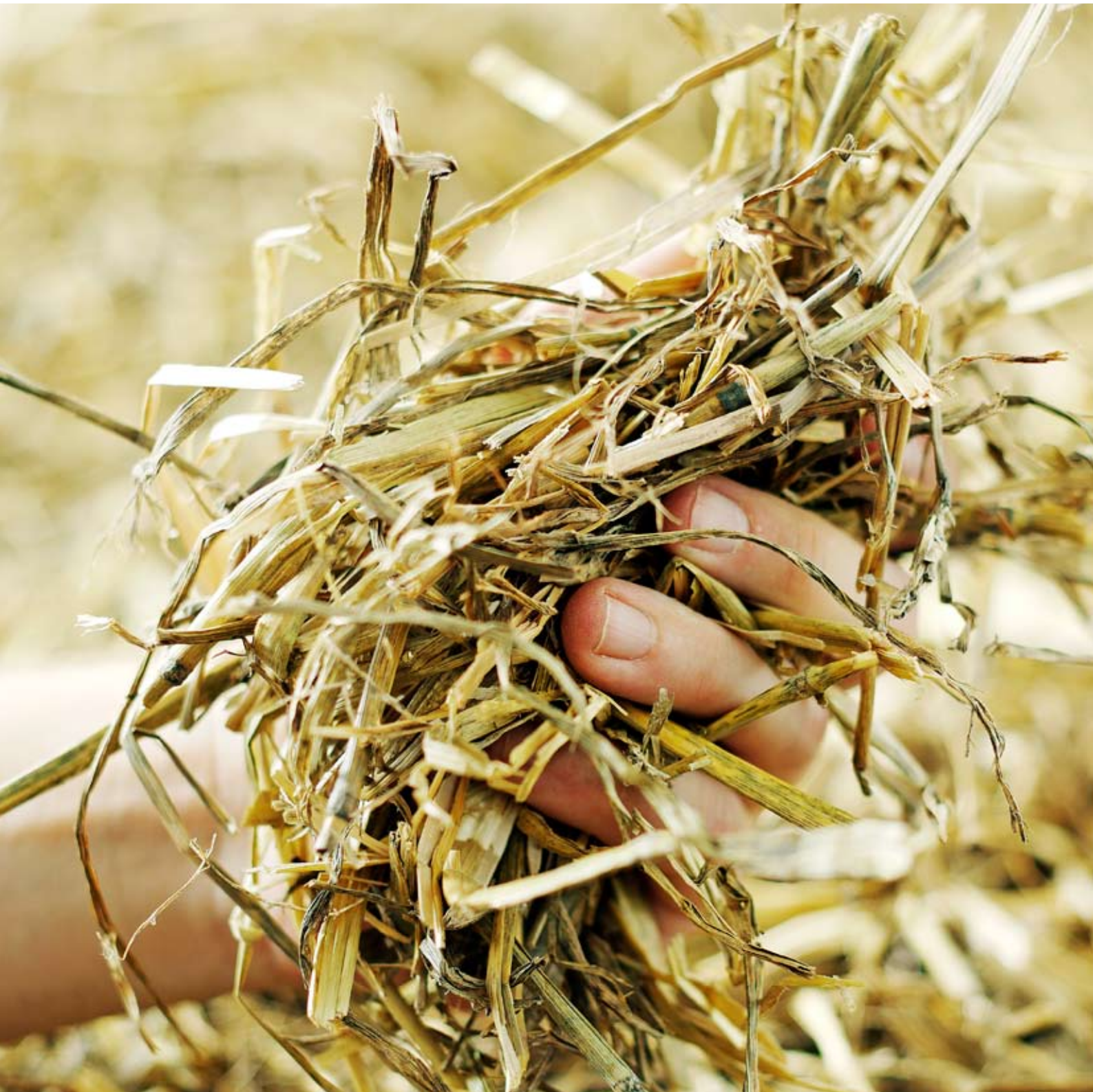




BIOETHANOL
THE CO₂ NEUTRAL FUEL OF THE FUTURE

DONG
energy



"Bioethanol – the CO₂ neutral fuel of the future"
has been prepared in December 2007 and revised in March 2008.

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BIOETHANOL

THE CO₂ NEUTRAL FUEL OF THE FUTURE

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DONG ENERGY IN THE YELLOW JERSEY

New unique technology for production of bioethanol

DONG Energy procures oil and gas from the North Sea and generates electricity and heat at power stations and via renewable energy sources such as wind. We sell and distribute the energy to our customers in Northern Europe.

Efficiency and responsibility are key words in connection with our procurement, production, distribution and trading in energy. Responsibility means, among other things, that we continuously develop and improve technologies and products that benefit our customers in their everyday lives, but also very much benefit the environment – now and in the longer term.

One of DONG Energy's focus areas is bioethanol, which can be used as fuel in cars and other means of transport. Bioethanol is produced from plants and is a CO₂ neutral fuel in the sense that the CO₂ released on combustion in the engines has been absorbed by the plants while growing.

Bioethanol is produced in many places across the world, and the existing first-generation production is based on grain, maize, sugar cane and other raw materials rich in sugar or starch. DONG Energy's second-generation technology is unique as we are able to produce bioethanol from cellulosic biomass such as straw.

CO₂ emissions from the transport sector are reduced

Transport of goods – and people – is an important means of connecting society. The products that we consume every day, at work and at home, have all been transported over a short or long distance. Many of us also rely on fuel-powered means of transport to commute to and from work every day. The vast majority of vehicles run on petrol or diesel.

According to the Danish Energy Agency, transport currently accounts for 60 per cent of Denmark's total oil con-

sumption and consequently a large proportion of Danish CO₂ emissions. There are no indications that transport will become less important in the future. DONG Energy would therefore like to contribute to a reduction in the transport sector's CO₂ emissions.

The UN climate panel recently concluded that global warming is, with 90 per cent certainty, predominantly triggered by human activity. Human emissions of CO₂ and other greenhouse gases must be reduced. Due to society's heavy reliance on transport, and the growing proportion of CO₂ emissions generated by transport, a reduction of CO₂ emissions from specifically cars, buses, lorries and other means of transport will thus be vital in the battle against global warming. By replacing part of the oil consumption with bioethanol, we will reduce CO₂ emissions noticeably.

By combining DONG Energy's bioethanol expertise and efficient energy production with other Danish skills such as efficient farming and development of enzymes, Denmark can become a world leader when it comes to a new technology for bioethanol production.

The Danish government and the EU support bioethanol

The EU Commission wishes to see an increase in the use of biofuels. In 2003, the EU issued a directive on biofuels and, in 2006, the EU launched a strategy to accelerate the use of biofuels. The EU target is for biofuels to account for 5.75 per cent of all transport fuel by 2010 and 10 per cent by 2020.

The Danish government has allocated DKK 200 million to technological development in relation to second-generation bioethanol and to the construction of demonstration plants.

The Danish government and a broad majority of the parties in the Danish Parliament have agreed on the following targets within biofuels etc. for transport vehicles:



- The government's stated target is that biofuels etc. must make up 5.75% in 2010 and 10% in 2020 of the total fuel consumption for land transport. This corresponds to the target of the EU.
- For the fulfilment of the target, only biofuels complying with the EU's coming sustainability criteria (financial, environmental, social) may be applied.
- The parties are discussing whether the Commission's proposal for sustainability criteria should also be applied as Danish requirements, until they have been adopted and implemented in the EU.

- The instruments for the fulfilment of the targets are adjusted when the EU has decided which fuels may be included. This may also include power for electric cars, plug-in hybrids etc.

Bioethanol also features prominently on the agenda in many other parts of the world. The USA is focusing firmly on the use of bioethanol instead of oil. In Brazil, bioethanol is already very popular, and China, for example, is expected to become a future major bioethanol consumer.

FROM STRAW TO BIOETHANOL

The result of ten years of research and development

DONG Energy has been conducting research into the development of bioethanol for almost ten years, and we have made good headway. DONG Energy's concept for production of second-generation bioethanol is innovative in several respects. For example the process for pre-processing of the straw used as a raw material in bioethanol production. The challenge has been to create a continuous process during which the straw is exposed to high pressure simultaneously with the introduction of steam. This rough treatment opens the complex structure of the straw, allowing access to the cellulose molecules that lie protected within the plants. During the subsequent process, we can add the enzymes developed for this purpose, which convert the cellulose molecules to sugar. It is precisely this sugar that becomes bioethanol at a later stage in the process. No one has yet demonstrated that they can implement this process as efficiently as DONG Energy.

Symbiosis between a bioethanol plant and a power station

Energy savings as a result of the integration between a bioethanol plant and a power station are an important element of DONG Energy's bioethanol concept. Bioethanol production is traditionally energy-intensive, but in DONG Energy's concept the bioethanol plant is located at a power station, so that the waste heat from power generation can be utilised for processing the straw.

Utilisation of waste heat from power stations is a major advantage, as it limits the use of fuel for steam production

in the production of bioethanol. In Denmark, we often use this waste heat as district heating, but in other parts of the world with warmer climates and no district heating networks the waste heat is normally lost. If we look outside Denmark, DONG Energy's model consequently has even greater potential to generate energy savings in the production of bioethanol.

The symbiosis between a bioethanol plant and a power station goes both ways in DONG Energy's concept. That is because the production of second-generation bioethanol results in a solid fuel with a heating value almost matching that of coal, and which can be used directly in the power station. Calculations show that this solid fuel produces more energy than is used in the production of bioethanol, making the ethanol production process energy neutral.

Besides the combustible residual product, the bioethanol process also releases an energy-rich substance called C5-molasses. The C5-molasses contains sugars and is suitable for livestock feed. Alternatively, when the technology is commercially available, these sugars can be fermented into ethanol, and thus increase the ethanol output of the process up to 60%.

The bioethanol plant has been optimised so that it generates a very small volume of waste water. This waste water is used in the power station for scrubbing the flue gas. This reduces the power station's consumption of fresh water.

FROM CONCEPT TO INDUSTRY

From pilot plant to demonstration plant

In 2003, DONG Energy, together with several partners, constructed a pilot plant (= a small-scale plant for research and development). The purpose was to develop an overall concept for the production of second-generation bioethanol. The aim was also to show that the concept is environmentally sound and financially attractive for bioethanol producers that choose to invest in this technology.

The feedback from potential customers and business partners around the world is very positive. DONG Energy's next step is therefore to scale up the pilot plant to a large-scale bioethanol demonstration plant. The demonstration phase is necessary to complete the development of the complex technological processes, test them on a large scale and optimise them. The demonstration plant will be constructed at Asnæs Power Station in Kalundborg, and the vision is to be ready before the UN climate summit in Copenhagen in 2009.



The pilot plant pretreatment process has a capacity of 1000 kg/ hour

The difference between first-generation and second-generation bioethanol

A distinction is made between first-generation and second-generation bioethanol. The difference between the two is the raw material and the technology used for production. The finished bioethanol is the same product, regardless of the production method – i.e. 100 per cent pure alcohol. First-generation bioethanol is currently produced using known technology, and largely in countries such as the USA and Brazil, from sugar-containing raw materials (such as sugar cane, molasses, sugar beet) or starchy raw materials (such as wheat grain and maize). Second-generation bioethanol is produced at pilot level and from biomass such as straw from grain and maize, sugar cane waste, waste wood and garden waste. The main challenge for the researchers has been to develop a production process that is both eco-friendly, reliable, efficient and financially viable. DONG Energy has made good headway and will now be testing the technology in a large-scale demonstration plant.



KALUNDBORG ON THE MAP

DONG Energy's demonstration plant in Kalundborg

The principal purpose of the demonstration plant is to show that DONG Energy's second-generation technology can be applied on a large scale, i.e. that large-scale production of ethanol from straw is possible. The plant will also demonstrate that integration with a power station, enabling the residual biomass to be combusted, thereby generating more energy than is used by the plant itself, results in efficient and financially viable energy utilisation.

Unique collaboration at the port in Kalundborg

DONG Energy's demonstration plant for production of bioethanol will be located in Asnæs Power Station's area bordering on the dock in Kalundborg. This will enable the bioethanol plant to be part of the collaboration that involves many other companies in the port area.

The companies utilise each other's residual products in a sustainable cycle that benefits each company financially and is also environmentally beneficial. Statoil's oil refinery and Dansk Landbrugs Grovareselskab, DLG (Danish Co-operative Farm Supply) are situated at the port. The refinery can receive bioethanol from the demonstration plant and blend it with petrol. DLG and other agricultural enterprises can supply the bioethanol plant with straw and can sell the feed products from the bioethanol production.

More knowledge-intensive jobs in Kalundborg

DONG Energy hopes that the demonstration plant will also be used to demonstrate other new technologies in the slightly longer term. These could, for example, be smarter agricultural methods, biogas or "green chemistry", i.e. chemicals produced from biomass instead of oil. All the indications are that this will lead to the emergence of many companies, which will want to settle in this area. In this way the bioethanol plant may become the catalyst for the formation of new Danish growth companies and knowledge-intensive jobs in Kalundborg.

Global showcase in 2009

In December 2009, Denmark will be hosting the UN climate summit, COP 15, where it is hoped that a global political agreement on a resolution to the CO₂ problem will be reached. The Kyoto Protocol expires in 2012 and a new agreement will therefore concern post-2012 CO₂ reductions.

Hosting the climate summit presents a unique opportunity to showcase Danish companies' skills within efficient energy production, renewable energy sources and development of new energy solutions, such as second-generation bioethanol that reduce atmospheric emissions of CO₂.

The plan is consequently for DONG Energy's demonstration plant in Kalundborg to be ready before the climate summit. That will give us an opportunity to show a Danish and international audience that we can produce bioethanol on a large scale using our second-generation technology.

Promising outlook

The outlook for future production of second-generation bioethanol, using the method developed by DONG Energy, is promising. We are consequently also well on the way to being able to help the transport sector reduce its CO₂ emissions in the future. The next step for us on the way from concept to industry is the demonstration plant in Kalundborg, as outlined above.

The development of the second-generation bioethanol production technology is the result of DONG Energy's constant search for new and even better energy solutions. Solutions that meet our customers' needs while at the same time reducing the impact on the surroundings by reducing CO₂ emissions from production and consumption.

Fact box about the plant

Location: Kalundborg (at Asnæs Power Station)

Scheduled start-up: Autumn 2009

Raw materials: 4 tonnes of straw per hour, equivalent to 30,000 tonnes of straw per year.
Enzymes from Danisco Genencor

Output: 4,300 tonnes / 5,400 m³ of ethanol per year
8,250 tonnes of biofuel per year
11,100 tonnes of molasses (65% DM) per year, which is used for feed, but could in the future also be used for bioethanol production



The ethanol plant is located in the front

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