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Danish bioethanol plant inaugurated

By means of the latest technology, the price of Danish bioethanol can become lower than that of petrol and fully competitive compared to Brazilian ethanol. This is the opinion of the researchers behind a new pilot plant for bioethanol production, which was inaugurated at the Technical University of Denmark in September.

By Torben Skøtt

- This is nothing less than a world sensation that we as Danes ought to be proud of, said Professor Birgitte K. Ahring in connection with the inauguration of the so-called Maxifuel plant at the Technical University of Denmark. She is one of the fiery souls behind the ambitious project, which is the precursor of a real demonstration plant at a price of just under DKK 200 million, which will be built within the next few years.

Unlike many of the other spokesmen for Danish ethanol production, Birgitte Ahring does not think that a tax reduction is crucial to boost the demand for the environmentally friendly fuel. To her, the first step is to mature the so-called second-generation technology so we can establish production plants to exploit residual products from farming and forestry.

– It is about ensuring optimal use of the raw materials. If we do that, Danish ethanol production will be able to compete with Brazilian ethanol without problems, says the professor and refers to a number of calculations that show that the production price of a litre of ethanol can get as low as DKK 2.35. That is cheaper than ethanol from the first-generation plants in Brazil and it is fully competitive compared to petrol - even with the current Danish tax system, under which biofuels are only exempt from the CO_2 tax.

Two types

Today, there are two main types of bioethanol production plants:

In the Maxifuel plant, the biomass is first subjected to a pre-treatment process, by which the lignin is broken down. After that there is a hydrolysis tank, where various enzymes are added to the biomass before it is passed on to two separate fermentative processes, by which glucose and xylose respectively are converted to ethanol. The wastewater is treated in a biogas plant, and the rest of the fibre mass from the process is converted to fuel pellets. The result is a plant that produces ethanol, hydrogen, biogas and fuel pellets.

photo: bo jarmer, danmarks tekniske universitet

- The first-generation plants, which are based on a simple and well-known process, by which sugary and starchy crops are converted to ethanol by means of yeast. This technology is especially widespread in Brazil and the USA, where large amounts of cheap raw material are available in the shape of sugar beets, maize and grain.
- The second-generation plants, which are based on a far more complicated process that has not yet been fully developed. Basically, it is about exploiting a number of cheap high-fibre residual products such as straw, wood chip and waste paper. The objective is to ensure maximum exploitation of the raw materials and combine various technologies, so that not only ethanol, but also other valuable products, such as methanol, hydrogen, biogas and fuel pellets, are produced.

In Denmark, the primary players behind the development of the second-generation technology are DONG (the former Elsam), Risø and the Technical University of Denmark, partly through the IBUS project, which has formerly been covered by this magazine, and partly through the Maxifuel plant, which was inaugurated on 13 September in Lyngby.

At first glance, the two projects may seem similar, but if you take a closer look, you will see that there are important differences. Fundamentally, the idea behind the IBUS project is that the technology should be integrated into a modern power plant, whereas Maxifuel has chosen to combine ethanol production and biogas production.

Challenges

In order to convert straw and wood to ethanol, it is necessary to break down the long sugar molecules, cellulose and hemicellulose.

A plant typically consists of 35-45 per cent cellulose, 25-40 per cent hemicellulose and 5-25 percent lignin. The lignin is what gives the plant its stiffness and strength, but it also "wraps up" the cellulose and the hemicellulose, which means that it is quite a challenge to break down the lignin.

Another challenge is to exploit all the sugar molecules of the plant. When the cellulose and the hemicellulose have been broken down, a large amount of the sugar takes the form of glucose, but there are also considerable amounts of xylose that may be exploited. Straw for instance consists of approx. 40 per cent glucose, which can easily be converted to ethanol by means of ordinary industrial yeast, but apart from that there is approx. 30 per cent xylose that cannot be exploited by means of yeast. Here, it is important to develop new methods to ensure efficient conversion of xylose to ethanol.

Last but not least, second-generation plants use considerable amounts of process water. This normally entails large amounts of wastewater, which may be expensive and difficult to clean. The Maxifuel plant thus integrates the production of ethanol in a biogas plant, so that the wastewater is cleaned and methane gas is produced at the same time.

A "carbon slaughterhouse"

– The keyword of the Maxifuel plant is maximum exploitation of the raw materials. The plant can be described as a "carbon slaughterhouse", where every single carbon atom of the raw material is exploited, explains Birgitte K. Ahring. She believes that the technology has great potential - not only as regards energy production but also in connection with the production of a number of chemicals that are currently produced on the basis of oil products.

BioGasol

BioGasol ApS was established in January 2006 with Professor Birgitte K. Ahring as a co-founder. The core product of the company is development and sale of process technologies for the production of biofuels such as bioethanol, methane and hydrogen.

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In essence, the process of the Maxifuel plant comprises a pre-treatment process, by which the lignin is broken down. After that there is a hydrolysis tank, where various enzymes are added to the biomass before it is passed on to two separate fermentative processes, by which glucose and xylose respectively are converted to ethanol. The result is a plant that produces ethanol, hydrogen, biogas and fuel pellets.

According to Birgitte K. Ahring, the plant can convert 1,000 kg straw to 310 l ethanol, 70 m^3 methane gas, 20 m^3 hydrogen and 230 kg fuel pellets. In a full-scale plant, the production price of one litre ethanol will be around DKK 2.35 at a straw price of DKK 500 per tonne, but the price may be reduced even further if very large plants are opted for.

Transport or heat and power

Lately, there has been quite a lot of debate as to whether or not it is reasonable to use biomass for the production of liquid fuels. In particular, the critics have stressed that the raw materials are better exploited when biomass replaces coal and natural gas at the many CHP plants all over Denmark.

– But it is way to easy to reject bioethanol on the basis of a simple comparison of the energy outputs of the various technologies, says Birgitte Ahring.

– It is like comparing apples to pears. The quality of the various energy types differs, and it is easy to meet the demand for electricity and heating by means of renewable energy, but when it comes to replacing petrol, there are only very few methods available. Therefore, it is crucial that we develop alternative fuels for the transport sector, and do not let ourselves be hypnotized by the fact that we already have a number of efficient methods to meet the demand for electricity and heating by means of renewable energy.

– In the EU alone, the transport sector is responsible for 28 per cent of the total CO_2 emission, and after 2015 our own oil wells will start to dry out. Furthermore, we know that the hydrogen community is far in the future, so there are not a lot of alternatives to biofuels, says Birgitte K. Ahring.

Test plant

The Maxifuel project is the result of close cooperation between public research institutions and the business sector. The pilot plant has received funds from Denmark's Energy Research Programme, Energinet.dk, the Technical University of Denmark, Energi E2 and Novozymes. The project owns a large number of patents, and today the various activities are gathered in the BioGasol company, which is responsible for the further development including the construction of a test plant that will produce approx. 10 million litres of ethanol a year.

Great expectations of the technology

photo: bo jarmer, danmarks tekniske universitet

– The government has great expectations of the development of the second-generation technology for production of biofuels, said Flemming Hansen, Minister for Transport and Energy, when he participated in the inauguration of the Maxifuel plant at the Technical University of Denmark.

– The new technology is necessary if biofuels are to become a real alternative to oil. Therefore, I am pleased that my ministry has been able to make a considerable contribution to the establishment of the new pilot plant, and I wish BioGasol the best of luck with their development work.

– The next step in the development is to build a large-scale plant in Denmark. Here the government's decision to allocate DKK 200 million to further development of the technology will be a shot in the arm to ensure a competitive alternative to oil, said the Minister.

The photo shows Flemming Hansen, Minister for Transport and Energy, cutting the red ribbon, and to the right it is professor Birgitte K. Ahring.

New research offices

On 1 September, the Ministry of Science, Technology and Innovation opened an office for Danish researchers and companies in Brussels. The most important task of the office is to promote Danish participation in EU research programmes.

Furthermore, the Ministry will establish an office in Silicon Valley in the USA this autumn, which will function as a link between Danish and American companies, investors and research environments. In the years to come, the Ministry expects to open a total of ten of these pier-heads - with varies focus areas - around the world.

How much do biogas plants smell?

Lately, the opposition against getting a large common biogas plant as a neighbour has been considerable. The primary concerns of the neighbours are odour nuisances from the plants, increased traffic and reduced house prices, but it does not have to be that way. That is the conclusion of a new report prepared by PlanEnergy.

By Torben Skøtt

Today, it is possible to avoid odour nuisances from normal operation of biogas plants completely, and if the plants are well-managed, odour nuisances can also be reduced in connection with breakdowns. Biogas plants will hardly become completely odourless, but the odour nuisances from new plants should not exceed 3-4 days a year in the nearest residential area. Other nuisances, such as increased traffic, can also be limited, so the local population really does not have to fear getting a biogas plant as a neighbour. That is the conclusion of a new report prepared by PlanEnergy for the Danish Environmental Protection Agency.

photo: torben skøtt/biopress

Solid waste should always be unloaded in a closed hall. Here, waste food from the municipality of Copenhagen is unloaded at the biogas plant in Hashøj.

photo: torben skøtt/biopress

Biological odour filters need maintenance to maintain the effect. Here, the filter material is being replaced at the biogas plant in Vester Hjermitslev.

At the same time, however, the authors of the report establish that most biogas plants have or have had problems with odour, and so far normal practice has been to leave the problems until the plants were fully established. It is thus the sins of the past that have given the biogas industry a bad reputation, which can hardly be changed overnight.

Over the years, many biogas plants have struggled with bad finances, but that is no excuse for not preventing odour nuisances from the plants. Prevention of odour nuisances amount to max. two per cent of the costs of construction, and the operating costs normally do not exceed 0.5 per cent of the total operating costs.

11 plants studied

Eleven common biogas plants are studied in the report from PlanEnergi, and municipal environment monitoring units and local estate agents were contacted in order to find out whether house prices are influenced by the fact that there is a biogas plant in the neighbourhood.

At 10 out of 11 plants, the extract air from pretanks and in some cases also the loading hall is cleaned in a biofilter. The standards of the filters vary from simple open bark filters to advanced biofilters with moisture and pH control. The worst odour nuisances are caused by leaks, emission of air that has not been sufficiently cleaned and unintended gas leakages.

The estate agents generally do not believe that house prices are affected by the fact that there is a biogas plant in the area, while for instance a large pig farm normally makes houses prices drop. Only in Snertinge, a local estate agent believes that the prices of existing houses have dropped for a period because of the biogas plant.

A short distance to the heat purchasers determined the location of many existing plants, but today several municipalities prefer a larger distance to residential areas, and a distance of 500 metres is considered appropriate. However, experience from existing plants shows that some plants have no problems though they are situated 100 metres from a residential area, while other plants may have problems at a distance of 250 metres from a residential area. The difference may be due to differences in the plants as well as differences in the acceptance of the plants among the neighbours.

What is odour?

Humans are able to distinguish approx. 10,000 different smells, but the way we perceive smell may vary considerably.

If the sensation is pleasant, we talk about fragrance or scent, while we say that something stinks if we do not like the smell of it.

The concentration of an odorant often plays a part in whether something smells good or bad. A number of substances smell good at low concentrations, while at high concentrations they smell bad. Similarly, a constant smell will be perceived as more unpleasant than a temporary smell. However, this may also work the other way around as we may get used to a constant smell. A farmer, for instance, will rarely find the smell of manure as unpleasant as townspeople tend to do.

Odours are often mixtures of a number of substances, and the smell of manure for instance contains more than 300 different substances, which together give us an impression of where the smell comes from. Individual substances, such as hydrogen sulphide and ammonia, can be measured with expensive instruments, but that does not say much about the odour as it is composed of a number of different substances. Instead odour panels are often used, which consist of six people of different age and gender, who are asked to assess the intensity and character of a given air sample.

Do biogas plants smell?

Many malodorous substances are generated at biogas plants, but even more are broken down. Overall, it is thus possible for biogas plants to help reduce the odour in areas with many domestic animals if they are designed right and operated correctly. Furthermore, effective digestion of the biomass is of great importance. The longer the retention time, the better the malodorous substances will be broken down, and the less odour will be passed on to the farmers' manure tanks and subsequently to the fields.

When the degassed manure is returned to the farmer, it will smell less than raw manure as long as the surface/supernatant is intact and the manure is left in peace. On the other hand, the odour of the degassed biomass is increased considerably when it is agitated, but fortunately treated biomass does not have to be agitated as much as raw manure, so that is of minor importance.

When the manure is later spread in the fields, it is once again advantageous to use degassed manure. It smells less and for a shorter period than raw manure.

Plant	Distance to solitary house	Distance to residential housing	Complaints
V. Hjermitslev	-	80 metres	Has had complaints
Vegger	-	80 metres	Has had complaints
Hashøj	400 metres	250 metres	Has had complaints
Fangel	200 metres	250 metres	Sometimes gets complaints
Filskov	250 metres	300 metres	No complaints
Snertinge	100 metres	400 metres	Has had complaints
Blåhøj	400 metres	1.000 metres	Has had complaints
Bånlev	250 metres	1.000 metres	Has had complaints
Ribe	250 metres	1.000 metres	No complaints
Thorsø	100 metres	1.000 metres	Has had complaints
Linkogas	300 metres	2.000 metres	Has had complaints

The majority of the 11 biogas plants that participated in the study has had complaints from their neighbours because of odour nuisances.

Technical solutions

Today, there are numerous techniques to prevent the neighbours from being bothered by foul smells from biogas plants, but fundamentally it is all about ensuring a partial vacuum in the unloading hall, the pretank and other places where odours occur. The ventilation air of course has to be cleaned efficiently before it is released to the surroundings, and it is important to ensure that the smell from reactors and gas tanks cannot leak through the membranes that are often used as covering. Experience has shown that for instance gas-proof plastic membranes are not always capable of retaining the smell.

Unloading of industrial waste has often led to problems, so particular care must be taken here. If possible, the waste should be charged as liquid in a closed system, where the displacement air is cleaned, and solid waste in containers should always be unloaded in a hall with partial vacuum.

The majority of common biogas plants uses simple or advanced biofilters for air cleaning, as this has proven to be cheapest with regard to the price of the equipment as well as the operation of it. Furthermore, biofilters are among the most suitable filters for cleaning of the type of air that is released from biogas plants, just as they are suitable for cleaning of air with varying amounts of odorants. A well-functioning biofilter should remove 90-99 per cent of the odour, but correct dimensioning is very important, and the filter also has to be maintained correctly.

Traffic

Apart from odour, the fear of increased traffic may be a reason to reject the construction of a biogas plant. The transport normally takes place with large trucks, which may affect the total amount of traffic on small roads, especially if they have to pass a small town.

However, none of the plants that were visited have had any problems with the traffic to and from the plants, though it is a fact that this problem is often emphasized when new plants are established. Therefore, it may be an advantage to use pipelines for the transport of manure. The system has not yet been used at Danish common biogas plants, but experience from other countries indicates no technical problems of any sort. Several of the plants that are being planned today are considering using pipelines for part of the manure, so the system will probably come into use in the future.

Grass is one of the most environmentally friendly crops, which may help reduce nitrogen leaching considerably. This also happens if a whole crop is followed by an aftercrop like fodder radish. If the growing of energy crops is carefully planned, it is possible to build up a nitrogen pool in the soil, which can be used by a crop sown in the spring.

photo: torkild s. birkmose

No energy crops - no biogas plants

Today, energy crops are more than environmentally friendly fuels. They are also a prerequisite for establishing a future-orientated and sustainable biogas plant. From an economic point of view, energy maize and green or whole crop are most interesting, but from an environmental point of view it is better to cultivate grass.

By Peter Jacob Jørgensen

With today's framework conditions for biogas production, it is not possible to establish viable common biogas plants based on gasification of animal manure alone. That is why practically all plants employ large amounts of organic waste from the food industry. Waste with a high gas yield that the plants are sometimes paid to receive. The system works well and ensures that the nutrients are returned to the farm land.

For new plants, however, the problem is just that there is no more attractive waste. Therefore it is either price competition with other plants or finding other solutions, and here energy crops are an obvious alternative.

However, we might as well admit it: The use of energy crops is not as profitable as the use of industrial waste. On the other hand, energy crops may entail other advantages for the individual farms. This is the conclusion of a project carried out by PlanEnergi in cooperation with Djursland Landboforening (agricultural advisory centre), Svend Brandstrup Consult, Landbocenter Randers-Viborg (agricultural advisory centre) and the Danish Agricultural Advisory Service.

A necessary prerequisite

Today, Danish farmers are very interested in participating in biogas projects. also applies to Kronjylland and Djursland, where three large common plants are being planned.

It is not hard to find suppliers of animal manure for the plants, but when it comes to energy crops the farmers are more reluctant. In a way, this is understandable as only few Danes have worked with energy crops.

Today, energy crops are, however, a prerequisite for establishing a future-orientated and sustainable biogas plant. Energy crops can contribute to environmental protection as well as viability in the plants, and it is no exaggeration to say that without energy crops there will be no more biogas plants.

The production of energy crops obviously requires energy, but generally the energy economy of using part of the farmland for energy production is good. At best, it is thus possible to "harvest" five to eight times more energy, measured as biogas yield, than is used for the production.

Many possibilities

At many farms, the traditional rotation of crops is based primarily on grain and rape, but energy crops will provide an opportunity to work with a slightly different rotation of crops. The farmer will be able to choose among a large number of different crops depending on for instance soil conditions and machinery. The possibilities are numerous, but generally it is important to

Report on energy crops

In connection with the project on energy crops, a report has been prepared with the following title "Demonstration af produktion og dyrkning af energiafgrøder til biogasproduktion" (Demonstration of production and cultivation of energy crops for biogas production). It can be downloaded from www.djursbioenergi.dk. The report has been prepared with funds from the Directorate for Food, Fisheries and Agri Business, Grønt Netværk (an organisation that works to promote various "green" initiatives), Kronjylland og Djurslands Erhvervsråd (trade promotion board).

choose crops with a limited amount of field work.

The incorporation of certain energy crops may entail a reduced need for plant production labour in peak periods for the individual farmer, partly because the work takes place at other times, and partly because a larger part of the work can be carried out by a machine pool. This is true of for instance maize and perennial grass. Furthermore, some crops can be harvested with higher water contents, as sap from for instance maize and grass is not a problem in biogas plants.

The energy crops may contain weeds as long as they are harvested before the weed seeds are shed and interfere with future crops. In this way, it is possible to reduce the use of crop sprays. This applies to for instance perennial grass and various mixed crops that are harvested early in the growth season. With maize, on the other hand, it may be difficult to reduce the need for sprays, as the plants are sensitive to sprouted weeds at the beginning of the growth season.

If energy crops are grown like traditional crops, the nitrogen leaching will remain practically the same. However, if for instance a grain crop is replace by perennial grass, the leaching can be reduced considerably. This is also the case if a whole crop is followed by an aftercrop like fodder radish. If the growing of energy crops is carefully planned, it is possible to build up a nitrogen pool in the soil, which can be used by a crop sown in the spring.

Environmental advantages

- Nitrogen leaching can be reduced.
- The pesticide consumption can be reduced.
- Wind and water erosion is reduced by perennial crops.
- The content of organic matter in the soil is increased.
- Perennial crops entail better conditions of life for plants and animals.
- Biogas production reduces the emission of greenhouse gasses.

Profitability

A total of four Djursland and Kronjylland farms have been selected for calculation of the profitability of energy crops. They have been selected so as to ensure that the analysis comprises cattle as well as pig farms. For all scenarios, approx. ten per cent of the farmland would be used for the production of energy crops to be delivered to a common biogas plant at a price of DKK 0.45/kg dry matter.

The results show that it is possible to incorporate certain crops in the rotation of crops without reducing the contribution margin for the cultivation of plants, provided that the distance to the biogas plant does not exceed ten kilometres. The most interesting crops are energy maize and green or whole crop as for instance triticale. It is also possible to obtain a positive contribution margin from aftercrops, and here marrow-stem kale and fodder radish are particularly interesting.

The project also proves that subsidies to areas with perennial grass of DKK 300-500 per hectare ought to be considered in order to protect aquatic environments from nitrogen leaching.

Improvements

The higher use-value of nitrogen in degassed manure has not been taken into account in the calculations. And neither has the fact that nitrogen absorbed by the energy crops can subsequently be used almost as efficiently as fertilizer, nor the improved nutrient distribution in degassed manure. If these factors were taken into account, the profitability would of course improve, as the added value of degassed manure alone is estimated to amount to DKK 7-15/tonne depending on the type of manure.

Various bodies are working intensely on improving the framework conditions for biogas plants. At the time of writing, these negotiations show promise, and this might mean that the settling price for energy crops exceeds the DKK 0.45/kg dry matter that has been budgeted for the planned plants on Djursland and in Kronjylland. In this way, production of for instance perennial grass or grass-clover may become interesting to farmers.

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photo: torben skøtt/biopress

Grøngas near Hjørring is one of the few biogas plants in Denmark that has experience of using energy crops. Especially maize is used as the yield is high and the crop is easily incorporated into the rotation of crops.

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New technology for the production of bio-oil

A small Danish high-tech company has developed a technique, which can convert organic matter as for instance sewage to bio-oil in no time.

While the Danish debate about biofuels has primarily been concerned with the development of bioethanol as a replacement for petrol, SCF Technologies has developed brand new technology that can convert organic waste to oil.

In essence, organic material is heated and under very high pressure pumped into a tank, where a number of catalysts imitate the process that has created the world's oil reserves. The process is called CatLiq and is particularly suitable for treatment of organic waste with a high water content, for instance sewage. No less than 85 per cent of the calorific value of sewage can be converted to oil by means of this technique.

An important part of the process is when the catalysts split water to hydrogen, which forms part of the oil molecules. Furthermore, chlorine and sulphur are split off, so the oil contains less pollutants than fossil oil.

The bio-oil has the same type of carbon chains as conventional crude oil and can thus be processed at existing refineries. The oxygen content, however, is as high as 10-20 per cent, which entails a lower calorific value, but on the other hand the high oxygen content also entails cleaner combustion. This is important not least when the oil is used in diesel cars as a replacement for traditional diesel.

SCF Technologies has entered into a cooperation with Grundfos in order to develop the technology for use at large-scale plants. The management at SCF Technologies expects that the company will be ready to make agreements with multinational oil companies on using the technique at large scale as soon as 2008 or 2009.

photo: scf technologies

SCF Technologies has developed brand new technology that can convert organic waste to oil.

At the end of September, the Danish National Advanced Technology Foundation granted approx. DKK 10 million for improvements of the CatLiq technology. A little more than DKK 6 million go to SCF Technologies directly, while the rest of the funds will be distributed to the company's cooperation partners at the University of Aarhus og Aalborg University.

The CatLiq technology has attracted so much attention that the company was awarded a prestigious prize at the international congress on sustainable handling of waste on 2 October in Bella Center in Copenhagen The prize was awarded by DAKOFA, an organisation for everyone who works with waste.

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