



Mapping of climate research in Denmark

Research: Analysis and evaluation 2/2009

Prepared by the Ministry of Science, Technology and Innovation, Coordination Unit for Research in Climate Change Adaptation and the Ministry of Climate and Energy



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Mapping of climate research in Denmark

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Preface

Climate research plays a key role in understanding the challenge posed by climate and in developing the necessary solutions to benefit the environment, society and the business sector.

This mapping of Danish climate research creates for the first time a comprehensive view of climate research, including the field of adaptation, in both the private and the public sectors in Denmark.

It is encouraging that many areas of Danish climate research are in the international top class and that this is a research field with tremendous potential for development.

It is our hope that this mapping will form a firm analytical point of departure for the further development of climate research in Denmark, and that the mapping will benefit the research environments, society and the private sector.

The mapping has been carried out in a fruitful process of collaboration with the Coordination Unit for Research in Climate Change Adaptation under Aarhus University and on the basis of many valuable contributions from research environments in both the private and public sectors.

The climate mapping will form part of the Government's further efforts in the field of climate and in the follow-up to the Government's climate adaptation strategy.



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Minister for Science, Technology and Innovation



Connie Hedegaard
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Summary



When Danish climate research is mapped, a picture emerges of a relatively small research field with a strong international position. Measured in terms of researcher full-time equivalents (FTEs), the scope of climate research in the public sector corresponds to approximately one and half per cent of all state-employed researcher FTEs. With respect to the private sector, climate R&D activity corresponds to 3% of total private R&D expenditure in Denmark. In an international perspective, Danish climate research has extensive publication activity compared with the rest of the world, and has, in addition, significant impact in terms of the number of citations received.

In the public sector, which also includes GTS - Advanced Technology Group in this report, 929 climate researchers have been identified, 520 of whom have taken part in the mapping. The mapping shows that the researchers have only spent a small part of their FTE on climate research, meaning that a total of only 160 FTEs were performed during the last year. This figure, however, must be regarded as a conservative estimate of the size of the research field in the public sector. One third of total researcher FTEs is performed by women. Aarhus University has the most researcher FTEs, followed by the Technical University of Denmark, the University of Copenhagen, and the Danish Meteorological Institute. Measured in terms of peer reviewed academic papers, Copenhagen University dominates with 32 % of all publications

on climate. Public climate research is predominantly in the field of natural science and its main focus is on the scientific basis of climate change and on the mitigation of greenhouse gases. More than half of the researchers use less than 25 % of their FTEs on climate research, meaning that quite a large share of the researchers use a relatively small part of their FTEs within this field. Associate professors, senior scientists and senior associate professors are, moreover, over-represented within climate research relative to postdocs and PhD students.

A total of 60 enterprises with R&D climate activities have been identified in the private sector in Denmark. In 2007 they performed a total of 1,348 climate related R&D FTEs. 38 % of these were researcher FTEs, while the remainder was performed by research technicians and other R&D personnel. The total climate-related R&D expenditures of the business sector were DKK 727 million in 2007. The major part of the R&D FTEs in the private sector is carried out in the metropolitan area, and the largest part of the R&D expenditures can be attributed to enterprises with more than 200 employees. 22 % of total FTEs were performed by women. In 2007 the state research councils contributed to the financing of R&D costs at 35 % of the enterprises and overall are responsible for 8 % of private R&D climate research costs. The most frequent R&D partners for the enterprises are the Danish universities followed by the enterprises' own clients and subcontractors. The enter-

prises' primary R&D focus is the mitigation of greenhouse gases followed by the impact of climate change on anthropogenic and natural systems.

In the international context Denmark is number 19 on the list of publishing countries, and the country is in fifth place when measured per head of population. Denmark's publication activity rose in general between 2003 and 2007, and in areas with Danish research activity, the research is generally cited either on a level with the global average or significantly above it. Danish ice core research and palaeontology research are particularly visible in the international context. The most frequent partner countries for Denmark are the USA, Germany and the United Kingdom, and Norway and Sweden.

In the field of climate adaptation, which

comprises a minor part of climate research in the public sector, a total of 256 researchers who have climate adaptation as one of several focus areas have been identified. 79 of these – corresponding to 19 FTEs – focus primarily on climate adaptation. The largest institutions in the area are Aarhus University, the Technical University of Denmark and the University of Copenhagen. The major part of climate adaptation research lies within the natural and social science fields. As in the rest of the climate research area, the field of adaptation has an over-representation of associate professors, senior associate professors and senior scientists relative to postdocs and PhD students. The main emphasis is on adaptation capacity and proactive adaptation, while the primary sector areas in focus are nature and nature protection, building and construction and soil science and forestry.



Chapter 1 - Background



This mapping stems from the shared need of the Ministry of Science, Technology and Innovation, Coordination Unit for Research in Climate Change Adaptation, and the Ministry of Climate and Energy for comprehensive overview of Danish climate research and its present-day potentials.

From the perspective of the Government, in the light of the United Nations climate conference, COP15, in Copenhagen in 2009 there is a definite anticipation that in the coming years Danish climate research will attract a great deal of social, political and commercial attention. In all probability climate research will play a key role in understanding the climate challenge and in developing the necessary solutions that benefit the environment, society and trade and industry. At the same time this implies that in the next few years many actors will have to take decisions regarding the future development of Danish climate research and the application of its results. It is the hope of the Ministry of Science, Technology and Innovation and the Ministry of Climate and Energy for this mapping to contribute an active, factual basis for these deliberations.

The Government published its strategy for adaptation to a changing climate in Denmark in March 2008. Some of the initiatives in the strategy are the appointment of a crosscutting Coordination Forum on Adaptation, with the Ministry of Climate and Energy in the chair, which is

to ensure coordinated climate adaptation efforts across the sectors and authorities, the establishment of an Information Centre on Adaptation, and the setting up of a Coordination Unit for Research in Climate Change Adaptation.

The Government's Strategy for adaptation to a changing climate emphasises the necessity of Denmark adapting to a changed climate in all sectors of society. On the basis of previous studies, the strategy points out the need for enhanced harmonisation, coordination and knowledge sharing in the field of climate adaptation. The coordination forum, the information centre and the Coordination Unit for Research in Climate Change Adaptation are to play a part in securing this. The main task of the Coordination Unit for Research in Climate Change Adaptation in this context is to strengthen knowledge sharing and cooperation between the Danish research centres and to further Danish participation in international climate adaptation research collaboration. A mapping of Danish climate research, supplemented by specific focus on climate adaptation will enhance the sharing of knowledge across the research environments and sectors that the climate adaptation strategy is specifically calling for.

The mapping as a whole is the result of fruitful cooperation between the Ministry of Science, Technology and Innovation, the Coordination Unit for Research in Climate Change Adaptation and the Ministry of

Climate and Energy. The mapping is the first of its kind to provide a comprehensive overview of climate research in Denmark in both the private and the public sectors, and it also describes Danish research in an international perspective. The most recent mapping of Danish climate research in the public sector was carried out by the Danish Environmental Protection Agency in 2003¹.

1.1 Definition of climate research

There is no clear definition of "climate research" as a research field. It is true to say that climate research contains sub-elements within such areas as environment, energy, transport, economics, political science and anthropology. The intention of this mapping has been to include the sub-elements of the other research fields that are explicitly carried out with a basis in the area of climate. In light of this, the present mapping is based on the overlap between two definitions: the Intergovernmental Panel on Climate Change's (IPCC) definition of the area of climate and OECD's definition of research and development. Thus, the definition of climate research is two-fold, consisting of "climate" and "research and development". These two parts are described separately in the following.

The mapping of Danish climate research takes its point of departure in research and

development within the five focus areas under the IPCC's three working groups². The definition therefore includes research and development in one or more of the following areas:

1. The scientific basis – i.e. the physical aspects of the climate system and climate change.
2. Vulnerability – i.e. the degree to which systems (natural or anthropogenic) are susceptible to and unable to cope with adverse effects of climate change.
3. Impact – i.e. the effects of climate change on natural and anthropogenic systems.
4. Adaptation – i.e. adjustment in natural and anthropogenic systems which moderates harm or exploits beneficial opportunities of actual or expected climatic stimuli or their effects.
5. Mitigation of greenhouse gases – i.e. anthropogenic intervention to reduce the anthropogenic forcing of the climate system. It includes strategies to mitigate greenhouse gas sources and emissions and measures to enhance greenhouse gas sinks.

The OECD's definition of research and development (R&D) as formulated in the Frascati Manual³ is applied in this mapping:

¹ "Mapping of Danish climate research and proposals for strengthening action areas", Ministry of the Environment, Danish Environmental Protection Agency, Center for Economic Analysis, Environment Report no. 763, 2003.

² <http://www.ipcc.ch/about/how-the-ipcc-is-organized.htm>.

³ Frascati Manual, OECD 2002.

- R&D comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, and the use of this stock of knowledge to devise new applications.
- All R&D activity must include an appreciable element of novelty.
- The R&D concept encompasses research and experimental development in the fields of technology, natural science, health care, the agricultural and veterinary area and within knowledge of human beings, culture and society. This means that it also includes research and development in connection with administration, economic planning, systems analyses, sales and marketing.

A broad, inclusive definition of climate research that is to be found in the overlapping between the two definitions has been chosen for the purposes of this mapping.

1.2 The method utilised

The mapping comprises three new studies of climate research in Denmark as well as background information from existing research statistics. The following new surveys have been conducted to support the mapping:

1. A questionnaire survey among 929 climate researchers in the public sector and at GTS – Advanced Technology Group –referred to in the following by

the term ”the public sector”

2. A questionnaire survey among 627 enterprises in Denmark
3. A bibliometric survey of 58,592 academic publications in the field of climate research.

The three surveys were carried out independently of each other but they are all based on the definition of climate research as described in section 1.1 above. The individual surveys are described in more detail in the following. The annex report contains a more elaborated description of the individual surveys. In conclusion, the strengths and weaknesses of the three surveys are discussed.

1.2.1 Questionnaire survey of climate research in the public sector

The mapping of climate research activities in the public sector is based on a questionnaire survey carried out between October and December 2008 among public research institutions and GTSs in Denmark. The survey was conducted by the Coordination Unit for Research in Climate Change Adaptation in cooperation with the Danish Agency for Science, Technology and Innovation. In addition, the research advisory panel, which is associated with the Coordination Unit for Research in Climate Change Adaptation and consists of representatives of the key institutions in the field of climate, has helped to qualify the survey by, for example, contributing to the identification of respondents.

Prior to the survey key persons at the institutions in question were requested to identify climate researchers. This took place by direct application to climate researchers at the individual institutions (inter alia by referring to the institutions' climate websites) and by making inquiries of the institutions' climate secretariat and/or management or rectorate. Finally, the research advisory panel, which is associated with the Coordination Unit for Research in Climate Change Adaptation and consists of representatives of the key institutions in the field of climate, have assisted in the identification of respondents at their own institutions in cooperation with the staff of the secretariat of the Coordination Unit for Research in Climate Change Adaptation. The researchers that had been identified then received two electronic questionnaires: one dealing with the researchers' individual professional competence in research, and one aimed at the projects for which the researchers have or have had project managerial responsibility from 2003 and onwards. In this context a "project" was defined as an R&D activity carried out over a defined period of time with an associated formalised budget line.

It was possible for new respondents to join the survey during the whole survey period and for participating researchers to recommend colleagues for participation in the survey. At the beginning of the survey, the secretariat of the Coordination Unit for Research in Climate Change Adaptation

forwarded information about the survey to the public institutions to be used in internal announcements.

Against this background, a total of 929 climate researchers received a personal invitation to respond to the questionnaire. 520 of these (56 %) answered the questionnaire about their individual professional research competence and a total of 263 research projects were registered. The results of the survey are thus based on two fundamental premises: 1) the institutions' overall response to the requests to enrol researchers in the survey; 2) the individual researcher's assessment of own and any projects' position in relation to the questions asked.

1.2.2 Questionnaire survey of climate research in the private sector

The mapping of climate research in the private sector is based on a questionnaire survey among 627 enterprises in Denmark carried out between November 24th 2008 and January 9th 2009. The survey was conducted by Statistics Denmark at the request of the Danish Agency for Science, Technology and Innovation, and it focuses on the enterprises' climate-related R&D activities in 2007.

The survey population consisted of 581 enterprises identified by the Ministry of Economic and Business Affairs in connection with an earlier study of the climate

field⁴. Statistics Denmark supplemented this population with a further 46 enterprises from existing research statistics of enterprises active in energy research.

The first contact with the 627 enterprises was by telephone in order to identify which of them were initially relevant for the survey. In these enterprises a contact person was identified with an overview of the R&D –activities of the enterprise for the further purposes of the investigation.

Statistics Denmark made contact with 593 of the 627 enterprises, and 306 of them stated that they were relevant to include in the study. The contact persons who had been identified in these enterprises subsequently received an electronic questionnaire.

60 of the 306 enterprises registered R&D activities in the area of climate in 2007, while 207 stated that they did not have climate-related R&D activities. 39 could not be contacted by telephone and thus did not take part in the survey.

1.2.3 The bibliometric survey

The bibliometric survey of climate research in Denmark is based on 58,592 scientific publications on climate identified in the interdisciplinary database “Web of Science” for the 2003-2007 period. The survey was carried out by the Royal School of Library and Information Science at the request of the Danish Agency for

Science, Technology and Innovation and it was implemented between November 2008 and January 2009. The bibliometric survey thus covers only peer-reviewed articles and, to a limited extent, contributions to conferences, while, for example, books and reports written as part of authorities processing are not included.

The publications were identified by means of a search strategy grounded on word and phrases related to the area of climate. The search strategy was based on the Danish Agency for Science, Technology and Innovation’s definition of climate research (cf. section 1.1), The Hot Topic by Walker & King (2008), and various reports from IPCC (Intergovernmental Panel on Climate Change). “Noise” from, for example “indoor climate” was excluded by means of random samples in the search set as a whole.

The search strategy resulted in a search set of 58,592 publications for climate research on the global level, 980 of which were publications with a minimum of one Danish co-author. It is these publications that form the basis of the bibliometric analysis.

1.2.4 Strengths and weaknesses of the three sub-surveys

As can be seen from the above, the three surveys are based on different methods and thus each takes its starting point in different data. The questionnaire survey of

⁴ ”Danske Styrkepositioner på Klimaområdet” (Danish positions of strength in the climate area), Ministry of Economic and Business Affairs, August 2008

researchers and research projects in the public sector reaches far out into the research environments, but is based the individual scientist's assessment of his/her own involvement in the climate area and recollection of the research projects that were completed. The population for the questionnaire survey among enterprises was carefully examined, but the survey depends on the right population having been identified from the start. While the bibliometry survey draws a varied picture of scientific publication and citation activity in the area, it is dependent on the limited coverage of the database and includes peer-reviewed publications only.

Although the three surveys are based on different methods and have different strengths and weaknesses, each survey contributes a different perspective on climate research in Denmark. However, a comparison of the results across the boundaries of the three surveys can only be undertaken against the background of a simultaneous assessment of their premises.

1.3 The structure of the report

In addition to this background chapter, the mapping is divided up into four chapters dealing with different aspects of climate research. Chapters 2 and 3 discuss the scope, profile and organisation of climate research in the public and the private sectors, respectively. The fourth chapter places Danish research in the international

context. The fifth chapter, drawn up by the Coordination Unit for Research in Climate Change Adaptation, focuses on that part of climate research that has to do with climate adaptation.

Chapter 2 - Climate research in the public sector



This chapter focuses on climate research in the public sector and at the Advanced Technology Group (GTS). It is based on the results of a questionnaire survey conducted among climate researchers in Denmark and on a bibliometric survey of publication activity in the climate area. These two surveys are described in more detail in chapter 1.

The chapter begins with a description of the scope of climate research in Denmark, after which the Danish climate research is profiled. The final section characterises the scientists working on climate research in the public sector.

The scope of the climate research is estimated as 160 FTEs (full-time equivalents) in the chapter. Measured in terms of researcher FTEs, Aarhus University, the Technical University of Denmark, the Danish Meteorological Institute and the University of Copenhagen are the largest institutions in the area. When the measurement is carried out in terms of scientific publications, the University of Copenhagen produced the largest share of publications on the climate with 32 % in the 2003-2007 period, followed by Aarhus University and the Technical University of Denmark. 163 of the climate research projects that were registered were active in 2007 with a total annual budget of DKK 262 million. The chapter shows, furthermore, that the main emphasis in Danish public sector climate

research is on applied and basic research rather than development work. The most important areas of focus are the scientific basis for climate change, the mitigation of greenhouse gases and the impact of climate change. The research is predominantly within the natural sciences covering a wide range of major disciplines within climate research. The University of Copenhagen, Aarhus University and the Technical University of Denmark all have broad climate research profiles, while, for example, GEUS (the Geological Survey of Denmark and Greenland) and the Danish Meteorological Institute are more specialised within a smaller number of climate-related subject areas. The chapter also demonstrates an over-representation of senior levels of climate research staff relative to PhD students and postdocs, and that the researchers use only a minor part of their total FTE on climate research. Finally, the chapter shows that just under one third of FTEs are performed by women. Although this is a smaller share than in the rest of the public sector, there are more women researchers in public than in private climate research.

2.1 Scope

In order to create a general overview of the scope of climate research in the public sector in Denmark, the section opens with a description of the number of

climate researchers, FTEs and publications divided by institutions. This is followed by a description of the climate research projects in progress in 2007.

Table 2.1 contains an overview of the number of researchers, FTEs and projects as well as the total annual budget for active climate-related projects in 2007. In contrast to the survey of climate research in the private sector, this survey includes only FTEs of academic researchers and not FTEs for research technicians and other R&D personnel.

Table 2.1. Number of researchers, FTEs and projects in climate research in 2007/2008

Researchers, FTEs and projects	
Number of identified climate researchers	929
Number of climate researchers participating in the mapping	520
Number of identified FTEs in the area of climate	160
Number of active projects	163
The active projects' overall annual budget sum	DKK 262 million

The period is 2007/2008 as the respondents were asked how much of their research time they had spent on climate research during the previous 12 months.

Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008.

As table 2.1 shows, the mapping identi-

fied a total of 160 researcher FTEs in the area of climate research in 2007/2008. The FTE statement includes GTS - Advanced Technology Group, although the latter comprise a relatively small share of the overall FTEs. As only 520 of the in all 929 identified climate researchers took part in the survey, the real number of FTEs is assumed to be greater. The number of identified FTEs in climate research is, however, on a level with the FTE estimates for the area in previous years in the form of the 2003 mapping by the Danish Environmental Protection Agency and the 2006 R&D statistics⁵.

In 2003 the Danish Environmental Protection Agency conducted a mapping of climate research in Denmark for the 1998-2001 period. The survey showed that there were 256 researcher FTEs in the climate area in 2001. It is, however, important to stress that the Danish Environmental Protection Agency's mapping is based on a different definition of climate research and a different method of calculation, making it difficult to directly compare the two surveys. There are, however, no indications that the number of researcher FTEs has increased during the period.

Climate research was also one of the strategy areas addressed in the R&D statistics for 2006. The statistics show that in 2006 there were 207 R&D FTEs for the climate area – that is when both

⁵”Danske Styrkepositioner på Klimaområdet” (Danish positions of strength in the climate area), Ministry of the Environment, Danish Environmental Protection Agency, Center for Economic Analysis, Environment Report no. 763, 2003.

scientific and technical personnel are included. But it is important to emphasise here also that the results of the R&D statistics should be interpreted with caution as the various strategy areas overlap. In addition, the “Climate” strategy area is based on a different definition than the one employed in this mapping⁶.

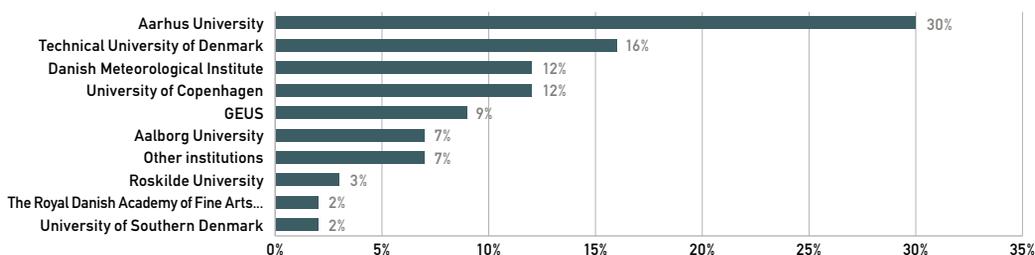
Despite the fact that the area of climate research may be bigger than shown by the result of the mapping, it is still a relatively small field of research. Researcher FTEs in this area comprise only one and a half per cent of all researcher FTEs in the public sector.

Figure 2.1 below shows that 30 % of

researcher FTEs in the climate area is carried out at Aarhus University. This is followed by the Technical University of Denmark, with 16 %, and the Danish Meteorological Institute and the University of Copenhagen, both of which have 12 % of the FTEs. With its 2 %, the University of Southern Denmark is the institution in the figure which has registered the fewest FTEs. The other institutions comprise 7 % and include 13 institutions that have less than three researcher FTEs in the area of climate. In general the distribution shows that climate research is spread over relatively many institutions with few FTEs.

Figure 2.1 is based on a questionnaire survey carried out among climate

Figure 2.1. Climate FTEs in 2007/2008 allocated by institutions with more than three FTEs in the areas of climate research



The figure is based on a total of 160 researcher FTEs. The category “Other institutions” covers the following: the Danish Road Directorate, the National Museum, the Danish Technological Institute, the Aarhus School of Architecture, the Danish Institute for International Studies, DHI, the Danish Economic Council, Statens Serum Institut - SSI, the Danish Institute of Governmental Research – AKF, the Danish National Gallery, Agrotech, the Danish Institute of Fire and Security Technology, and the Natural History Museum Aarhus. The full name of the shortened institution is The Royal Danish Academy of Fine Arts - School of Architecture.

Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008.

⁶The Danish Centre Studies in Research and Research Policy, 2006

researchers. Another measure of the Danish institutions' share of climate research in Denmark is the institutions' share of scientific publications within the climate area. The bibliometric survey is based on peer-reviewed scientific articles. When interpreting the results it is important to keep in mind that scientific publications comprise only a part of the institutions' production. Reports, published books etc. are not covered by the bibliometric survey.

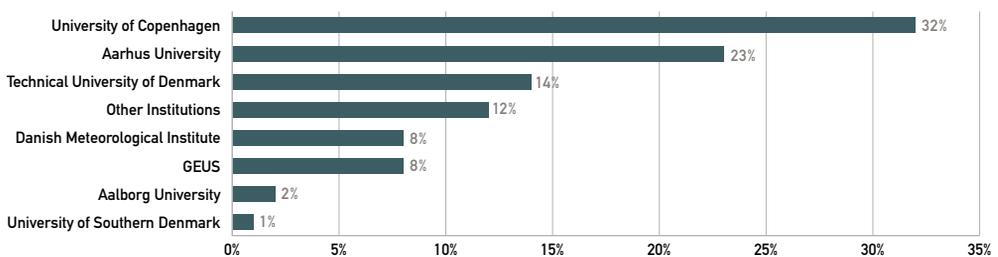
Figure 2.2 shows that the University of Copenhagen is the institution with the most publications in Danish climate research between 2003 and 2007 among the types of publications included in the survey. The University of Copenhagen's

share of publications comprises 32 %, Aarhus University's is 23 %, while the Technical University of Denmark has a share of 14 %.

In the questionnaire survey among the institutions, the respondents were asked to report some key data for research projects ongoing in the 2003-2008 period. In this context, a "project" was defined as a research effort conducted over a limited period of time with an associated formalised budget line. The results below are based on these reports.

The survey has identified 263 research projects in all in the area of climate between 2003 and 2008. The focus in the following will only be on the 163 projects

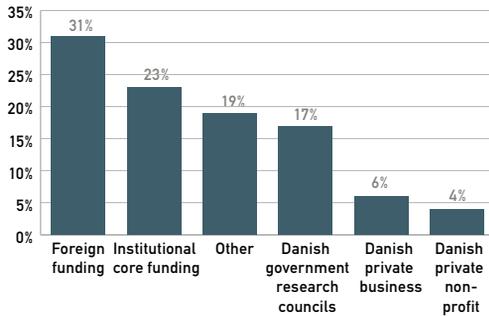
Figure 2.2. Institutions' shares of peer-reviewed Danish publication



The figure shows Danish institutions' shares of publications within climate research. The category "Other institutions" contains institutions with a share of less than 1 % of the publications.

Source: Bibliometric survey carried out by the Royal School of Library and Information Science, 2008.

Figure 2.3. The total annual budget sum for active climate research projects in 2007, by sources of financing



The overall budget sum for active projects was DKK 262 million in 2007. The total budget sum for 2007 was calculated by taking the total budget sum of the individual project and dividing it by the number of years in the project period. All the annual project budgets were then added up for the projects that were active in 2007. The category "Other financing" covers, for example, funds from ministries, the Nordic Council of Ministers etc.

Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008

that were active in 2007, i.e. the projects that were commenced, were ongoing or were completed in 2007.

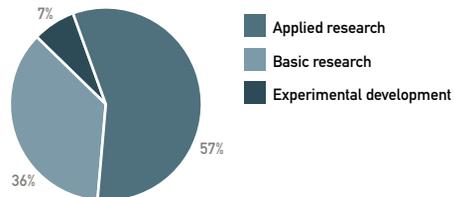
2.2 Research profile

This section draws a profile of Danish climate research. It starts by focusing on the way in which Danish climate research is distributed over IPCC's focus areas and among the fields of science. This is followed by a description of the Danish institutions' climate research profile.

Figure 2.4 shows the annual overall budget sum for the 163 projects active in 2007 divided by type of research.

As the figure shows, applied research represents 57 % of overall budget funds in 2007. Applied research encompasses original studies with the objective of obtaining fresh knowledge that is primarily aimed at a particular application or target.

Figure 2.4. Total annual project budget for climate research projects in 2007, by type of research



The total annual budget sum for active projects in 2007 was DKK 262 million. The total budget sum for 2007 was calculated by taking the overall budget sum for the individual project and dividing by number of years in the project period. All the annual project budgets were then added up for the projects that were active in 2007.

Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008

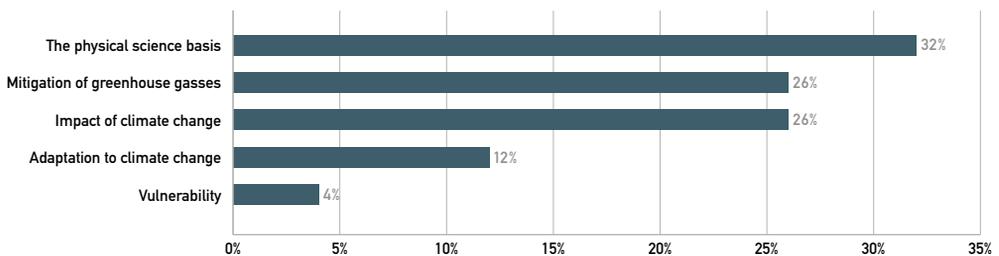
36 % of the total annual budget funds in 2007 were spent on basic research, i.e. theoretical or experimental work with the goal of obtaining fresh knowledge concerning the background of phenomena and observations that are not directed at any particular use or application. Finally, 7 % of the budget funds are utilised in development activity that involves systematic work aimed at the production of new products, materials and instruments etc. on the basis of knowledge from research and practical experience.

Figure 2.5 shows how the number of FTEs is distributed over IPCC's five focus areas. The figure is based on the focus area most highly prioritised by the individual researchers.

Figure 2.5 shows that 32 %, corresponding to 52 researcher FTEs, are in the physical science basis, which includes research in the physical aspects of the climate system and climate change. This is followed by the mitigation of greenhouse gases and the impact of climate change, each with 26 % of the researcher FTEs. As described in Chapter 1, the mitigation of greenhouse gases includes measures that mitigate anthropogenic impact on the climate system and sources

of this. It also includes measures that enhance greenhouse gas sinks, while the impact of the climate change covers the impact of climate change on natural and anthropogenic systems. Climate adaptation and vulnerability are the two IPCC focus areas with the fewest FTEs.

Figure 2.5. Climate FTEs in 2007/2008 distributed over IPCC's five focus areas



The figure is based on a total of 160 FTEs, and it was drawn up by taking the individual researcher's FTE and assigning it to the researcher's first priority. No allowance has thus been made for the researcher using part of his/her time on the focus area to which he/she has given 2nd, 3rd, 4th or 5th priority in the questionnaire. IPCC's five focus area are defined in Chapter 1. Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008

Box 2.1. Examples of research within each of IPCC’s five focus areas

THE PHYSICAL SCIENCE BASIS
 Registered research projects with the main focus on the scientific basis include subjects such as improved model simulations of regional climate change, the role of the Arctic regions in the global climate system, or studies of the hydrological cycle in the North Sea.

MITIGATION OF GREENHOUSE GASES
 Registered research projects with the main focus on the mitigation of greenhouse gases comprise subjects such as light and energy in buildings, trapping and storage of carbon dioxide or methods of production for bioenergy.

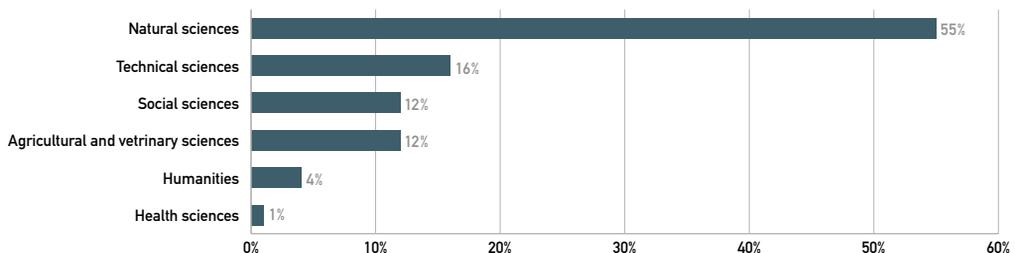
IMPACT OF CLIMATE CHANGE
 Registered research projects with the main focus on the impact of climate change include subjects such as historical studies of humpbacks, the development of drought-warning systems, or changes in tundra ecosystems.

CLIMATE ADAPTATION
 Registered research projects with the main focus on climate adaptation include subjects such as the optimisation of waste water systems, decision support systems for adaptation measures and the dimensioning of drainage systems.

VULNERABILITY
 Registered research projects with the main focus on vulnerability include subjects such as the vulnerability of buildings to climate change, crop production vulnerability, and vulnerability in relation to increased CO₂ concentrations in the atmosphere.

Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008

Figure 2.6. Climate FTEs in 2007/2008, by field of science



The figure is based on a total of 160 FTEs, and it was drawn up by taking the individual researcher’s FTE and assigning it to the researcher’s first priority. No allowance has been made for the researcher using part of his/her time on the field of science which he/she has stated as, for example, 2nd or 3rd priority.

Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008



Figure 2.6 shows the distribution of FTEs over the six fields of science.

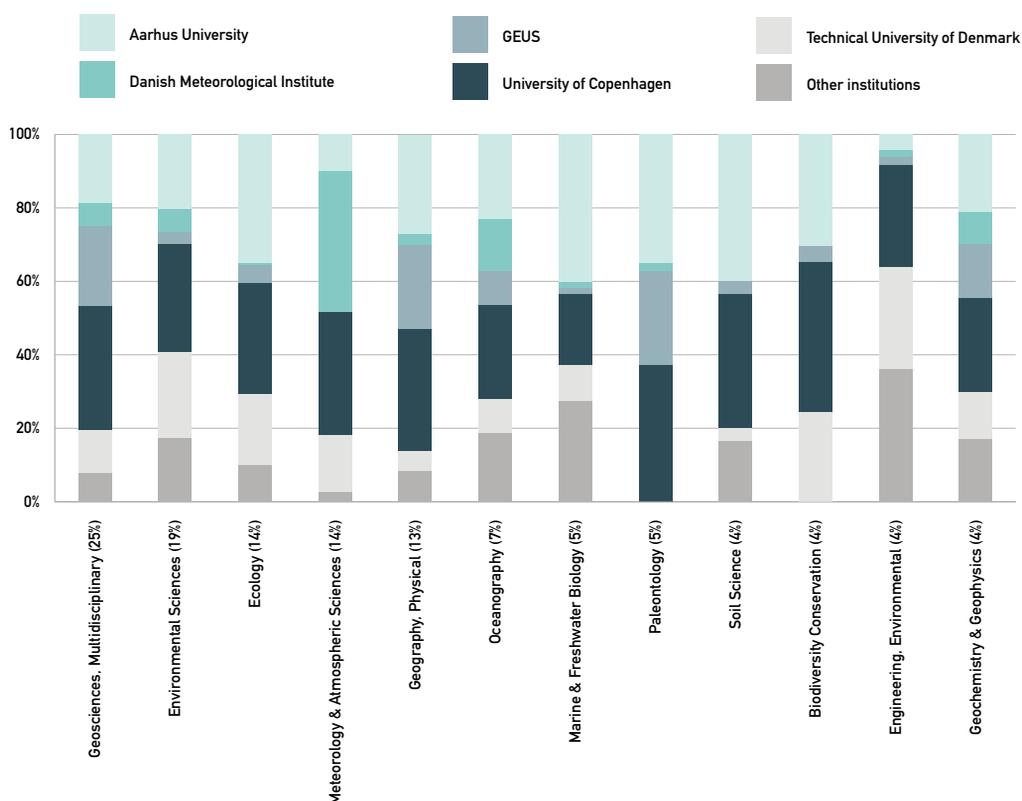
Figure 2.6 shows that climate research primarily takes place within the natural science area, in which 55 % of the FTEs are placed. This is followed by the technical sciences with a 16% share. 12 % of climate research takes place within social science, and a further 12 % in agricultural and veterinary science. The humanities

and health science are the two fields of science where the least climate research is performed.

The individual institution's main research focus provides a further perspective on the Danish climate research profile.

Figure 2.7 contains an overview of the institutions' shares of Danish peer-reviewed publications in selected subject categories.

Figure 2.7. Danish institutions' share of publikations within selected subject categories 2003-2007



The subject categories' share of the total volume of Danish publications in the climate area is stated in parentheses. The publications are included for each institution, and the individual subject categories are described in more detail in Annex 1. Source: Special run, Royal School of Library and Information Science, 2008.

Figure 2.7 shows the 12 subject categories in which Denmark publishes most. The figure also shows the Danish institutions' percentage-wise share of production within each subject category. It is only the institutions with the most publications that are included in the figure. The individual subject categories are described in Annex 1.

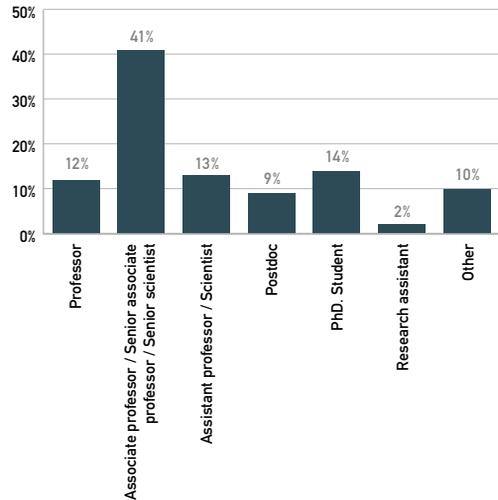
The figure shows that among the institutions selected the climate research profile of the University of Copenhagen has the widest coverage, closely followed by Aarhus University and then by the Technical University of Denmark. GEUS is mainly present in the subject categories of Geosciences (Multidisciplinary, Geography (Physical) and Paleontology, while the Danish Meteorological Institute's climate research profile shows its main activity within the subject categories of Meteorology & Atmospheric Sciences and Oceanography.

2.3 The climate researchers

The climate researchers are in focus in this section. It starts with an overview of the way in which the climate researchers are distributed in terms of job category and gender. It goes on to describe how much of their FTE individual researchers used on climate research in 2007/2008.

As the figures shows, 12 % of the 160 FTEs are associated with professors while 41 % are performed by associate

Figure 2.8. Climate FTEs by job category



The figure is based on a total of 160 FTEs. The category "Other" covers, for example, research management and staff outside of the job structure. Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008.

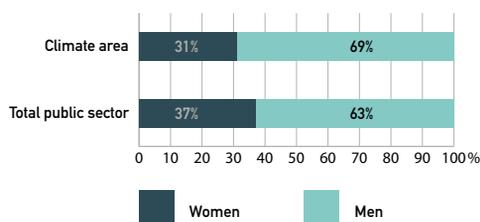
professors, senior associate professors and senior scientists, making this the largest group in terms of FTEs. 13 % of the FTEs can be assigned to assistant professors and researchers, while 9 % and 14 %, respectively, are performed by postdocs and PhD students. Research assistants perform only 2 % of total FTE.

Figure 2.9 shows researcher FTEs distributed by gender in the climate area and in the public sector as a whole.

The figure shows the gender distribution of researcher FTEs in the field of climate research compared to the public sector as a whole. Women perform 31% of all 160 researcher FTEs in the climate area. This



Figure 2.9. Researcher FTEs in the climate area and in the public sector as a whole, by gender 2007/2008



The figure is based on a total of 160 FTEs. The gender distribution in the public sector is based on the R&D statistics 2006

Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008 and the Danish Centre for Studies in Research and Research Policy

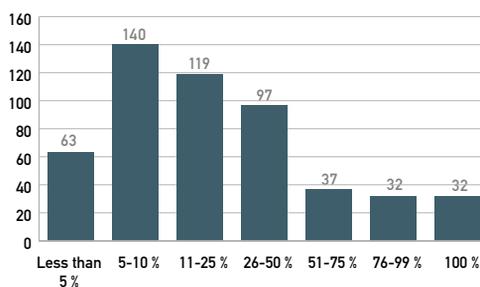
is six percentage points less than in the whole of the public sector, where 37 % of total R&D FTEs are performed by women. On the other hand, public climate research is nine percentage points higher than in the private sector, where 22 % of the R&D FTEs are performed by women (cf. Chapter 3).

If weight is assigned in relation to the representation of the fields of science in the area of climate (cf. figure 2.6), however, the share of women in climate research is higher than anticipated. Given the general gender distribution in the fields of science, it might have been expected that only 29 % of the FTEs were performed by women, while in reality the share is 31 %.

Figure 2.10 below contains an overview of how large a share of his/her total FTE the individual researchers used on climate research in 2007/2008.

The figure shows that a large share of climate researchers use a relatively small part of their FTEs on climate research. 63 of the 520 used less than 5 % of their FTEs on climate research, while 419

Figure 2.10. Share of the individual researcher's R&D FTE used on climate research 2007/2008



The figure is based on a total of 520 researchers.

Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008

(81 %) used less than half their FTEs on this research. 32 researchers used all their FTEs on climate research, corresponding to 6 %. It is, however, important to stress that some of the individual researcher's FTE is used on other things than research, for example teaching etc.

The figure thus shows that a large share of climate researchers use relatively little of their time on climate research. In order to put this into perspective, it means, for example, that a total of 85 professors work with climate research, while there are only 19 professor FTEs in the climate area. The same applies to the other job categories, including the categories of senior associate professor, associate professor and senior researcher. The 230

researchers working with the climate area are to be found in these categories, but if the time they use is added up, then in fact only 66 FTEs are used on research in the area.

Chapter 3 - Climate research in the private sector



This chapter describes the scope of Danish climate research in the private sector, and is based on a questionnaire survey conducted by Statistics Denmark among enterprises in Denmark. The survey is described in more detail in Chapter 1. The chapter deals with the scope of climate research in the private sector, the profile of the climate research and the enterprises' most important collaboration partners. Finally, there is an account of the composition of R&D personnel in the private sector.

As the chapter shows, there are a total of 1,351 climate-related R&D FTEs in the climate area in the private sector, while total R&D costs comprise DKK 727 million in 2007. The climate area thus stands for 3 % of total private R&D costs in Denmark. It is mainly the larger enterprises that have climate-related R&D activities, and the research is primarily financed by the enterprises themselves through foreign financing or through the Danish research councils. The majority of the enterprises' R&D costs are in development work while the majority of the R&D FTEs are performed in the metropolitan area. The researchers represent just over one third of the enterprises' R&D FTEs and research technicians just over a half. Women perform 22 % of the enterprises' climate-related R&D FTEs.

Consulting engineering enterprises are the most prominent line of business in climate research, and the main product group is electricity, gas, heat and water supply. In general energy products and heavy indus-

trial products are the most predominant product groups in private sector climate research. The focus of the enterprises' R&D activities is the mitigation of greenhouse gases and the secondary effects of climate change. Most of the enterprises participate in formalized R&D collaboration in the climate area, with the universities and institutions of higher learning as the most important collaboration partners at national and international level.

3.1 Scope

This section describes the scope of climate research in the private sector in Denmark, including R&D costs and FTEs, the most important sources of financing and the geographical distribution of R&D activities. In contrast to the survey of the public sector, this survey includes researchers, research technicians and other R&D personnel.

Table 3.1 shows that 1,351 R&D FTEs were identified in the private sector in 2007 while total R&D costs amount to DKK 727 million. Thus the climate area comprises 3 % of total private R&D costs in Denmark⁷. The table also shows that firms of consulting engineers perform 64 % of the FTEs while the manufacturing industry represents 31 %.

Although only 3 % of the FTEs are performed within energy and building and construction, the share is 24 % of R&D costs. This may be due to the fact

⁷ Danish Centre for Studies in Research and Research Policy, 2006



Table 3.1. Climate-related R&D FTEs and costs, by lines of business 2007

Line of business	R&D FTE	Distribution	R&D costs (DKK million)	Distribution
Consulting engineers	860	64 %	272	37 %
Manufacturing	424	31 %	257	35 %
Energy and construction	40	3 %	177	24 %
Trade and transport	17	1 %	14	2 %
Other lines of business	10	1 %	7	1 %
Total	1,351	100 %	727	100 %

*Distribution of climate-related R&D costs gives a total of 99 %, which is due to rounding off.
Source: Questionnaire survey conducted by Statistics Denmark, 2008.*

that this line of business is more investment heavy.

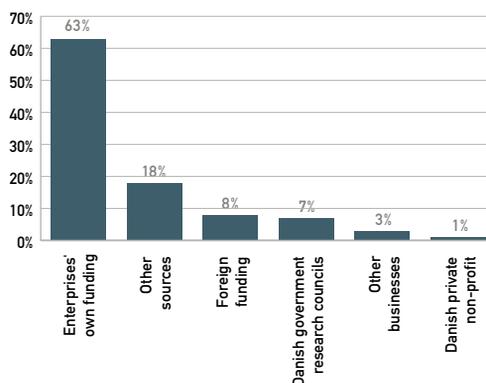
The table shows additionally that the firms of consulting engineers and the manufacturing industry are the businesses that are most active in research in the climate area measured in terms of both costs and FTEs.

The survey also shows that 75 % of climate-related R&D costs can be assigned to enterprises with more than 200 staff.

Figure 3.1 shows that the enterprises themselves finance the greater part (63 %) of their climate-related R&D costs, while 8 % of R&D is financed by sources outside of Denmark. 7 % of the climate-related R&D costs are financed by the Danish research councils and 3 % by other enterprises. A further 18 % of the costs are financed from other sources, including research funds from trade asso-

ciations, ministries and agencies etc. the survey also shows that 35 % of the enterprises included in the mapping received financing for climate research from the Danish research councils in 2007.

Figure 3.1 Enterprises' climate-related R&D costs by sources of financing



*In 2007 total R&D costs amounted to DKK 727 million. The category "Other financing" includes research funds from trade associations, ministries and government agencies, including EUDP (Energy Technology Development and Demonstration Programme), EFP (Energy Research Programme), PSO (Public Service Obligations) etc.
Source: Questionnaire survey conducted by Statistics Denmark, 2008.*

Table 3.2. Enterprises' climate –related R&D FTEs by main geographical area 2007

Main geographical area	R&D FTEs	Distribution	Number of enterprises	Distribution
Metropolitan area	895	66 %	26	43 %
Jutland	416	31 %	26	43 %
Islands exclu. metropolitan area and Zealand	26	2 %	6	10 %
Funen	11	1 %	2	3 %
Total	1,348	100 %	60	100 %

The distribution of the number of enterprises gives a total of 99 %, which is due to rounding off.
 Source: Questionnaire survey conducted by Statistics Denmark, 2008.

Table 3.2 shows the distribution of R&D FTEs and the number of research active enterprises by main geographical areas.

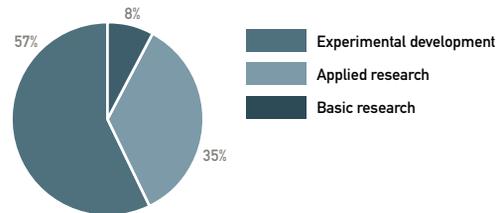
As can be seen, 66 % of the climate-related R&D FTEs are performed in the metropolitan area, followed by 31% in Jutland. Funen and the Islands excluding the metropolitan area and Zealand represent the remaining 3 % of the R&D FTEs.

Note that the R&D FTEs in the metropolitan area and Jutland are both distributed over 26 enterprises. This means that more than double the number of R&D FTEs per enterprises is performed in the metropolitan area as in Jutland.

3.2 Research profile

This section describes the professional profile of climate research in the private sector and includes types of research,

Figure 3.2. Enterprises' climate-related R&D costs distributed by types of research 2007



Total R&D costs in 2007 are DKK 727 million.
 Source: Questionnaire survey conducted by Statistics Denmark, 2008. The types of research are taken from the Frascati Manual, OECD 2002.

orientation towards product groups, strategic focus areas and the most important partners.

Figure 3.2 above shows the enterprises' climate-related R&D costs distributed by types of research.

Figure 3.2 shows that the majority (57 %) of the enterprises' climate-related R&D costs are spent on development. In this

context development is defined as systematic work based on knowledge gained through research and practical experience. The goal is to create materials, goods, services, processes, systems or other activities with a significant innovative element for the market.

Applied research represents 35 % of the R&D costs. Applied research is experimental or theoretical work that aims at achieving fresh knowledge and understanding. The work is, however, aimed primarily at specific forms of application such as energy, ICT or transport.

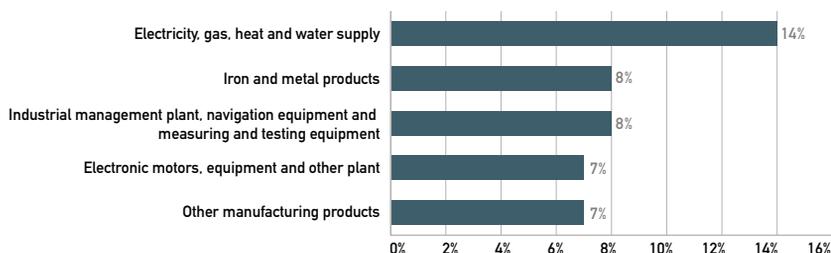
The remaining 8 % of enterprises' R&D costs are used on basic research, i.e. experimental or theoretical work with the primary objective of achieving fresh

knowledge and understanding with no specific application in view.

Whereas development work is the dominant type of research in the private sector, in the public sector only 7 % of project costs are aimed at development. On the other hand a larger share of the funds (36 %) is aimed at basic research in the public sector. Likewise, applied research plays a greater role in the public sector in comparison with the private sector. Thus, more than half (57 %) of public project costs are used on applied climate research.

Figure 3.3 below shows the climate-related R&D costs distributed over the five largest product groups.

Figure 3.3. Enterprises' climate-related R&D costs distributed over the five largest product groups 2007



The product groups are not mutually exclusive and consequently the R&D costs can be aimed at more than one product group. The distribution of the R&D costs is accordingly presented in relative shares.

Source: Questionnaire survey conducted by Statistics Denmark, 2008. The classification in product groups is taken from the Frascati Manual, OECD 2002



The enterprises' climate-related R&D costs are in general divided between a broad range of product groups. No product group has a share of R&D costs higher than 14 %. Energy products and heavy industrial products are predominant in general.

Electricity, gas, heat and water supply are the largest single group with a 14 % share of total R&D costs. Then follow iron and metal products and industrial process management plant, navigation equipment and measuring and testing equipment, both of which have an 8 % share of the R&D costs.

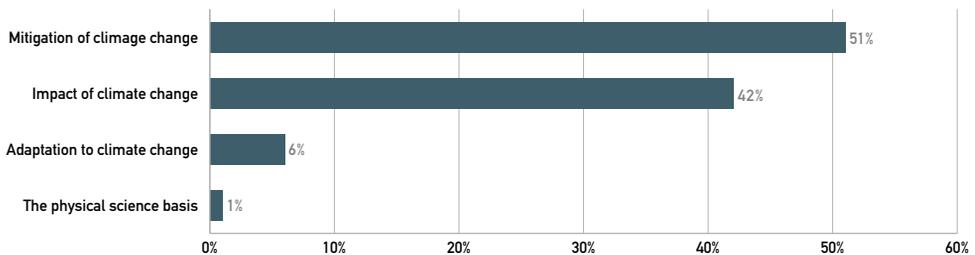
The category comprising iron and metal products contains iron and steel works, production of pipes, iron and steel

processing, production of other iron alloys, production of non-ferrous metals and casting of metal products.

The two final product groups in the top five – both of which have a 7 % share of total R&D costs – are electronic motors, equipment and other plant as well as other manufacturing products.

The first-mentioned of these includes the production of electric motors, generators, transformers, wind turbines, electric distribution and control boards, circuit breakers, accumulators and dry cells, electronic equipment for motors and vehicles and other electronic equipment. The category "Other manufacturing products" covers production of jewellery, gold and silver goods, musical instruments, sports

Figure 3.4. Enterprises' climate related R&D FTEs distributed over IPCC's focus areas 2007



The figure is based on a total of 1,351 FTEs, and was drawn up by taking the individual enterprise's FTE and giving it to the enterprise's first priority. No allowance has thus been made for the enterprise using some of its focus areas stated as 2nd, 3rd, 4th or 5th priority in the questionnaire. IPCC's five focus areas are defined in Chapter 1. "Vulnerability" is not included as no enterprise has this category as its first priority.

Source: Questionnaire survey conducted by Statistics Denmark, 2008.

apparatus, toys and recycling of waste products.

Figure 3.4 shows that mitigation of greenhouse gases is the biggest primary focus area for enterprises with 51% share of R&D FTEs. As described in Chapter 1, this includes measures that mitigate greenhouse gas emissions and sources as well as measures that enhance greenhouse gas sinks. The impact of the climate change on natural and anthropogenic systems is the second largest primary focus area, with 42 % of R&D FTEs.

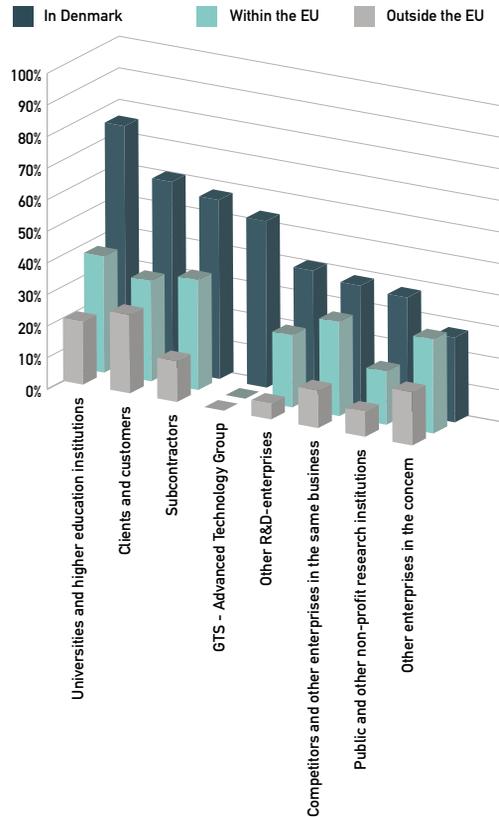
The remaining 7 % of de climate-related R&D FTEs comprise the focus "vulnerability" as the primary focus of their R&D activities.

The mitigation of greenhouse gases is a key focus area in both the private and the public sector. Vulnerability is, similarly, the area with the lowest priority in both the public and the private sector. The greatest difference between the two sectors is in relation to the scientific basis, which is the dominant area in the public sector, while it is accorded low priority in the private sector.

Figure 3.5 below shows the share of enterprises distributed by R&D partners and their geographical location.

All in all 50 of the 60 enterprises (83 %) participated in formalised R&D collaboration in the climate area during 2007. As

Figure 3.5. Share of enterprises distributed by R&D partners and their geographical location 2007



The figure is based on responses from 50 enterprises. Source: Questionnaire survey conducted by Statistics Denmark, 2008.

figure 3.5 shows, 75 % of these enterprises collaborated with Danish universities and higher education institutions in 2007, making them the partners that figure the most frequently among the enterprises, followed by clients and customers (60 %), subcontractors (57 %)

and GTS - Advanced Technology Group (53 %) – all within Denmark.

Within EU the enterprises collaborate primarily with universities and higher education institutions (37 %), suppliers of equipment, material, components and software (35 %), and clients and customers (32 %).

Outside of the EU the Danish enterprises mainly collaborate with clients and customers (25 %), universities and higher education institutions (20 %), and other enterprises in the concern (17 %).

3.3 The climate researchers

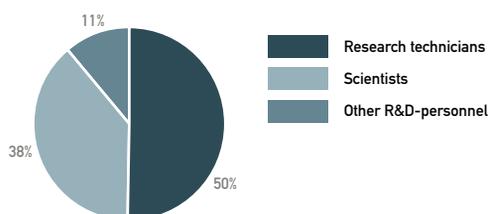
This section describes the composition of the R&D personnel in the private sector, including categories of personnel and gender distribution.

Figure 3.6 below shows the enterprises' R&D FTEs in the climate area distributed by categories of personnel.

Research technicians constitute the largest category of personnel (50 %) among the enterprises' R&D-personnel. Research technicians are R&D personnel who support the researchers' work by means of their technical knowledge and experience. They may be, for example, engineers and laboratory research technicians.

The researchers represent 38 % and in this context are defined as specialists

Figure 3.6. Enterprises' climate-related R&D FTEs distributed by categories of personnel



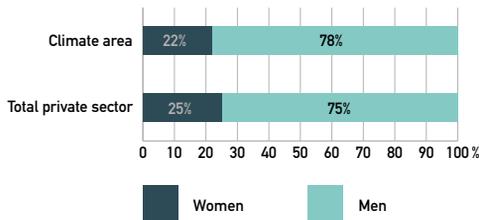
The R&D FTEs amount to 1,351. The three shares amount to 99 % due to rounding off.

Source: Questionnaire survey conducted by Statistics Denmark, 2008. The classification in personnel categories is taken from the Frascati Manual, OECD 2002.

engaged in developing and creating new knowledge, products, processes, methods or systems and in planning and directing these R&D projects. It must be stressed that this definition does not require a researcher to have a PhD.

The remaining 11 % of R&D personnel are neither researchers nor research technicians, but auxiliary staff providing direct service in connection with R&D projects. They include skilled and unskilled tradesmen, secretaries, office staff and machine operators. This personnel group also includes staff engaged in economic, administrative and HR matters to the extent that their activities are a direct service for climate-related research and development.

Figure 3.7. Researcher FTEs in the climate area and in the whole of the private sector distributed by gender 2007



*The figure is based on a total of 1,351 R&D FTEs.
Source: Questionnaire survey conducted by Statistics Denmark, 2008. The figures for other private research are from the private R&D statistics from 2005.*

As can be seen, 22 % of the enterprises' R&D FTEs is performed by women and 78 % by men. The figure shows that the distribution on the climate area is only very small in comparison with total private R&D. As described in Chapter 2, women FTEs comprise 31 % in the public sector – a difference of nine percentage points. As in the public sector, the natural and technical science profile of climate research may be the reason for a smaller share of the FTEs being performed by women than in the private sector in general.

Chapter 4 - Danish climate research in an international perspective >



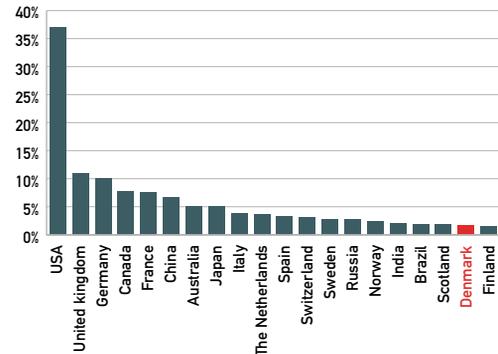
This chapter focuses on Danish climate research in an international perspective. The chapter is based on a bibliometric survey, which is described in more detail in Chapter 1.

The chapter opens with a description of how Danish climate research measures up to research in other countries. This is followed by a description of the extent of collaboration between Danish and foreign climate researchers.

The chapter shows that Denmark is one of the most productive countries in the world in the field of climate research in terms of number of academic publications per 1,000 head of population. In the subject areas in which Danish climate research is most active, productivity exceeds the global average in general. The same pattern applies to the impact of Danish climate research. In general Danish climate research is cited on a level with or significantly above the global average within the areas where Danish climate research is most active. Danish climate research is internationally embedded, and Danish climate researchers collaborate with a broad range of countries inside and outside of Europe. In general, the most important partners are also among the most productive countries in the climate area in the world.

Figure 4.1 shows how Denmark is placed among the 20 most productive countries in the world in the climate area.

Figure 4.1. Share of publications for the 20 countries in the world with the most publications in the climate area



The figure is based on 58,592 publications from the Web of Science, December 2008.

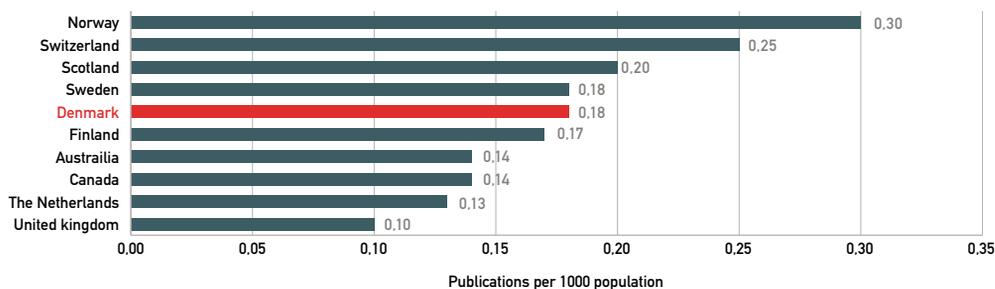
Source: Bibliometric survey, Royal School of Library and Information Science, 2008

The figure shows that the USA dominates and contributes to more than 37 % of the publications, followed by the United Kingdom, Germany, Canada and France. With 980 publications, Denmark's share is 1.7 % of global production, placing Denmark as the 19th most productive of the more than 180 countries included in the survey.

Figure 4.2 also shows that Denmark manages well internationally in the climate area. The figure also shows the countries' productivity in relation to population.

The figure shows that when the countries' production is seen in relation to population size, Denmark is in fifth place among the most productive countries in the world in the climate area, surpassed only

Figure 4.2. Number of publications in the climate area per 1,000 head of population 2003-2008



The figure is based on 58,592 publications from the Web of Science, December 2008

Source: Bibliometric survey, Royal School of Library and Information Science, 2008

by Norway, Switzerland, Scotland and Sweden. Danish production, moreover, increased in the 2003 to 2007 period, but showed a slight fall in 2005.

In the following the profile of Danish publications is examined in relation to the rest of the world.

The point of departure for figure 4.3 is the Web of Science's subject categories (cf. Annex 1). The figure shows the 22 most common categories at global level. Denmark's profile is stated as percentages in parentheses after the name of the category. As can be seen, productivity is greatest in the subject categories Geosciences (Multidisciplinary) (25 %), Environmental Sciences (19 %), Meteorology & Atmospheric Sciences (14 %), Ecology (14 %) and Geography (Physical) (13 %).

An investigation can be made using the Relative Specialisation Index (RSI) of the

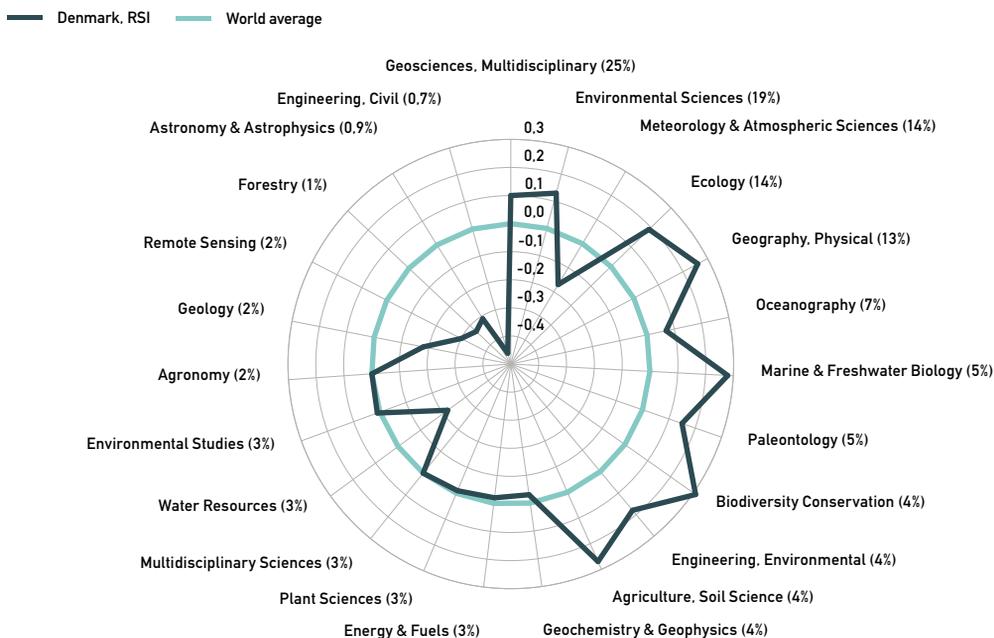
areas where Denmark has a special focus in relation to the international average.

The index takes the world profile as its starting point (the light blue line in the figure), and shows Denmark's deviations in relation to this (the dark blue line). An RSI of 0 means a relative activity as expected seen in relation to the size of the subject area for Denmark and the World, and thus Denmark's relative share of the subject area. An RSI of approximately 0.3 in the subject category Biodiversity Conservation means that Denmark produces approximately 30 % more publications than expected within this category compared with the world, and that in Water Resources with an RSI of approximately -0.2 Denmark produces approximately 20 % fewer publications in relation to the World.

It can be seen that Denmark focuses in particular on the following subject areas in climate research: Biodiversity Conservation, Marine & Freshwater Biology,



Figur 4.3. The Danish publication profile in the area of climate research 2003-2007



The figure includes the 23 categories that are most common internationally (categories with 1 % or more publications, corresponding to approx. 75 % of all publications). Denmark's profile over these categories is stated in parentheses. Denmark's publication profile (dark blue line) is stated in relation to the global average (= 0.0, light blue circle) in the categories and is calculated relatively after document type. A production of more than 0.0 indicates that Denmark has more publications than expected in this category in relation to the global level. The individual subject categories are described in more detail in Annex 1.

Source: Bibliometric survey, Royal School of Library and Information Science, 2008

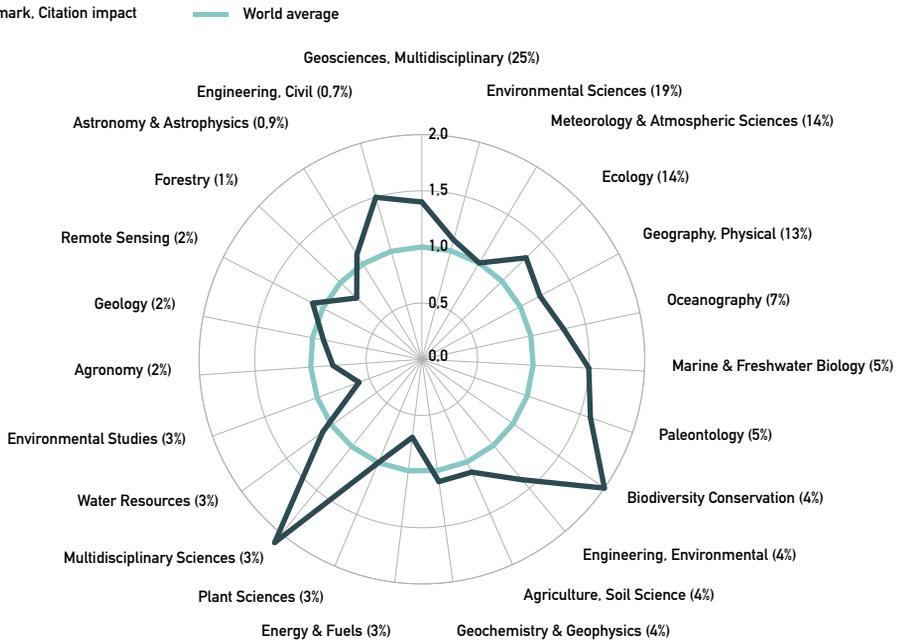
Soil Science, Geography (Physical), Ecology and Engineering (Environmental). On the other hand there is relatively less focus on the following areas in Danish research: Engineering (Civil), Astronomy & Astrophysics, Forestry, Remote Sensing, Water Resources, Geology and Meteorology & Atmospheric Sciences. It is worth noting here that Meteorology & Atmospheric Sciences, which is one of the heavy areas in Denmark's profile with 14 % of the publications, has a relatively low special-

isation index. This means that there is even greater scientific focus on this area at global level than in Denmark, even though it is one of the largest areas in this country. However, the two largest areas, Geosciences (Multidisciplinary) and Environmental Sciences, are above the world profile.

The Danish citation profile is compared in more detail with the world profile in the following.



Figur 4.4. Citation profile for Danish climate research in the period 2003-2007



The figure includes the 23 categories that are most common internationally (categories with 1 % or more publications, corresponding to approx. 75 % of all publications). Denmark's profile over these categories is stated in parentheses. Denmark's Citation impact (dark blue line) is stated in relation to the global average (= 1.0, light blue circle) in the categories and is calculated relatively after document type. A citation impact of more than 1.0 indicates that Denmark has more citations than expected in this category in relation to the world level. The individual subject categories are described in more detail in Annex 1.

Source: Bibliometric survey, Royal School of Library and Information Science, 2008

As the above analysis of Denmark's publication profile, the point of departure is 23 categories in climate research where the production is largest at world level. The world average for number of citations received is calculated for each category. A corresponding average is calculated for the Danish publications in the same categories, which can thus be compared with the world average.

The world average has been set at 1.0 (light blue line), and the Danish impact is shown relative to this (dark blue line). A value of 2.0 for an given category can thus be interpreted as meaning that Danish research in this area has received double as many citations as expected in relation to the world average. A value close to 1.0 indicates that a category is in line with the world average.

In general Danish climate research has a high impact measured in number of citations received. The most productive areas are either on a level with the world or are significantly above. At the same time, the areas that are under the world average comprise only a minor part of Danish climate research. Denmark is thus on a level with or over the world average in 17 out of the 23 subject categories. Biodiversity Conservation and Multidisciplinary Sciences in particular have a high impact, about double of what was expected. It is, moreover, worth noting that the most productive Danish category, Geosciences (Multidisciplinary) with 25 % of the publications, is well above the world average with approximately 40 % more citations received than expected.

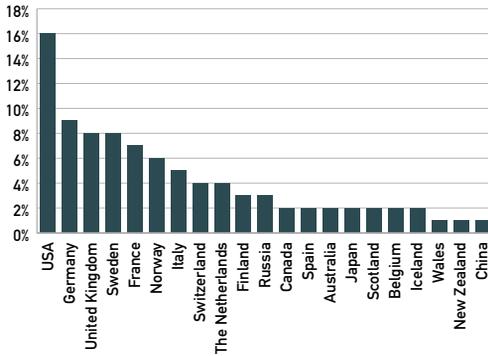
A coupling analysis was also conducted in connection with the bibliometric survey. The coupling analysis was carried out on the Danish publications in order to identify research specialities on the basis of the mutual relation of the publications. The analysis should be viewed as a supplement to both the publications and the citations analyses and their dependence on the Web of Science's subject categories at the level of journals. A coupling analysis can group publications on the basis of the publications' own lists of references. In this way subject groups can be created that cross the boundaries of the sometimes arbitrary journal-based groups defined in the Web of Science. For example, it is possible to break down Multidisciplinary Science to make it

possible to examine what these documents are dealing with in reality.

The coupling analysis identifies a number of interconnected, central and specifically Danish climate research specialties. It appears from and is confirmed by the coupling analysis that Denmark has number of central and specifically interconnected Danish climate research specialties. What is perhaps the most interesting, the coupling analysis confirms that palaeoclimatic research and ice core research are key Danish climate research specialties and that they simultaneously have great international impact. These research specialties constitute a significant share of the publication and citation activity in Geosciences (Multidisciplinary) and Multidisciplinary Sciences. In this way the coupling analysis supplements the publication and citation analyses by rendering Danish climate research specialties visible within Geosciences (Multidisciplinary), for instance.

It is evident from the bibliometric survey that climate research is an international research area to a high degree. The degree of collaboration between Danish researchers and researchers from other countries is analysed below. 200 of the 980 publications included in the survey have one author only while the remainder has two or more. There is an average of 3.9 authors per publication. These can be other Danish co-authors or partners from abroad.

Figure 4.5. Joint publications between Danish and foreign climate researchers 2003-2007



Source: Bibliometric survey, Royal School of Library and Information Science, 2008

USA is the biggest partner followed by German, the United Kingdom, Sweden, France and Norway. Denmark thus collaborates with a wide range of countries in the area of climate research. The picture emerging from figure 4.5 above is to some extent backed up if the most frequent partners among the 163 climate research projects active in 2007 are examined. Of the 163 projects, 107 were purely Danish projects corresponding to 66 %, while the remaining 56 projects, corresponding to 34 %, were projects conducted in collaboration with one or more partner from abroad. The most frequent partner countries were the United Kingdom, Germany, France, Norway and Sweden. In general the most frequent partner countries for Danish climate research are also among the most productive countries in the world.

Chapter 5 - Research in climate adaptation



This chapter elaborates the mapping of Danish climate research in relation to research in climate adaptation in the public sector. This takes place in light of The Government's strategy for adaptation to a changing climate in Denmark, which inter alia points to the need for a coordinated research effort to support the knowledge demand within and across the eleven societal sectors the strategy deals with. The research coordination effort in this area is facilitated by the Coordination Unit for Research in Climate Change Adaptation, which is one of the initiatives in the Government's climate adaptation strategy. This chapter was prepared by the Coordination Unit for Research in Climate Change Adaptation, and it is based on the same questionnaire survey that formed the basis of Chapter 2 on climate research in the public sector. The survey is described in Chapter 1.

In the survey a total of 256 out of 520 participating climate researchers (49 %) stated climate adaptation as one of several focuses for their research, while 103 out of a total of 263 research projects (39 %) deal with the area of climate adaptation to varying degrees.

Research in climate adaptation thus constitutes a relatively small area of overall climate research. Most of the researchers who have prioritised climate adaptation focus on adaptation capacity and the fewest on autonomous adaptation. The research competences are

primarily to be found in the natural sciences and the social sciences, but there is also significant potential within technical science, agricultural and veterinary science and the humanities. Most of the scientists are oriented in terms of the sectors of Nature management, Agriculture and forestry, and Building and Construction. The same pattern is seen in the calculation of number of projects that have been prioritised in relation to climate adaptation. If, however, the projects' budgets are used in the calculation, it can be seen that projects where the main focus is on climate adaptation are primarily to be found in the areas of Agriculture and forestry, Buildings and infrastructure and Land use planning.

The mapping of climate adaptation is presented in the following with special focus on the potential that exists for a coordinated research effort in the area of climate adaptation. In other words, there is focus on the capacity that could contribute to climate adaptation research and thus be included in a research coordinating effort. All researchers and projects that have stated climate adaptation as a major or minor focus of their climate research are included for the same reason.

5.1. Scope and research profile

This section describes the scope of current public research within the area of climate adaptation.

Table 5.1. Number of researchers and FTEs within the focus area of climate adaptation 2007/2008

Institution	Researchers with climate adaptation as one of several focus areas		Researchers with climate adaptation as primary focus area	
	Number of researchers	Number of researcher FTEs	Number of researchers	Number of researcher FTEs
Aarhus University	77	18	19	5
Technical University of Denmark	45	13	17	4
University of Copenhagen	30	12	11	3
Aalborg University	22	5	9	2
GEUS	9	4	0	0
Royal Danish Academy of Fine Arts – School of Architecture	15	4	6	0,5
Danish Meteorological Institute	6	3	0	0
Roskilde University	10	2	3	0,5
Other	42	8	14	4
Total	256	69	79	19

The FTEs stated are calculated as the researchers' total climate research. They cannot therefore be directly assigned to the part of their research that concerns adaptation. The following have been gathered under "Other", because the total number of FTEs at the institution has been stated in the survey at less than two FTEs: the Danish Institute of Governmental Research – AKF, the Danish Institute of Fire and Security Technology, DHI, the Danish Institute for International Studies, the Secretariat of the Danish Economic Council, the Natural History Museum Aarhus, the National Museum, the University of Southern Denmark, Statens Serum Institut - SSI, the Danish Technological Institute, the Danish Road Directorate and Aarhus School of Architecture.

Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008

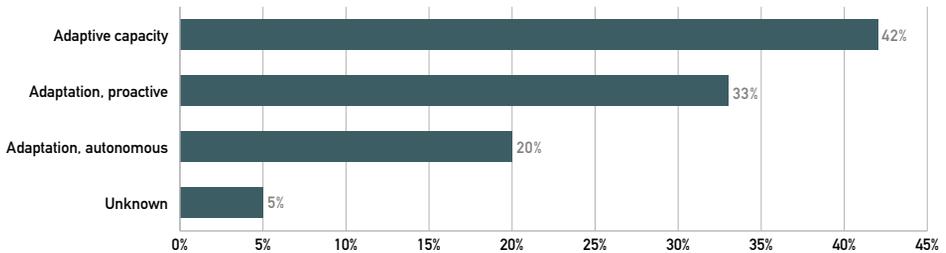
Table 5.1 shows the number of researchers who have stated climate adaptation as one of their focus areas, distributed over public research institutions.

The table shows that the number of researchers whose primary research focus is within the climate adaptation area comprises approximately one third of all researchers who have prioritized climate adaptation at the institutions stated. This corresponds to 79 researchers and 19 FTEs

in all. The remainder (177 researchers in all corresponding to 50 FTEs) have another focus area as first priority and have thus prioritized climate adaptation as a secondary or lower focus area.

Measured in number of researchers, the majority with a focus on climate adaptation are at Aarhus University, the Technical University of Denmark and the University of Copenhagen. If the researchers are assessed according to job

Figure 5.1. The share of climate researchers with climate adaptation as one of several focus areas distributed by primary adaptation focus 2007/2008



The figure is based on a total of 256 researchers.

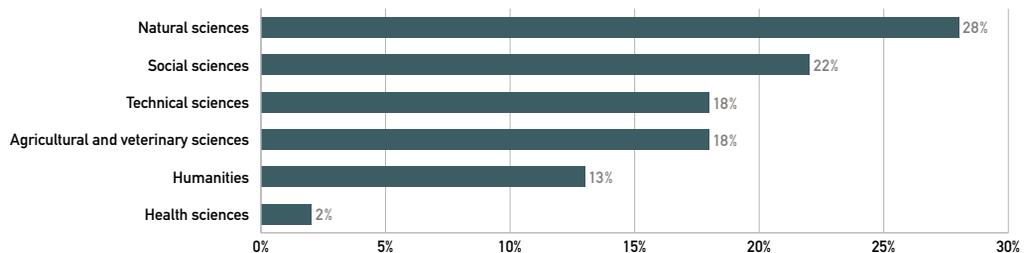
Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008

category, it appears that, like in climate research in general (cf. Chapter 2), there is a tendency for relatively few PhD students and postdocs to engage in climate adaptation research in relation to professors, senior associate professors, associate professors and senior scientists.

Figure 5.1 shows the distribution of researchers over the three focus areas within climate adaptation. The figure shows that researchers primarily focus on adaptation capacity. This focus area encompasses the capacity of a system

(natural as well as anthropogenic) to adapt to climate change, limit potential damage, exploit favourable possibilities or manage the consequences. Next comes proactive adaptation, including adaptation that takes place before the impacts of climate change are observed. The fewest number of researchers focus on autonomous adaptation, i.e. adaptation that does not constitute a conscious response to climatic stimuli, but which in natural systems is triggered by ecological changes and in anthropogenic systems by changes in market conditions or welfare.

Figure 5.2. The share of climate researchers within climate adaptation as one of several focus areas distributed by primary adaptation focus 2007/2008



The figure is based on a total of 256 researchers.

Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008



This trend is found again within the research projects dealing with climate adaptation.

Figure 5.2 shows the share of researchers in the area of climate adaptation distributed over fields of science.

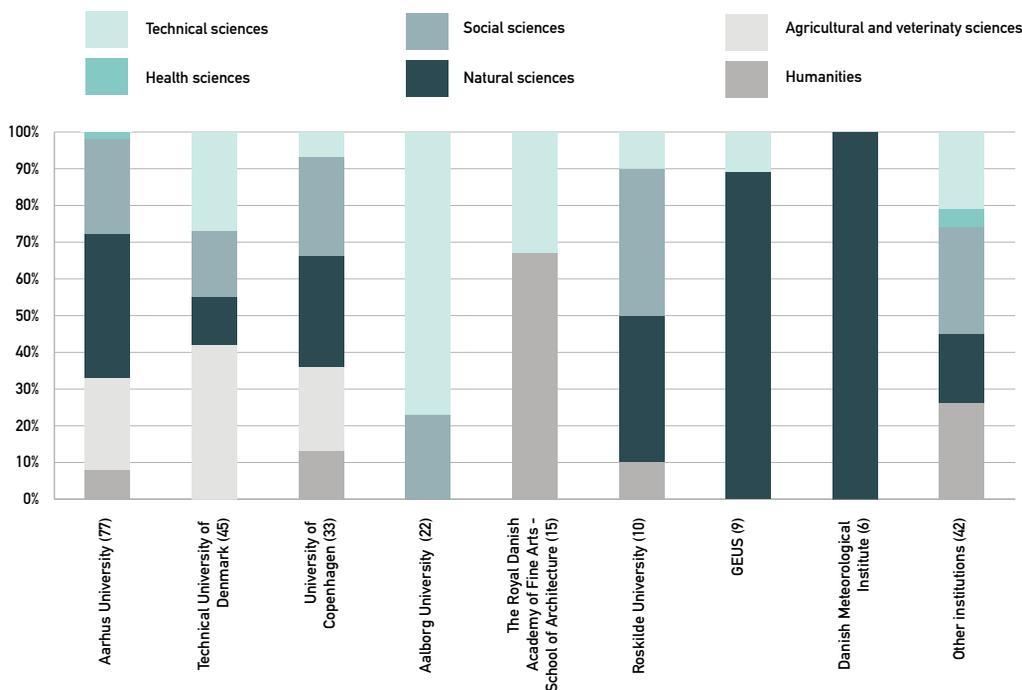
The figure shows that the majority of researchers in the area of climate adaptation (28 %) are to be found within natural science, followed by social science (22 %). Next are technical science and agricultural and veterinary science, both of which have a share of 18 % of

researchers. Last comes health science with 2 %. The placing of health science may be an expression of the fact that researchers within this area traditionally do not consider their research as adaptation research.

Figure 5.3 shows the relative distribution of researchers within the six fields of science.

The figure shows that in general the public research institutions can be divided into "generalists" and "specialists", where Aarhus University, the

Figure 5.3. The relative distribution of researchers within main fields of science 2007/2008



The figure is based on a total of 256 researchers. The number of researchers at each institution is stated in parentheses. Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008.

Table 5.2 below shows the distribution of the adaptation-related research projects and project budgets among the public research institutions.

Table 5.2. Number of research projects and project budgets related to the area of climate adaptation 2003-2008.

Institution	Projects with adaptation as research focus		Projects with adaptation as the primary research focus	
	Number of projects	Total annual budget sum (DKK million)	Number of projects	Total annual budget sum (DKK million)
Technical University of Denmark	30	45	16	33
University of Copenhagen	12	33	7	29
Aarhus University	23	21	8	7
Aalborg University	4	11	0	0
GEUS	2	5	0	0
Danish Meteorological Institute	9	5	0	0
DHI	2	4	1	4
Roskilde University	7	3	1	0,5
Other institutions	14	8	5	3
Total	103	135	38	76.5

Only institutions with a total annual project budget of more than DKK 3 million have been included. Projects are assigned to the institutions that hold the project leadership (are coordinating) for the individual research projects.

Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008

University of Copenhagen, the Technical University of Denmark and Roskilde University have a broad coverage of the area while GEUS, the Danish Meteorological Institute, the Royal Danish Academy of Fine Arts – School of Architecture and the other institutions have a more specialised profile within climate adaptation research. Like climate research generally, the area as whole is dominated by the natural and technical scientific disciplines.

The questionnaire survey identified 103

research projects in the area of adaptation out of a total of 263 registered projects, of which 38 projects had climate adaptation as the primary focus.

It can be seen that the universities stand out as the most important institutions for climate adaptation research projects. A closer analysis of the individual projects also shows that the research projects are to a high degree carried out in the form of collaboration between research institutions, nationally and internationally.

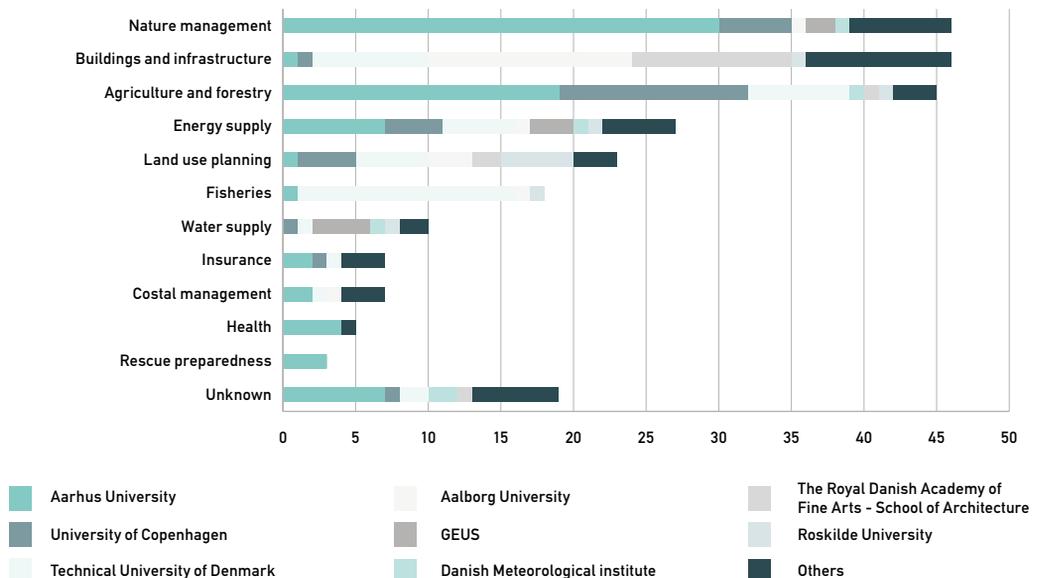
5.2. Research competences in the individual sectors

This section focuses on the orientation of climate adaptation research in relation to the eleven sectors that the Government’s strategy for adaption to a changing climate.

As appears from figure 5.4, the focus within the individual sectors is generally present at more than one institution. The fisheries sector is, however, a significant exception and is mainly represented by the Technical University of Denmark and

the sectors health and rescue preparedness, found primarily at Aarhus University. The last observations should be treated with caution, as there are very few researchers within both sector areas in the survey. Within the sectors Nature management and Agriculture and forestry Aarhus University and the University of Copenhagen, respectively, dominate. Most researchers in the survey focus on the sectors Nature management, Buildings and infrastructure, Agriculture and forestry and Energy supply, while the fewest researchers focus on Water supply, insurance, Coastal management and

Figure 5.4. Number of researchers distributed by primary sector focus and institutions 2007/2008



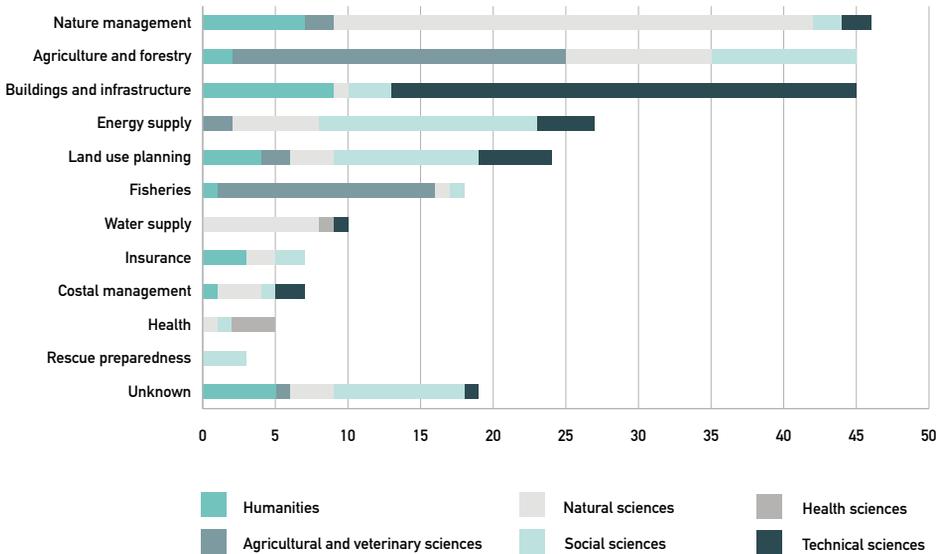
The figure is based on a total of 256 researchers. The projects are assigned to the institutions that hold the project leadership (are coordinating) for the individual research projects.

Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008



The figure below shows the sector focus within each of the fields of science.

Figure 5.5. Number of researchers distributed by primary sector focus and field of science



The figure is based on a total of 256 researchers.

Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008

Health and Rescue preparedness. It should also be noted that more researchers than shown in the figure relate their research to these sectors but with a lower priority.

Figure 5.5 shows the composition of the researchers' fields of science related to the eleven sectors of the climate adaptation strategy. The figure shows the tendency of natural science, technical science and agricultural and veterinary science to dominate in most of the sectors, but both the social sciences and

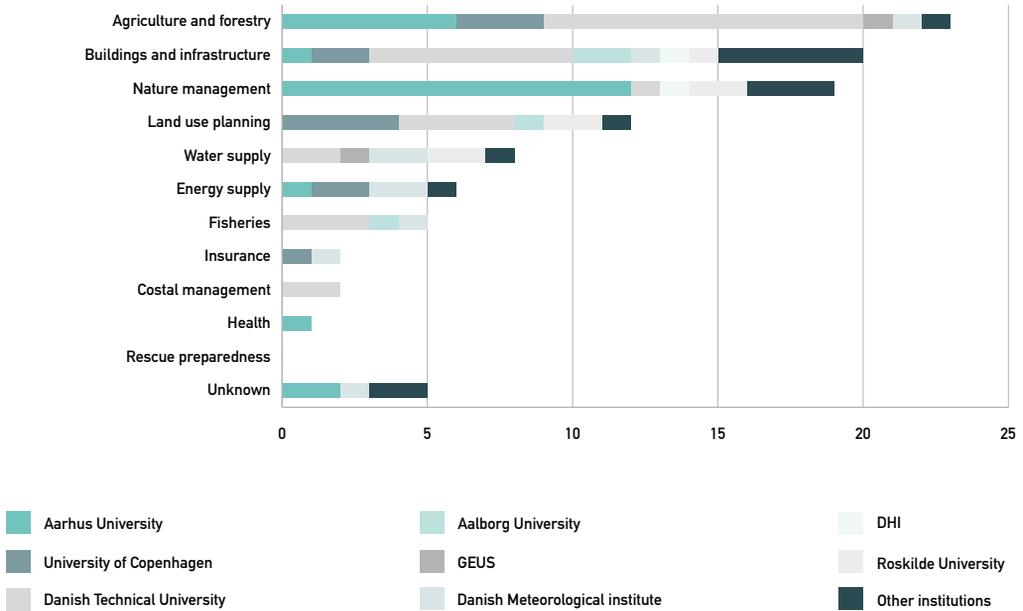
the humanities are present within almost all sectors. In other words, there exists a potential for being able to meet the knowledge demand within and across the individual sectors by involving a broad range of academic disciplines.

5.3 Research projects related to the individual sectors

This section examines the sector focus of the 103 research projects with relation to the area of climate adaptation.



Figure 5.6. Number of research projects with a relation to the climate adaptation area distributed by primary sector focus 2003-2008



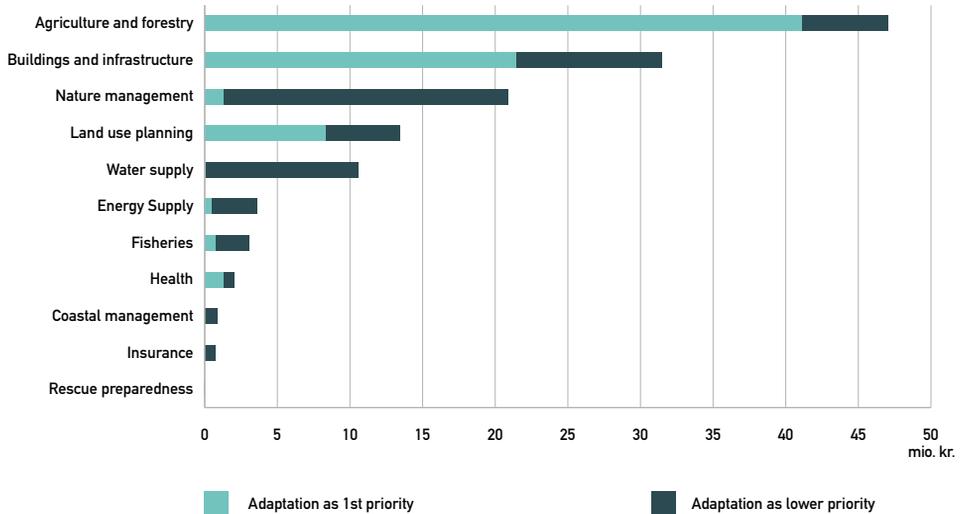
The figure is based on a total of 103 projects. The projects are assigned to the institutions that hold the project leadership (are coordinating) for the individual research projects.

Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008

Figure 5.6 above shows the primary sector focus of research projects associated with the area of climate adaptation.

Four sectors stand out from the others by virtue of higher research activity: Agriculture and forestry, buildings and infrastructure, nature management, and land use planning. The same pattern can be observed from the projects' average annual budgets distributed over the individual sectors.

Figure 5.7. Total annual budgets for research projects with climate adaptation as first or lower priority



The project volume within the individual sectors calculated on the basis of the total annual budgets for adaptation-related research projects in 2007. The number of projects with climate adaptation as first priority adds up to 38, while the projects with adaptation as a lower priority add up to 65.

Source: Questionnaire survey conducted by the Coordination Unit for Research in Climate Change Adaptation, 2008

The figure shows that the projects with climate adaptation as their primary focus are to be found in agriculture and forestry (42 DKK million), Buildings and infrastructure (22 DKK million) and Land use planning (8 DKK million), while the

projects within Nature management (22 DKK million) and Water supply (12 DKK million) have predominantly stated focus on climate adaptation as a lower priority.

Annex 1 – Overview of bibliometric subject categories



This annex contains description of the 23 Web of Science subject categories contained in the bibliometric study (from <http://scientific.thomsonreuters.com/mjl/scope/>).

SUBJECT CATEGORY: SOIL SCIENCE

DESCRIPTION: Soil Science covers resources concerning many aspects of the formation, nature, distribution, and utilization of soils including soil biology and fertility, soil conservation and tillage research, soil contamination and reclamation, soil biochemistry, and soil chemistry and physics.

SUBJECT CATEGORY: AGRONOMY

DESCRIPTION: Agronomy covers resources on the selection, breeding, management, and post-harvest treatment of crops including crop protection and science, seed science, plant nutrition, plant and soil science, soil management and tillage, weed science, agroforestry, agroclimatology, and agricultural water management.

SUBJECT CATEGORY: ASTRONOMY & ASTROPHYSICS

DESCRIPTION: Astronomy & Astrophysics covers resources that focus on the science of the celestial bodies and their magnitudes, motions, and constitution. Topics include the properties of celestial bodies such as luminosity, size, mass, density, temperature, and chemical composition, as well as their origin and evolution. This category includes some resources on planetary science that focus on astrophysical aspects of planets. General resources on planetary science are placed in the GEOCHEMISTRY & GEOPHYSICS category.

SUBJECT CATEGORY: BIODIVERSITY CONSERVATION

DESCRIPTION: Biodiversity Conservation covers resources on the conservation management of species and ecosystems. Topics include conservation ecology, biological conservation, paleobiology, natural history and the natural sciences.

SUBJECT CATEGORY: ECOLOGY

DESCRIPTION: Ecology covers resources concerning many areas relating to the study of the interrelationship of organisms and their environments, including ecological economics, ecological engineering, ecotoxicology, ecological modeling, evolutionary ecology, biogeography, chemical ecology, marine ecology, wildlife research, microbial ecology, molecular ecology, and population ecology. This category also includes general ecology resources and ones devoted to particular ecological systems.

⁸ The journals for the individual subject categories can be seen here: <http://scientific.thomsonreuters.com/cgi-bin/jmlst/jlsubcat.cgi?PC=D>



SUBJECT CATEGORY: **ENERGY & FUELS**

DESCRIPTION: Energy & Fuels covers resources on the development, production, use, application, conversion, and management of nonrenewable (combustible) fuels (such as wood, coal, petroleum, and gas) and renewable energy sources (solar, wind, biomass, geothermal, hydroelectric). Note: Resources dealing with nuclear energy and nuclear technology appear in the NUCLEAR SCIENCE & TECHNOLOGY category.

SUBJECT CATEGORY: **ENGINEERING (CIVIL)**

DESCRIPTION: Engineering (Civil) includes resources on the planning, design, construction, and maintenance of fixed structures and ground facilities for industry, occupancy, transportation, use and control of water, and harbor facilities. Resources also may cover the sub-fields of structural engineering, geotechnics, earthquake engineering, ocean engineering, water resources and supply, marine engineering, transportation engineering, and municipal engineering.

SUBJECT CATEGORY: **ENGINEERING, ENVIRONMENTAL**

DESCRIPTION: Engineering, Environmental includes resources that discuss the effects of human beings on the environment and the development of controls to minimize environmental degradation. Relevant topics in this category include water and air pollution control, hazardous waste management, land reclamation, pollution prevention, bioremediation, incineration, management of sludge problems, landfill and waste repository design and construction, facility decommissioning, and environmental policy and compliance.

SUBJECT CATEGORY: **ENVIRONMENTAL SCIENCES**

DESCRIPTION: Environmental Sciences covers resources concerning many aspects of the study of the environment, among them environmental contamination and toxicology, environmental health, environmental monitoring, environmental geology, and environmental management. This category also includes soil science and conservation, water resources research and engineering and climate change.

SUBJECT CATEGORY: **ENVIRONMENTAL STUDIES**

DESCRIPTION: Environmental Studies covers resources that are multidisciplinary in nature. These include environmental policy, regional science, planning and law, management of natural resources, energy policy, and environmental psychology.

SUBJECT CATEGORY: **FORESTRY**

DESCRIPTION: Forestry covers resources concerning the science and technology involved in establishing, maintaining and managing forests for various uses, including wood

production, water resource management, wildlife conservation and recreation.

SUBJECT CATEGORY: GEOCHEMISTRY & GEOPHYSICS

DESCRIPTION: Resources in this category may focus on either Geochemistry or Geophysics or both. Geochemistry covers resources that deal with the chemical composition and chemical changes in the Earth or other planets or asteroids. Topics include research on related chemical and geological properties of substances, applied geochemistry, organic geochemistry, and biogeochemistry. Geophysics covers resources on the application of the methods and techniques of physics to the study of the structure of the Earth and the processes affecting it. Topics addressed include seismology, tectonics, tectonophysics, geomagnetism, radioactivity, and rock mechanics.

SUBJECT CATEGORY: GEOGRAPHY (PHYSICAL)

DESCRIPTION: Geography (Physical) covers resources dealing with the differentiation of areas of the Earth's surface as shown in the character, arrangement, and interrelations over the world of such elements as climate, elevation, soil, vegetation, population, land use, industries, or states, as well as the unit areas formed by the complex of these individual elements. Resources which focus on economic, human, and urban topics are covered in the SSCI GEOGRAPHY category.

SUBJECT CATEGORY: GEOLOGY

DESCRIPTION: Geology covers resources that deal with the physical history of the Earth, the rock of which it is composed, and the physical changes (not the physics) that the Earth has undergone or is undergoing. Resources in this category cover sedimentology, stratigraphy, hydrogeology, ore geology, structural geology, regional geology, and petrology. These resources are somewhat narrow in scope and are not given to the interdisciplinary study of the Earth Sciences.

SUBJECT CATEGORY: GEOSCIENCES (MULTIDISCIPLINARY)

DESCRIPTION: Geosciences (Multidisciplinary) covers resources having a general or interdisciplinary approach to the study of the Earth and other planets. Relevant topics include geology, geochemistry/geophysics, hydrology, paleontology, oceanography, meteorology, mineralogy, geography, and energy and fuels. Resources having a primary focus on geology, or geochemistry & geophysics are placed in their own categories.

SUBJECT CATEGORY: MARINE & FRESHWATER BIOLOGY

DESCRIPTION: Marine & Freshwater Biology covers resources concerning many aquatic sciences, including marine ecology and environmental research, aquatic biology,

marine pollution and toxicology, aquatic botany and plant management, estuarine and coastal research, diseases of aquatic organisms, molluscan and shellfish research, fish biology and biofouling.

SUBJECT CATEGORY: METEOROLOGY & ATMOSPHERIC SCIENCES

DESCRIPTION: Meteorology & Atmospheric Sciences covers those resources that deal with the atmosphere and its phenomena, especially weather and weather forecasting. Resources in this category are concerned with the atmosphere's temperature, density, winds, clouds, precipitation and other characteristics, as well as the structure and evolution of the atmosphere in terms of external influences and the basic laws of physics. This category also includes resources dealing with climatology.

SUBJECT CATEGORY: MULTIDISCIPLINARY SCIENCES

DESCRIPTION: Multidisciplinary Sciences includes resources of a very broad or general character in the sciences. It covers the spectrum of major scientific disciplines such as Physics, Chemistry, Mathematics, Biology, etc. Nature and Science are the preeminent resources in this category and serve as typical examples. The Web site of the National Science Foundation is a good example of a web resource included in this category. Some specialized resources that have a wide range of applications in the sciences also may fall under this category. The journal *Fractals---Complex Geometry Patterns and Scaling in Nature and Society* would be an example of such a resource.

SUBJECT CATEGORY: OCEANOGRAPHY

DESCRIPTION: Oceanography covers resources concerning the scientific study and exploration of the oceans and seas in all their aspects, including the delimitation of their extent and depth, the physics and chemistry of their waters, and the exploration of their resources.

SUBJECT CATEGORY: PALEONTOLOGY

DESCRIPTION: Paleontology includes resources that focus on the study of life and physical conditions, such as climate and geography, of past geological periods as recorded by fossil remains.

SUBJECT CATEGORY: PLANT SCIENCES

DESCRIPTION: Plant Sciences covers resources concerning many aspects of the study of plants including systematic, biochemical, agricultural, and pharmaceutical topics. This category includes materials on higher and lower plants, terrestrial and aquatic plants, plant cells, entire plants, and plant assemblages.

SUBJECT CATEGORY: **REMOTE SENSING**

DESCRIPTION: Remote Sensing includes resources on the technique of remote observation and of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiation from space. This category also covers resources on the applications of remote sensing in environmental, atmospheric, meteorological, geographic, and geoscientific observations. Resources on geographic information systems that deal in large part with remote sensing are also included.

SUBJECT CATEGORY: **WATER RESOURCES**

DESCRIPTION: Water Resources covers resources concerning a number of water-related topics. These include desalination, ground water monitoring and remediation, hydrology, irrigation and drainage science and technology, water quality, hydraulic engineering, ocean and coastal management, river research and management, waterways and ports.

