million of SEK 435 million.

The entire initiative will be evaluated in 2015.

In addition to the funding allocated to the universities directly, the government agencies also announced calls for grants within the twenty strategic areas. This funding, which has been paid out from 2009 onwards, is included where suitable in the summary of Swedish environmental research for the year 2009.

### **3. Benefit and commercialisation**

Environmental research has many roles in environmental work in addition to generating new knowledge. Important tasks in society are to measure, monitor and evaluate environmental conditions and to provide support for decision makers in policy-making and the provision of information to society. Environmental research is also expected to lead to the commercialisation of new products and to develop and make public activities more efficient. All of the funding bodies named in this review with the exception of the Scientific Research Council (VR), distinct links to utility and/or commercialisation.

Formas evaluates applications with regard both to scientific quality and value to society. Mistra places equal emphasis on regard to environmental strategic value to society and scientific quality. The Swedish Environmental Protection Agency, the Swedish Transport Administration and the Swedish Radiation Safety Authority couple research funding directly to their authority mandates. They initiate research initiatives according to their requirements and have the capabilities to manage and fund research results in practice.

The Swedish Energy Agency's funding of research and innovation is directed towards building the knowledge and skill base needed to facilitate conversion to a long-term, sustainable energy system and to develop technologies and services that can be commercialised and thereby contribute to growth and the development and conversion of the energy system. The Swedish National Space Board has a separate programme dedicated to carrying the environmental research funded through to utilisation. VINNOVA's investments in environmentally related research are aimed at solving environmental problems, creating good prerequisites for the development of environmental innovations and improving information for decision-making. The research encompasses issues concerning

management control measures, policy instruments, behavioural changes, planning, infrastructure, system and technical development. Utility is a central aspect in the evaluation and prioritisation of applications and in many cases there are customers or users of the results represented in the projects.

In the 2008 government research bill an amendment was initiated for introduction into the Swedish Higher Education Act (1992:1434) so that the so called third reform from 2009 came to encompass even "to act for research results generated in universities and colleges to be utilised". The utilisation of environmental research results should be able to be made more efficient by increasing the level of collaboration between the Swedish bodies funding research and development within the area of the environment and by increased dialogue with users of the research results.

As has already been mentioned, environmental research is of great importance in providing support for decision makers in terms of development of legislation, regulations, policy development and other political decisions. The Swedish Environmental Protection Agency includes dialogue with researchers in its programme for evaluating how scientific results can be made accessible for specific purposes, such as international negotiations and the like.

When it comes to the commercialisation of research results it was concluded in the action proposal for Swedish environmental technologies (Swentec 2009) that Sweden devotes much resources to research and development and comes out top in international comparisons of powers of innovation, but should be able to produce more companies as a result of the research. Swentec means that opportunities to obtain funding need to be improved in Sweden and that there are few efforts made to stimulate access to private risk capital. Another area highlighted in the Swentec proposal is the need for better coordination and increased collaboration between different stakeholders.

#### **4. Organisation**

##### **Division of responsibilities among the funding bodies, their different roles and collaboration**

From the summary presented in section 1 it can be concluded that the environmental research funding bodies complement each other in such a way that the area is well covered. The funding bodies in respective sectors (The Swedish Transport Administration, the Swedish Energy Agency, the Swedish Radiation Safety Authority) fund research intended for application within their own sectors and that would probably have difficulty attracting funding from the research councils. A certain degree of overlap between funding bodies can function as a guarantee that ideas do not fall between the cracks. The foundations have an important role as they

have the possibilities to award funding support different from that of the research councils. The different forms adopted by funding bodies in their work also contribute flexibility and diversity. This means that new concepts and ideas, both thematic and structural, can be relatively easily introduced under the existing organisational structure. The funding bodies participating in this review perceive the current divisions of responsibilities and roles as being distinct and functional and do not see a need for changes at the organisational level. Diversity does however impose demands for efficient collaboration between the funding bodies.

Since the previous government research bill there has been heightened cooperation between the different funding bodies. A collaboration committee comprising the heads of Formas, FAS, the Swedish Research Council (VR) and VINNOVA work together on a number of issues. The purpose of this collaboration is to act to enable government agencies to jointly develop analyses, strategies and research programmes and also to take initiatives in developing and revising forms of research collaboration. This group has, for example, compiled supporting material for new joint initiatives, including areas such as the health of children and adolescents. A number of sub-committees have been established for the development of cooperation within specific areas, such as analysis and information issues. The government agencies are also working together to a greater extent within specific initiatives, such as the strategic initiatives in which Formas, together with VR, FAS, VINNOVA and the Swedish Energy Agency, perform annual follow-ups and are to undertake a review of after five years.

### **Organisation of the research**

The majority of Swedish environmental research is performed by the universities. In recent years a number of centres with an environmental research focus have been established by Swedish universities. Some of these have arisen from specific government initiatives that have taken the form of what has been termed the Linnaeus grants. The CeMEB – the Linnaeus Centre for Marine Evolutionary Biology at the University of Gothenburg and LUCID – the Lund University Centre of Excellence for Integration of Social and Natural Dimensions of Sustainability belong to this category. Some centres have been established on the initiative of the research funding body, such as the Mistra-funded Stockholm Resilience Centre at Stockholm University and the Mistra Urban Futures centre in Gothenburg. Other centres have resulted from the universities themselves taking the initiative, such as the GMV, Gothenburg’s centre for environmental science. The building of centres is characterised by interdisciplinary collaboration within and between educational institutions, as well as by close contact with stakeholders from outside the academic environment.

## The EU framework programme

The EU's seventh framework programme (FP7) runs from 2007-2013 and is the largest research programme in the world with its total budget of Euro 53 000 million. Swedish participants in this EU project have been awarded close to SEK 6 000 million since 2007<sup>6</sup>, making FP7 an important source of financing for Swedish actors within research and development. FP7 was the third largest source of funding in 2009 in terms of competitive grant funding, excluding faculty funding (see Figure 4).

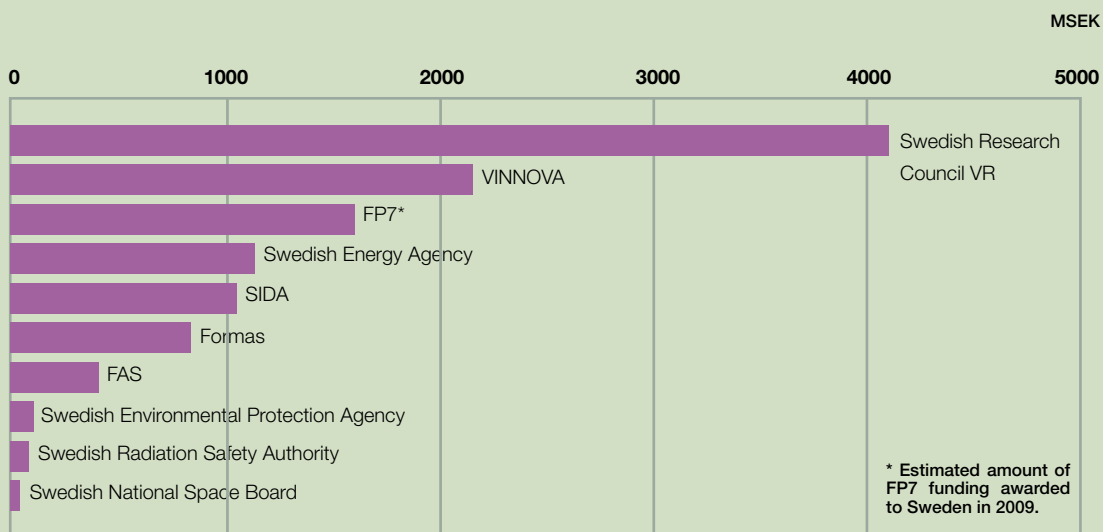


Figure 4. Comparison of FP7 funding awarded to Sweden in 2009 and state funding of R&D in 2009, excluding faculty funding.

FP7 is structured and focused on four main topics: *Cooperation*, *Ideas*, *People* and *Capacities*. Cooperation, which comprises ten thematic programmes, is the largest topic area within FP7, with 61 percent of the total budget. The environmental programme is, in terms of budget, one of the smaller theme areas under the Cooperation section of FP7, but environmental research is also included as an integrated part of the other thematic programme areas and is also included in the main topics of Ideas and People. Environment as a specific thematic area has an allocation of 6 percent of the Cooperation budget and in total accounts for 3.5 percent of the entire FP7 budget.

The estimation of how large a fraction of the FP7 budget has been allocated to Swedish environmental research has been based on the total FP7 grant funding awarded to Swedish participants in 2009. From that point onwards it has been assumed that the Swedish environmental research share is proportionate to the fraction of the entire FP7 funding allocated for environmental research. The fraction of FP7 allocated for environmental research has in turn been estimated

<sup>6</sup> Commission figures from October 2010.

based on how large a portion of each of the thematic area budgets has been allocated for environmental research. A rough estimate is that around 30 percent of the total budget within Cooperation, 25 percent within People and 10 percent within the Ideas main category sections has on average been directed towards environmental research. Based on these assumptions it has been estimated that around SEK 400 million was awarded to Swedish participants in environmental research in 2009. This is a very gross estimate as the contribution of Swedish participants to environmentally related projects can be both more or less than the fraction set aside to fund environmental research in the framework programme's budget.

Within programme committee 6 'Environment (including climate change)' the main areas that have been addressed during the initial FP7 period are: Climate Change, Pollution and Risks, Sustainable Management of Resources, Environmental Technologies and Earth Observation and Assessment Tools for Sustainable Development, as well as horizontal activities such as research communication. Each of these main areas has two to three sub-topic areas, which in turn are sub-divided into from two to nine sub-categories. The objective has been that each and every sub-category should have been announced in at least one call during the FP7 period. Some of the sub-categories have been regarded to be of greater importance than others and so a number of projects have been allocated, or can expect to be allocated, funding within these. The texts announcing the calls have in general been very precise and the numbers of projects applying for funding within each of the respective categories have as a result been relatively few. Beginning with the calls for the working programme for 2012 it has been decided to apply a different type of sub-division. The major societal challenges will be prioritised and within the area of the environment there will be a focus on five problem issues: Coping with Climate Change, Sustainable Use and Management of Land and Seas, Improving Resource Efficiency, Protecting Citizens from Environmental Hazards and Mobilizing Environmental Knowledge for Policy, Industry and Society. The text used in the calls will be significantly broader and more than one project is anticipated to be funded under each respective category. Another very distinct change is a much stronger focus on research that will also be of benefit and will be utilised. This is illustrated by the increased demands on the participation of small and medium-sized enterprises in the projects that are to be funded within several of the sub-categories.

### **The Nordic Top Research Initiative, TFI**

In the autumn of 2008 the Nordic countries joined forces to create the largest Nordic research and innovation effort to date. Nordic stakeholders and a large number of national institutions are participating and the budget is around SEK 500 million

distributed over five years. Sweden (VR, VINNOVA, Formas and the Swedish Energy Agency) will contribute SEK 21 million annually, according to an appropriation directive. The initiative focuses on areas that concern climate and energy research of mutual interest to the Nordic countries and where the regions can contribute to international solutions.

Over five years researchers in the Nordic countries will jointly generate new knowledge about the climate, the environment and energy. An initial call for applications was announced in 2009 and funding could be sought for user-driven research projects, Nordic research networks and for financing for the new Nordic Centres of Excellence (NCoE) within six sub-programmes: Effect Studies and Adaptation to Climate Change (Klima), Interaction between Climate Change and the Cryosphere (ICCC/Kryo), Energy Efficiency with Nanotechnology (Nano), Integration of Large-scale Wind Power (Wind), Sustainable Biofuels (Bio) and CO<sub>2</sub> Capture and Storage (CCS).

In the Klima and Kryo sub-programmes the funding instrument is research networks and Nordic Centres of Excellence and the objective is to generate synergies and raise the profile of Nordic research through collaborations. The grants awarded have primarily been used to fund mobility, visiting researchers, network activities and other joint research boundary-spanning activities and are not direct project funding. In the other sub-programmes (Nano, Wind, Bio and CCS) funding has been awarded to user-driven research projects. These sub-programmes have co-financing by commercial entities as a prerequisite. The portion of funding that will return to Swedish research groups in the form of project grants awarded over the entire period will be in the region of around SEK 50.6 million.

## **5. Environmental research funding in other countries**

### **Denmark**

In Denmark research and innovation policy is coordinated by the Ministry of Science, Technology and Innovation (Ministry of Science), which is therefore responsible for the majority of Danish research funding. Within the Ministry of Science there is a Danish Agency for Science, Technology and Innovation (FI), which administers and coordinates research and innovation issues in accordance with current political prioritisations. The FI in turn oversees two independent research councils who distribute research funding: The Danish Council for Independent Research and the Council for Strategic Research. There is also a Council for Technology and Innovation, which most closely comparatively resembles VINNOVA.

The Council for Independent Research also handles researcher-initiated and curiosity-driven research, while the Council for Strategic Research handles needs-driven research that is based on political initiatives. Both of these councils also function as advisers to the Danish Government. In addition, Danish research is funded by the Danish National Research Foundation and the Danish National Advanced Technology Foundation, which are independent bodies within the government administration that award research funding. The Council for Strategic Research works to ensure that research is directed towards the major challenges faced by Danish society. The focus is on problem-based research. There is a large element of interdisciplinary research in the projects that are funded. Since 2006 the council has awarded environmental research funding totalling DK 360 million to 25 projects focussing on water, environmental technologies and climate adaptation.

The majority of Danish research is performed by universities. There are only a few government institutions following a reorganisation performed in the middle of the last decade, which involved merging a number of research institutes with Denmark's universities.

In both 2009 and 2010 the Danish Ministry of Science published a so called research barometer, providing an overview of the quality and standing of Danish research in the international arena. According to this source Denmark's public spending on R&D within the areas of environmental and energy research in 2008 amounted to around DK 2 500 million<sup>7</sup>. This funding is however increasing. In 2009 the Danish Ministry of Science presented a plan for so called 'green research and innovation', based on the report "Green Research – Status and Perspectives"<sup>8</sup> that mapped out important research areas. Based on this an increased investment in environmental research was initiated to the tune of DK 700 million over three years, which began in 2010.

## **Finland**

Environmental research in Finland receives funding from several sources. Finland's Ministry of the Environment funds research into natural habitats, living conditions, construction and social planning. Other ministries also directly fund environmental research. In addition there is also funding provided for research and development within the area of the environment by the Academy of Finland and Tekes – the Finnish Funding Agency for Technology and Innovation. The funding provided by the Finnish Ministry of the Environment itself in 2010 for research and development totalled

<sup>7</sup> <http://www.fi.dk/publikationer/2010/forskningsbarometer-2010>.

<sup>8</sup> <http://vtu.dk/publikationer/2009/groen-forskning-status-og-perspektiver>

Euro 8.7 million and included projects within nature conservation and biological diversity. The Finnish Ministry of the Environment defines operational priorities in accordance with strategy guidelines. The projects funded by the Finnish Ministry of the Environment should generate information that facilitates management of the environment with respect to decision-making and the development and implementation of environmental policies.

The Academy of Finland and Tekes are other important sources of funding. The Academy of Finland has recently initiated the programme "*Climate Change – its impacts and management*" to respond to the scientific challenges that climate changes bring. A central principle of the research programme is to support multidisciplinary scientific research that concomitantly addresses social and environmental issues. In the first year (2010) the Academy awarded a total of Euro 12 million to eleven consortium projects. Tekes also has a new programme addressing climate issues (Climate Economy), which will be run in close collaboration with the Academy of Finland.

There is also a partnership between research institutes on environmental issues. This has the collective name LYNET (Finnish Partnership for Research on Natural Resources and the Environment). The following institutes are involved: Evira (Finnish Food Safety Authority), GL (Finnish Geodetic Institute), MTT (Agrifood Research Finland), Metla (Finnish Forest Research Institute), RKTL (Finnish Game and Fisheries Research Institute) and SYKE (Finnish Environment Institute). Other Finnish stakeholders within the area of the environment are Tukes (the Finnish Safety and Chemicals Agency), the Meteorological Institute and the Geological Survey of Finland (GTK). SYKE is also an important stakeholder. This is a research and expertise centre with a total budget of Euro 58.9 million, of which 61 percent comprises state funding. The work of SYKE encompasses both environmental research and environmental monitoring. Research performed by SYKE concerning environmental changes and environmental problems covers a broad spectrum, from local to global issues, including climate changes and the loss of biodiversity.

## **Norway**

Norway has a research council that is responsible for national R&D within all subject areas. The council, the Research Council of Norway, administered a total of NOK 6 138 million in 2009. The Research Council of Norway receives appropriations from the Norwegian Ministry of Education and Research, the Ministry of Trade and Industry and the Ministry of the Environment (NOK 282 million). Several initiatives target environmental areas under the themes including the environment, genes and health, the sea and coastlines and

polar research. The programme "Environment 2010" is also included within the environmental research area and spans the period 2007–2016. In 2009 there were 85 projects within the programme, receiving a total support collectively of NOK 70 million. Discussions were held in conjunction with the preparations for the implementation of Environment 2015 of the pros and cons of broad programme initiatives compared to integrating new environmental initiatives into existing programme structures. Challenges concerning both the requirements for in-depth, discipline-specific research and broad interdisciplinary approaches were identified, including what expertise would be required by a programme council with responsibility for such a broad and multifaceted subject area as that of the environment. The advantages of gathering environmental efforts into a single programme were found to outweigh the disadvantages. The possibilities were recognised for generating synergistic effects by the programme establishing procedures for working across traditional divides within and between research organisations and different elements of funding administration.

The institute sector, together with the universities and commerce, are the principal actors within Norwegian R&D activities. In 2007 the institute sector represented around 22 percent of R&D activities, which can be compared to the 31 percent represented by the university and higher education sector. The institutes are autonomous and are organised as foundations or companies. The Research Council of Norway has the overall strategic responsibility for the institute sector and contributes basic funding. There are approximately 65 institutes primarily performing R&D, of which seven are under the jurisdiction of the Ministry of the Environment.

### **The Netherlands**

The main sources of research funding in the Netherlands are NWO, the Netherlands Organisation for Scientific Research, and KNAW, The Royal Netherlands Academy of Arts and Sciences. NWO has recently published a new strategy in which six thematic areas are highlighted and from which it can be seen that the NWO is placing great importance on environmental research. The thematic categories are: Healthy Living, Water and Climate, Cultural Encounters: challenges of complex societies, Sustainable Energy, Connecting Sustainable Cities, and Materials: solutions for scarcity. The NWO points out in its strategy the increasingly important role of research in society and its opinion that the themes selected are those that will stimulate solutions being found to the most pressing societal issues.

### **United Kingdom**

The UK has many actors involved in financing environmental research, including discipline-specific research councils and

government agencies responsible for various sectors. Within the public sector 22 research funding stakeholders and users of environmental research have created a forum for working together – Living with Environmental Change (LWEC). This forum has the following objectives: “to ensure that decision-makers in government, business and society have the knowledge, foresight and tools to mitigate, adapt to and benefit from environmental change”. Within the group there are joint efforts ongoing, including a very ambitious effort to map all environmental research. The material is open access via a database that is a tool to facilitate the identification of prior and current research, knowledge gaps and possibilities for collaborations. This mapping was presented in a “Strategic analysis of UK environmental research activity” report<sup>9</sup>, compiled in 2007. The definition of environmental research was very broad and similar to the definition adopted in this review, with the exception that energy research was only included to a limited extent. The report did state, however, that the UK has a large amount of energy research and that this is closely aligned with environmental research. The report determined that the twelve research funding bodies included funded 6 000 projects during 2004–2005 that could be classified as environmental research, where GBP 260 million was awarded to environmental research projects and programmes and GBP 23 million went to “environmental research training”. In addition to this there was also funding awarded to infrastructural initiatives. Collectively all of the funding in total amounted to GBP 500 million. The database developed during the project has been maintained and updated and now includes 20 000 projects and programmes, which have been funded by 20 public research funding bodies.

## Germany

In Germany environmental research is funded primarily by the Federal Ministry of Education and Research (BMBF). The programme is administered by the PT-DLR project management agency, which is part of the German Aerospace Centre. In addition there is also regional research funding. A greater part of the national research funding is focused on boosting competitive potential by investing in collaborative projects involving research and industry. BMBF:s funding of research and innovation<sup>10</sup> in 2007 amounted to approximately Euro 16 000 million, of which Euro 2 500 million was awarded for sustainability research (€ 1 million), energy (€ 0.7 million), biotechnology (€ 0.6 million), agriculture (€ 0.2 million) and geoscience (€ 0.04 million). Areas such as space and health research also include environmental research elements.

<sup>9</sup> <http://www.lwec.org.uk/sites/default/files/2007-04-strategic-analysis-research.pdf>

<sup>10</sup> Source Cordis Erawatch.

## USA

The USA has several major funders of environmental research, of which the most important are the US Environmental Protection Agency (US EPA), the National Science Foundation (NSF), the National Institutes of Health (NIH), the National Aeronautics and Space Administration (NASA) and the defence and energy departments.

The US EPA can most closely be compared to the Swedish Environmental Protection Agency and the Swedish Chemicals Agency. The US EPA has several centres that fund research aimed at improving the scientific basis for national decision-making within the area of the environment. The total budget in 2011 was around USD 10 000 million, of which USD 846 million was devoted to science and technology.

The NSF is a federal authority that supports basic research and science and technology education. The NSF accounts for around 20 percent of all state funded basic research at academic institutions in the USA. In 2009 the NSF had a total budget of USD 9 500 million, of which USD 7 600 million was appropriated for research and areas related to research. During 2009 the NSF received 45 181 applications for funding, of which 14 595 were granted, equating to an average funding rate of 32 percent. Included in the NSF strategic objectives is a specific environmental objective: “Discovery – Foster research that improves our ability to live sustainably on Earth”. The NSF has the ambition of stimulating interdisciplinary research. The annual funding awarded by the NSF has in principal remained constant throughout the 1990s and a large part of the 2000s, but increased sharply at the end of the 2000s.

The NSF has a traditional discipline-based organisational structure and in the year 2000 a decision was taken to improve the efficiency of the work performed in the area of the environment. In a report compiled by external experts it was proposed that “a high-visibility, NSF-wide organizational focal point” should be created and given the responsibility, among other things, to identify knowledge gaps and determine priorities with a particular focus on interdisciplinary research areas. Two advisory committees have since been formed as an integrated part of the NSF’s funding of environmental research: an internal Working Group on Environmental Research and Education, which comprises representatives from the different departments within the NSF and an Advisory Committee on Environmental Research and Education, which is comprised of external researchers from different disciplines. This group establishes syntheses that problematize the challenges facing society and for which environmental research must contribute to solving.

## 6. Research funding bodies

### Baltic Sea 2020

Baltic Sea 2020 is a private, autonomous foundation with the aim of promoting "meaningful measures that in all probability are good for, and almost certainly have no negative impact on the Baltic Sea." The foundation was established in 2005 through private donation. The foundation finances research, tangible initiatives and development projects that broaden knowledge or provide more in-depth knowledge of the Baltic Sea, as well as measures that have political or media influence, with the objective of raising the awareness of decision-makers and the general public.

### Swedish Energy Agency

The Swedish Energy Agency lies under the jurisdiction of the Ministry of Enterprise, Energy and Communications and funds a diverse range of activities, from energy-focused basic research to large-scale demonstrative projects and support for business development. Support is directed to higher education establishments, companies, branch organisations and public stakeholders. The operations of the Swedish Energy Agency have a distinct beneficial profile with a focus on providing unified benefits to society and businesses through commercialisation via enterprise, municipalities and other stakeholders. The Agency works both to utilise and validate the results of research and development by supporting innovations and the commercialisation of new products and services that are initiated "bottom-up". The parliamentary bill 2005/06:127 focusing on research and new technologies for future energy systems is of major importance for the current operations of the Swedish Energy Agency. This parliamentary bill is also the basis of the strategy for the period 2011–2014, which specifies priorities for the long-term research programme. The research funding awarded by the Swedish Energy Agency is divided between external and internal programmes, as well as individual projects. Calls are announced continuously. The programme is developed in close dialogue with the users of the long-term strategy programme and is reviewed every 3–4 years. The Swedish Energy Agency, as the authority with sector responsibility for the energy system, supports and drives activities to meet environmental targets and energy policy objectives. This primarily concerns the environmental quality objective *Reduced Climate Impact*. The operations of the Swedish Energy Agency span the entire development chain, from (energy-focused) basic research to business development, demonstration and innovation.

### Swedish Research Council Formas

Formas is a government agency within the Ministry of the Environment, but also receives appropriations from the Ministry for Rural Affairs. Formas supports basic research and

needs-driven research within the areas of the Environment, Agricultural Sciences and Spatial Planning. The amount of funding awarded in 2009 was allocated through open calls, programmes and specific initiatives. Some of the funding was appropriated directly to other recipients (Skogforsk, IVL, JTI and others) in accordance with the terms of two appropriation directives. Formas is tasked with “evaluating the research and development that has received funding from the research council and in these evaluations to specifically assess the quality, relevance and potential value to society”. Applications are evaluated with respect to scientific quality and societal benefit. In the parliamentary bill ”Research for a better life” (2004/05:80) the amount of appropriation allocated to Formas was increased and *sustainable development* was highlighted as a priority area. This led to specific initiatives for research within the areas of *climate, biological diversity and sustainable development*. The same parliamentary bill included specific initiatives to strengthen research environments, qualified recruitments and research education. The most recent parliamentary bill “A boost for research and innovation” (2008/09:50) highlighted *sustainable use of natural resources, impacts on natural resources, ecosystem services and biological diversity, climate models and marine environment research* as prioritised areas, resulting in Formas being allocated extra resources to fund efforts on these themes.

#### **International Institute for Industrial Environmental Economics (IIIEE)**

The International Institute for Industrial Environmental Economics (IIIEE) was founded in 1994 with employee fund endowments. The foundation funds research and education at the eponymous institute. Operations are run by Lund University. The focus of the research and tuition at the institute lies within the area of industrial environmental economics, with special importance placed on the development and application of governance and environmental policy-making tools.

#### **IVL Swedish Environmental Research Institute**

IVL, the Swedish Environmental Research Institute, is an independent, non-profit research institute, owned by SIVL, a foundation jointly established by the Swedish Government and Swedish industry. IVL works with applied research and contract assignments for ecologically, economically and socially sustainable growth. R&D represents around half of all activities. Operations are organised according to six priority areas: Climate and Energy, Sustainable Building, Air and Transport, Sustainable Production, Resource-efficient Products and Water. The research is partially jointly funded by the state and industry and partially by grant funding awarded following application to research funding bodies. The state currently guarantees an annual appropriation of SEK 30 million in research and development funding on the provision that industry provides funding that matches this amount. The state appropriation is allocated via Formas

(SEK 15 million) and the Swedish Environmental Protection Agency (SEK 15 million).

### **The Kempe Foundation, Sweden**

The Kempe Foundation is a private foundation established in the 1940s. The aims of the foundation are stated in the company statutes as "in issues concerning Västernorrland, Västerbotten and Norrbotten counties, to promote scientific research and scientific and other tuition and education, as well as religious, welfare, social, artistic and other comparable cultural objectives, including promoting agricultural production in the counties stated." Grants are awarded in the first instance for education and research. Several of the grants within the environmental area concern scientific equipment.

### **Knowledge Foundation (KK Foundation)**

The Knowledge Foundation was established in 1994 with employee fund endowments. The KK Foundation aims to help Sweden's new universities and university colleges to create internationally competitive research environments, promote the exchange of knowledge and skills between higher education establishments and commerce and promote the use of IT in Sweden. Research funding from the KK Foundation necessitates equal co-financing from industry. The KK Foundation was not able to differentiate out environmental research funding from total funding and has therefore not been included in this mapping.

### **The Knut and Alice Wallenberg Foundation**

The Knut and Alice Wallenberg Foundation has the primary objective of promoting scientific research and tuition or study activities of benefit to Sweden. According to the company statutes, funding should be awarded as direct grants or as appropriations to institutes for such activities. The Wallenberg Foundation probably funds research that can be classed as environmental research but the Foundation has elected not to participate in this mapping.

### **Mistra**

The Foundation for Strategic Environmental Research, Mistra, was established in 1994 with employee fund endowments. Mistra supports research of strategic importance to a good living environment and sustainable development. As a foundation Mistra can make long-term investments, which the government agencies cannot do to the same extent. All of Mistra's operations can be classed as environmental research. Annually around SEK 200 million is invested in twenty major interdisciplinary research programmes that run for 6–8 years. Since the beginning the focus of investments has turned from primarily natural science and conservation-oriented research to having more of a focus on social science, policy-oriented environmental research. Investments in research centres comprise the largest single long-term investments.

For the last few years this has involved the interdisciplinary Stockholm Resilience Centre and recently the Mistra Urban Futures centre for sustainable urban development has been introduced.

### **Swedish Environmental Protection Agency**

The Swedish Environmental Protection Agency is a government agency within the Ministry of the Environment and provides research funding to contribute to the generation of knowledge required to meet environmental targets and to facilitate efficient implementation of environmental policy. The research funding is distributed to different research programmes (investments of SEK 3–6 million annually over periods of 3–8 years), to projects and to finance reviews.

### **Swedish Central Bank Funding – Riksbankens Jubileumsfond (RJ)**

Riksbankens Jubileumsfond supports research within the areas of the humanities and social sciences. The foundation was established in 1962 and has the aim of promoting and supporting scientific research associated with Sweden. The research is funded by one-time grants to programmes, projects, postdoctoral funding, infrastructural support and research start-up studies. Only a small fraction of the funding allocated can be regarded to be related to environmental research.

### **The Swedish National Space Board**

The Swedish National Space Board is a government agency within the Ministry of Education, but also receives appropriations from the Ministry of Enterprise, Energy and Communications. The agency should work for space operations and space research to contribute to the knowledge community and to the innovation and competitive power of industry, as well as to meet the needs of society within areas including transportation, communication, the environment and the climate. The Swedish National Space Board is responsible for administering all government-funded national and international space operations in Sweden, in terms of research and development, and supports in the first instance space and remote sensing research utilising equipment in space, on rocket probes or using high altitude balloons. The research funding is distributed via open calls. In addition the Swedish National Space Board runs a programme for researchers, developers and users to work jointly to develop and implement remote sensing methods. The Swedish National Space Board is also responsible for payments made by Sweden to ESA (the European Space Agency), which among other things are used to develop satellites for research and applications within environmental and climate areas.

### **The Geological Survey of Sweden, SGU**

The Geological Survey of Sweden (SGU) is an agency within the Ministry of Enterprise, Energy and Communications

that is responsible for issues concerning the country's geological composition and mineral management. SGU funds both internal R&D activities and other geoscience research, awarding funding in alignment with research council formats. The projects that receive funding should be of benefit to SGU operations.

### **The Swedish Geotechnical Institute, SGI**

The Swedish Geotechnical Institute (SGI) is an agency within the Ministry of the Environment and is a research institute with overall responsibility for Sweden's geotechnical issues. Since 2010 the SGI has been responsible for research, technology and knowledge development on issues concerning the decontamination and restoration of polluted areas. Applied research and development account for around one third of the total operations of the institute. The research supports the functions of the SGI as a government agency and society in general. During 2009 the SGI ran around thirty environmentally related R&D projects, some of which were aligned with the environmental quality objectives *Reduced Climate Impact* and *A Non-Toxic Environment*. Around 40 percent of the R&D budget funds EU research. The SGI participates in twelve EU projects and is the coordinator of two of these.

### **Sida**

Sida is an agency under the jurisdiction of the Ministry of Foreign Affairs. Sida's programme for developmental research has the ultimate objective of supporting research of high quality and relevance to Sweden's joint development collaborations in accordance with Sweden's policies for global development. Environment and climate is one of the three strategic priority areas for Swedish joint development collaborations. The overall aim of joint research collaboration for the period 2010–2014 is to strengthen and develop research of relevance to combating poverty in developing countries.

This work focuses on three areas:

- 1) expanding research capabilities in developing countries and regions;
- 2) research of relevance for developing countries, and
- 3) Swedish research of relevance for developing countries.

Within the environment and climate area the focus has been on research that contributes to an increased understanding of the effects of climate change for low income countries, as well as adaptation strategies.

### **Skogforsk**

The Skogforsk Foundation is Sweden's forestry research institute. Operations should contribute to Swedish forestry knowledge, services and products that contribute to profitable, sustainable utilisation of forest land in order to strengthen commercial competitiveness and to meet important societal

targets. The nucleus of operations are within the areas of forest renewal, forestry technologies and forestry logistics that principally are not covered by other researchers, such as timber use, forestry stewardship and nature and environmental husbandry with respect to the biodiversity of forests, land and water. Skogforsk is funded by both commercial forestry and by the state.

### **SMHI**

SMHI is an agency under the jurisdiction of the Ministry of the Environment and has expert knowledge of meteorology, hydrology, oceanography and climatology. SMHI performs grant funded research under the direction of the Swedish Government, performs commissioned work for other agencies, runs commercial operations according to company economic principles and awards research grants funded by the EU and Swedish funding bodies. SMHI is an important stakeholder when it comes to environmentally related infrastructure in Sweden.

### **SP Group**

In addition to the parent SP company, the SP Group includes the companies CBI, Glafo, SIK, YKI and JTI. The Group has approximately one thousand employees and annual turnover for 2009 was SEK 950 million. SP is part of RISE Holding AB. SP creates, utilises and provides international competitive skills for the evaluation and development of technologies, materials, products and processes of benefit to commerce and society. This is done in close collaboration with universities and university colleges. One of the strategies of the Group is to develop an internationally leading institute for energy and environmental technology. SP focuses on the development of long-term sustainable technologies and energy and environmentally efficient renewable materials, products and construction. The Energy and Environment division of the Group employs around 400 people, many of whom are highly educated researchers. SP funds around 35 doctoral students within the area of energy and the environment. SP has established a number of internal skill platforms within the Group, spanning major portions of the energy and environmental technology area. In addition there are external skill bases that are managed by the SP Group within the area of energy and environmental technology.

### **Swedish Foundation for Strategic Research**

The Swedish Foundation for Strategic Research, SSF, was established in 1994 with employee fund endowments. The purpose of the foundation is to support natural scientific, technical and medical research. The statutes of the Foundation state "to promote the development of strong research environments of the highest international standards that are significant for the development of Sweden's future competitiveness".

### **Swedish Radiation Safety Authority**

The Swedish Radiation Safety Authority is a government agency under the jurisdiction of the Ministry of the Environment and has the collective responsibility for radiation protection and nuclear safety. The agency works to protect people and the environment from undesirable effects of radiation. This research is funded partially by grants from the Ministry of the Environment and partially by fees paid by the nuclear industry, with the latter comprising the major fraction. The Swedish Radiation Safety Authority both announces open calls and commissions research in accordance with its research plan. As a large portion of the research performed is commissioned research initiated in accordance with requirements the research results are of direct benefit to the agency. The agency does not however work with commercialisation.

### **Swedish Transport Administration**

The Swedish Transport Administration is a government agency that lies under the jurisdiction of the Ministry of Enterprise, Energy and Communications and is responsible for the long-term planning of the transport system for road, rail, shipping and air transport, as well as for the construction, operation and maintenance of national roads and railways. The Swedish Transport Administration works to meet transport policy targets. In addition the agency also orders, documents and disseminates research, development and demonstration activities within the transport area that are justified according to the mandate of the Swedish Transportation Administration. The agency was established in April 2010 following the merging of the separate state road and rail agencies, Vägverket and Banverket. As the Swedish Transportation Administration is a new government agency, the work of finalising strategies and programmes for research and innovation is still ongoing.

The research funded by the Swedish Transportation Administration should contribute to the development of the transport system so that this satisfies the requirements and expectations of citizens and commerce. In 2009 the separate state road and rail agencies together invested around SEK 865 million in the whole innovation system. This was distributed along the length of the innovation chain, with around 25 percent being allocated to research, 35 percent to development, 10 percent to demonstration and 30 percent to utilisation. This analysis includes only the fractions that can be related to environmental research.

### **Swedish Research Council (VR)**

The Swedish Research Council (VR) is an agency under the jurisdiction of the Ministry of Education. In 2009 VR's total research funding amounted to SEK 4 160 million. Of this SEK 3 200 million was allocated to the budget post Research

Support. Major portions of VR's grant funding is awarded to projects and is therefore not regulated investment. It is the researchers who decide what to investigate. Applications are assessed according to their scientific quality within established disciplines. Relevance is not a selection criteria for the assessment of applications submitted to VR. In addition to project support, there is currently funding available for young researchers and research appointments, as well as travel and planning grants. All of the funding originates from parliamentary decisions. Funding within the area of the environment comprises Linnaeus grants and grants for research concerning biological diversity and sustainable development.

## **VINNOVA**

VINNOVA is an agency under the jurisdiction of the Ministry of Enterprise, Energy and Communications that is intended to promote sustainable growth in Sweden by funding needs-driven research and development of efficient innovation systems. VINNOVA has the internal objective of funding efforts coupled to an increase in Green Growth. Total funding for research and development in 2009 amounted to just over SEK 2 000 million, of which SEK 1 100 million was allocated to universities, university colleges and institutes. In practice VINNOVA investments are doubled, as projects are normally 50 percent co-financed by industry. VINNOVA has a focus on providing unified benefits to society and businesses through commercialisation and on results that will be utilised by enterprise, municipalities and other stakeholders. Much of the research funded by VINNOVA has indirect effects on the environment. These effects can in practice be of just as great significance to environmental objectives as the more focused initiatives addressing environmental challenges. In previous VINNOVA strategies environmental objectives have not been particularly prioritised, but in the current long-term strategic work the climate, water and biological diversity have been given more prominence. VINNOVA funding is normally awarded in collaboration with commercial enterprise and is established in close dialogue with both companies and public stakeholders.

## **Foundation for Baltic and East European Studies**

The Foundation for Baltic and East European Studies was founded using employee fund endowments following a parliamentary decision in 1994. The Foundation for Baltic and East European Studies has the mission of supporting research and education at Södertörn University. The Foundation funds research, doctoral studies and the improvement of academic infrastructure at Södertörn University, primarily within the humanities and social sciences.

## 7. Comments regarding the mapping of the portfolios of the respective funding bodies

Below is presented the comments of the different stakeholders to the figures the respective funding bodies have contributed to the mapping of environmental research funding in terms of amounts and the topics funded in 2009.

**Swedish Energy Agency.** A large portion of the research funding by the agency lies at the interface between energy research and environmental research. The material documenting the decision basis for granting project applications states how the project relates to the environmental objectives. This has enabled amassing of information from the agency's database about projects that have stated alignment with one or several environmental objectives. The operations of the Swedish Energy Agency span the entire development chain, from (energy-focused) basic research to business development, demonstration and innovation, and these are funded by several different types of grants. The agency also administers funding included in separate initiatives, such as energy and environmental aspects of the FFI programme for strategic vehicle research and innovation. In addition to research, in 2009 the Swedish Energy Agency also funded development, pilot and demonstration projects, market launches and business development within the area of the environment. The Swedish Energy Agency notes that projects in the latter stages of the development chain tend to be significantly more resource demanding than pure research projects. There are also activities that have been difficult to assign to these specific categories, such as planning grants, for example. In 2009 new research projects were awarded SEK 49.3 million in funding grants. The Swedish Energy Agency has since estimated that when ongoing projects are included the total sum is four times larger. This is probably a low estimate.

**Swedish Research Council Formas.** Project grant applications submitted to Formas are registered in a file and case management system known as FRAPS. The search and reporting functions in this database enabled all of the grants awarded in 2009 to be collated (in total 1 040 awards). Extraction and aligning according to environmental quality objective was performed manually with the assistance of a combination of parameters such as file number allocation (Environment, Agriculture, Forestry, Spatial Planning), call and evaluation panel. General grants (travel information dissemination etc.) have not been included.

**IIIIEE.** The figures presented in Table 4 concern the portion of funding allocated by the institute to support research-related activities at the IIIIEE (i.e. excluding tuition).

**IVL.** The figures presented in Table 4 concern only grants allocated directly via Formas and the Environmental Protection Agency. Information activities have been excluded. Funding

has been categorised by environmental objective in accordance with IVL's own assessment of the profiles of activities in 2009.

**Mistra.** All of Mistra's operations can be classed as environmental research. Mistra's administrators have manually sorted and categorised every project funded in 2009 by environmental objective. Mistra supports a few projects with larger sums of funding and the decision to focus on mapping by specific year (in this case 2009) has had a major impact on accounting for funding by categorising by environmental objective. For example a major initiative has recently been completed, funding a project related to the environmental quality objective *A Magnificent Mountain Landscape*, but the figures presented show SEK 0 for this environmental objective.

**Swedish Environmental Protection Agency.** When applying for grant funding to the environmental research programme applicants state the environmental objective(s) addressed by the research. Alignment with environmental quality objective is therefore based on the researcher's own assessment. For other research projects the Swedish Environmental Protection Agency has performed its own assessment of the environmental quality objective each projected should be categorised as being aligned with. In addition to the funding documented in this report, a further SEK 220 million is allocated by the Swedish Environmental Protection Agency to universities, university colleges and research institutes. Much of this additional funding is coupled to environmental monitoring and is not distributed according to methods equating to those of the research councils.

**The Swedish National Space Board.** Only research funded by the Swedish National Space Board's research programme has been included. In addition to this the agency funds development projects (around SEK 8 million) and infrastructure within the area of the environment (approximately SEK 130 million). The projects have been manually categorised according to environmental objective. The identification of causal or intervention research has been made by the research administrator.

**Sida.** Sida's programme for developmental research with an environmental focus in 2009 amounted to SEK 253 million divided according to the categories of Global (SEK 74 million), Regional (SEK 89 million), Bilateral (SEK 53 million) and Swedish (SEK 37 million). The first three of these categories have elements of research but also encompass other forms of support. Therefore only the category "Swedish" has been taken into account as all of the funding in this category concerns the financing of Swedish research that has been allocated in the form of research council-like calls.

**Skogforsk.** The figures presented in Table 4 concern only grants allocated directly via Formas. The portion of the funding regarded to be environmental research funding has been assigned to the environmental quality objective *Sustainable Forests*.

**SMHI.** SMHI has its own research department and the portion of activities regarded as relevant to this mapping are performed there. Environmental monitoring on behalf of the Swedish Environmental Protection Agency has not been counted as environmental research. It is not always clear where the cut-off boundaries lie. The majority of SMHI's environmental research can be classified as belonging to the environmental quality objective category of *Reduced Climate Impact*. SMHI activities also have associations with *Clean Air*, *A Balanced Marine Environment* and the other hydrologically related objectives.

**SP.** The SP Group has a turnover of around SEK 300 million within the operational area of Energy and the Environment. The figures presented for environmental research represent 15 percent of this turnover, which is an estimate of the portion of state funding allocated to the SP Group. This funding has not been categorised according to environmental quality objective. The Swedish Institute of Agricultural and Environmental Engineering, JTI, is part of the SP Group and in 2009 the JTI was awarded SEK 6.4 million in direct appropriations from Formas' budget. The industrial research institutes that are part of the SP Group perform research within a broad area of activities, many of which are related to the area of the environment. The figures presented represent a rough estimate of state funded environmentally related research performed within the SP Group.

**Swedish Radiation Safety Authority.** Research funding in 2009 amounted to a total of SEK 84.5 million. This figure is low due to temporary reallocations in connection with the establishment of the new government agency. In 2010 the total research funding amounted to SEK 96 million. In 2009 it can be estimated that SEK 47 million relates to environmental research. Of this, SEK 4 million can be directly coupled to the environmental quality objective *A Safe Radiation Environment*. In addition, SEK 15 million was used to fund research into the final storage of nuclear waste and SEK 28 million was allocated for reactor studies; two areas that are defined here as environmental research. The categorisation of projects has been performed manually. Funding for research focused on radiation protection is allocated via open calls. The remaining research is commissioned or negotiated in accordance with the agency's research plan.

**Swedish Transport Administration.** In total it is estimated that around SEK 70 million was allocated to environmental research in 2009, which is around 8 percent of the total research

budget. As we have only had access to the total project costs, funding has been calculated from the monthly funding for the entire research period and multiplied by twelve to give an estimate of the amount allocated to environmental research annually. Environmentally related activities have been categorised generally into seven of the sixteen environmental quality objectives, with the largest portion being allocated to the objective *Reduced Climate Impact*. The funding of landscape-related activities has been categorised as *Other*.

**Swedish Research Council (VR).** The VR case management database system has no simple function for the extraction of information about grant awards of relevance for the environmental quality objectives. The project database is very extensive. The manual selection for this analysis comprised 195 project grants that equate to a sum total of allocated funding of SEK 149 million. VR stress that the selection is “stringent”. Projects that have been assessed as being relevant have primarily been extracted from the database subject categories *Ecology and Biodiversity*, *Geology and Geophysics*, and *Processes in Air and Water* in combination with the specific initiative *Sustainable Development*. Linnaeus grants and postdoctoral grants have been included. Energy-related framework funding has not been included. Infrastructural funding has been presented separately.

**VINNOVA.** In the scope of environmental research funded by VINNOVA only investments in the activity area “Environment” in accordance with the 2009 annual report have been included, which amounts to SEK 115 million. In addition to research VINNOVA’s total operations also encompass development and innovation. Around SEK 800 million is regarded as having direct or indirect relevance to the environmental quality objectives. The categorisation according to environmental objective is based on an analysis of the project portfolio within the framework for the call in 2009 entitled Environmental Innovations.

**Other foundations.** Information about the research funding by other foundations is based on replies to questionnaires. In several cases it was not possible for the foundation to present an exact figure for the sum allocated to environmental research for a specific year. The figures in these cases represent projects, that often run for several years, that were awarded funding in 2009. Within this group only the grants awarded by Baltic Sea 2020 are categorised according to environmental quality objective. The Wallenberg Foundation and the Knowledge Foundation, KK, elected not to participate in the mapping of funding.

## **8. Prior evaluations performed in the area of environmental research**

Table 6 presents a compilation of the evaluations of environmental research that have been performed by the nine funding bodies named in this review since the year 2000.

**Table 6. Compilation of environmental research evaluations.**

**Formas**

<b>Title</b>	<b>Results</b>
Formas-BIC 2003–2006, 2011	Good programme but shortcomings in the dissemination of research results. The project has not been implemented in companies to the extent anticipated. Recommend increasing the proportion of interdisciplinary science.
Mobilising Swedish Social Science Research on Sustainability, R3:2010	Research within the area has increased and developed positively. Communication between users and the research community need strengthening.
Evaluation of Marine Environmental Research in Sweden 2003–2008, R2:2010	The scientific quality of the research is in general very high. Projects within biodiversity, eutrophication and toxicology are particularly outstanding in their scientific excellence. The research is of high relevance to society. The communication of the research results to users is less well developed.
Evaluation of Research Conducted by the Stockholm Environment Institute, 2010	Good scientific production of improving quality. A bridge between science and politics.
Evaluation of SLF-funded Research 2002–2007. R3:2009	High practical relevance. Relatively limited scientific production. International collaboration and communication with users requires strengthening.
Evaluation of JTI's R&D Activities 2005–2008, R8:2008	High skill level, good international collaboration. Limited scientific production.
Evaluation of Skogforsk's Framework Programme 2005–2008. R6:2008	Fulfils specified goals. Has improved international joint collaboration. Good interaction with users. Limited scientific production.
Bibliometric Evaluation of LIV & DUST, Cities as Living Environments & the Resilient City, 2008	The research programme has contributed to improving the capacity of the research groups to solve research problems. The frequency of international publications is in general limited.
Evaluation of Research on Organic Production in Sweden. R6:2007	The project demonstrated very variable scientific quality. The research needs to be made more visible internationally.
International Activities for Researchers with Formas Grant Funding 2005–2007	Distinct difference between areas in terms of international activities. Most frequent collaborative countries: England, USA, Germany Australia.
Evaluation of Swedish Architectural Research 1995–2005, R7:2006	Better dialogue between stakeholders required. More international publication is necessary.
Evaluation of the healthy building key action stage 2 2001–2004, R2:2005	Generally good scientific quality. Several projects were clearly of societal relevance. Both further research and systematic dissemination of research results is required within the area.
Evaluation of Crop Breeding Research 2000–2004, R10:2004	Projects well selected, but projects are too extensive, which makes it difficult to achieve project objectives.
Evaluation of Swedish Building Research 1993–2002, 2004	
Electrical use in built environments, 2003	
Environment and waste management, 2003	
Construction companies with a customer focus, 2002	

**Swedish Energy Agency**

<b>Title</b>	<b>Results</b>
Save and protect. R&D programme for energy efficiency in valuable cultural heritage buildings, 2010	The area should be continued to be funded over the long-term. The interdisciplinary collaborations and establishments of centres of excellence should be maintained and developed. The potential of the programme can be developed further.
Energy Systems in Road-Bound Vehicles Research Programme, 2010	Good programme. Relevant project, productive industrial collaboration. Need for more international collaboration. Few scientific publications.
Evaluation of project collaboration within the research programme Waste Refinery, 2009	Fulfilment of objectives in the programme is high, but not complete. Project has high energy relevance. It is assessed that there is a need for continued research within each of the focus areas.
Evaluation of the ELAN programme Electricity Research Report 09:110	A successful research programme. The research is of good quality. Greater spread of knowledge within user organisations is needed.
Evaluation of seven competence research centres co-financed by the Swedish energy agency	The research centres demonstrate high scientific quality and productivity. Important contribution to technology skill development. High relevance for industry and society.

**Mistra**

<b>Title</b>	<b>Results</b>
The first ten years of Mistra, 2003	Mistra's administration received praise in for the selection, structuring and implementation of the programme.
Start-up Review of the Stockholm Resilience Centre, 2009	
Evaluations of Mistra's programmes.	

### Swedish Environmental Protection Agency

Title	Results
Evaluation of IVL's jointly funded environmental research 2001–2006, R 5944, 2009	The research is highly relevant and can often be related to environmental objectives. There are deficiencies in reporting/result dissemination.
Research Programmes and Meeting Environmental Quality Objectives, R 5953, 2009	The research is relevant to the environmental objectives. Application of the research results can be improved.
Bibliometric evaluation of research programs, R 6321, 2009	Activities are on a par with the resources allocated and several of the programmes are internationally competitive at the highest level.
Evaluation of COPE, 2007	Research of high scientific quality with high practical relevance.
International review of Swedish Wildlife Research 1997–2001, R 5179, 2002	High scientific quality and very high relevance. Good communication with users.

### The Swedish National Space Board

Title	Results
Evaluation of the remote sensing programme, 2010	Good scientific quality. Increased international research collaboration and increased collaboration between research funding bodies is recommended.

### Swedish Research Council (VR)

Title	Results
Evaluation of Swedish Biodiversity Research, VR14:2010	Some strong groups have developed. Increased national and international collaboration, as well as more user-driven research is recommended. Better coordination between research funding bodies is recommended.
Initial evaluation of Linnaeus environments grants, 2008, VR 7:2010	Fundamental organisational structure is in place and collaborations have begun. In some cases the added value conferred by the Linnaeus environment is not clear.
International evaluation of meteorology, 2004	Swedish atmospheric research assessed to be of high quality. Need for overall strategy, particularly for monitoring.

In summary it can be concluded that the science evaluated is often assessed to be of good quality and of great relevance to society. The number of resultant publications have however been assessed to be fewer than expected in certain areas, in particular concerning research with commercial co-financing. A recurring recommendation has been to encourage increased collaboration between research groups, both nationally and internationally. The dissemination of research results to potential users has also often been cited as a weak area. In some instances the need for increased cooperation between funding bodies has been identified.

## 9. Workshop on the future of environmental research in Sweden

Formas arranged a workshop in Stockholm on 15 February 2011 on the future direction, conditions and challenges of environmental research. Participants were the Formas Scientific Council and other key resource staff identified by the reference group. The objectives were to highlight and define future research issues from the starting point of today's major environmental challenges. Notes on the workshop are presented below.

**Definition of research needs.** Environmental research has many roles in environmental efforts. This may be, for example, monitoring, measuring, evaluating, raising the alarm, prioritisation, informing, providing support for policy development and compiling supporting information for negotiations

and environmental policies. Who should define what research needs there are? There needs to be a more distinct structure for this. Government agencies have a role in identifying and supporting the research that needs to be developed. It is important that the problem owner is involved in formulating the research challenge. Stakeholders within research, politics and commerce need to clarify their mutual interests, define common goals and be involved in the collaboration surrounding the R&D programme. New solution-oriented paradigms must be given room to develop. Perhaps investments in different types of think-tanks can be made.

**Increased collaboration, better coordination.** There is a great deal of agreement on the need for increased collaboration and better coordination to improve environmental research conditions. Here can be named both better cooperation between the research funding bodies and the researchers themselves, including between different research environments and between disciplines. Environmental research needs functional links to other stakeholders, such as commerce, government agencies and politicians. The need for governance and incentives to stimulate such collaborations and networks is highlighted.

**Research/application – the need for the entire chain.** Many were strongly interested in the links between research and application. Several of the groups highlighted the need for both unconditional basic research and needs-driven applied research and also pointed out the necessity of exchanges and a strong interrelationship between the two. Feedback mechanisms are needed between basic and applied research and this is particularly important in the environmental research area. In addition mechanisms to ensure that research results come to be utilised are needed, that is to say that applied research is developed and taken forward to be used. For this there is the need for better, more integrated links between research and industry. There is a need to stimulate mechanisms that lead to innovation. This often comprises structures, such as networks, between research and industry. Another problem is that solution-oriented research is not encouraged in the structure of incentives that apply within the academic world today.

**Environmental research conditions.** There must be a balance between small and large projects. If we are to work at an ecosystem level, larger, more long-term investment is required. But it is also important that there are opportunities to carry out research in the form of small projects, without the requirements for research networks, primarily for young researchers who have not yet become established within networks. Research funding bodies must have an increased capacity to make quick decisions and to adapt funding to the needs that arise. This can be problematic if the politicians govern the "what" question. Funding should be available to develop syntheses and make research results applicable. The Swedish

structure of R&D institutes can in certain areas be a limitation. Other countries, for example, have public sector financed marine research institutes with their own research vessels, laboratories and technology development sections. There is no place for this type of initiative within the framework of research grant funding for universities and university colleges. Here it should be pointed out that marine research is also ongoing within industrial research institutes.

**System perspective.** A system perspective is gaining an increasingly important role within environmental research. Research areas are emerging that have the aim of better understanding feedback mechanisms and scalability, or in other words the prerequisites for ramping up and applying solutions at different levels. Evaluation and follow-up is necessary, but this can be more difficult when working at system levels. The system itself needs to be defined and delimited. It has been pointed out that Sweden has a prominent role within the area of systems research today. Here there can be opportunities for the mutual enrichment of environmental research and other research areas.

**More interdisciplinary research and more social sciences research.** The major challenges in the environmental area will require an increase in interdisciplinary efforts. The social sciences perspective must be given a greater position within environmental research and social scientists must be allowed to participate on their own terms. Some participants envisaged a potential role for Sweden as a role model for other countries. The performance of interdisciplinary scientific activities may however claim more time and resources and here there is a need for flexibility and capacity in the funding system to allow new research fields to develop.

**Swedish environmental research in an international perspective.** Sweden began environmental research at an early stage and has occupied a leading position in the identification of and solving of important environmental issues. International confidence in Swedish research must be maintained. Sweden's strengths function as ticket admitting Sweden to enter international environmental research collaborations; but one must have something to contribute to be an attractive collaborative partner. We must consolidate our position in the application areas we are strong in, such as forestry, IT and vehicles, but also in areas where we are collaborators and have an early adapter role. Limited possibilities to fund foreign researchers using grants from Swedish research funding bodies was cited as a bottle-neck in the development of international research collaborations and the establishment of networks.

Research issues and research needs related to eight challenges were discussed:

## 1. Climate change

- Consolidate adaptation research as well as research into vulnerability, resilience, risk and opportunities.
- How much are measures allowed to cost? Research about governance, for example within agriculture.
- International regimes for the implementation of measures need to be developed. How?
- Climate prognoses/global systems – we have to know more.

## 2. Energy provision (the participants changed this heading to: **A sustainable energy system**)

- System perspective; the area in principle is linked to all of the other seven categories and to human prioritisation and behaviour.
- Policies and incentives for collaboration between sectors. Target conflicts.
- Environmentally driven technology research is required.

## 3. Efficient and Sustainable Use of Natural Resources (including water)

- Growth without depletion of natural resources. Consumer patterns.
- Resource-efficient use of material in the production chain.
- System view – how do we develop from today's system to that of tomorrow's. Incentives.

## 4. Protecting biological diversity

- Ecosystem services.
- Strategies are necessary to maintain biological diversity in Sweden.
- Diversity research must be included in a wider system perspective.
- Less focus on conservation – focus on functions, for example in the physical landscape, both in terms of diversity and ecosystem services.

## 5. Chemicals in society (the participants changed this heading to: **Chemical environments – and health risks**, but it was also pointed out that chemical research can also contribute to solving social problems).

- Identifying new environmental chemical and health risks. Basic research can provide a basis for minimising risks and implementing corrective measures.
- Chemicals in the spatial planning sector. Materials, for example nanomaterials, bis-phenol A, POPs and semi-POPs. Early mapping and consequence assessment is needed here.
- Substances that interfere with hormones; reproduction/paediatric populations; low level effects; substance identification; exposure analysis.

- Synergistic effects; developing risk assessment methods.
- Coherent regulatory system with links between chemicals/articles, waste cycles and environmental quality.

## **6. Sustainable cities**

- Decision-making processes and governance at all levels; local, city, by individual building.
- Urbanisation – the management of complex systems. The movement flow of goods and people.
- New buildings – how do we build efficiently to achieve sustainable administrative management?
- Existing buildings (energy, indoor habitats) and cities; renovation/refurbishment leads to higher administrative management demands. EU/zero energy buildings; new regulations, new skills are required.
- Architectural research with a clear focus on collaboration with other disciplines.
- "General practitioners" for entire buildings/sites. We lack knowledge of how different systems in buildings interact. There is a paucity of research and researchers.
- Cities as systems, interactions between different elements, flows.
- The robustness and resilience of society, recovery capabilities following accidents, flooding, snow chaos etc.

## **7. Marine environments**

- Problem areas, eutrophication, environmental pollution, invasive species, over-fishing, climate changes and acidification, climate change and ocean cycles.
- How do we improve prognostic abilities/capabilities?
- Understanding ecosystems, system analysis.
- Process studies, biogeochemistry,
- Infrastructure and technology development.
- Links to land and air environments.
- Perseverance, long-term research.
- Stronger links between research and administrative management; a role for the stakeholders in the research.

## **8. Governance for the management of complex systems**

- Development of common conceptual frameworks, internationally and nationally.
- Understanding systems as a research area.
- How do we scale-up functional models in larger contexts?
- Research to examine power structures, institutions, behaviour, financial incentive structures.
- Adaptive management.
- Exchange of information between environmental research and other areas. Testing of methods and experience from other research fields on the "environmental governance" area and vice versa.



The mission of Formas is to promote and support basic research and needs-driven research in the areas of Environment, Agricultural Sciences and Spatial Planning. The research supported should be of the highest scientific quality and of relevance to the areas of responsibility of the Council. Formas may also fund development projects to a limited extent.



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