Think Denmark

White papers for a green transition

FROM SUSTAINABLE BIOMASS TO COMPETITIVE BIOENERGY

Insights into Danish bioenergy solutions

INSIDE THIS WHITE PAPER

Technical and regulatory approaches to encourage bioenergy use

State-of-the-art bioenergy solutions

Biomass challenges and potentials

State of Green

Join the Future. Think Denmark

FROM SUSTAINABLE BIOMASS TO COMPETITIVE BIOENERGY
- Insights into Danish bioenergy solutions

Front page picture
This photo is made by Kollision and illustrates the transformation of biomass into heat, power and fuels.

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BIOBASED FOR GROWTH

Turning sustainable biomass into competitive bioenergy solutions

Bioenergy is a cornerstone in the Danish renewable energy mix. Today, approximately 70% of renewable energy consumption in Denmark is bioenergy-based, mostly in the form of straw, wood and renewable wastes.

Lars Chr. Lilleholt, Danish Minister of Energy, Utilities and Climate

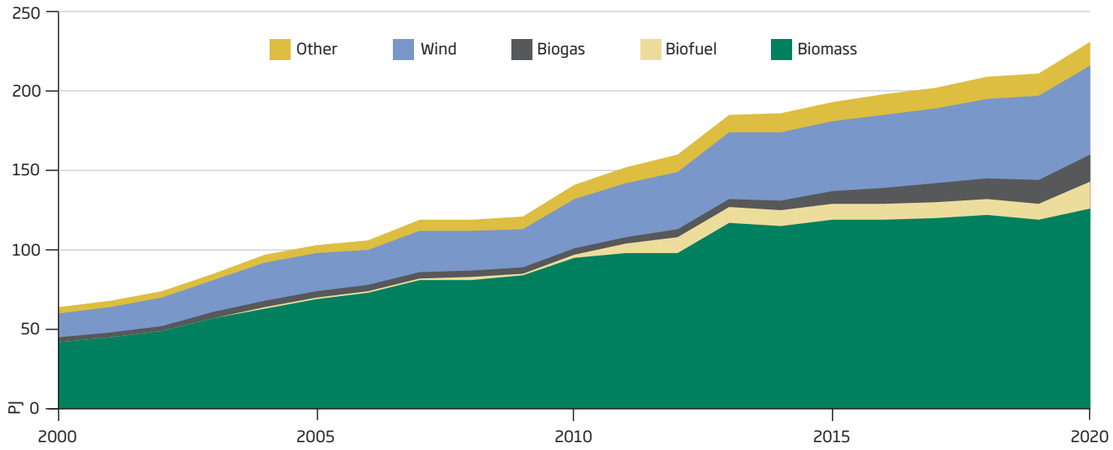
Due to the extensive use of bioenergy, there is an abundance of expertise available in this field. In addition to hosting several top-efficient, full-scale biomass plants, Denmark is an industry hub and testing ground for modern energy technologies based on biofuels and biogas, and Danish companies and universities cooperate closely to offer world-class bioenergy solutions globally.

Bioenergy developments in Denmark
Denmark has utilised biomass to produce bioenergy for decades, in fact, the consumption of biomass for energy production in Denmark more than quadrupled between 1980 and 2009, and towards 2020, bioenergy will continue to make up the majority of total renewable energy consumption in Denmark. From a global perspective, Denmark has one of the most efficient bioenergy clusters in the world. This is possible due to well-developed technologies for bioenergy production, biomass handling and exploitation.

State-of-the art bioenergy solutions
Specifically, Danish companies rank among the world's leading developers of biomass boilers as well as developers of enzymes for production of second-generation bioethanol. With regard to biomass and biofuels, increased use in combined heat and power production and transport continues to improve Danish companies' opportunities for development, innovation and exports. Within agriculture, Denmark is spearheading new technologies to turn biogas and liquid biomass into energy, and dozens of plants, private and public alike, are already in operation today.

Unleashing the potential of bioenergy solutions
According to 2014 export figures for energy technology released by the Danish Ministry of Energy, Utilities and Climate, the Danish Energy Industries Federation and the Danish Energy Association, Danish businesses producing energy technology exported more than ever before in 2014. Exports of green energy technologies have experienced rapid growth for the past three years, standing at DKK 43.6 billion in 2014, which exceeds the level before the financial crisis in 2008.

In this white paper, we have gathered a selection of knowledge-driven and solutions-based cases, each demonstrating opportunities and lessons-learned from the Danish bioenergy sector. The content is meant to inform and inspire by facilitating Danish developments and framework conditions for bioenergy, as well as state-of-the-art case examples, which are sustainable, not only in terms of the environment but in terms of economics as well. I hope you will be inspired.



With a significant increase in solid biomass, biogas as well as biofuels, bioenergy will continue to make up the majority of total Danish renewable energy consumption in 2020.

ABOUT THIS WHITE PAPER

The aim of this White Paper is to share some of Denmark's solutions and experiences in transforming sustainable biomass resources into competitive bioenergy solutions.

We have gathered a selection of knowledge-cases and technological examples, each demonstrating opportunities and lessons learned from different stakeholders across the Danish bioenergy landscape. The content provides insights into the development of bioenergy solutions in Denmark, and the frameworks needed to further enable these developments.

We hope that you will be inspired.

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The Danish Energy Agency working abroad on bioenergy.

Denmark has several bilateral government-to-government cooperations focusing on sharing Danish experiences and knowhow on renewable energy policies.

One of these cooperations is the Danish-Mexican cooperation on climate change, energy efficiency and renewable energy. An important part of the Mexican cooperation is the exchange of Danish regulatory experiences on increasing the share of bioenergy in order to help the Mexican government reach their target for renewable energy power generation. The cooperation includes assistance on the preparation of a biomass road map for Mexico that maps their current resources and utilization as well as identifying barriers for an intended increased use of biomass.

The Danish Energy Agency (DEA) is specifically assisting the Mexican Ministry of Energy (SENER) on establishing a biomass baseline and is looking to develop a technology catalogue for biomass technologies in Mexico. Furthermore, Danish experts are aiding the Mexican authorities in identifying sector specific possibilities for biomass based electricity generation using residuals from the sugar industry and assessing the potential for sector-wide policy approaches.

Avedøre Power Plant is the largest straw fired CHP plant in the world. With an annual straw fuel consumption of up to 170.000 tonnes/ year it produces electricity and district heating for the Copenhagen area.

THE DANISH STORY OF BIOENERGY DEVELOPMENT

How regulatory development has encouraged the use of bioenergy

Since the mid-1980s, parliamentary majorities in Denmark have persisted in a proactive, resource-based and environmentally responsible energy policy. As a result, Denmark has now taken a leading global position within several fields of renewable energy, including various forms of bioenergy.

Per Bach Svendsen, Advisor, Danish Energy Agency

Before the first oil crisis in 1973, the Danish energy sector had little experience with centralised political energy regulation. The Danish Energy Plan from 1976 took the first steps in transforming the energy system and functioned as a safeguard against a potential supply crisis, as more than 90% of the Danish energy demand came from oil. The following Energy Plan 81 (1981) continued to focus on reducing fuel imports to ensure long-term security of supply, but also gave high priority to socio-economic and environmental considerations. Following Energy Plan 81, the first subsidy schemes were implemented, which aimed at the utilization of straw and wood chips, making biomass a competitive fuel through an increased taxation of fossil fuels.

The Biomass Agreement from 1993

On 14 June 1993 the Danish Parliament made an agreement concerning increased use of biomass in the energy supply sector. A vital element of the agreement stipulated that the centralised electrical power plants were obliged to buy 1.4 million tonnes of biomass per year, including at least 1 million tonnes of straw. The agreement resulted in a significant shift towards substituting coal-based CHP plants with biomass-based CHP plants. Furthermore, the biomass agreement meant that biomass based CHP generation got a higher priority in many local areas, including areas with natural gas.

Bioenergy - the primary renewable energy source

Today, bioenergy is the most used renewable energy source in Denmark covering more than 75% of the total Danish renewable energy consumption. The bulk of the bioenergy production in Denmark is used for heating. Almost half of Denmark's district heating is produced from biomass and bio-degradable waste and 11.5% of the electricity generation in 2013 was biomass-based. Today there are more than 250 biomass plants supplying Denmark with sustainable energy. Whereas straw, firewood and biodegradable waste used to be the primary source of biomass in Denmark in the 1980s and 1990s, there has been significant shift towards using wood chips and wood pellets as well as straw because these sources are the most price competitive. Today, more than 60% of biomass for energy derives from wood materials of which a significant part is imported.

Bioenergy towards 2020

With the approval of the Renewable Energy Directive (RE Directive) in 2009, Denmark committed to ensure that 30% of its energy consumption derives from renewable sources in 2020. Nonetheless, estimates show that Denmark will reach around 35% renewable energy in 2020 of which more than half will be produced from biomass. Denmark more than doubled its bioenergy consumption in the last decade and is expected that the total biomass consumption will further increase from 136.5 PJ in 2012 to 173 PJ in 2020. The renewable energy transition that Denmark has made is now also being shared with other countries through bilateral government-to-government cooperations. The experiences that Denmark is providing assist growth economies such as China, Mexico, Vietnam, South Africa and Indonesia in transforming their energy system towards a green and sustainable energy system that can substitute the use of fossil fuels.

Wood pellets are the most used source of biomass for combustion in Denmark. The wood pellets are often imported by sea from the Baltics, Poland, Germany, Russia and Sweden. In 2012, Denmark imported 35% of the total biomass consumed. Wood pellets accounted for around two thirds of this volume.

The national objective is that half of Danish slurry should be treated in biogas plants. Straw and slurry will therefore be able to contribute, not only to the Danish political objective of becoming fossil-fuel independent by 2050 but also to establish a fully developed bioeconomy.

BIOGAS AND STRAW-TO-ENERGY

Utilising agricultural residues for energy production

The Danish agricultural and food cluster demonstrates world class efficiency and quality when it comes to food production but also in regards to utilising residues from food production, such as straw and slurry, Denmark is the place to get inspired.

Mads Helleberg Dorff Christiansen, Chief Policy Advisor, Danish Agriculture & Food Council

By creativity among our farmers, a unique cooperative advising system, innovation in our industry and collaboration with national and European authorities, Denmark practices one of the world's highest utilisation rates of residual products from agriculture. The frontrunner position within bioenergy was established back in the mid-1980'ies as a response to the energy crisis. Decentral heating plants were built and should be supplied by domestic energy sources such as straw, wood, manure and gas. Since then Denmark has invested heavily in developing better crops, biomass supply systems & logistics and energy infrastructure & technology.

An alternative to natural gas

The natural gas transmission network can be used to transport upgraded biogas produced from residues and waste. It is an alternative to natural gas used for both heating and electricity, and total capacity in Denmark will reach about 179 million m3 by the end of 2016. The production of biogas reduces emissions of CO2 and other greenhouse gases, as well as reducing water pollution from nutrient run-off.

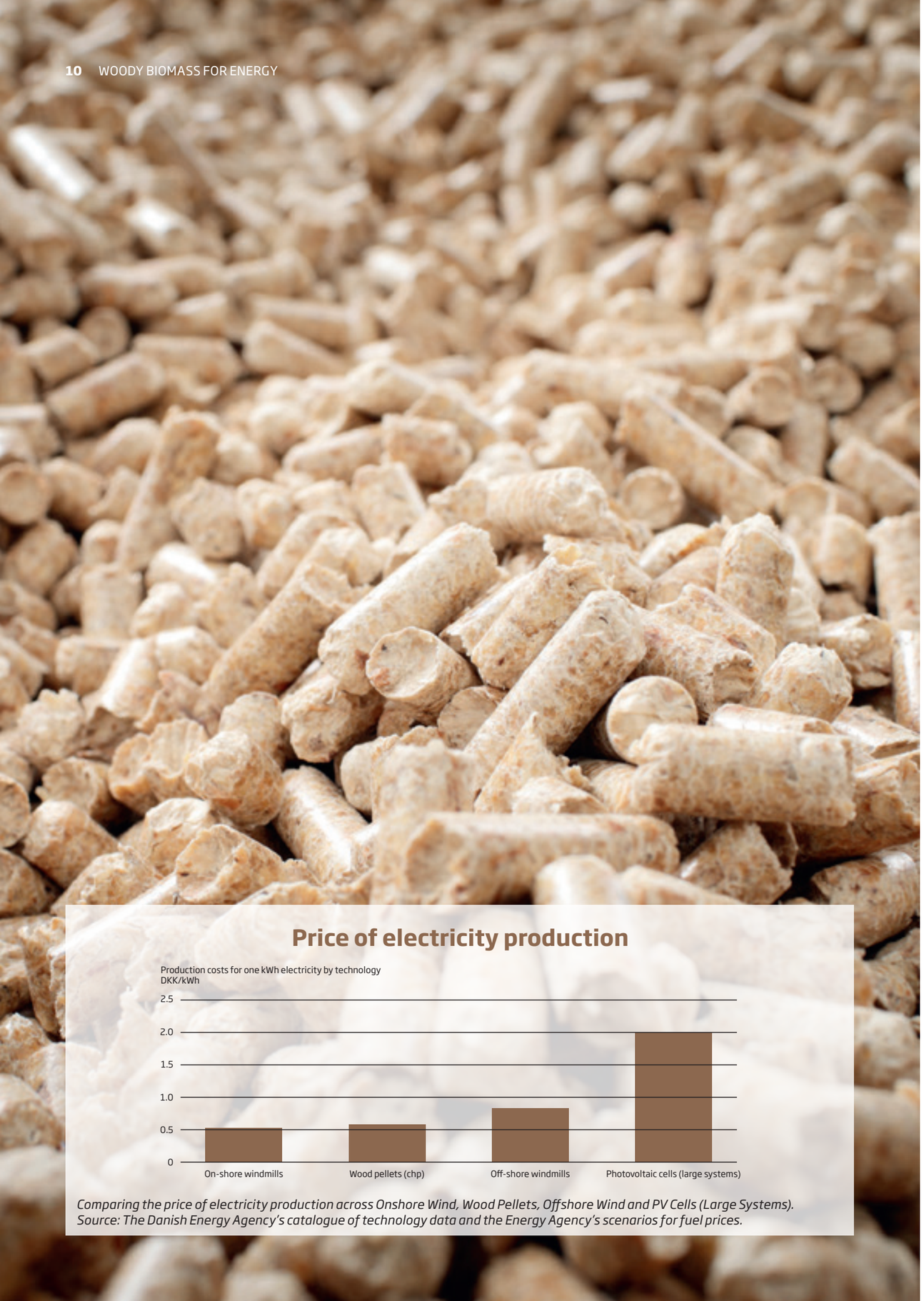
A strong infrastructure

Agricultural residues based on dry fibres, such as straw, has been used as an energy resource for more than 25 years. It has developed into a strong tradition for the use of small scale straw boilers in agriculture and medium scale boilers for district heating. During the last couple of decades, straw consumption for electricity production in central heating plants and power plants reached almost 1 mill tons per year. Today, Danish agriculture is known for having one of the world's best and most developed infrastructure and logistics for collection, storage and delivery of straw to power plants. The system is based on direct contracts between the farmers and the power company. Usually, the power companies have limited storage, typically 3-5 days, so the farmers have developed systems to store and deliver the straw according to a tight schedule.

1.5 million tons of straw ready to be used

Today, there is still another 1.5 million tons of straw at the Danish fields to be collected for industrial purposes. This figure is waterproofed by the National Bioeconomy Panel and takes into account both the collection costs and environmental considerations. The Danish Agriculture & Food Council works hard to ensure the construction of advanced, state-of-the-art, big-scale biorefineries that can produce bioethanol and bio-based products. In Denmark there is straw for at least five big scale facilities. However, just one biorefinery can kick-start the transition to a fossil-free and advanced bioeconomy. Greater use of straw and biogas secures Denmark's energy supply and ensures a stable energy system, and the greatest benefit might be that it reduces the climate emissions and the transition to an advanced bioeconomy.

The total straw production in Denmark is about 5.5 million tons, of which approximately 1.5 million tons of straw/year is used for energy. However, the Danish Agriculture & Food Council invites international actors to use the remaining 1.5 million tons of straw for industrial purposes.



Price of electricity production

Comparing the price of electricity production across Onshore Wind, Wood Pellets, Offshore Wind and PV Cells (Large Systems). Source: The Danish Energy Agency's catalogue of technology data and the Energy Agency's scenarios for fuel prices.

WOODY BIOMASS FOR ENERGY

Replacing coal and gas with woody biomass for electricity and heating

The amount of electricity from wind and solar power fluctuates widely. The combined heat and power plants (CHP plants) in Denmark are a prerequisite for having power when we switch on the light, and replacing coal and natural gas with wood pellets and wood chips is the most inexpensive and effective way to utilise the existing efficient CHP plants, instead of building new capacity.

Kristine van het Erve Grunnet, Senior Advisor at the Danish Energy Association

In addition, the CHP plants play a substantial role in supplying district heating to most Danish households – this role cannot presently be taken by wind and solar power. By switching to woody biomass sourced from sustainable forestry, the Danish CHP plants contribute significantly to the green transition and the overall reduction of Danish carbon dioxide levels in an economically sustainable manner.

The Danish approach to woody biomass

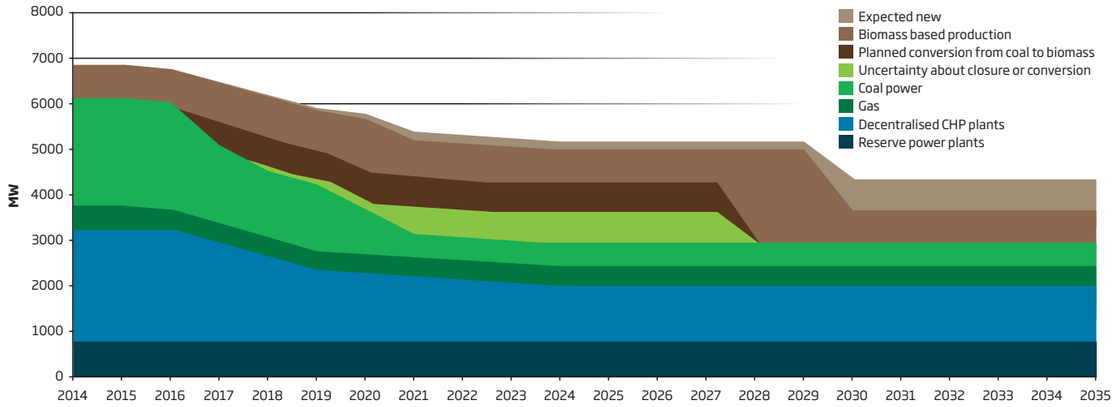
Denmark has used biomass sustainably for more than 20 years because Danish heating plants have utilised straw, wood chips and wood pellets for efficient heat production since the 1980s. We will continue to do so, and in the future wood pellets and wood chips will represent a larger part of this production. Wood pellets will primarily be used in large CHP plants, largely supplied by Europe and North America where the forest areas are growing and national legislation ensures sustainable forestry. In North America alone the growth in forests is 400 million m^3 per year. This corresponds to 150 million tons of wood pellets per year, which is 10 times Europe's total consumption per year today. Wood chips will be used primarily in small and medium sized CHP plants and will mainly come from Denmark and neighboring areas.

Ensuring sustainable woody biomass

To guarantee the CO_2 reducing effect, wood pellets and wood chips must come from sustainable forestry. For us it is not an issue for discussion that the biomass we use today has to be sustainable. The Danish energy industry ensures sustainable biomass, locally and imported, through a voluntary agreement which was signed by the Danish Energy Association and the District Heating Association in 2014. The agreement requires CHP utilities to document sustainability with regard to range of criteria notably: calculations of the carbon footprint in all parts of the value chain – from forest to incineration; a guarantee that the productivity of the forests is preserved by replanting, and that forestry has minimal impact on the ecological system and assurance of health and vitality; that forestry must ensure conservation of biodiversity; and that companies and suppliers have to respect local and national legislation. Three certification schemes can be used to show compliance. The three systems are Sustainable Biomass Partnership, FSC and PEFC.

Sustainable Biomass Partnership

The Sustainable Biomass Partnership (SBP) is an industry-led initiative formed by major European utilities that use biomass, including DONG Energy, mostly in the form of wood pellets, in large thermal power plants. To date, SBP has developed a certification framework to provide assurance that woody biomass is sourced from legal and sustainable sources allowing companies in the biomass sector to demonstrate compliance with regulatory requirements. The SBP Framework is designed as a clear statement of principles, standards and processes necessary to demonstrate such compliance. Wherever possible, use is made of the FSC and PEFC standards and processes already applied to other forest product streams. Further refinement and strengthening of these SBP standards will follow as necessary.



The total Danish power plant capacity declines from about 7,000 MW in 2014 to between 4,700 MW and 5,400 MW in 2021. Precise capacity depends on whether a number of power plants are rebuilt to accommodate biomass or shut down, but is lower than previously predicted. Source: Figure 1 from the report. "Expectations for power plants 2014-2035." Published by the Energinet.dk, the Danish TSO responsible for the overall security of supply of electricity and gas: http://energinet.dk/SiteCollectionDocuments/Danske%20dokumenter/El/Energinet%20dks%20analyseforuds%C3%A6tninger%202014-2035%20maj%202014%20final.pdf

BIOENERGY FOR THE FUTURE

A first mover market for new bioenergy solutions

Denmark is a leader within research and development throughout the entire value chains for the utilisation of biomass and organic waste residues for energy production. Danish competencies within bioenergy technologies are much in demand and Denmark serves as a perfect industry hub and live testing ground for modern bioenergy technologies combined with a favourable public funding framework.

Programme Manager Energy R&D, Jan Engelbreckt Bünger, Danish Energy Agency

Today, approximately 70 % of renewable energy consumption in Denmark stems from biomass. For the future and according to the national transition plans, Danish consumption of biomass will continue to grow bringing biobased heat, power and fuels to the market to replace fossil fuels. The challenges connected to a cost effective conversion of the energy system calls for the development of new and approved bioenergy technologies and thus this will be adressed under the comprehensive Danish energy R&D programmes that covers the entire range from applied research to demonstration in full scale.

Green gasses balancing wind and solar

Consumption of natural gas is expected to fall dramatically from 2020, as natural gas is phased out in electricity and heat supply. Instead, it will increasingly be possible to use the gas system to distribute renewable energy gases such as upgraded biobased gases. Furthermore the gas grid has a large storage capacity that can serve to balance the fluctuating wind and solar energy production. Thus new technologies for the production of green gases based on biomass and combined with the utilisation of excess power production from wind and solar producing for instance hydrogen, has one of the highest priorities for the Danish R&D programmes.

Green fuels for transportation and biorefining

Denmark is among the world's leading developers of enzymes for production of 2nd-generation bioethanol. And steady progress is being made in the development of biorefinery technologies to replace products currently based on fossil fuels with biorefined products. The further development of biological as well as termo-chemical routes for the production of 2nd generation and advanced liquid biofuels and building blocks for green chemicals and materials is another focus area for the national R&D efforts.

State-of-the-art facilities and international partnering

Both companies, universities and public funding programmes in Denmark are very open towards strategic collaborations with foreign investors, companies and research institutions. Due to the strong foundation and long-standing tradition for continuous research and development, Denmark is the ideal place for bioenergy activities in this field. Particularly production and test facilities, demonstration plants and R&D centres have excellent conditions. Collaboration with Danish bioenergy companies and academia gives access to a dynamic and internationally oriented network that understands high-tech energy solutions.

The efforts to reduce capital and operating costs for biogas plants based on manure are adressed by the Danish EUDP - Energy Development and Demonstration Programme through a range of projects. The COMBIGAS biogas plant situated in Western Jutland demonstrates how to minimise the total energy consumption for process heating in smaller biogas plants by new concepts and how to reduce investments through standardisation of plant components. Image credits: BioPress

The aim of the Danish EUDP - Energy Development and Demonstration Programme is to promote especially development and demonstration of new energy technologies with a view to commercialising the results of the supported projects within a time frame of 1-5 years after project termination. EUDP is bridging the gap between proof-of-concept and proof-of-business. High-quality projects within all relevant bioenergy value chains has one of the highest priorities for EUDP and EUDP administrates grants for a comprehensive portfolio of large-scale projects within this area. Image credits: BioPress

Danish Bioenergy Association is a section of DI Energy which unites the bioenergy industry in Denmark. The members represent three main groups of companies:

- *Companies developing and manufacturing bioenergy technology and installations*
- *Advisors designing stand-alone and integrated energy solutions*
- *Energy companies using bioenergy as fuel*

ENERGY TECHNOLOGY EXPORTS MAKE DENMARK PUNCH BEYOND ITS WEIGHT IN GLOBAL CLIMATE ACTION

Strong pipeline of bioenergy projects

According to new 2014 export figures for energy technology, released by the Danish Energy Industries Federation, Danish energy technology companies increased their exports with 10.7% compared to 2013. Bioenergy technologies, systems and solutions play a pivotal part.

Michael Persson, Head of secretariat, Danish Bioenergy Association at the Confederation of Danish Industry

Transforming sustainable biomass resources into competitive bioenergy products such as heat, power, biogas and biofuels is essential to undertake a green changeover and shift energy supply from fossil fuels to renewable energy sources.

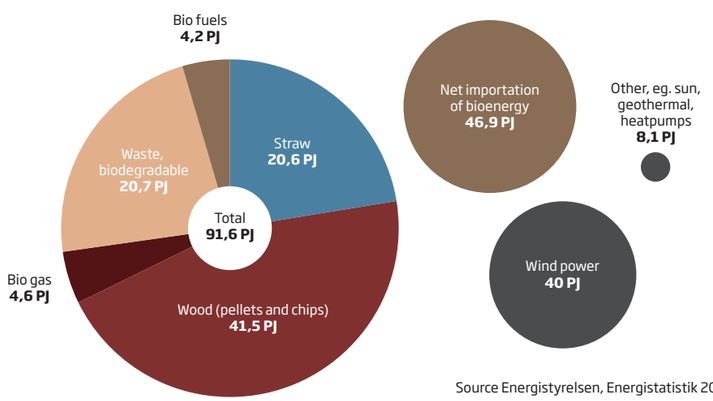
Strong growth in biomass and waste technologies
Within bioenergy, particularly technologies associated with CHP (combined heat and power) plants based on biomass combustion and waste incineration are experiencing increased international attention and demand. For instance Babcock &Wilcox Vølund, that you can read more about in this white paper, exports 85% of the installations developed and manufactured by the company. Same success can be found at BWE and BWSC, which have secured orders for two turnkey power plants, Brigg and Snetterton, based on technologies that allow greater fuel flexibility by burning straw and miscanthus in combination with wood chips. Both projects, Brigg and Snetterton, are carried out in joint ownership between PensionDenmark, a Danish pension fund, and BWSC with BWSC as operations and maintenance (O&M) provider for 15 years.

Exports across the world
In a greater international perspective, we see a great demand for energy-efficient waste incineration plants in the U.K, as well as growing interest in the United States, Singapore and from our Scandinavian neighbours. As for CHP installations, the international trend is that customers are seeking turn-key installations where providers develop, construct and then service the plants. From an EU perspective, implementing these projects poses a challenge because regulations and incentives differ among EU member states. Thus every project must undergo stringent analysis to verify the business case. As for waste treatment within EU, the speed with which member states implement targets and regulations postpones the penetration of responsible handling of waste. A more stringent implementation would increase the possibilities to offer sustainable Danish solutions. In general, common EU rules is a driver for the implementation of these technologies, and for Danish companies to share their competences within technological solutions, energy and waste systems and advice.

Essential for a green changeover
In Denmark, energy and district heating companies are converting central power plants on a grand scale from coal to biomass and building new district heating plants based on biomass. The mostly used biomass are wood pellets and wood chips, but Denmark is among the few countries in the world that also uses straw in large power plants, something that is gaining increased interest abroad. Many plants have already been converted and more operators are on the way. A major incentive for energy companies is that biomass in Denmark is not taxed as oil, coal and natural gas. That makes it economically attractive while at the same time companies contribute to the green changeover.

Renewable energy in Denmark

distributed on energy sources for 2013 (measured in Petajoule, PJ):



Source Energistyrelsen, Energistatistik 2013

SOLUTIONS THAT FUEL THE ENERGY NEEDS OF TOMORROW

Explore Danish bioenergy technologies

Biomass - be it solid, liquid or gaseous - is the only renewable energy source able to replace fossil fuels directly. In a future, low-carbon economy, bioenergy can play a significant role and contribute substantially to the global energy supply.

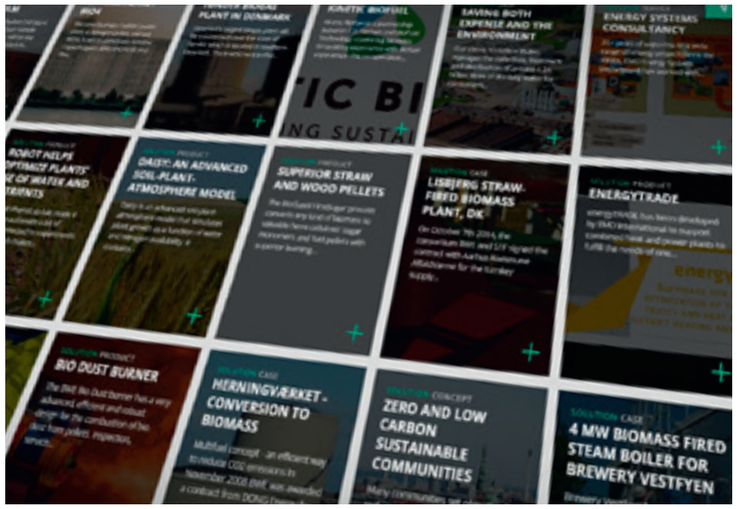
Finn Mortensen, CEO of State of Green

Since 1980, Denmark has grown to become a global leader in the development of new sustainable technologies and solutions. During the same period, the Danish economy has grown by more than 70% without increasing gross energy consumption. We proud to be able to share our solutions and inspire nations, companies and citizens all over the world to invest in green growth. State of Green is your gateway to this knowhow.

2G bioethanol development
Traditionally, the transportation sector has been almost entirely dependent on fossil fuel based products. As transport is a major contributor to energy consumption and CO_2 emissions, it is important to push developments of alternative fuel sources, which can replace a significant part of traditional fuels. Denmark has a leading position in 2G (cellulosic) bioethanol development with public, private and research institutions working closely together to develop this technology. Needed waste products are readily available and the production of 2G ethanol may result in valuable byproducts that can be used for animal feed and solid fuels.

Creating synergies to other environmental challenges
There are huge potentials for synergies between the use of biomass for energy and other environmental challenges. When livestock manure and organic residues from households and industry is utilised in biogas plants there is a production of renewable energy, where emission of greenhouse gases from both the energy sector and agriculture is reduced. In addition, the bad smell of manure is reduced thus improving the life quality of the people living in the countryside. Moreover, phosphorus and other scarce minerals are recirculated. Finally, growing of willow or other perennial crops along environmentally sensitive habitats can contribute to protect the aquatic environment from leaching of nitrates while at the same time contributing to carbon sequestration in the soil and production of renewable energy.

Experience implemented green solutions
Efficient utilisation of biomass such as straw and residual sources to create end-products such as energy, biofuels, nutrients and bio-based products requires a strong infrastructure for logistic handling and processing, as well as access to sufficient resources. A corner of the Danish vision is to inspire others and demonstrate how the transition to a sustainable society and is both possible and profitable – and we invite people to come and see for themselves. We offer international commercial and political decision makers, as well as journalists, a chance to take advantage of the technologies and lessons-learned by leading Danish companies and institutions across the green Danish landscape. For more information about State of Green Tours, please visit www.stateofgreen.com/tours.



Explore, Learn and Connect online
Stateofgreen.com is your online entry point for all relevant information on green solutions in Denmark and around the world. Here you can explore more than 1500 solutions, learn about products and connect with more than 650 Danish profiles. Many of the featured profiles welcome visitors and offer investment opportunities.

About State of Green
State of Green is a public-private partnership founded by the Danish Government, the Confederation of Danish Industry, the Danish Energy Association, the Danish Agriculture & Food Council and the Danish Wind Industry Association. H.R.H. Crown Prince Frederik of Denmark is patron of State of Green. Connect through: **www.stateofgreen.com**

REnescience utilises enzymes to recover value and energy from unsorted municipal solid waste. When adding the enzymes the organic fractions is liquefied and the other parts are effectively cleansed and separated for recycling. The bioliquid is highly suitable for green biogas production.

MOVING TOWARDS BIOBASED SOCIETIES

Value from agricultural residues and household waste

We need to recover the value in our waste to tackle global challenges. This can be done through utilising agricultural residues and ensure recycling of our ordinary household waste to develop sustainable energy products. Two enzyme-based biotechnologies can do just that.

Anna-Lena Jeppsson, Vice President, DONG Energy

On a global scale, we see a growth in population, and the demand for energy increases. This requires us to see our resources in a new perspective.

There are huge unexploited potentials both in agricultural biomass residues that are often left in the fields and in household waste that are landfilled. Agricultural biomass residues and household waste is filled with unused sustainable energy that can benefit our society.

The EU has set a 2020 target for 10% renewable energy in the transport sector and 50% recycling of our household waste. Currently, the transport sector is 94% dependent on oil that is primarily imported. While only a quarter of the household waste is reused, and approx. 80 million tonnes of waste per year is landfilled, entailing valuable resources are lost.

Two enzyme-based biotechnologies for agricultural residues and waste management

Moving towards biobased societies and circular economy requires a more intelligent use of our resources.
For more than a decade, DONG Energy has been working on two enzyme-based technologies that convert agricultural residues and ordinary household waste to valuable resources such as second generation bioethanol, biogas and other types of bioenergy.

The two biotechnologies, Inbicon and REnescience, contribute to handle global challenges concerning pollution and resource scarcity, and they fit well with the increasing focus on responsible handling of our valuable resources to develop more sustainable societies.

REnescience - recycling of unsorted household waste and green energy

REnescience recovers valuable products from unsorted municipal solid waste. The enzyme treatment of the waste turn the organics into a bioliquid and enables separation of the recyclable materials. Value is efficiently recovered in the waste and the bioliquid is highly suitable for biogas production.

REnescience is a tried-and-tested technology at the demonstration plant in Copenhagen. DONG Energy is currently developing two projects for a full-scale REnescience plant in the UK and in Holland. In full operation, the capacity of each plant is 15,000 tonnes of waste per hour, which equals waste from more than 250,000 people per year. Other countries are looking into the REnescience technology as part of the solution for sustainable waste management.

Inbicon - agricultural residues become valuable fuel

The Inbicon technology turns agricultural residues such as wheat straw, corn stover and bagasse into second generation bioethanol and valuable products. Bioethanol is highly suited to lower carbon emissions in the transport sector, while creating rural development and lowering dependence on oil. The other valuable products from the process can generate additional sustainable energy - the lignin can be burned in power plants to produce renewable electricity and district heating, and the vinasse is beneficial for biogas production, while the leftover can go back to the fields as fertiliser.

The Inbicon technology is a proven technology, which has been tested in continuous operation for more than 15,000 hours at our demonstration plant in Denmark.

The focus of both biotechnologies is to make more out of less and turning waste into valuable products that can lower our dependence for fossil fuels.

Using the Inbicon technology, residual products such as straw from agriculture are converted to renewable fuel that can be used to supplement gasoline in transport. Bioethanol can also be used instead of oil in many different products such as plastic and a whole range of chemicals.

Standard equipment ensures flexible and reliable movement of feedstock.

Loading a process module.

Methanation of the liquid extracted in the batch process modules takes place in a biogas reactor.

The last phase of the composting process takes place outside the process modules.

The biogas is used for generating electricity and heating.

Local farmers use the fully sanitized, stable and specified compost instead of imported NPK fertilizer.

SIMPLE DOES IT

Transforming biowaste into valuable resources using standard technology

Surprising amounts of valuable resources can be extracted from kitchen waste and other organic residues. With a 12-year track record, a Danish full-scale plant shows how it can be done with a cost-effective, simple and yet elegant solution.

Christian B. S. Christensen, Managing Director, Aikan A/S and Solum Gruppen

'Waste' is rapidly becoming a concept of the past. Now, the question is how best to capture and transform residual resources in a simple, cost-effective and reliable way. The concept of a circular economy is gaining increased traction. The European Commission is preparing an ambitious strategy for a circular economy to be launched late in 2015. The key principle of a circular economy is to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles.

Full-scale operation since 2003

Ten Danish municipalities are now providing a good example of how a circular approach to the biological cycle can be established using existing and well-proven technologies.

Haulers collect household waste using waste bins and trucks with dual compartments. They deliver a total of 25,000 tonnes per year to the BioVaekst plant, located approximately one hour west of Copenhagen.

The plant, established in 2003 as a full-scale facility, transforms the organic residual fractions to saleable biogas and nutrient rich fully specified compost. The biogas is used for generating electricity and heating. In the future it can be upgraded and fed into the existing national natural gas grid or used as fuel in vehicles. Local farmers use the sanitized and stabilized compost on their fields. This replaces imported NPK fertilizer.

A single work-flow
- robust, reliable and flexible

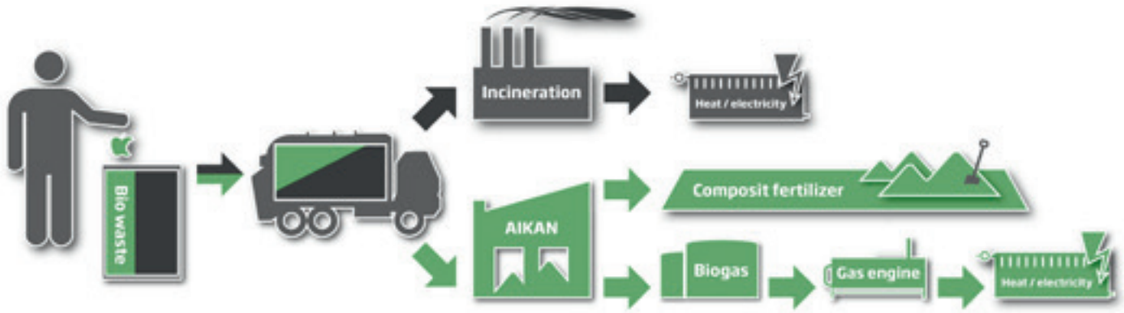
The plant uses Aikan Technology, a simple and yet elegant solution which integrates anaerobic digestion and in-vessel composting into a single work-flow. This does away with the need for the costly movement of material. Feedstock is loaded into batch modules, which allows for the extraction of liquid used for methanation. Once this step has been completed, composting takes place. Staff use wheel loaders and other standard mobile equipment to handle both input and output materials.

The process is robust, reliable and flexible and can easily be adapted to current market conditions and available supply.

Aikan Technology can process all types and grades of organic waste, including those with high levels of impurities. Initial investments are low and the solution integrates easily with existing landfill and incineration facilities.

New enlarged plant ready in 2017

Denmark is a world-leader when it comes to incineration, and this is widely reflected in national regulations and public investments. Even under these conditions, the circular approach to creating value has now proved viable and economically successful for more than a decade. The full-scale BioVaekst plant was established by a private company. It is now also co-owned by two semi-public regional waste management companies. As demand for a sustainable circular approach is growing, plans are now ready to almost double its capacity. The new enlarged plant will be ready in 2017.



Biowaste value is optimised through the use of Solum's AIKAN technology

As part of the efforts to tackle global climate change, the world needs fuel that preserves natural resources. Reduced CO_2 emissions, less soot, fewer harmful substances and a sustainable foundation - the advantages of the Daka ecoMotion products are many. The EU has classified ecoMotion TME (Tallow Methyl Ester) as a 2G biodiesel because of Daka ecoMotion's solid carbon footprint accounts and its utilization of by-products.

2G BIODIESEL FROM ANIMAL FAT

A sustainable substitute for conventional diesel

Overcoming the turmoil of the BSE crisis and the following feed ban in the early 2000s, Daka ecoMotion developed an innovative use case for animal fat and began producing sustainable 2G biodiesel in 2008. Based on waste material, Daka ecoMotion biodiesel is a sustainable substitute for conventional diesel, used as a CO_2 neutral additive in conventional diesel. As natural resources become scarce, biodiesel is crucial to future mobility.

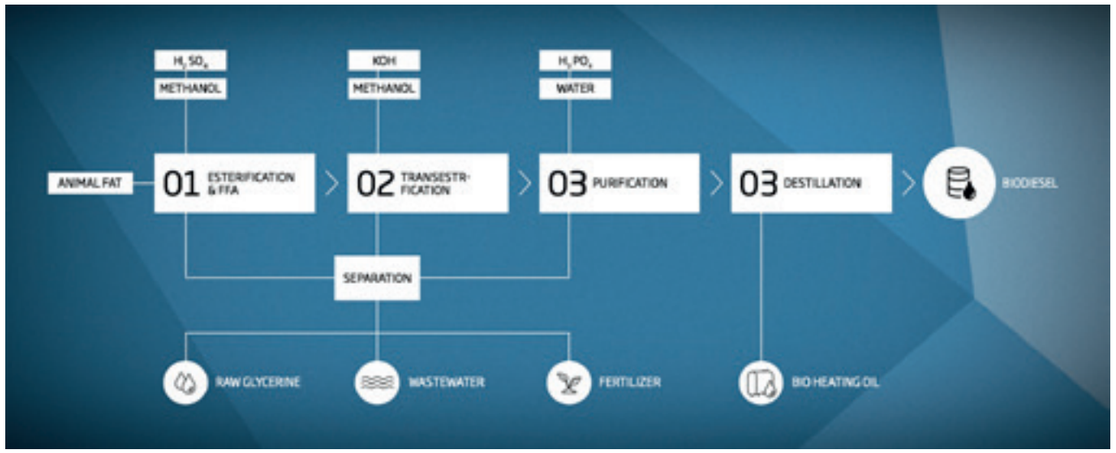
Erik Mansig, Plant Manager, Daka ecoMotion

The quest for sustainable fuels
As the world and the European Union in particular have increased the focus on reducing greenhouse gas emissions, the quest of finding alternative fuels for the transportation sector has intensified. The development towards greater resource efficiency has become very rooted in Danish industry. Continuous focus on sustainable growth has generated several environmentally friendly businesses and models, accommodating future challenges. Daka ecoMotion is one of the companies meeting these challenges through the production of 2G biodiesel. Daka ecoMotion utilizes animal by-products, mainly from Danish agriculture, and refines animal fat into biodiesel. Hence, the biodiesel is made from waste products reducing CO_2 emission by at least 83% compared to mineral oil.

Crisis driven innovation
Daka ecoMotion emerged as an innovative response to the challenges posed by the BSE crisis, which overnight limited the use of animal by-products, as they were banned as ingredients for livestock feed. At first, the need for alternative applications meant that the animal fat was used for heat production in furnaces, but as it proved more sustainable and profitable to use the animal fat in the production of biodiesel, this became the main application. Following thorough testing and research, the Daka ecoMotion production plant was established in 2007.

Unique value addition in large scale
Animal carcasses collected from Danish livestock producers enable Daka ecoMotion to produce 55 million liters of biodiesel yearly. The biodiesel is predominantly utilized in the Danish transportation sector and represents approximately 30% of the biodiesel blended into all mineral diesel in Denmark. Daka ecoMotion biodiesel is ISCC-certified, approved by the European Commission as a renewable source of energy. Daka ecoMotion is continuously improving the efficiency of its production processes, as improvements in the utilizations of the collected resources increase yields and production output.

A substitute to conventional diesel
The European directive on renewable energy determines that 10% of the energy consumed in the transportation sector has to be renewable by 2020. Biodiesel plays a major role in achieving the EU goals, as biodiesel has the potential to partially substitute conventional diesel, which has found hard to replace, especially within the transportation sector. EcoMotion biodiesel can be used as a CO_2 neutral fuel in any conventional diesel engine. Furthermore, the biodiesel has a cleaner combustion and lubricates the engine, which can replace some of the usual additives.



Biodiesel consists of fatty acid methyl esters (FAME) created as the result of a reaction between alcohol and oils/fats of vegetable or animal origin. Methanol (wood alcohol) is usually the alcohol of choice, but ethanol may also be used. The conversion process releases glycerine, a by-product of the biodiesel production process.

The biogas plant NGF Nature Energy Holsted has a biomass capacity of 393,000 tonnes per year. Approximately 75% will be livestock manure, including deep litter and slurry from cattle and pigs. The remaining biomass is organic residues from the food industry and supermarkets. The energy produced will be 11-13 million m³ of biomethane per year. Photo credits: NGF Nature Energy

BIOGAS – THE FUTURE OF AGRICULTURAL WASTE RECYCLING

Agriculture holds the key to green energy and sustainable fertilisers

The world is facing great challenges in producing enough fertilisers for a fast growing global population, and at the same time reducing carbon footprint. Anaerobic digestion technology has an efficient way of meeting these challenges through the recycling of residues from agriculture and the food industry.

Jørgen Ballermann, CEO, Xergi A/S

Through more than 30 years of experience of design and construction of biogas plants, Xergi has learned that most biogas plants will be able to increase their profitability if they can process a great variety of biomasses and waste resources.

This gives the biogas plants the opportunity to choose the best composition of available resources in order to optimize gas yields, fertiliser quality and production cost.

Based on this experience, Xergi has developed an anaerobic digestion system which provides great flexibility for the recycling of organic residues from agriculture and the food industry.

Working with farmers and energy suppliers

In the case of the Danish NGF Nature Energy Holsted biogas plant, Xergi worked closely with both farmers and energy suppliers to develop the project.

This included a thorough evaluation of available waste resources in order to build a solid business case. The farmers wanted to process large quantities of manure because anaerobic digestion increases fertiliser quality of manure which is beneficial to both crops and the water environment.

The energy company NGF Nature Energy also engaged in the project wanting to supply CO_2-neutral biogas to the Danish gas grid in order to replace fossil natural gas.

The best business case

The evaluation of the available resources showed that the best business case would include processing a number of different types of waste and biomasses.

Xergi biogas plants are designed to process almost any type of organic matters such as animal slurry, deep litter, energy crops, vegetable waste, industrial and commercial waste as well as household waste.

Therefore, the conclusion was that the Xergi biogas design was well adapted to the needs of the biogas plant in terms of flexibility and ability to handle both a great variety of biomasses and possible future changes in feedstock.

Profitable and sustainable growth

Xergi has designed and constructed more than 60 biogas plants processing millions of tons of organic waste from agriculture, the food industry and households every year. The plants are located in a number of European countries including UK, France, Denmark and Sweden, as well as in USA.

From this experience Xergi has developed a business strategy and a biogas plant design which is focusing on optimizing the profitability of organic waste recycling, biogas production and production of sustainable fertilizer. This will contribute to a more sustainable growth in global food and energy production.

The biogas plant NGF Nature Energy Holsted was constructed in 2014-2015. Image credits: NGF Nature Energy

Project management to implement the solution:

2 months: Pre-study
1 month: Project description and application for a grant from the Danish Energy Agency
1 month: Danish Energy Agency's processing time
1 month: Final approval from the board of directors at Brewery Vestfyen
5 months: Planning and procurement
4 months: Construction work

14 months in total

BIOENERGY IN BEER PRODUCTION

Switching from fossil fuels to primary biofuels at Brewery Vestfyen

The shift from heating with oil to wood chips, sourced from residual wood in the Danish forestry and wood works industry, demonstrates that it is not only environmentally and technically sustainable - it is also a good business case.

Jens-Ole Aagaard Jensen, Manging Director at Focus BioEnergy
Poul Mark, Managing Director at Brewery Vestfyen

"It can't be done". "It is not possible to use renewable energy sources in production with variable consumption loads". "It is also too expensive". "It is too difficult to operate". These are the words we often hear at Focus BioEnergy when we approach companies with our solutions based on primary biofuels. However, we have proven technology that demonstrates how this is in fact not the case, and we have shown that it is both technically possible, easy to operate and economically sound to make the switch to renewable energy.

Brewery Vestfyen
Take for instance Brewery Vestfyen, where two boilers running on 700,000 litres of heating oil each year have been replaced with a boiler running on wood chips sourced from residual wood in the Danish forestry and wood works industry, which has been producing CO_2 neutral energy since January 2015, with an expected yearly consumption of 10,000 m^3.

The brewery is medium-sized with a yearly production of cans and bottles containing beer and soft drinks exceeding 120 million units. The brewery uses steam at 5 bar for a number of different processes, of which a few run around the clock, while most process run between a few minutes to 3-4 hours. The yearly energy consumption is around 30,000 GJ, with highly variable energy consumption across the day.

The secret lies in the pressure
The secret to overcome the challenge of variable consumption lies in the high pressure boilers, which, at Brewery Vestfyen, utilises steam at 60 bar at 280 0C, as well as designing the solution in such a way, that the entire system acts as a spring for fluctuations. The 14-month time span to implement the solution came at a cost of EUR 2.05 million with a simple payback time of 2.6 years. The plant helps the brewery save 2000 tonnes of CO_2 each year.

Achieving operational success
After operating for 1 year, the wood chip boiler solution has proved its operational merits. Originally, 900 hours per year had been allocated for operational support to ensure a stable supply of green energy, but looking back at the past year, only 200 hours of support was needed, including the 24/7 support. In fact, the plant operates at such a high level of stability and efficiency that a project has been initiated to experiment with other biomass resources, for instance corn husks, in order to bring down the costs even more. Investing in this solution has thus enabled Brewery Vestfyen to reduce its carbon impact, minimise its energy expenses while also gain a competitive advantage through a green company profile that is not just writing on the wall, but integrated into the heart of our brewery operations.

Economics behind the solution:

Machinery and planning: EUR 1.65 million
Building and infrastructure: EUR 0.44 million
Grant from the Danish Energy Agency: EUR 0.94 million
Self-payment: EUR 1.15 million

Simple payback time: 2,6 years

Sleaford plant project setup

Developer:	*Eco2 Ltd*
Plant Owner:	*Eco2 Lincs Ltd. Owned by Glennmont Partners*
Lenders:	*4 International Banks*
EPC Contractor:	*BWSC A/S and BWE A/S in Consortium*
O&M Contractor:	*BWSC A/S - 12 years*
Contract start:	*December 2011*
Delivery Time:	*30 Months*

The core of the plant is a vibration grate fired drum type boiler, the fuel is supplied to the site as rectangular bales (Heston, Claas and New Holland), which is stored in two 2200 m² straw barns, and the grate is an integrated part of the evaporator system of the natural circulated boiler, which is inclined to a low angel, still allowing it to be a part of the evaporator system, without the risk of steam build-up and thus overheating of the membrane. Typically, the grate membrane has a lifetime of more than 10 years of operation.

HIGH EFFICIENT BIOMASS ENERGY PRODUCTION

Best available technological solution for dry agro biomass combustion

200 million tons of straw is harvested in EU alone [6]. Half of it is needed for livestock as well as other agricultural purposes, which means that up towards 100 million tons of straw is available for energy production, corresponding to 124,000 GWh/year [5][7].

Flemming Skovgaard Nielsen, VP, Engineering, BWE and Kasper Fröhlich, General Manager, Biomass, BWSC

Combustion is far the most effective generation of heat and power from dry solid biomass. Electrical efficiency of 33,5% [1] (LHV) has been proven on straw and new plants [2] are under construction with fuel efficiency above 103% in combined heat and power (CHP) mode.

Utilising biomass residues for energy

Residual biomass from agriculture such as straw provides an indisputable source for sustainable energy production. However, the straw is a very problematic fuel due to high chlorine, potassium and sodium content resulting in a corrosive ash with low melting point and requires a special boiler design. In Denmark, biomass boilers have been in operation on straw from wheat and maize for three decades. Step by step, the design has been improved and the steam parameters increased up to today's standard of 110 bar and 540 °C are considered as best available technology (BAT). The biomass combustions plants provide dispatchable power supply and support to the increased amount of renewable on the grid. The wide control range 30-105% in combination with heat accumulators ensure the connection to the grid and the possibility to ramp up and down in parallel to the supply of district heating.

The Sleaford plant in Lincolnshire

The Sleaford plant in Lincolnshire, UK, is an example of BAT for straw fired boilers for power production. The project was executed in a consortium between BWSC and BWE with the latter as boiler supplier. It is built for a heat input of up to 120 MWth equivalent to a straw consumption of 30 tons/hour, summing up to 240.000 tons/year and generating up 38.5MW power, corresponding to approximately 65,000 households and businesses. It is also possible to use up to 22 % wood chips in the boiler. Replacing coal at the Sleaford plant reduces CO_2 emissions by more than 150,000 tons/year.

Recycling resources, utilising surplus heat and spurring jobs

The Sleaford plant's proven technology is designed for clean and efficient combustion of straw supplied mainly by farms within a 30-mile radius of Sleaford. Ash produced by the plant will be recycled as crop fertilizer.

The Sleaford plant is equipped with a flue gas cleaning system meeting the required emission limit values (IED ELV) for NOX, SO2 and particulate. As well as generating 38.5 MW electrical power, the surplus heat generated by the plant is used for district heating purposes in the Sleaford area (public swimming pool, bowling centre, football club and District Council's office). Long term contract with local farmers on fuel supply and 80 jobs during operations support the local economy by approximately £10 million/year.

Positive spin-off from Sleaford

In addition to Sleaford, another two turnkey straw-fired power plant projects have been secured with BWSC as consortium lead with BWE, allowing a further fuel flexibility by burning straw and mischanthus in combination with wood chips. Both projects, Brigg and Snetterton, are 10% larger in capacity compared to Sleaford and carried out in jointly ownership between PensionDenmark and BWSC with BWSC as O&M provider for 15 years

Boiler Characteristics

Steam parameter:	*540 °C @ 112 bar*
Boiler type:	*Drum, three pass, bottom supported*
Fuel:	*Rectangular straw bales (New Holland, Heston or Claas type),*
Additional fuel:	*22% Wood chips*
Start up fuel:	*Combined LDO/gas Burner*
Boiler efficiency:	*92,5% (LHV, EN12952-15)*
Load range:	*40-100% load*
Load change rate:	*3 %/min (4%/min with support fuel)*
Combustion:	*4 Screw stokers firing on water cooled vibrating grates*

The upcoming EU requirements 3) for emissions valid from 2020/21 have forced the suppliers to improve flue gas treatment (FGT). Today integration of boiler and FGT 4) is well recognized as the best way to fulfill the new requirements.

1) Sleaford (117 MWth)performance test
2) Lisbjerg (110 MWth)steam cycle CHP performed by COWI
3) LCP BREF AELs. Data can be verified by EU Environmental Agencies.
4) Snetterton (130 MWth) tail end SCR integrated with boiler flue gas cooler packages and Lisbjerg (110 MWth) tail end SCR, air humidification and flue gas condensing.
5) Average heating value 14 MJ/kg, average plant electrical efficiency32%. Future plant > 100 MWth with reheat cycle can reach > 35%. Steam cycle can be confirmed by BWSC.
6) IEEP May 2012, Biomass future Feb 2012, Bioboost June 2013 etc.
7) Denmark is using33% of the available straw for energy production (up to 2 mill tons / year)

HydroFlex™ produces synthetic ultra-low sulfur diesel and A1 jet fuel meeting the European standards, meaning that the renewable fuels are perfectly interchangeable with fossil fuels. Topsoe renewable diesel is, however, superior to fossil diesel, particularly regarding the cetane number. While specifications require 40/51, Topsoe renewable diesel has as high a cetane number as 80-90. Hence, refiners have the possibility to blend it with poorer quality fossil diesel cuts to uplift the value of the latter, thereby improving the overall refinery margins.

HELPING EUROPE REACH ENVIRONMENTAL TARGETS ON RENEWABLE FUELS

Topsoe partners with refiners in the pursuit of a sustainable future

In Europe, the demand for diesel and jet fuels is growing, while the crude oil fields are depleting. At the same time, the world is facing significant environmental challenges. Topsoe's HydroFlex™ technology provides solutions, which meet concerns about greenhouse gas emissions and climate change and ensure long-term fuel production.

Anne Grydgaard, Refinery Marketing, Haldor Topsoe

The EU Renewable Energy Directive (2009) stipulates a minimum share of 10% renewables in transportation fuel in EU by 2020. Currently, the average renewables content is approximately 5% (2013), forcing refiners in Europe to think of new greener production methods in order to comply with legislation. For more than a decade, Topsoe has been developing the HydroFlex™ catalysts and technologies in collaboration with European refiners, enabling conversion of feedstocks derived from biomass and waste materials into drop-in ultra-low sulfur diesel and A1 jet fuel.

Applying 75 years of experience to overcome the challenges

Converting renewables into valuable fuels is challenging, and in-depth understanding of catalysis and mapping of the reactions involved are of paramount importance in order to succeed. The processes take place at severe conditions in catalytic reactors requiring dedicated stable catalyst systems. The high oxygen content in renewable feeds presents a number of challenges, including control of the high heat release and fouling due to gum formation. High acidity of the feeds can lead to excessive corrosion of process equipment. Topsoe's core strengths, fundamental research and technical excellence, are utilised to address and manage these challenges.

Meeting the energy requirement of tomorrow - with full feedstock flexibility

As the world's resources are growing scarce, there is increasing focus on feed for renewable fuels which do not exhaust global water, food, and land resources. Topsoe's HydroFlex™ solutions provide full feedstock flexibility, and it is possible to produce clean fuels from a wide range of feeds, such as plant and vegetable oils, non-edible waste from paper industry, "black liquor", animal fat, pyrolysis oils, and extracts derived from wood chips, plastics, and coal.

Commitment to a sustainable future - taking the lead

Dr. Haldor Topsøe founded the company in 1940, and it has been the frontrunner within catalysis ever since, specializing in supplying high-performing robust solutions tailored to meet the exact needs of our clients. We share our commitment to catalysis with our clients, and Topsoe's HydroFlex™ solutions for renewable fuel production have been in operation for several years in 20+ units, primarily in Europe and North America.

TK-341 is one of the bestsellers within catalysts for biofuels hydroconversion. A full 40% of the world's production of low sulfur diesel is produced by the help of Topsoe catalysts, making Topsoe the market leader in this segment. Topsoe has catalyst production sites in Frederikssund, Denmark, and in Houston, USA.

Copenhagen's upcoming waste fired power plant, Copenhill, Amager Bakke, features an artificial ski slope inspired by the ski slopes in the Alps.

SETTING NEW STANDARDS FOR ENVIRONMENTAL PERFORMANCE, ENERGY PRODUCTION AND WASTE TREATMENT

Copenhill, Amager Bakke: Waste fired power plant with multiple purposes

Copenhagen's state of the art plant sets new standards for environmental performance, energy production, waste treatment and recovery of material resources. Innovative technology and architecture integrate to form a future in which waste-to-energy plants are welcomed in any backyard.

Ole Hedegaard Madsen, Marketing & Technology Director at Babcock & Wilcox Vølund

In 2017, Copenhageners and visitors will witness a waste-to-energy plant that is not only one of the best performing European plants in terms of energy efficiency, waste treatment capacity, and environmental consideration, but also in terms of visual rendition and local acceptance.

The plant, Copenhill, Amager Bakke, is being constructed by Amager Resource Center (ARC), owned by five Danish municipalities. Copenhill, Amager Bakke will be equipped with two furnace lines and a joint turbine- and generator system. The plant replaces a 45-year-old plant with four furnace lines.

A ski slope and so much more

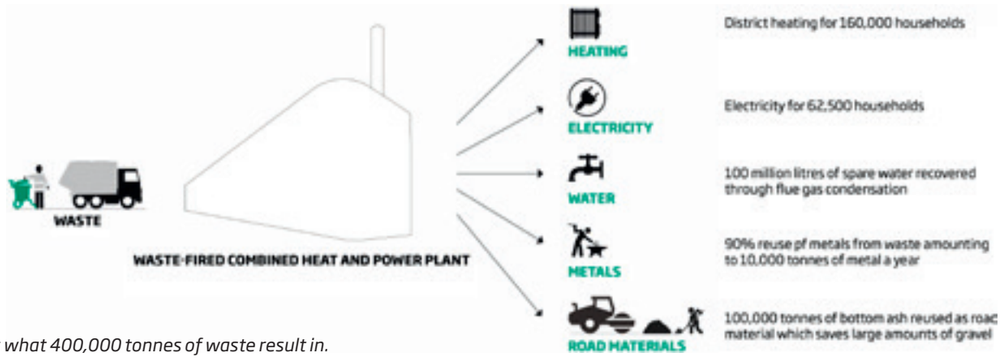
It is a multi-purpose plant that is already catching the eyes of the world because of its local appeal. The plant provides energy and waste treatment, and will be an architectural landmark and a leisure facility. In addition to the technological merits, the plant´s architecture includes a roof-wide artificial ski slope open to the public. The ski slope is designed by renowned ski-slope designers who will ensure the best possible experience for the coming users. On the façade, the highest climbing in the world is planned to be established, inspired by some of the best climbing passes from the most challenging mountains in the world. 85 metres above the ground, a cafeteria will cater visitors, who can also enjoy the marvellous view of the city skyline.

Taking technology further

The ever innovative technology of the DynaGrate® is unique in its fuel flexibility and optimised combustion. The state of the art technology at Copenhill, Amager Bakke has an incredibly high environmental performance. Not least because the plant makes full and efficient use of the energy contained in the waste. It will also be possible to process all types of waste as fuel and still obtain a high level of energy recovery. For instance, the plant will be able to use the wet organic fraction contained in the waste very efficiently and recover not only the water but also 98 % of the energy.

Energy and resources recovered from the waste

By 2017, ARC will run a plant that burns 2 x 35 tonnes of waste per hour. This means that the plant will treat around 400,000 tonnes of waste annually produced by 500,000 – 700,000 inhabitants and at least 46,000 companies. The plant will supply district heating for 160,000 households, electricity for 62,500 households. Furthermore, the waste-fired plant will recover 100 million litres of spare water and will recover 90 % of metals from the waste amounting to 10,000 tonnes of metal a year. The full capacity of the plant is 560,000 tonnes annually and therefore ready for the increasing number of citizens in Copenhagen.



This is what 400,000 tonnes of waste result in.

Behind the concept stands a consortium of companies consisting of energy company DONG energy, enzyme producer Novozymes, local utility companies Vestforsyning and Struer Forsyning.

FINDING SYNERGY BETWEEN BIOGAS, BIOETHANOL, HEAT AND POWER GENERATION

Maabjerg Energy Concept showcases an innovative technological approach to energy economics and sustainability, through the capture and re-use of industrial and household by-products

The concept merges several energy supply objectives in a holistic system concept, where the synergy between the individual solutions is used with great effectiveness by utilising the energy and resource streams between the individual plants.

Jørgen Udby, CEO of Maabjerg Energy Concept

The Maabjerg Energy Concept envisions a comprehensive, sustainable energy solution, based on local and CO_2 neutral raw materials, using the latest biorefining technologies. The concept satisfies several aims: it produces heat and electricity through a biomass fuelled CHP plant and biogas from local household waste. In 2016 it is expected to start construction of the third part for the production of second generation bioethanol transport fuel from straw and other agricultural residues.

Synergy between individual solutions
Maabjerg Energy Concept combines social, environmental and economical sustainability. Key to the concept is bringing together specific technologies in a holistic system concept, and utilising the synergies gained between the individual solutions to develop strong biobased platform. The total investment budget for the entire Maabjerg Energy Concept is about EUR 360 million and was by the EU Commission awarded EUR 39 million in funding from the NER300 programme for the future production of second generation bioethanol.

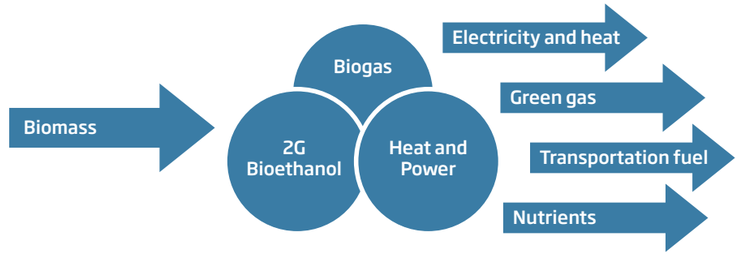
Bioethanol plant for transport fuel and energy production
The upcoming bioethanol plant will use DONG Energy's Inbicon technology to produce 80 million litres 2G bioethanol based on 300,000 tonnes of straw. The products from the bioethanol production, which consists of lignin biofuel and vinasse, is used for energy production. The lignin is used to produce steam and electricity in the existing cogeneration plant, and the vinasse is used as raw material for biogas production, while the leftover from the biogas production can go back to the fields as fertiliser.

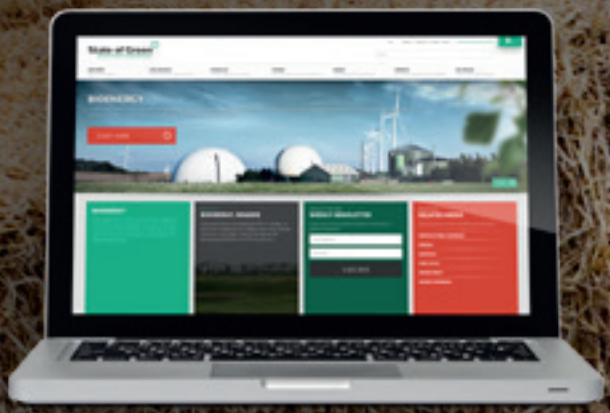
Upgraded biogas using wind power
The biogas plant, which is already in operation, processes up to 800.000 tons of biomass yearly, of which about 500,000 tons are liquid and solid manure, supplied by the local farming community. Along with manure, the plant co-digests wastewater sludge, dairy waste and food waste, producing 20 million Nm^3 biogas for use in district heating and electricity generation, as well as digestate for use as fertilizer and fibres. When 2G bioethanol production begins, the biogas production volume is expected to increase to a total of 50 million Nm^3 biogas annually. The surplus of biogas will be upgraded to sustainable natural gas and distributed, stored and sold through the existing natural gas network.

The energy in the fibre from the biogas plant and the lignin from the ethanol production is designed so that the nutrients in the fibre and lignin are collected and recycled. In particular, using the phosphorus is essential, since this component has a large and global significance.

District heating grid acts as a cooling medium
The combined system is dimensioned so that the local heating market can use the whole heating load from the plant, without energy being lost to additional cooling. The district heating grid acts as a cooling medium for the steam required to produce ethanol, so the extent of the ethanol production and the amount of raw materials is based on the district heating system's base load.

The concept reduces the climate load by 172,000 tons. The intended application of new incineration technology means that the concept can collect and use the nutrients in the materials that are incinerated, including 240 tons of phosphorus. In addition, nitrate and phosphorus leaching to the aquatic environment will be reduced by 25 and 75% respectively for the liquid manure that was added to the original Maabjerg BioEnergy project.





Learn more about Danish bioenergy solutions, find more cases from around the world and connect with Danish expertise at:

www.stateofgreen.com/bioenergy

State of Green is a non-profit, public-private partnership founded by:

Confederation of Danish Industry

DANISH ENERGY ASSOCIATION

Danish Agriculture & Food Council

DANISH WIND INDUSTRY ASSOCIATION

Ministry of Business and Growth Denmark

DANISH MINISTRY OF ENERGY, UTILITIES AND CLIMATE

Ministry of Environment and Food

Ministry of Foreign Affairs of Denmark