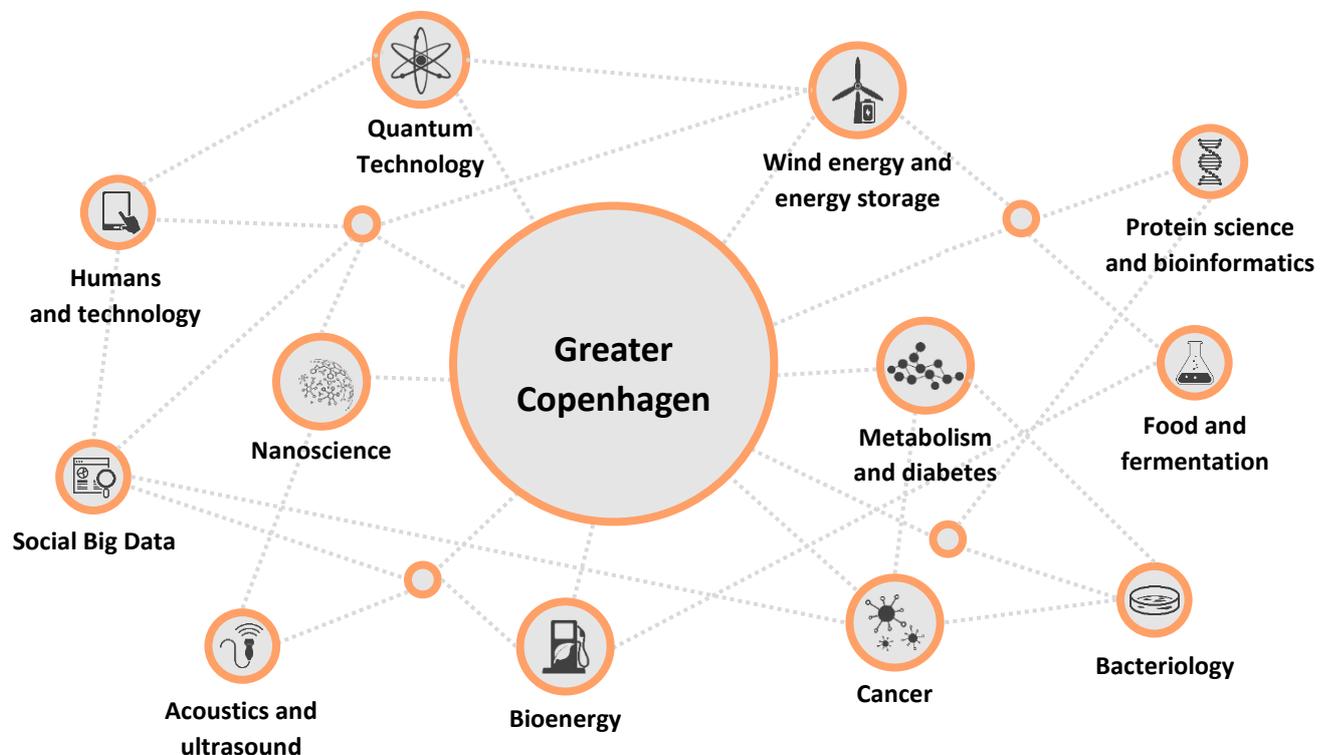

Research strengths of Greater Copenhagen with investment prospects

Background Report

November 2016



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Preface

Greater Copenhagen is among Europe's leading science cities. The region is home to numerous, absolutely world-class research environments.

Research provides answers and solutions to many of the societal challenges facing us worldwide. This relates for example to new types of treatment targeting diseases, which are spreading globally such as cancer, obesity and diabetes. It relates to the development and design of the sustainable energy systems of the future. And it provides methods and new insights that can help us reap the benefits of new digital technologies and products.

At the same time, companies and investors globally are seeking access to new cutting-edge science and technology that can prove crucial to the development of new products, services or new business models that can strengthen their position in intense international competition.

This report has identified research strengths in Greater Copenhagen from the perspective of investment promotion. What these research areas have in common is their ability to merge world-class science with a range of other value offerings that help attract foreign R&D investment to the region, such as a strong physical research infrastructure (labs, test facilities etc.), a large, competent pool of talent and well-developed university-industry relations.

Based on a combination of qualitative and quantitative methods, the report singles out 12 particularly promising areas of research with great potential for attracting investments to Greater Copenhagen. These areas are described in detail in 12 factsheets.

The 12 positions of strengths are wide-ranging, from research into new forms of treatment for life-threatening disease to quantum technologies that can constitute the basis for the supercomputers of the future.

Foreign investment in research and development leads to new jobs, growth and productivity, thereby providing an economic boost to the regions which succeeds in attracting it. Thus, Greater Copenhagen's special scientific strengths comprise an important starting point for efforts targeted at attracting investment.

We hope that the 12 selected fields of research constitute a strong basis for attracting future foreign investment to Greater Copenhagen.

This analysis has been compiled for the Capital Region of Denmark and Copenhagen Capacity in connection with the Capital Region's growth and development strategy (ReVUS).

Chapter 1

Research strengths with investment prospects

1.1 THE COMPETITIVE SITUATION OF GREATER COPENHAGEN

Companies worldwide are increasingly investing in ground-breaking research that can lead to the development of the products and services of the future.

This could be the development of new supercomputers for processing big data as well as new individualised therapies that can cure life-threatening disease with very few adverse reactions. Or the development of new sustainable energy storage technologies that can stabilize the power supply when the wind is not blowing.

When companies decide on making physical investments in R&D-activities abroad, it is often to gain from a close proximity to leading research environments, access to specialists and talented personnel or to make use of special research facilities, such as laboratories or big-science infrastructure (e.g. the “super microscope”, European Spallation Source (ESS), in Lund, Sweden).

States and cities compete globally to attract business R&D activities. Investments, which in many cases are accompanied by productive, well-paid labour, an influx of knowledge and increased economic activity. Greater Copenhagen participates in this competition, especially vis-à-vis other Northern European cities such as Stockholm-Uppsala, Amsterdam and Hamburg.

Greater Copenhagen performs strongly on several parameters that matters when seeking to attract research-related investment to the region. Generally, Danish research performs well in international comparisons. Greater Copenhagen is home to the greatest concentration of research institutes and higher education institutions in Scandinavia together with several world-leading research clusters, e.g. within life science and cleantech.

But competition among metropolitan areas to attract investments is intense. It is important for Greater Copenhagen to successfully differentiate itself and highlight the region's research strengths and their potential when it comes to developing breakthrough science and technology.

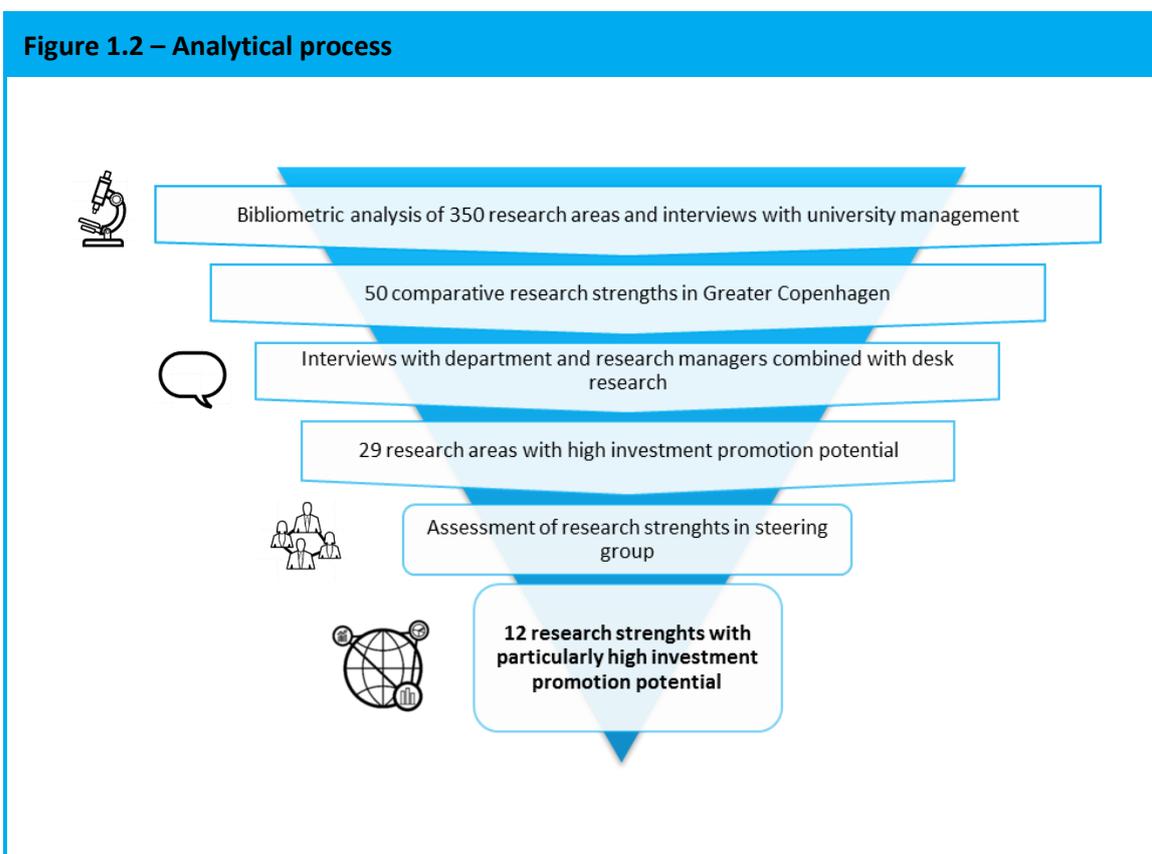
1.2 OBJECTIVE AND APPROACH

The aim of this report is to identify research strengths in Greater Copenhagen that carry significant prospects for attracting foreign investment.

The ambition has been to generate a strong foundation of fact-based knowledge that can serve as a basis for investment promotion and to provide new insights into what motivates foreign companies to collaborate with universities in Greater Copenhagen, e.g. for establishing R&D facilities in Denmark.

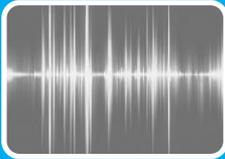
The analysis was conducted from April to November 2016 and resulted in the identification of 12 research areas with a particularly high potential for attracting investments. The 12 areas are described in detail in the factsheets that form the main output of the analysis. This report describes the analytical model and the methodological approach that led to the selection of the 12 areas.

The approach is based on a combination of a comprehensive bibliometric analysis, qualitative in-depth interviews with university management representatives, heads of departments, heads of research groups as well as companies. Furthermore, the analysis has drawn on an extensive desk research and accessible statistics. The figure below summarises the different phases of the process, which are elaborated in more detail in Chapter 2.



The 12 research strengths have not only been selected on the basis of research quality (measured by proxy through bibliometrics). Importantly, the selection should not be construed as a *ranking* of Greater Copenhagen’s many excellent research environments. Instead, the research strengths have been selected on the basis of a comprehensive assessment of a wide array of criteria, which are expected to carry weight for potential investors.

The figure below summarises the 12 fields of research identified in the process as well as the departments and centres in which the research is centred.



Acoustics and Ultrasound

Development of new advanced audio and hearing aid solutions. Application of ultra sound and 3D imaging for complex diagnosing.

Anchored: DTU Electrical Engineering (including Oticon Centre of Excellence for Hearing and Speech Sciences and Center for Fast Ultrasound Imaging).



Bacteriology

Solutions to counter antibiotic resistance and block biofilms. *Anchored:* Department of Biology, Department of Immunology and Microbiology, and Department of Veterinary Disease Biology at the University of Copenhagen, DTU Food.



Bioenergy

Application of enzymes, fermentation technology and the biochemical processes in developing 2nd generation biofuels. *Anchored:* Department of Geosciences and Natural Resource Management, Department of Plant and Environmental Sciences, Department of Chemistry, and Department of Biology at the University of Copenhagen. Chemicals Technology, Environment and Biosustain (NNF) at DTU. Center for Corporate Social Responsibility and BioBusiness Innovation Platform at CBS



Cancer research

Fundamental understanding of how cancer cells develop and spread, cancer diagnostics and strong environments focusing on developing and testing new drugs and new therapies. *Anchored:* Biotech Research and Innovation Centre (BRIC), DanStem stem cell center, Department of Immunology and Microbiology, and Department of Cellular and Molecular Medicine at the University of Copenhagen. DTU Bioinformatics, Copenhagen University Hospital.



Food and fermentation

Quality control of food using spectroscopic methods, food preservation, uptake of minerals in the body, nutritional research and food fermentation. *Anchored:* Department of Food Science and Department of Veterinary Disease Biology at the University of Copenhagen, DTU FOOD, DTU VET, DTU Bioengineering, DTU Chemical Engineering, Biosustain, and BioBusiness Innovation Platform, CBS.



Quantum Technology

Application of quantum properties of elementary particles in developing quantum-based supercomputers, ultra precise sensors and super fast communication. *Anchored:* Niels Bohr Institute at the University of Copenhagen, DTU Physics and DTU Photonics



Protein research and bioinformatics

Cutting edge research into the use of proteins for diagnostics using biological markers, new protein and sugar-based methods for drug delivery and personalised medicine. Anchored: Department of Cellular and Molecular Medicine and the Novo Nordisk Foundation Centre for Protein Research at the University of Copenhagen



Humans and technology

Understanding human interaction with, and use of, new technology. Anchored: Faculty of Humanities and Faculty of Social Sciences at the University of Copenhagen, Copenhagen Business School.



Metabolism and diabetes

Understanding metabolic processes and causes underlying life-style-related diseases such as obesity and type 2 diabetes. Anchored: Department of Biomedical Sciences, Novo Nordisk Foundation Centre for Basic Metabolic Research, and Department of Nutrition, Exercise and Sports at the University of Copenhagen, Department of Organization at CBS, Herlev Hospital.



Nanoscience

Manipulation of materials/substances at the molecular level, for example for developing materials with new properties, manipulation of the properties of plants, development of new therapies, for example in personalised treatments and new precise methods for drug delivery. Anchored: Nano Science Centre at the University of Copenhagen, DTU Nano and DTU Mechanical Engineering.



Social big data

Use of Big Data analysis to identify attitudes and trends amongst individuals and groups using algorithms that combine data from social media and registers. Anchored: Faculty of Humanities and Faculty of Social Sciences (including Department of Economics and Department of Anthropology) and Department of Computer Science at the University of Copenhagen, Department of IT Management, Department of International Business Communication and Department of Economics, CBS, DTU Compute.



Wind and energy storage

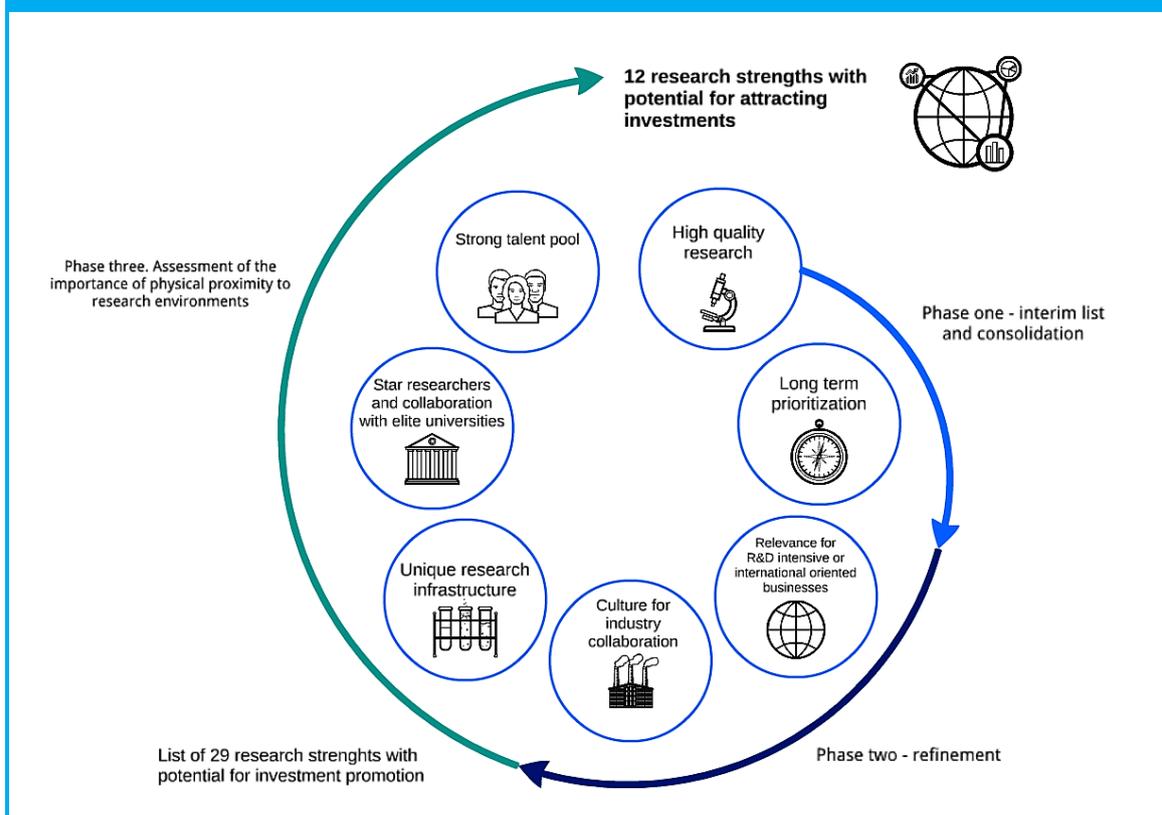
Development of wind turbines and new forms of energy storage such as flow batteries, electrolysis and fuel cells. Development of smart grid solutions for more efficient and even use of sustainable energy. Anchored: DTU Wind, DTU Energy, DTU Mechanical Engineering, DTU Electrical Engineering and DTU Compute.

1.3 RESEARCH STRENGTHS WITH INVESTMENT PROSPECTS

As part of the analysis of Greater Copenhagen's research strengths, IRIS Group developed a model for assessing the investment prospects for a specific research field. The model features seven key parameters that in many cases constitute important value offerings for companies considering locating R&D operations in another country.

The seven parameters are thus all reasons for companies to be geographically close to the research environments. We use these seven criteria to assess the investment potential of the research in Greater Copenhagen. The figure below illustrates the analytical model;

Figure 1.3 – Analytical model



High quality research is a fundamental precondition for a research area to attract investments to Greater Copenhagen. This spans excellent basic research as well as high-quality applied research. In many (but far from all) instances, high quality research is reflected in a high performance on bibliometric indicators, e.g. measuring the frequency of citations of research articles.¹

Second, the decision to invest in Greater Copenhagen may be influenced by the extent to which the area is subject to a **long-term strategic prioritisation** by the university and/or national and regional actors. Strategic prioritisation sends out an important signal that a research field will maintain its current momentum in the years to come. This could, for example, be by way of long-term research funding (e.g. by the Danish National Research Foundation, the Novo Nordisk Foundation etc.), or by the internal priorities of a research institution, for example funding for special excellence centres. Such strategic priorities constitutes an important forward-looking supplement to the bibliometric data.

Third, the **research area has relevance for industries with a high level of R&D intensity and/or businesses with a high level of cross-border, international operations**. High-quality research may be of limited interest from an industrial perspective (at least in the short-term), for example if the research activities is oriented towards gaining new fundamental insights into a new field².

Fourth, **culture and tradition for industrial collaboration** is an important condition for attracting investments. E.g. though a tradition for co-publishing research results with industrial partners. Or environments that performs well with respect to technology transfer and commercialisation of research results, e.g. licensing or spin-outs. It is important to have a strong culture of industrial collaboration if an area is to be attractive to potential foreign investors. At the same time, a promising spinout may be the direct aim of foreign investors.

Fifth, for many companies, **access to unique research infrastructure**, such as facilities for trialling and testing, high-tech systems, equipment, specialized technical and scientific staff or big science facilities (such as ESS in Lund), is a strong reason for investing in Greater Copenhagen. Unique research infrastructure and access to researchers and specialists who know how to use it, may for example enable companies to test and demonstrate new materials or drugs.

Sixth, the **presence of elite researchers and/or researchers that collaborate with leading global environments in their field** can be a key reason for investing. This could for example be research teams that are international frontrunners in producing high impact research, or environments that are highly capable in transforming research into practice.

¹ Bibliometric indicators provide a retrospective picture of research strengths and is thus often inadequate for identifying new, upcoming areas. Bibliometrics is furthermore categorised according to pre-defined, journal-based headings that do not always provide a correct depiction of the content, interrelationship and properties of a particular strength.

² However, it is important to emphasize that it is extremely difficult to establish a general relevance criterion for research from a commercial point of view. For example, industrial players with very long-term development horizons (e.g. in life science) are often highly interested in new fundamental discoveries.

It is also important for companies to be able to recruit younger talented scientists who have collaborated with international star researchers.

Seventh, **industrial access to talent** (highly qualified workforce/graduates/PhDs) from universities is an important driver for foreign investment. Access to a competent talent pool and specialists constitutes an important channel for transferring knowledge from research environments as well as an important source of recruitment for foreign companies.

Thus, it is not in itself sufficient for a particular research field to perform well according to bibliometric indicators for research quality. In the individual case, the various reasons for investing may carry more or less weight than in other cases. Furthermore, other factors may play a part such as cost of living, market access, airports, liveability in the region etc.

1.4 READING THE FACTSHEETS

The main outcome of the analysis are 12 factsheets, which provide a detailed description of a research field and its potential in an investment promotion context. The factsheets are structured in a standardised form:

The front page summarises the fact sheet with a brief introduction to the content, key environments and the investment attraction potential of research field.

The introduction provides an general description of the research strength, and highlight the key areas of high research quality as well as international collaboration.

The bibliometric key figures in the table illustrate some of the key bibliometric indicators that document Greater Copenhagen's leading position. This includes research output, level of excellence, industrial co-publication and Greater Copenhagen's ranking among the regions of comparison (see Sec. 2.1.2).

The section on key arguments for the area's investment promotion potential generally follows the figure above and emphasises the arguments for an area's potential by virtue of:

- The presence of star researchers and major scientific breakthroughs
- Talent pool
- Unique research facilities/infrastructure
- Strong collaboration with leading international research environments
- Extensive industrial collaboration

Finally, some of the factsheets provides examples of spin-outs or quotes emphasizing the potential of the area.

Chapter 2

Methodological approach

2.1 BIBLIOMETRIC ANALYSIS AND INTERVIEWS WITH UNIVERSITY MANAGEMENT

The first step in the process consisted of a comprehensive bibliometric analysis of a total of 334 pre-defined research fields. The aim of the bibliometric analysis was to narrow down the 334 fields to an interim list of approximately 50 areas, displaying high quality research.

The international research database Scopus was used for the bibliometric analysis. Scopus contains approximately 55,000,000 records of research articles, conference contributions and patents granted to researchers and research institutes worldwide.

2.1.1 Regions of comparison

The first task was to define a number of European metropolitan areas that would serve as regions of comparison vis-à-vis Greater Copenhagen. These regions were basically chosen as the European regions that Greater Copenhagen typically competes with in attracting foreign investment. These reference regions are listed in Table 2.1.

Table 2.1. Nine regions of comparison in the bibliometric analysis

Amsterdam	Geneva Lausanne	Munich
Berlin	Hamburg	Oslo
Dublin	Helsinki	Stockholm/Uppsala

Source: IRIS Group (2014).

In Greater Copenhagen, the analysis included the three big universities: University of Copenhagen (UCPH), Copenhagen Business School (CBS) and the Technical University of Denmark (DTU).

In all nine regions of comparison, the analysis covered a similar combination of technical universities, business schools and at least one classic university offering research in the humanities, social sciences, theology, etc.

Furthermore, research conducted in the regions' university hospitals was also included in the analysis.³

³ Appendix 2 lists the research institutions covered by the analysis.

2.1.2 Key bibliometric indicators

Phase I consisted of defining relevant indicators for research output and quality research. The key indicators are briefly described below:

Research production: The target indicator used was scholarly output, covering published research in the form of articles, reviews and conference contributions. To ensure that only areas of research with a significant volume were included in the analysis, a minimum threshold was set at least 250 articles between 2005-2015.

Quality of research: The following two indicators were employed to measure quality research:

- *Research excellence:* The proportion of articles among the 10% most cited globally within the specific academic area in the period 2005-2015.
- *Field Weighted Citation Impact (FWCI)* measure the relationship between citations per publication in the research field, locally, and the average number of citations per publication in research field worldwide. FWCI is an index in which $FWCI = 1$ indicates that the average impact of a local field of research corresponds to the global average. $FWCI > 1$ indicates that the impact is greater than the global average, whereas $FWCI < 1$ indicates a lower average impact than the global average.

In **Phase II** the research fields were listed on the basis of research quality. First, we normalised the two indicators for quality research and merged them into one overall indicator for quality.

We furthermore calculated Greater Copenhagen's ranking, within each field, among the comparator regions for the three indicators of research output, number of highly cited articles and Field Weighted Citation Impact.

Next, we sorted all fields of research according to their scores on the consolidated quality indicator. We then reviewed the list from the top to assess the rankings of individual research fields according to scholarly output, number of highly cited articles (research excellence) and field weighted citation impact vis-à-vis the comparator regions.

The criteria for inclusion in the initial overall list were that the field of research:

- 1) Scored highly on the weighted quality indicators.
- 2) Ranked in the Top 3 among the regions of comparison and satisfied at least one of the three indicators (scholarly output, number of highly cited articles (research excellence) and field weighted citation impact).

In the first instance, we consolidated an overall list of about 70 research fields with high scores on the overall indicators for research quality and which, at the same time, were in the Top 3 among the regions of comparison with at least one of the indicators noted above.

2.1.3 Focus group interview with university managements

Subsequently, we conducted group interviews with university management representatives at each of the three universities (Copenhagen Business School, Technical University of Denmark and the University of Copenhagen). The aim of the focus group interviews was to qualify and refine the list of research strengths and potential areas of strength.

Initially, the overall list of (potential) strengths was submitted to university managements followed by a thorough discussion in order to qualify the list. The focus group interviews were structured according to the following overarching themes:

- 1) A review of the overall list of research strengths in order to assess the validity of the bibliometric findings and identify possible interrelated fields of research, which should be analysed as a consolidated, overall strength.
- 2) Identification of research strengths that did not appear in the bibliometric analysis.
- 3) Discussion of the underlying reasons for the university's strengths in the research areas identified in the bibliometric analysis.
- 4) Information about recent realised or planned investments in the identified fields of research, e.g. with excellence funding, etc.

The overall result of the bibliometric analysis and focus group interviews with senior university managements led to a consolidated list of about 50 research fields that could be potential candidates for a Top 10 listing of research fields with a high potential for attracting foreign investment.

2.2 INVESTMENTS IN RESEARCH FACILITIES AND TRADITION FOR INDUSTRY-COLLABORATION

The next step in the analysis was to screen the approximately 50 research areas on the interim list in order to assess their prospects for attracting investment.

- *First*, we sought to identify, whether the nature and content of research was relevant for R&D-intensive companies in sectors with a tradition for cross-border investment.
- *Secondly*, whether there was a culture and tradition for university-business collaboration within the specific research fields. For example, in the form of joint research projects with involvement from private companies, licensing agreements and spin-outs.

2.2.1 Interviews with heads of department

In order to gain a deeper understanding of the content of research and an overall assessment of the relevance of the research field with respect to foreign investments, we conducted interviews with relevant heads of departments, which have contributed with important research in the selected areas.

The relevant departments were singled out by initially identifying the most cited researchers from the University of Copenhagen, CBS and DTU within each research area, using the Scopus database, and subsequently investigated the departments at which the top researchers were employed.

Relevant heads of department were contacted for a telephone interview to discuss the fields of research on the overall interim list to which researchers in their department had contributed significant research.

Interviews with heads of department were structured in line with the following questionnaire:

Box 2.1. Themes for interviews with heads of department

- a) Assessment of bibliometric findings
- b) Brief introduction to the content of the research field
 - Important commercial applications and potentials for attracting investment, including the significance of geographical proximity.
 - Figures for FTE researchers in the specific environments as well as collaboration with other departments.
- c) Excellence funding for the research environment over the past 3-5 years (Danish National Research Foundation, ERC grants, private foundations, etc.).
- d) Collaboration with leading foreign research environments
- e) Recent or planned research investments, e.g. in research infrastructure.
- f) Talent - how many Master's graduates, PhDs and postdocs are trained on an annual basis?
- g) Commercialisation and industrial relations, i.e. tradition for industrial collaboration with Danish or international companies, spinouts, etc.

Source: IRIS Group

The interviews with heads of department helped to provide a deeper understanding of the content and scope of research as well as identifying key elite researchers, major scientific breakthroughs and relevant future investments.

2.2.2 Supplementary desk research

Subsequently, we carried out supplementary desk research.

The first step focused on merging the listed research headings into coherent fields of research based on input from the heads of departments and by merging different research categories, featuring the same highly cited researchers, under common headings.

The second step in the research process focused on clarifying and assessing the research fields according to the following key parameters:

- Attraction of excellence funding (ERC grants, basic research funding, private foundations, etc.)
- Major, extraordinary research investments

- Tradition for industrial interaction (e.g. via organisational units for research-industry collaboration).
- International collaboration partners and ability to attract guest researchers, etc.
- Parameters that necessitate physical proximity to research, e.g. special laboratories and other research facilities, access to talent. etc.

The outcome was a consolidated general interim list of 29 research strengths and an overall assessment of the investment attraction potential of each of these areas. Appendix 1 shows the overall list of the 29 areas and an assessment of the areas' investment attraction potential.

2.3 PRIORITISING THE SELECTED STRENGTHS

The consolidated interim list, featuring 29 research fields was submitted to the project steering group, in which the three universities were represented. The steering group reviewed the fields and helped select 10-12 fields deemed to have strong prospects for attracting investments.

It was decided by the steering group to prioritise 12 areas of strength. Subsequently, detailed factsheets were compiled for all 12 areas, describing their potential for attracting foreign investment. Table 5.2 sums up the 12 prioritised areas.

Table 2.2. Research areas with a high potential for attracting investments to Greater Copenhagen

Bacteriology	Food and fermentation	Nanotechnology	Protein research and bioinformatics
Bioenergy	Metabolism	Quantum technology	Social Big Data
Cancer research	Humans and technology	Sound and ultrasound	Wind and energy storage

Source: IRIS (2014).

2.4 FACTSHEETS

An in-depth analysis was carried out in all 12 areas in order to achieve a thorough understanding of the potential of the areas for investment promotion. The aim was to increase awareness of the particular properties of the research fields, which are crucial for attracting investment, cf. Figure 1.2.

The analytical process comprised of the following steps:

- Phone interviews with research group managers and star researchers in the field

- Interviews with selected Danish and foreign companies with R&D operations within the research field and which know the environments in Greater Copenhagen.
- Supplementary quantitative indicators for the 12 areas:
 - Masters and PhD production
 - Inventions and spin-outs
- Identifying major research breakthroughs rooted in Greater Copenhagen's strong fields of research.

Interviews with top researchers and companies focused on gaining a deeper understanding of the importance of active physical presence and operations in Greater Copenhagen in giving companies a competitive edge that they could not achieve elsewhere. This furthermore related to the importance of access to special expertise, talent, research equipment, data, etc.

The outcome of this phase was 12 factsheets with in-depth descriptions of the selected research strengths with strong prospects for attracting foreign investment, cf. the general model in Chapter 1.

Appendix 1

Overall list of 29 strengths following Phase II

2.5 INTRODUCTION

As described in Chapter 2, phase II led to 29 research strengths that are expected to carry a high potential for attracting investment. These are listed and described briefly in the table below.

In phase III, the broad list was narrowed down to twelve areas with particularly great investment attraction potential. Interlinkages and overlaps between the individual areas were identified through this process. It should be noted that the list it is an "intermediate product". The 12 factsheets include relevant elements of areas that did not in themselves give rise to a separate fact sheet.

The indicators used in the table are described in more detail in Chapter 2. The colours indicate our overall qualitative assessment of the presence of the listed factors that are significant for the areas' potential for attracting investment.

- Green indicates the clear presence of the factor
- Yellow indicates the partial presence of the factor
- Red indicates a weak or non-existent presence of the factor

Name	Overall assessment	Description	Impact rank	Top 10 ranking	Specialism	Output ranking	Excellence funding	Guest researchers	Major research efforts	Commercial collaborations	Requirement for proximity
Cancer	1	Covers basic research examining the causes behind the development and spread of cancer (including stem cells), as well as clinical research and testing. Biotech Research and Innovation Centre (BRIC), Novo Nordisk Foundation Stem Cell Center and Copenhagen University Hospital all contribute to the research strength. The interaction between medical and clinical research is emphasized as one of the regions' assets. Moreover, many researchers are being trained in a wide array of medical disciplines related to cancer. Early application of personalised medicine technologies is for example carried out at the Phase I Unit at Copenhagen University Hospital.	2	2	0.8	5					
Food research	1	Copenhagen has a strong position within food research. Research is undertaken at a wide range of departments and research environments e.g. the Department of Food Science, Department of Food and Resource Economics, Department of Public Health, Department of Sport and Nutrition, Department Veterinary Disease Biology at the University of Copenhagen as well as the National Food Institute at DTU and DTU Chemical Engineering. Particularly promising areas from an investment perspective include white biotechnology, including fermentation (with weighty industrial players such as Chr. Hansen, Carlsberg, etc., in the area), food safety, development of high value-ingredients such as probiotics, nutraceuticals as well as the application of mass spectrometry. The research is underpinned by new investments in state-of-the art facilities, e.g. DTU's Center for Hygienic Design, experimental animal housing at the University of Copenhagen's Faculty of Science, DTU Biosustain and DTU's coming building for Life Science and Bioengineering.	2-4	2-5	2.1	1					
Sound/ultrasound	1	Traditional Danish research strength, both with respect to hearing aids, sound technologies and ground-breaking ultrasound-technologies for medical applications. The majority of research is carried out at DTU Electrical Engineering. Important centres include the Center for Acoustical/Mechanic Micro Systems, Center for Hearing and Speech Sciences, Center for Applied Hearing Research and Center for Fast Ultrasound Imaging. The research constitutes the basis for Denmark's unique position within development and produc-	1	2	1.7	1					

		tion of hearing aids, as well as new medical applications. For example, the ultrasound research environments have made new breakthroughs in 3D-imaging, e.g. of blood-flows. They have also worked with BK Ultrasound to develop the most powerful ultrasound scanner in the world and has recently developed a compact, portable scanner, enabling new ultrasound applications for practitioners and paramedics.									
Metabolism and diabetes	1	Significant research strength focusing on the application of biochemical processes for the conversion of nutrients, and which form the basis for effective new therapies for obesity, Type-2 diabetes and other hormonal diseases. Novo Nordisk's successful product Victoza was based, among other things, on the University of Copenhagen's medical research. An important factor is the industrial engagement, as well as close general interaction between medical research and research at the Department of Sport and Nutrition and the Department of Public Health. The focus is on understanding the mechanisms of prevention, developing new drug candidates and large-scale randomised studies (medical treatments and studies of diets, etc.)	2-4	1	1.7	1-2	■	■	■	■	■
Bioenergy	1	Greater Copenhagen's universities, especially DTU, is strong within the development of environmental recycling technologies (for materials/substances and energy-production, e.g. through incineration and biofuels). DTU Environment feature a range of strong environments, including Environmental Chemistry and Residual Resource Engineering. The Department's laboratories are used by companies for trials and jointly funded research projects. The Department collaborates with some of the strongest research environments in the world and has recently been awarded an ERC grant. DTU Biosustain is a Novo Nordisk Foundation funded institute with 260 researchers working with biochemical and biological processes in this field.	1	1	2.0	1	■	■	■	■	■
Wind and smart grid	1	The Capital Region, and in particular DTU, performs strongly within research in wind energy and smart grid systems. DTU Electrical Engineering and DTU Wind, including the Center for Electric Power and Energy (CEE), are particularly strong in the area. The research is especially engaged in three main areas: designing wind turbines, energy storage and designing flexible electrical systems, including components and systems that can handle fluctuating power supplies.	4	4	1.7	1	■	■	■	■	■
Bacteriology	2	Research strength within bacteriological research anchored at both DTU and the University of Copenhagen. There are particularly strong niches within 1) antibiotic resistant bacteria and 2) methods for interrupting biofilms, both of which have significant commercial importance. Research into antibiotic resistance is a matter of understanding	3	3	1.9	1	■	■	■	■	■

		the genetic and bacteriological processes that lead to antibiotic resistance in bacteria and the development of new types of antibiotics. Methods for interrupting bacteriological films involve developing ways to interrupt the bacteriological films that make bacteria resistant - this is a problem for many different industries.									
Big Data	2	A highly interesting growth area, but also very broad and transversal. Links between the Niels Bohr Institute, ESS, the Department of Computer Science and DTU. The Department of Computer Science and the Niels Bohr Institute are generally highly competent in developing algorithms and machine learning. Big Data competency can be used in a many different fields of research from bioinformatics to social big data.	4	2	0.7	8	■	■	■	■	■
Bioinformatics and protein research	2	The combination of protein research and bioinformatics' strives to gain a deeper understanding of the biological processes underlying the development of diseases and apply the knowledge to develop new drug candidates and therapies. Copenhagen DTU and the University of Copenhagen both have special strengths in using big data and bioinformatics to study gene and proteins. A particular research strength is the ability to link data from electronic patient records, biobank data and advanced methods for analysing molecular structures.	2	2	1.0	4	■	■	■	■	■
Sustainable construction	2	Denmark is strong in this field. It covers construction, indoor climate, energy-efficient housing, urban development, etc., as well as architecture, urban development, GIS systems and climate change adaptation. DTU Civil Engineering, including the Center for Building Design, Center for Building Energy and Center for Internal Environment and Building Physics are all strong research environments in the area. Furthermore, the former SBi, which today is part of Aalborg University's Copenhagen branch. The field is being driven among other things by increasing global demand for energy and healthcare standards. The weakness is that construction markets are nationally-oriented due to tradition, differences in weather and climate, etc.	3	3-4	1.6.	1-2	■	■	■	■	■
Cardiology	2	A strong cardiological environment derives among other things from the now closed Basic Research Centre (DARC). There is a relatively large group of young promising researchers studying the ion channels that govern the heart's contraction and the causes of arrhythmia and cardiac arrest. The research is now being moved to the new Maersk Building with its state-of-the-art facilities. The environment is characterised by a highly outward-facing commercially-oriented culture with considerable experience in commercial interaction and a significant number of licences and spin-outs. There are also collaborations with a highly qualified clinical hospital research environment.	4	3	1.0	5	■	■	■	■	■

Quantum physics	2	Over the past century, Copenhagen has occupied a very strong position in the field of quantum physics. The Niels Bohr Institute has been awarded more ERC grants than all other departments at the University of Copenhagen - a total of 11 of which six relate to quantum physics. The field has attracted four Danish National Research Foundation grants to the Center for Quantum Optics, Center for Particle Physics, Center for Quantum Devices and Center for Stem Cell Decision Making. The Niels Bohr Institute has set up QUBIZ.dk in conjunction with DTU Physics, the University of Aarhus and 14 companies. The area carries great potential, but the weakness is that many companies regard quantum physics is very basic research-oriented.	3	3	0.8	5	■	■	■	■	■
Nanoscience	2	Nanoscience relates the manipulation of particles between 1 - 100 nanometres. DK has a strong position by virtue of the Nano Science Center established in 2001 as a collaboration between the Niels Bohr Institute and the Department of Chemistry. Since then, the collaboration has expanded to include the Department of Biology, Department of Neuroscience and Pharmacology and the Faculty of Health Sciences. The Centre has 150 researchers and has received significant funding from the EU and the Danish National Advanced Technology Foundation. The Centre has also been awarded basic research grants for a Centre for Synthesis Biology and a Sino-Danish Center for Molecular Nanoelectronics.	-	-	-	-	■	■	■	■	■
Plant science	2	Greater Copenhagen displays international top class within plant science. The field is made up by research at several Departments at both the University of Copenhagen and DTU, but is mainly centred at the Faculty of Science at the University of Copenhagen, including the Department of Biology and the Department of Plant and Environmental Sciences (PLEN). PLEN also works on energy production through reversed photosynthesis, synthesis biology, glycobiology and plant breeding. The University of Copenhagen's Plant Science Center is located at PLEN.	3-4	3	1.2	1	■	■	■	■	■
Technology and people	2	Copenhagen is home to the largest anthropological environments in Europe and has a strong research profile focusing on interaction between technology and people. It was e.g. one of the first in Europe to focus on Business Anthropology. There is a strong interdisciplinary research collaboration on communication and computer use in everyday life at the Department of Media, Cognition and Communication, Department of Computer Science and the Royal Library. There is a tradition for collaboration between anthropology and companies within medtech, healthcare, the environment, etc. The field educates graduates for a growing consultancy sector providing advi-	4	5	1.5.	2	■	■	■	■	■

		sory services on products and business development, user understanding, etc. The field has attracted research funding from the Velux Foundation, the Carlsberg Foundation, Laurits Andersens Foundation, etc.									
Water	2	Greater Copenhagen has a range of strong competencies in water research and technology. Most of the research is done by DTU Department of Environmental Engineering, featuring three elements: Urban Water Systems, Water Resources Engineering and Water Technology. DTU also collaborates closely with DHI (Danish Hydraulic Institute). Copenhagen also features competencies within urban and landscape planning and climate adaptation at the University of Copenhagen Department of Geosciences and Natural Resource Management. One weakness with respect to commercial exploitation of water skills is the culture and regulation of the Danish water companies and significant national differences in water systems.	-	-	-	-	■	■	■	■	■
Allergy	3	An exciting growth area in Denmark and in many other countries. The leading facility is the Danish Allergy Research Center at Gentofte Hospital, which is associated with the Department of Clinical Medicine at the University of Copenhagen. The centre has twice been awarded the Capital Region's Global Excellence Prize. The Environmental Protection Agency also established a knowledge centre for allergy in 2001, which carry out research in, and provides guidance on, substances that may cause allergy. So far there appears to be limited industrial interest in this field although there is close interaction with Leo Pharma Nordic and Lundbeck, among others.	3	3	1.3	3	■	■	■	■	■
Automation, robotics and space	3	DTU Electrical Engineering and DTU Space display top class research. DTU Space is an alliance partner with both ESA and NASA and has played a significant role in sending a space probe to Mars. DTU Electrical Engineering has a strong Center for Automation and Control. The centre collaborates with the Maersk McKinney Møller Centre at University of Southern Denmark. Both departments' research is relevant for developing fine measuring instruments and communication equipment.	1	4	0.7	4	■	■	■	■	■
Bodytech	3	Bodytech covers research into prosthetics and endoscopy. The Danish capital has a strong medical environment. Prosthetics and implants are based at Bispebjerg Hospital, and endoscopy at Herlev and Gentofte Hospitals. The downside is the lack of Danish manufacturers.	-	-	-	-	■	■	■	■	■
Energy conversion and storage	3	With DTU as the hub, Copenhagen is strongly positioned within a range of energy technologies, each of which has the potential to make significant contributions to a more coherent, sustainable energy system, through the use of fuel cells, electrolysis, batteries and plastic solar cells. At	3	3	2.0	2	■	■	■	■	■

		DTU, research is especially being done at DTU Energy and DTU Electrical Engineering and especially into disruptive technologies. Their strength lies in their strong international position in selected technologies. The weakness is due to the fact that some environments in Germany, France, Korea and Japan are just as strong, and larger.									
Fertility and reproduction	3	This area relates to fertility, gynaecology, obstetrics, (paediatrics, neonatal patients (premature babies)), etc. Denmark is strongly positioned in this area, e.g. due to the research and treatment of patients at the Juliane Marie Center, Copenhagen University Hospital. The research at the centre is world-class, with Denmark's internationally acclaimed patient registers being a contributory factor. Another issue is that in most of the world, fertility treatment is private. Copenhagen University Hospital works closely with Lund University. There is a certain amount of commercial interest in this field.	1	1	1.4	2-3					
Materials technology	3	Materials Technology relates to materials and surface technologies and the development of polymers. Research is carried out at DTU Mechanical Engineering, DTU Nanotechnology and DTU Chemical Engineering, which has also established the Danish Polymer Center. Materials Technology is interdisciplinary and is based on a range of physical and chemical specialisms that have a wide range of commercial applications. There is strong commercial collaboration in this area, and one significant strength would be the new research opportunities arising in Lund with the recently opened MAX IV and the upcoming ESS. The weakness is the tough international competition in this field.	1.3	1-2	0.9	4-5					
Neuroscience	3	DK is strongly positioned within neuroscience, focusing on the development of brain cells, signalling mechanisms and ageing processes in the brain. The focus is also on a deeper understanding of energy levels and biological processes in the brain. Among other things, research addresses the underlying mechanisms for diseases such as Alzheimer's, dementia, etc. the University of Copenhagen has a range of strong research teams, but the University of Aarhus is also strong in this field and has established a top European research centre with funding, e.g. from the Lundbeck Foundation.	4	2	0.9	6					
Algebra/topology	4	A high quality international research environment in a broad range of mathematical disciplines, featuring strengths in algebra and topology located at the University of Copenhagen Center for Symmetry and Deformation. Generally high quality research and a significant amount of mathematical talent. The Department ranks in the International Top 50, although interest in commercial collaboration and investment is believed to be modest.	2	2	0.7	6					

Arctic re- search	4	Denmark feature high class Arctic research. The Niels Bohr Institute at the University of Copenhagen hosts the Centre for Ice and Climate, while the Department of Geosciences and Natural Resource Management hosts the Center for Permafrost that carries out basic research. DTU hosts the Center for Arctic Technology. Denmark's historical role in Greenland constitute the backdrop for these operations and in the longer term, there could be major commercial potential, for example for extraction of raw materials, maritime trading routes, etc.	1	1	1.4	2					
Geogenetics	4	The Natural History Museum of Denmark carry out world class research, which is the reason why they have been awarded a grant for basic research for establishing a new Center for Geogenetics. The centre furthermore received an ERC grant to study human migrations in the 2nd and 3rd millennia BC. The Department of Forensic Medicine at the University of Copenhagen also does some research here, although there is limited commercial interest.	3	2	1.1.	3					
International poli- tics	4	The capital displays a leading international position for research in international politics. Research centres on the Department of Political Science at the University of Copenhagen. Special strengths within research in security and conflict resolution (Center for Advanced Security Theory and Centre for Resolution of International Conflicts at the University of Copenhagen), EU research (Center for EU Politics).	2	1-2	2.0	2					
Management and International business	4	CBS Management Research performs strongly internationally, especially by virtue of research in international business. The area is distributed across departments such as the Department for International Economics, the Department for Strategic Management and Globalization, and the Department of International Economics and Management. CBS interacts closely with the business sector.	2	1	1.5.	1					
Funding and finance	4	There has been a major improvement in the quality of research at the Department of Economics, University of Copenhagen over the past 10-20 years. Today, the Department is among the international Top 20 and collaborates with some of the best research environments in the world. At CBS, FRIC – the Center for Financial Frictions, Department of Finance, is an outstanding research environment. The Department of Economics at UCPH has been awarded two grants for basic research and two ERC grants. Graduates are in demand in the business sector, but the weakness from the point of view of attracting investment is that companies probably have little need for close physical proximity to research environments. As with international business, this area does have a significant complementary effect when it comes to attracting foreign investment.	4	4	1.7	1					

Appendix 2

Regions of comparison and institutions

Amsterdam	University of Amsterdam VU University Amsterdam Municipal Health Service of Amsterdam
Berlin	Technical University of Berlin Free University of Berlin Humboldt University of Berlin Helmholtz Centre Berlin for Materials and Energy Federal Institute for Materials Research and Testing Berlin Max Delbruck Center for Molecular Medicine Robert Koch Institute Max Born Institute 5 Leibniz Institutes Stuttgart State Museum of Natural History Weierstrass Institute for Applied Analysis and Stochastics Federal Institute for Risk Assessment Paul Drude Institut für Festkörperelektronik (PDI) University Hospitals in Berlin Zuse Institute Berlin
Copenhagen	University of Copenhagen Technical University of Denmark Copenhagen Business School University Hospitals in the Capital Region
Dublin	University College Dublin Trinity College Dublin Dublin City University Maynooth University Dublin Institute of Technology Beaumont Hospital, Dublin Dublin Institute for Advanced Studies
Geneva/Lausanne	Ecole Polytechnique Federale de Lausanne (EPFL) University of Geneva University of Lausanne Business School Lausanne
Hamburg	University of Hamburg Deutsches Elektronensynchrotron (DESY) Hamburg University of Technology Helmut Schmidt University Bernhard Nocht Institute for Tropical Medicine Hamburg Outstation

Helsinki	<p>University of Helsinki Aalto University Hanken School of Economics Hospital District of Helsinki and Uusimaa Minerva Foundation Institute for Medical Research Helsinki</p>
Munich	<p>Technical University of Munich Ludwig-Maximilians University Munich Helmholtz Center Munich German Research Center for Environmental Health European Southern Observatory 7 Max Planck Institutes Bundeswehr University Munich Munich University of Applied Sciences Fraunhofer Institute for Embedded Systems and Communication Technologies ESK International Max Planck Research School for Molecular and Cellular Biology</p>
Oslo	<p>University of Oslo Norwegian University of Life Sciences Oslo University College Norwegian School of Sport Sciences BI Norwegian Business School</p>
Stockholm/Uppsala	<p>Karolinska Institutet Uppsala University Royal Institute of Technology Stockholm University Stockholm School of Economics Stockholm Environment Institute</p>