Bioenergy

Content and applications

Bioenergy is generated from organic matter such as waste or plant residues. Biomass can be incinerated or used to create biogas, which can then be used for heating or in gas engines, for example in large district heating stations or for refined energy products such as bioethanol that can be blended with petrol. Researchers in Greater Copenhagen based at the University of Copenhagen and the Technical University of Denmark (DTU) are among the best in the world and they can provide a significant contribution to making bioenergy cheaper by optimising all the sub-processes involved in converting waste or plants into fuel. DTU Bioinformatik

Key environments and star researchers.

In the field of bioenergy, Greater Copenhagen hosts a strong research environment. At DTU this is based at DTU Chemical Engineering and DTU Environment. At the University of Copenhagen there are strong environments at the Department of Geosciences and Natural Resource Management, the Department of Plant and Environmental Sciences and the Departments of Biology and Chemistry. The Department of Plant and Environmental Sciences is also home to the Copenhagen Plant Science Center. One major theme researched at Copenhagen Business School (CBS) is the link between sustainability, biotechnology and business development.

A possible game-changer in the field of bioenergy could be the discovery of 'reverse photosynthesis' in the spring of 2016 by a group of leading researchers, including Prof. Claus Felby of the Department of Geosciences and Natural Resource Management, Prof. Morten Bjerrum of the Department of Chemistry and Prof. Poul Erik Jensen, Director, Copenhagen Plant Science Center. This discovery is one of a series of examples of new technologies from researchers in Greater Copenhagen that could have major implications in the future.

Potential for attracting investment

The area is highly relevant for attracting investment. Danish companies and researchers are among the best in the world in developing efficient processes for incinerating biomass and have also been involved in the first bioenergy plant to be set up in Europe in recent years. Various states nowadays require biofuels to constitute 5.75% of petrol and diesel. So-called 1st generation biofuels (made from plant matter) currently account for most of the biofuels. But Danish research is aimed at developing 2nd generation biofuels (made from waste or plant residues) and these are making progress.

Characteristics of the research area

In Greater Copenhagen, research is done in small teams at the University of Copenhagen and DTU. The key environments at the University of Copenhagen are the Department of Geosciences and Natural Resource Management, Department of Plant and Environmental Sciences and the Departments of Biology and Chemistry. In addition DTU has two strong environments - DTU Chemical Engineering and DTU Environment.

Researchers in these environments collaborate on a range of projects and combine different academic disciplines and areas. Total researcher headcount in the area amounts to around 200 permanent professors and associate professors.

CBS also does broadly-based commercially-oriented research into sustainable business development and support for bio-based entrepreneurship. This also involves the Center for Corporate Social Responsibility and Sustainability Platform which is engaged in wide-ranging aspects of green business development and sustainable business management and the BioBusiness Innovation Platform (a collaboration between CBS, DTU and University of Copenhagen), which focuses on bio-based entrepreneurship.

International top quality niches

There are several complementary tracks in bioenergy research. One track is efficient processes for incinerating biomass – a complicated challenge as biomass combustion also forms various residues that can corrode the combustion chamber, and which have to be dealt with using chemical processes. Another track is the conversion of plant residues and other organic matter using enzymes and fermentation processes. Then there are technologies based on catalysts, which in addition to generating bioenergy, can also produce bio-based chemicals. Finally, there are various chemical techniques and processes to extract waste products that have an adverse effect on biological processes or which can be extracted for use elsewhere.

There are several alternative links in the value chain mastered by Danish researchers and companies. Methane is produced from fermentation of waste and plant residues. Methane can be used in gas engines, for heating or as a precursor for producing biomethanol (by an oxidation process). Likewise bioethanol produced by a fermentation process of the biomass derived sugars can be used in combustion engines, especially for transport. Bioethanol is nowadays used in ordinary vehicle engines as a component of petrol.

Both fuels currently cost more per litre to produce than petrol or diesel, but will form an essential part of future energy supplies when international climate agreements take effect and when EU quota prices for CO_2 increase.

The EU VE Directive provides that 10% of energy for all land-based transport is to be sustainable by 2020. It has not yet been finally determined how this target in reality is to be met. It is expected that the efforts of reaching the target will involve 2nd generation biofuel. From the point of view of attracting investment, this places Danish research competencies in this field in the limelight.

Bibliometric key figures

The bibliometric indicators for research production and research quality indicate that Denmark has a leadership position in the field. The bibliometric figures provide an indication, but the indicators are not precise because 'bioenergy' or 'biofuel' is not a separate category when searched in the database. Greater Copenhagen is well-placed in the categories of Environmental Engineering, General Energy and Bioengineering. With a total volume of 2414 articles, this gives an overall first place among the eight regions of comparison. But in terms of excellence, too, research in Greater Copenhagen also takes the first place.

The high volume of co-publications reflects the high level of corporate involvement in research at the Departments of the University of Copenhagen and DTU noted above.

Key bibliometric indicators				
	Specialisation	Output ranking (No. articles)	Highly cited article ranking (%).	Co-publication ranking (%)
Environmental engineering	1.98	1 (948)	1 (24.7%)	1 (4.6%)
General energy	1.13	1 (502)	1 (28.1%)	1 (9.7%)
Bioengineering	1.16	2 (964)	2 (24.9%)	1 (10.4%)

Period: 2005 -2015. Regions of comparison: Amsterdam, Berlin, Dublin, Geneva-Lausanne, Hamburg, Helsinki, Munich, Oslo and Stockholm/Uppsala.

Specialisation is an expression of the size of a field of research compared to all research production at University of Copenhagen, DTU and CBS compared with its size in the regions of comparison. A specialisation level 1 indicates that Greater Copenhagen is on level with the regions of comparison. Specialisation of >1 indicates that Greater Copenhagen is more specialised in the field of research than the regions of comparison.

Output ranking measures Greater Copenhagen's position in the field concerned among the regions of comparison in terms of article production (with the absolute numbers of articles in brackets).

Highly cited article ranking indicates Greater Copenhagen's placing in the regions of comparison for the proportion of articles in the field of research in Copenhagen that are among the 10% most cited worldwide (percentage in brackets).

Finally, co-publication ranking indicates Greater Copenhagen's rank among the regions of comparison for the proportion of articles in the field published jointly with the business sector (percentage of overall article production in Greater Copenhagen in brackets).

Key arguments for the research area's potential to attract investment

Bioenergy research is highly relevant to society. The green transition to a non-fossil society demands that new energy technologies should be developed and made cheaper. Denmark is already a frontrunner in the green transition process and will continue to be so. In the coming years, when EU targets for discharging less CO_2 and increasing the proportion of sustainable energy take full effect, other countries will also increase the amount of bioenergy used in overall energy consumption, especially in the transport sector. By being located in Denmark, businesses can get first-hand access to the Danish experience and benefit directly from the competencies of Danish researchers and companies.

Star researchers and major scientific breakthroughs

Lead researchers at the University of Copenhagen include Prof. Claus Felby of the Department of Geosciences and Natural Resource Management and Prof. Morten Bjerrum of the Department of Chemistry, both key members of the team that announced their so-called 'reverse photosynthesis' discovery in 2016. This is one of a series of technologies that could provide a significant boost to the field of bioenergy.

The team discovered a natural process by which the sun's rays are used to break down plant tissue instead of generating it, as is usually the case in photosynthesis. The plant's chlorophyll and an enzyme use the energy of the sun's rays to break down plant biomass into chemical substances, for example, biofuel or other high value products which would otherwise take a long time to produce. The discovery could boost industrial production of bioenergy by increasing the speed of production and reducing contamination.

At the Department of Plant and Environmental Sciences, University of Copenhagen, Poul Erik Jensen, who was also a member of the photosynthe-

sis team, is also a key person in heading the Copenhagen Plant Science Center and as a professor in molecular plant biology.

DTU also has a range of key researchers. At DTU Environment, Irini Angelidaki is the most cited researcher in the world in the field of biosystems engineering and biogas - an area that also includes biorefineries. Thomas Fruergaard Astrup is another researcher investigating waste and resources. He is the head of the Center for Residual Resource Engineering.

The lead researchers at DTU Chemical Engineering are Prof. Anne Strunge Meyer (enzymes, silage and fermentation processes), Prof. Anker Degn Jensen (catalysis), Prof. Peter Glarborg (combustion and gasification) and Prof. Kim Dam-Johansen (combustion and pyrolysis). DTU Chemical Engineering has also helped develop processes that use pyrolysis to convert straw to biofuel in small, decentralised units that considerably cut the cost of transporting straw. In 2008 Kim Dam-Johansen was found the worlds most cited researcher in combustion based on work to a large extent directed to the utilization of biomass to replace coal for power production. A significant part of the research was performed in cooperation with DONG Energy A/S.

At CBS' Sustainability Platform, research is focused on green innovation and new sustainable business models, including how companies can optimise their consumption of resources and transform their business models in the light of rising raw material prices and climate change.

Large talent pool

The University of Copenhagen and DTU both educate and train a considerable number of talented scientists in this field. The departments involved at the University of Copenhagen educate and train several hundred Masters graduates every year, at least 200 of whom are engaged in one or more of the technologies described. A total of between 50 - 100 PhDs in this field complete their training as researchers every year, with slightly fewer being trained at DTU.

In conjunction with the University of Copenhagen and DTU, CBS runs a Masters course in Business Administration and Bioentrepreneurship, with 13 graduating in 2015.

Unique research facilities

Over the past 10 years, considerable amounts have been invested in research infrastructure in departments involved in bioenergy at the University of Copenhagen and DTU. Overall, the Departments of Geosciences and Natural Resource Management, Chemistry and Biology have invested several hundred million DKK over the past five years in state-of-the-art equipment for spectroscopy, mass spectrometry and X-ray crystallography. DTU has also invested several hundred million DKK in new world-class research infrastructure.

Strong collaboration with leading international research environments

Researchers in Greater Copenhagen collaborate with leading biotech researchers worldwide. DTU thus works closely with researchers at Lund University (where they investigate recycling of organic waste), at Helsinki University (where they also research the use of wood and cellulose for energy purposes) and Stanford University (where they also study catalysis for energy purposes). Researchers at the University of Copenhagen have close relations with scientists in USA at Berkeley, MIT, University of Wisconsin, University of Illinois and Oakridge, Colorado.

Extensive corporate collaborations

Researchers in the field have a longstanding tradition for collaborating closely with the corporate sector. In the field of combustion, B&W Energy, (Burmeister & Wain Energy), BWSC (Burmeister and Wain Scandinavian Contractors) and B&W Vølund (Babcock & Wilcox Vølund) are among the most innovative in the sector worldwide. FL Smidth produces cement production facilities and use biomass and waste/residues extensively in their facilities.

Haldor Topsøe has developed efficient catalytic processes for converting biomass into petrol and natural gas. They are furthermore developing processes to produce biochemicals, including bio-based monomers for making bioplastic. In biofuel, Novozymes and DONG are key collaborative partners.

DONG owns the companies Renescience and Inbicon and has invested more than DKK 1bn in developing these companies and other bioenergy projects. Renescience produces biogas and fertiliser, etc., based on household waste, and has supplied waste treatment plants to Danish municipalities and customers in Europe and Asia. Inbicon also produces bioethanol from plant residues, in which cellulose is converted to sugars for processing into biofuel.

In 2017, DONG is delivering a significant system to Northwich in UK, to deal with the waste from 110,000 households. DONG delivered a number of plants on a licence basis but the Northwich plant is the first to be constructed, owned and operated by DONG.

Novozymes, too, has invested considerable amounts in developing enzymes and is an important supplier to Renescience and Inbicon as well as two other major bioenergy plants worldwide.

Research has also led to technologies using start-ups in this field and in collaboration with foreign companies. One example is Aikan, a subsidiary of the Solum Group, which was established more than 10 years ago. Aikan sells biogrowth systems which separate food waste for biogas and fertiliser.

In terms of innovation, patents and spin-outs, biotechnology and bioenergy are far ahead. At DTU, bioenergy is the largest of the 12 selected areas in this analysis in terms of numbers of innovations registered at DTU´s central innovation department. The same applies to the University of Copenhagen where the biosector accounts for about 15% of all innovations registered throughout the university over the past three years.

”We believe that Renescience and Inbicon will both be profitable and that green energy will be an important area of growth. These green companies employ many of the talented individuals trained at our universities that are far ahead in the field of bioenergy. We want to help ensure that at least half of the electricity and heating produced by our power stations in 2020 is based on sustainable biomass instead of coal and gas.”

Niels Henriksen, Senior Manager, DONG

“Biofuels constitute a small but rapidly growing part of the global energy supply. They are a renewable energy sources with the potential to reduce CO_2 emissions in the transport sector and to create economic opportunities for rural areas and developing countries. So, biofuels will be an important part of the energy mix in future. That´s why we are investing in this area.”

Johan Mogensen, Director, Novozymes

”As a small, R&D-based company, for us it is important to operate in an environment where there is good interaction between more theoretical research and our more practical realities. And there is lots of that in Denmark.”

Morten Brøgger, Head of Technology, Aikan