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FiB
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Scientists are haggling over biofuels

Scientists are haggling loudly about the sense of using biomass instead of petrol and diesel, and politicians cannot really figure out which leg to stand on either. One day, biofuels hold great perspectives - the next day, the green oil is down for the count again.

By Torben Skøtt

On the 19th of January, the Danish government published its new energy plan entitled "A Visionary Danish Energy Policy", which has as one of its objectives that ten percent of the energy consumption in the transport sector is to be covered by biofuels in 2020 at the latest.

This means that biofuels are to replace part of our current consumption of petrol and diesel, but it is still unclear how this exactly is going to take place. The official documents from the publishing of the energy plan simply state that: "The government is prepared to set an intermediate objective earlier than 2020 provided that adequately economically competitive and environmentally sustainable technologies have been developed."

The wording of this statement is sure to cause debate. To put it mildly, scientists disagree on whether it is sensible at all to focus on biofuels, and the ones who are in favour of the green oil are far from agreed on which technologies to concentrate on.

– It can be difficult to figure out what the opinions of the experts actually are on this matter, says the Danish Liberal Party's spokesperson for energy policy, Lars Chr. Lilleholt.

– The Environmental Assessment Institute recently gave us a report that concludes that biofuels do not give you much environmental benefit for your money. Then, The Danish Academy of Technical Sciences wrote a report concluding that the area holds great perspectives – particularly if we concentrate on 2nd generation technologies. Finally, the Danish consulting engineering company Niras has published a study that shows that there is practically no difference between the environmental performance of the 2nd generation technologies and the facilities that we are familiar with today.

– It would be nice if the experts could sit down and agree on what is up and down in this matter, says Lars Chr. Lilleholt. He has personally been an enthusiastic advocate for biofuels and he has, among other things, suggested that the green oil should cover two percent of the energy needs in the transport sector already in 2007.

1st or 2nd generation

The present Danish government as well as former governments have to a wide extent been very sceptical towards biofuels. Time and time again, the argument has been that you do not get enough environmental benefit for your money and that it is much more efficient to use biofuels for production of electricity and heat. Among other things, this is the answer that the government coalition has given as the reason why Denmark has not wanted to comply with the European Commission's objectives in the area.

So far, the government has retained that it is the 2nd generation technology that is worth betting on. Here, the raw materials are waste and residual products from agriculture, and the environment minister as well as the energy minister find this much more promising than fuel produced on the basis of traditional agricultural crops such as maize, cereal grains and sugar beets.

On this matter, the government is entirely in line with the recommendations from the EU summit in March 2006, and the government is also complying with the recommendations from the Danish Energy Agency's strategy for research and development of biofuels, which was published in June 2005.

Government under pressure

However, the government is under a lot of pressure to get biomass into the transport sector right now, and it is not just agriculture and different interest organisations that are applying pressure. The demand to start using the green oil comes from far into the government's own ranks, and several experts are currently questioning whether there is any reason at all to wait for the 2nd generation technology.

Thus, a few days before the government published its energy plan, the Danish Board of Technology came forward with a report advising the government against dropping the current technology. The report emphasises that Denmark can easily live up to the EU's objective for 5.75 percent of the energy consumption in the transport sector to come from renewable energy. In the case of diesel oil, this can be done by using animal fat supplemented by the Danish production of bio-diesel, which is based on rape oil, but which is only used for export today. Similarly, it is possible to replace 5.75 percent of the petrol consumption with ethanol by growing beets on 1.5 percent of the acreage devoted to agriculture. If you choose to grow grain instead, this will tie up three percent of the agriculture acreage, which corresponds to 86,000 hectares.

As conclusion of the report, the Danish Board of Technology has asked ten important players on the market whether they prefer clear focus on 2nd generation technology or whether the 1st generation facilities should be supported as well. Eight players respond that it would be best to start with the technology that is available today. Only the Environmental Assessment Institute and the Technical University of Denmark think that it would be best to wait until the 2nd generation facilities are ready for commercial operation.

Most energy from 1st generation

In another report from the consulting engineering company Niras, the experts point out that you do not achieve more CO_2 displacement or a higher energy output by focusing on the future facility types. On the contrary, calculations show that the energy output is a bit lower for the 2nd generation facilities, while the

photo: torben skøtt/biopress

At Skærbæk power station at Fredericia, DONG Energy is far ahead with the development of a technology that makes it possible to extract ethanol from straw and use the residual product as fuel.

New reports

CO_2 reduction costs using biodiesel (CO_2 reduktionsomkostninger ved biodiesel), The Environmental Assessment Institute, www.imv.dk.

Visions for Danish bioethanol (Visioner for dansk bioethanol), The Danish Academy of Technical Sciences, www.atv.dk.

Production of bioethanol in Denmark - energy outputs and CO_2 displacement using different technologies (Produktion af bioethanol i Danmark - energiudbytter og CO_2 fortrængning med forskellige teknologier), Niras, www.niras.dk.

The transport fuels of tomorrow – Danish perspectives (Morgendagens transportbrændstoffer – danske perspektiver), The Danish Board of Technology, www.tekno.dk.

CO_2 displacement is roughly the same for the two types of technologies.

This may come as a surprise, but according to civil engineer Anne Seth Madsen from Niras, the reason for this is that it requires more energy to produce ethanol on the basis of residual products such as straw than to use agricultural crops such as grains and maize. Therefore, the total energy output will usually be lower, but on the other hand, it is possible to produce more ethanol per hectare.

Using 1st generation facilities, grains are transformed into ethanol through a relatively simple fermentation process. It is possible to produce 2,800 litres of ethanol for every hectare with grains, which corresponds to a bit more than 16 MWh, but apart from that, the straw can be used for production of electricity and heat, while the residual product from the ethanol production can be used for feed. This results in a total energy output of a bit more than 24 MWh.

Using 2nd generation facilities, almost 4,000 litres of ethanol are produced per hectare, but on the other hand, the production of electricity, heat and feed goes down, which typically results in a total energy output below 20 MWh per hectare. The CO_2 displacement is approx. 6 tonnes per hectare or roughly the same as for the 1st generation facilities.

Apart from comparing different 1st and 2nd generation technologies, the people from Niras have calculated the effect of using the entire plant - i.e. grains as well as straw - in a CHP station. This results in an energy output of over 35MWh and a CO_2 displacement of more than 7 tonnes per hectare. Thus, CHP is definitely preferable, if the objective is to get the best energy output and the highest CO_2 displacement per hectare.

photo: torben skøtt/biopress

CHP is the most efficient way of utilising the biomass, if the objective is to get the best energy production and the highest CO_2 displacement.

Debate

Reports about biofuels often cause debate, and in this area, the investigation from Niras is no exception. A few days after the report had been published, the engineering magazine Ingeniøren brought an interview with Professor Claus Felby from the University of Copenhagen, who drew attention to the fact that Niras has not included C5 molasses in the calculations regarding 2nd generation technology. This would result in further CO_2 reduction of 0.8 tonnes, and thus, the two technologies would be relatively equal with regard to displacement of greenhouse gases.

– But we have already pointed out that circumstance, says Anne Seth Madsen from Niras. She explains the lacking inclusion of C5 molasses with the fact that it is uncertain how it would be best to utilise it in practice.

One of the fiercest critics of biofuels, senior lecturer Henrik Wenzel from the Technical University of Denmark also comments the investigation from Niras in Ingeniøren. Among other things, he emphasizes that the investigation does not take the new possibilities of using hydrogen and gas in the transport sector into account, but primarily notes that CHP gives the best energy efficiency and the best CO_2 displacement.

And in that area, the scientists actually seem to be starting to agree. Just as most people today do not dispute that the greenhouse effect is a fact, there are practically no experts that question the fact that CHP is the most efficient way of utilising the biomass. ■

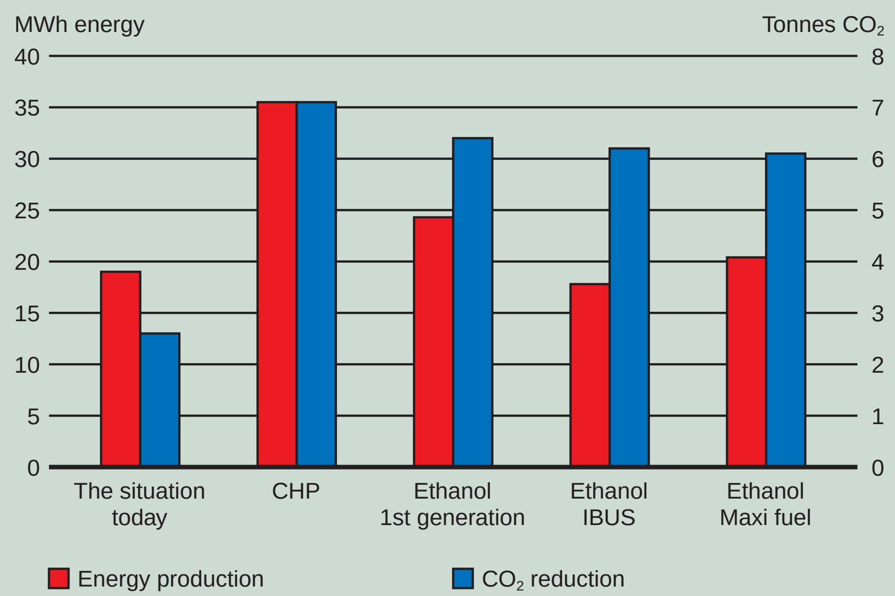

Figure 1. The energy production and the reduction of greenhouse gases when using grains and straw from one hectare, which corresponds to 7 tonnes of seeds and 4 tonnes of straw. Currently, grains are being used as feed, while only part of the straw is being used for production of electricity and heat. IBUS and Maxi fuel represent two different methods of producing ethanol using the so-called 2nd generation technology. Source: www.niras.dk.

Clover grass is one of the most environmentally friendly crops there are. It can absorb nitrogen from the air, it does not require fertilization or pesticides, and it has a very extensive root system that can store CO_2.

photo: torben skøtt/biopress

Let the cars run on grass

American studies show that grass can improve the environmental accounts for biofuels significantly. If you use natural grass species, you get five times as much energy back as you use on growing the crops and producing the fuel, while you only get one and a half time as much energy back if the production of bioethanol is based on maize.

By Torben Skøtt

In the USA, the production of bioethanol is mainly based on maize, while bio-diesel is primarily produced with soya. Both crops give a high output per hectare and the transformation to biofuels takes place through well-known and inexpensive methods. Therefore, maize and soya have been a natural choice for the manufacturers of biofuels, and this model has suited agriculture well. The farmers are used to handling these crops and they both give a rather good contribution margin per hectare.

But now, a group of American scientists have questioned whether this strategy is sustainable in a long-term perspective. The continuously rising demand for traditional agricultural crops will lead to large areas being assigned for growing of monocultures, and, all other things being equal, this will have a negative effect on the diversity that characterises unspoilt nature. Add to this that agricultural crops such as maize and soya require artificial manure and pesticides, which pollute the aquatic environment.

In the light of these findings, scientists has investigated how it would affect the environment if the production of biofuels was based on more environmentally friendly crops or LIHD crops, as they are called in the American investigation. This stands for Low-Input High-Diversity and mainly comprises different types of lasting grass species. Therefore, a number of trials have been carried out since 1994 with growing of these crops, which have subsequently been harvested and used for production of biofuels.

As expected, the output per hectare was lower than with maize and wheat, but the energy economy was significantly better because of the lesser use of energy

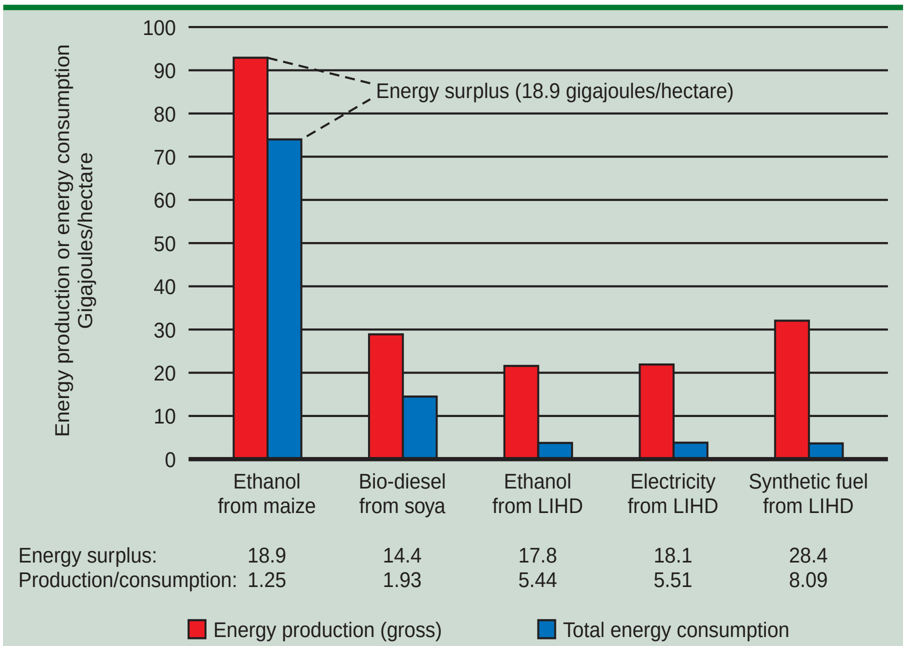

Figure 1. Energy outputs for biofuels produced using traditional agricultural crops and LIHD crops (grass species). For comparison, the energy outputs from production of electricity and synthetic fuels have been included. The energy economy indicates how much energy you receive compared to the amount of energy used for field work and production of the fuel, among other things. Source: Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass, Science 8, December 2006.

for field work, including less energy for artificial irrigation, fertilization and spraying with pesticides. In total, the natural grass species thus gave five times as much energy back in the shape of biofuels as the energy that was used for growing and production of the fuel. Maize and soya only gave 1.25 and 1.93 as much energy back as was used.

Similarly, the reduction of greenhouse gases was between 6 and 16 times better for the LIHD crops than for maize and soya, and this has resulted in the scientists referring to biofuels from LIHD crops as not just CO_2-neutral, but CO_2-negative.

Use grass

In Denmark, no similar investigations have been made on how environmentally friendly crops can be used for production of biofuels, but there is some material about grass as "feed" for biogas plants. This is an area that biologist Peter Jacob Jørgensen from the consulting company PlanEnergi has thorough knowledge of:

- Clover grass is one of the most environmentally friendly crops there are. It can absorb nitrogen from the air, it does not require fertilization or pesticides, and it has a very extensive root system that can store CO_2, explains Peter Jacob Jørgensen. He finds the results in the American investigation interesting, but estimates that grass in biogas plants would result in even better environmental accounts.

However, Professor Claus Felby from University of Copenhagen, who does research on biofuels, does not think that the American investigation contributes with anything new for the Danish debate about the subject.

– The energy output per hectare is simply too low for Danish farmers to be interested in those crops, says Claus Felby.

– Different species of grass may have a good energy balance, but it is not a method that we can use if we are to replace 20 percent of the energy consumption in the transport sector with biofuels. Something that has a real impact in that connection are traditional agricultural crops such as maize, which is one of the best solar collectors in our part of the world, concludes Claus Felby.

Source: Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass, Science 8, December 2006.

The environmentally friendly wood-burning stove

Development of the environmentally friendly wood-burning stove has moved one step closer. This summer, scientists from Aalborg University can present a new computer tool that makes it possible to reduce the release of harmful substances from wood firing.

Wood-burning stoves and small boilers are some of the worst culprits when it comes to release of harmful particles. According to an investigation from the Danish National Environmental Research Institute, the release of small particles (PM 2.5) from wood-burning stoves and small boilers is at 643 grams/PJ, while the corresponding number for a CHP station is only 1.2 grams/PJ. This means that the pollution from small individual facilities is 500 times larger than from the large collective facilities.

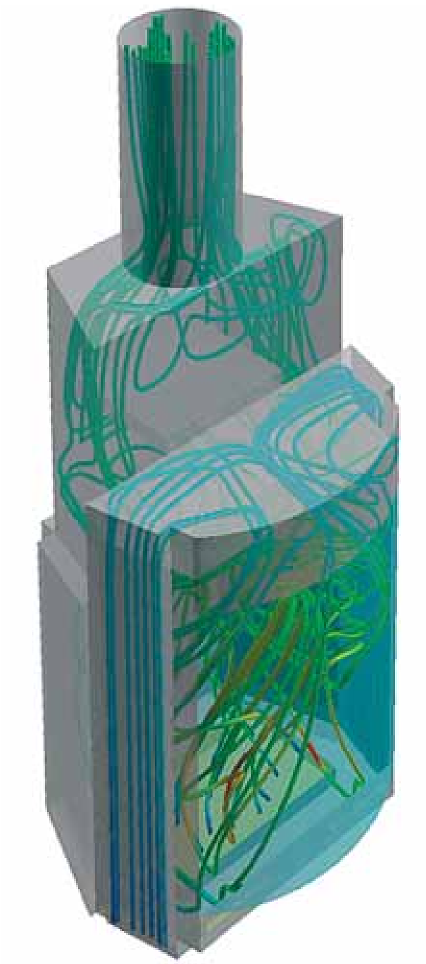

photo: aalborg universitet

Scientists will soon be ready with a computer model that can be used to design environmentally friendly wood-burning stoves.

In Denmark, scientists have spent decades on optimising the combustion in the large boiler plants, and that is one of the reasons that we are currently able to produce some of the world's most efficient CHP stations. Even though the experiences cannot be transferred directly to wood-burning stoves, the scientists have still been able to make use of the methods that have been used for development of the large plants.

– The combustion in a power station boiler is completely different than in a wood-burning stove, but the methods needed to develop computer models for design of wood-burning stoves are not significantly different than the methods we know from power stations, explains senior lecturer Lasse Rosendahl from Aalborg University. Together with Danish Technological Institute in Aarhus and two manufacturers of wood-burning stoves, he is close to being able to complete a computer model that describes in detail how the combustion proceeds during the first half hour after the stove has been lighted up.

– This is the period that is most critical with regard to release of harmful particles. If the manufacturers can construct a stove where the release of particles is minimal during the first half hour, we have come a long way, says Lasse Rosendahl. However, he does admit that it is probably going to take a long time before we can register a decrease in the pollution from wood firing:

– First, we have to complete the computer model, then the manufacturers have to start designing new wood-burning stoves, they have to be introduced to the market, and then we have to teach the population how to use a wood-burning stove in a way that does not pollute.

One of the major challenges for manufacturers will be to construct stoves where the effect is suitable for modern well-insulated houses. Today, most wood-burning stoves are overdimensioned, which means that people turn down the supply of air and thus turn up the pollution. *TS*

Biogas plants:
20 percent more electricity with two reactors

With pre-treatment of biomass at around 70 °C, it is possible to increase the production of electricity from biogas plants by approx. 20 percent while achieving much better hygienization of the biomass. On the other hand, the heat surplus from the plant is minimal during the winter months, which makes the system particularly suitable in areas where there are not good possibilities of selling the heat production.

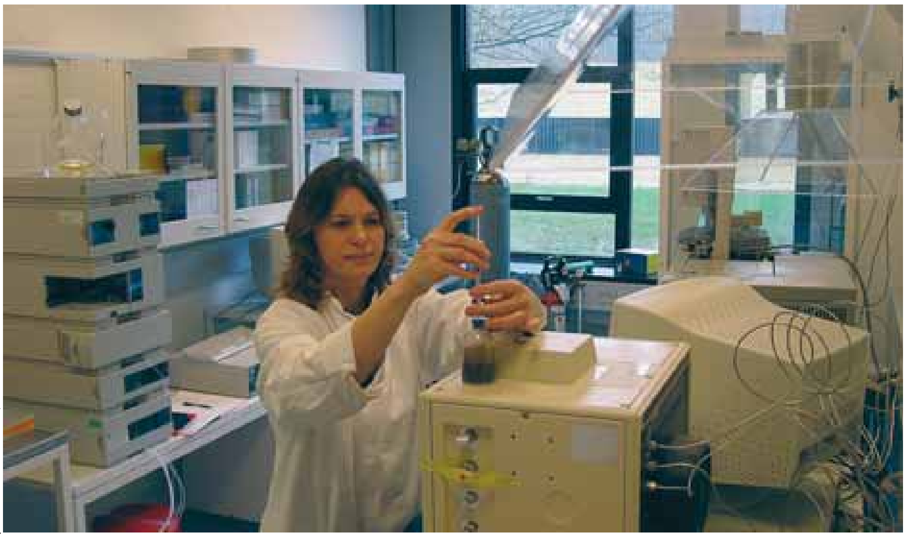

photo: biocentrum, danmarks tekniske universitet

Zuzana Mladenovska works in the laboratory at BioCentrum, where research is carried out on processes for production of biogas and other types of biofuels, among other things.

By Zuzana Mladenovska and Birgitte K. Ahring

The production of biogas, based on slurry or sludge, is characterised by relatively low decomposition of organic material and thus a relatively low gas output. It is common knowledge that are large part of the biogas potential of slurry and sludge is hidden in the fibre fraction, which is not decomposed effectively in the existing facilities, and a significant part of the biodegradable material is led out of the facility without being decomposed.

At BioCentrum at the Technical University of Denmark, we have spent a long period testing different methods for improving the biogas production from slurry and sludge. One of the most promising methods has turned out to be pre-treatment of the biomass at a high temperature before the actual biogas process.

In a biogas reactor, different groups of micro-organisms carry out a process that decomposes the organic material through several steps. In a healthy and well-balanced process, the organic material is first decomposed into smaller components, after which biogas is produced without any notable accumulation of the so-called fatty acids (VFA), which can inhibit the process.

The bacteria that handle decomposition of plant fibres can be divided into two sub-groups. One sub-group is active at 50 – 65 °C, while the other group thrives the most at 60 – 75 °C. Thus, they cover a wide temperature area between 50 and 75 °C as a whole. However, the activity of the VFA-decomposing bacteria and the main part of the bacteria that produce biogas is limited to a narrow temperature interval of 50 – 55 °C.

Most biogas plants use a reactor temperature of 50 – 55 °C, which means that there are bacteria groups that are not included in the process. In order to get a successful result, it is necessary to establish a separate reactor for pre-treatment with an operating temperature of about 70 °C. The temperature level of the main reactor cannot exceed 60 °C, as this would result in incomplete decomposition with a significantly reduced biogas output.

Reactor trials

In the laboratory at BioCentrum, we have tested a two-step process consisting of two days of pre-treatment at 73 °C followed by a 13-day biogas process at 55 °C. This system was tested in parallel to two traditional one-step facilities that ran at 55 °C for 15 days and 37 °C for 20 days respectively.

Biomass was added to the reactors three times a day, which ensured a guaranteed retention time of eight hours. The substrate was a mixture of raw cattle slurry, pig slurry and sewage sludge, which was mixed in the ratio 40:40:20. The content of volatile solids (VS) was measured to be 37 kg/m^3 biomass, while the theoretical biogas potential was estimated to be 350 litres/kg VS.

The most important results of the trials are shown in table 1. The table shows that the biogas output, and particularly the specific methane output, was the lowest in the mesophile reactor, where the output was approx. 30 percent below the theoretical potential of 350 litres of methane/kg VS. In the thermophile one-step reactor, the output was a bit better, but still, approx. 25 percent of the biogas potential was wasted.

However, the two-step reactor turned out to have a surprisingly good output capacity with an output of only approx. 13 percent below the workable potential. All operating parameters confirmed a highly efficient and balanced decomposition with the largest reduction in the amount of organic material and the highest biogas output. Methane production mainly took place in the main reactor, which produced 99 percent of the total amount of methane.

Hygienization

The hygienization effect of the specific processes was estimated on the basis of survival of extremely heat-resistant spores of the genus Clostridium perfringens after the biomass had been in the reactors for eight hours (figure 1). During the trial, both one-step systems managed to reduce

Parameter	Unit	One-step facility		Two-step facility		
Temperature	Degrees C	37	55	73	55	73/55
Organic load	Grams of VS/litre of reactor/day	1.9 ± 0,2	2.6 ± 0.3	16.6 ± 0.4	–	2.3 ± 0.3
Biogas output	Litres/litre of biomass	13 ± 2	14 ± 1	0.7 ± 0.2	16 ± 3	–
Methane	Percent	69 ± 2	68 ± 2	19 ± 2	69 ± 2	–
Specific methane output	Litres/kg of VS	246 ± 36	261 ± 29	4 ± 1	300 ± 45	303 ± 45
VS removal	Percent	42 ± 3	52 ± 1	–	–	59± 8
COD removal	Percent	47 ± 7	55 ± 4	–	–	64 ± 6
VFA	Grams of Ac/litre	0.2 ± 0.1	0.4 ± 0.1	9.6 ± 1.3	0.2 ± 0.1	0.4 ± 0.1
Total N	Grams/litre	3.5	3.4	–	3.2	–
NH_4^+ - N	Grams/litre	2.3	2.2	–	2.1	–

Table 1. The results of digestion of biomass in one-step and two-step facilities respectively. The biomass consists of cattle slurry, pig slurry and sewage sludge in the ratio 40:40:20. The content of volatile solids has been measured to be 37 kg/m^3 of biomass, and the biogas potential has been estimated to be 350 litres/kg of volatile solids.

the number of spores by 0.7 logarithmic units, while a decrease of 1.7 units was achieved in the reactor at 73 °C. Combination of the two reactors at 73 °C and 55 °C respectively resulted in a total reduction of 3 units. Thus, the number of viable spores was reduced from a concentration of more than 200,000 spores per millilitre of biomass to a couple of hundred spores per millilitre of digested biomass.

Energy balance

Expansion of the existing one-step systems to two-step systems would result in additional costs for operation and not least for heating. In that connection, we have carried out a number of calculations for the following facilities:

- A one-step facility with a 3,600 m^3 reactor that is heated to 37 °C.
- A one-step facility with a 3,000 m^3 reactor that is heated to 55 °C.
- A two-step facility with pre-treatment in a 400 m^3 reactor at 73 °C and degasification in a 2,600 m^3 reactor at 55 °C.

All facilities are equipped with a heat exchanger for recovery of heat from the digested biomass, but apart from that, the two-step facility has an additional heat exchanger, which is mounted between the two reactor tanks.

Because of the increased gas production, the electricity production as well of the heat production from the two-step system is approx. 20 percent higher than for the mesophile reactor. On the other hand, the two-step facility has a heat consumption that is more than twice as big as for the mesophile reactor. However, the heat production from the motor generator equipment is high enough to cover the heat requirement, even in January, but there is practically no surplus to be delivered to the district heating system. Thus, the two-step system is particularly suitable in areas where there are not good possibilities of selling the heat production.

The study of the various biogas systems has been financed by the Danish Council for Technology and Innovation as part of the framework programme "Optimisation of biogas processes", grant no. 26-01-0119.

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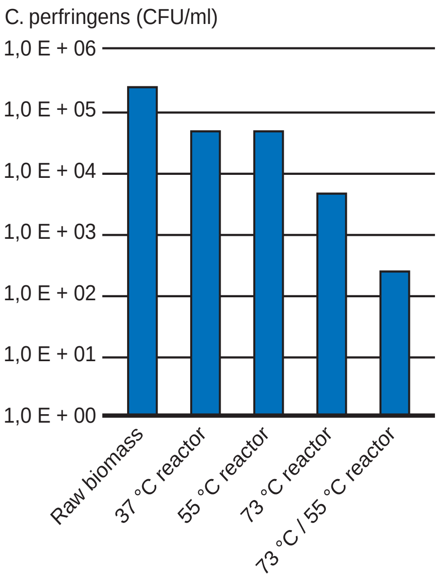

Figure 1. The number of viable spores of Clostridium perfringens in raw biomass and after being eight hours in the studied reactors.

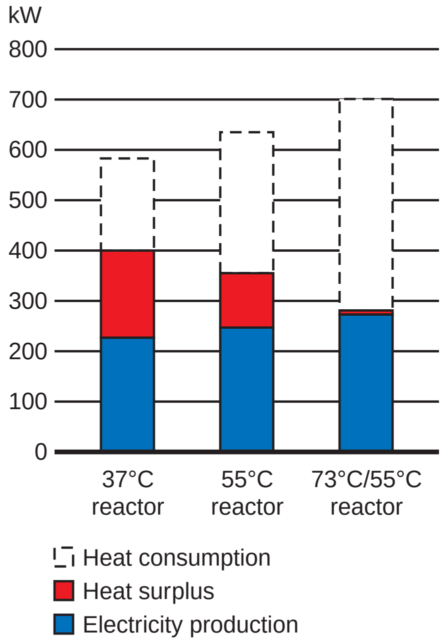

Figure 2. Energy production and heat consumption in the studied reactors in the month of January.

Tar-free gasification on a large scale

For several years, scientists at the Technical University of Denmark have been known for being able to create small-scale gasification facilities that can produce pure and tar-free gas. Now, the concept has been developed further, which means that the technology can be used for very large facilities as well.

By Jens Dall Bentzen

At the Department of Mechanical Engineering at the Technical University of Denmark, scientists have worked for a number of years on the development of a gasification technology where biomass is transformed into combustible gas through a process that is divided into several steps.

The process is documented on a smaller scale in the Viking gasifier, which is set up at the Technical University of Denmark. The facility has shown very positive results with regard to producing a combustible gas that is suitable for powering gas engines because of a low content of tar substances and particles. By connecting the engine to an electric generator, you get a small CHP station that is characterised by a high electrical efficiency and a low environmental impact.

In the Viking gasifier, the process is divided into two main steps: pyrolysis and coke gasification. During the first step, the biomass is led into a pyrolysis reactor, where the water evaporates and the biomass is transformed into coke and tarry gas. The next step is a reactor where the tar substances are decomposed and the coke is transformed into gas. Finally, the gas is cooled down using a heat exchanger and the soot particles are collected in a regular bag filter.

Also for large facilities

The Viking gasifier has represented a break-through within gasification technology, but the system has its limitations. It can be difficult to scale up the concept, in part because heat-up of the pyrolysis reactor takes place through exhaust gas from a gas engine.

Therefore, scientists at the Technical University of Denmark have worked together with the consulting company COWI on developing the multi-staged process further in order to make it possible to build very large facilities. The new concept has been given the name LT-BIG, which stands for Low Tar Biomass Integrated Gasification. This is a technology that is easy to scale up, but still includes the technical advantages that make the two-step process better than other gasification principles.

The principle

In the new facility, gasification of the biomass is divided into three chambers instead of just two, which provides a better possibility of controlling the entire process.

Before the biomass is added to the system, it is dried using steam, which means that the facility can be dimensioned to just processing fuel with a specific water content. In the original Viking gasifier, the drying took place in the actual gasification system, which could cause problems, if there where significant variations in the water content of the fuel.

The first step in the new facility is a pyrolysis reactor where the biomass is heated to 450 °C using steam. As there is no oxygen in the reactor, the biomass does not catch fire, but is transformed into tarry gas and coke instead. The latter is led directly to the gasification reactor, where it is transformed into gas by adding air, while the tarry gas is led to the oxygen chamber. Here, enough oxygen is added to decompose the main part of the tar substances, but not enough oxygen to cause the gas to ignite. After this, the gas

This is how the gasifier works

Dry fuel is led into the pyrolysis reactor, where it is heated to approx. 450 °C using steam. As there is no oxygen in the reactor, the biomass does not catch fire, but is transformed into tarry gas and coke instead. The latter is led directly to the gasification reactor, where it is transformed into gas by adding limited amounts of air, while the tarry gas is led to the oxygen chamber. Here, enough oxygen is added to decompose the main part of the tar substances, but not enough oxygen to cause the gas to ignite. After this, the gas as well as the remaining tar residues are led to the gasification reactor, where the tar content is reduced further when the gas is mixed with the coke fraction. Finally, the gas flows up into the floating section, where the last tar residues are decomposed.

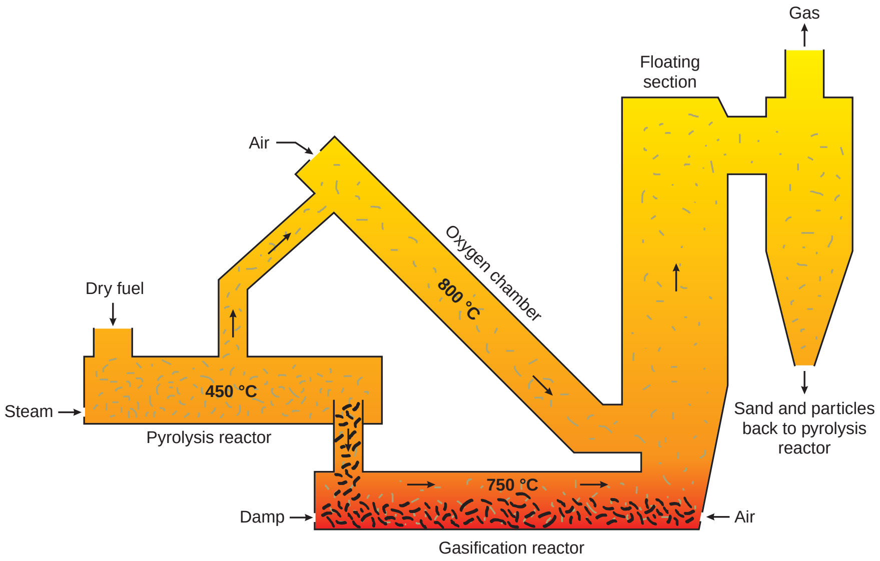

photo: jens dall bentzen/cowi

On the left: The laboratory model of the gasification facility at the Technical University of Denmark. The next phase of the project will be to build a pilot plant at a facility host.

On the right: Testing of the laboratory facility at the Technical University of Denmark. Initially, the gas was burned in a torch. Later, trials will be carried out where the gas is used in an engine that is connected to an electric generator.

photo: jens dall bentzen/cowi

as well as the remaining tar residues are led to the gasification reactor, where the tar content is reduced further when the gas is mixed with the coke fraction.

The gas from the gasification reactor is then purified in a bag filter and possibly an active coal filter, before it is used as fuel in a gas engine that is connected to an electric generator.

The new facility is based on the so-called fluid bed technology, which is familiar from large power plants. The basis of the principle is that a porous material such as sand is brought along around the facility, which makes quick heating of the biomass possible and ensures a correct temperature in the different steps that the facility is divided into.

Laboratory model

The scientists at the Technical University of Denmark have built a 100 kW laboratory model of the new gasification facility and carried out a number of trials that show that the process is stable and that the facility is capable of producing gas with very low tar content.

Simultaneously with the practical trials, a number of model calculations of the efficiency of the various energy systems have been carried out. These calculations show that it is possible to achieve electrical efficiency of up to 40 percent, even with relatively simple facilities. With more advanced facilities, it is possible to achieve an electrical efficiency of about 45 percent.

On the basis of the results from the project, there are now plans to establish a pilot plant at a facility host. Initially, the plan is to use fuel pellets, but it will be possible to carry out trials with different types of fuels.

The project regarding the LT-BIG gasifier has been carried out as a cooperative effort by COWI A/S, the Department of Mechanical Engineering at the Technical University of Denmark and Babcock & Wilcox Vølund. The project has received support from the PSO funds, which are currently being administered by Energinet.dk.

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Gasification - incomplete combustion

When biomass such as wood is heated, it is first transformed into tarry gasses and coke. If you then add oxygen, as is for example the case in a wood-burning stove, the gases as well as the coke are burned. The residual product consists of ash and particles that disappear up through the chimney.

In a gasification facility, you limit the supply of oxygen, which means that the gases are not burned initially, but can be utilised in for example an engine facility. The heating of the biomass usually takes place through burning of a smaller part of the biomass.

At a temperature of about 200 °C, the so-called pyrolysis begins, where the biomass is transformed into tarry gas and a solid residue of carbon (coke). After that, the coke can be transformed into gas by adding limited amounts of air, just as the main part of the tar substances from the pyrolysis can be transformed into gas by adding limited amounts of air.

Gasification facilities have been in use for more than 100 years, so in many ways, it is a well-known technology. During World War II, a lot of cars were equipped with small gasification systems that ran on dried beech blocks the size of tobacco tins. This resulted in relatively pure gas, but it is a type of fuel that is only available in very limited quantities.

The research within gasification facilities aims at constructing facilities that can produce pure gas when using many different types of biomass. Wet wood chips, straw and waste are some of the types of fuel that are available in significant amounts, but they are also fuels that are difficult to gasify.

Straw-fired district heating plants:

Clean the smoke and economise on the straw

A new type of scrubber facility can clean the smoke from straw-fired district heating plants efficiently and increase the efficiency of the boiler by approx. 10 percent. In Øster Toreby on Lolland, Denmark, this has resulted in savings of approx. DKK 320,000 a year for purchasing of fuel.

By Jens Dall Bentzen

Today, approximately 60 district heating plants in Denmark are using straw as primary fuel. The efficiency of these facilities is usually 85 – 90 percent, which is approximately 10 percent lower than the efficiency of wood chips-fired plants, where the energy content of the exhaust gas is utilised more efficiently.

Biomass has a water content that varies between 10 – 20 percent for straw and 40 – 50 percent for wood chips. When the biomass is burned in district heating boilers, the water content is transformed into steam, and if the energy of the steam is not utilised, significant amounts of energy go out through the chimney. Therefore, many facilities have been equipped with systems for exhaust gas condensation, where the smoke is cooled down below the dewpoint. This makes the steam start to condense, and the heat is released into the condensation water, which means that it can be used in the district heating system afterwards.

Today, practically all wood chips-fired district heating plants are equipped with exhaust gas condensation, as it is a relatively simple technology that results in significant improvement of the operating economy. In theory, it is also possible to install exhaust gas condensation in the straw-fired plants, but in practice, it has turned out to give rise to a lot of problems. When it has been attempted, there have usually been problems with corrosion, and the facilities have not been able to comply with current environmental requirements.

photo: jens dall bentzen/cowi

The district heating plant in Øster Toreby, where they have installed a condensation system for the largest of the two straw-burning boilers.

Hals Fjernvarme

One of the most successful projects with exhaust gas condensation in a straw-fired district heating plant is a facility at Hals Fjernvarme, east of Aalborg, Denmark. Here, the exhaust gases are first led through a multi-cyclone, which sorts out the coarsest impurities, after which the smoke is led into a so-called scrubber tower. Basically, it works like a large shower booth that cleans the smoke while the energy from the exhaust gas is transferred to the wash water and then on to the district heating water.

However, the system from Hals Fjernvarme cannot be transferred directly to the other straw-fired district heating plants in the country. The problem is that the particle content is higher than allowed according to the regulations of the Danish Environmental Protection Agency, and therefore, the district heating plant has had to be exempted from the regulations to be able to use the facility. This has been granted with reference to the fact that a large part of the particles consist of harmless salts, but it is uncertain whether other plants would be granted the same exemption.

EDDP is to replace ERP

New research programme focused on demonstration projects is to replace the old Energy Research Programme.

The world is full of abbreviations, and in that area, energy research is certainly no exemption. As follow-up on the government's new energy plan, ERP is to be replaced by EDDP, or more accurately: The Energy Research Programme, ERP, (EFP = Energiforskningsprogrammet) is to be replaced by a new Energy-technological Development and Demonstration Programme, EDDP (EUDP = Energiteknologisk Udviklings- og Demonstrationsprogram).

The most important task for the new programme will be to reduce the gap between research and demonstration. The objective is to make it easier to transform promising research results into commercial use. This means that the new programme will have some similarities with the old UVE programme that was discontinued in 2002.

In February, a legislative proposal about the new EDDP programme was submitted for hearing, and the proposal is currently included in the negotiations on energy policy that are taking place between the Minister of Transport and Energy and the spokesmen for energy policy of the Danish Parliament.

The legislative proposal proposes giving the EDDP a central role with its own independent board. The Minister is to appoint the seven members of the board on the basis of their individual qualifications. The chairman is to have a business-oriented background. The board is to be supported by an independent secretariat placed in the Danish Energy Authority.

According to the administrative head of department Hans Jürgen Stehr from the Danish Energy Authority, the EDDP is mainly supposed to give grants for establishment of pilot plants and implementation of demonstration projects, but the programme can also support actual research activities.

A secretariat will be established for the programme that, among other things, will be given the task of inspiring public and private companies to cooperate and establish concrete project consortiums. The secretariat is also supposed to help develop strategies for the research work and point out areas where a special Danish effort can make new and environmentally friendly technologies more cost-effective.

In connection with the establishment of the new EDDP programme, the Consulting Energy Research Committee (REFU = Rådgivende Energiforskningsudvalg) will be discontinued before the end of 2007.

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Øster Toreby

At the district heating plant in Øster Toreby Varmeværk on Lolland, Denmark, a new system for exhaust gas cleaning was to be installed in 2004, but instead of buying two new bag filters for the two straw-burning boilers, a decision was made to install a condensation system for the largest of the two straw-burning boilers.

The system is based on the experiences from the district heating plant in Hals with a scrubber tower, but in two significant areas, it is a completely new concept: Before the scrubber, there is a bag filter that removes salts from the exhaust gas, and a system has also been installed that neutralises the water in the scrubber. Thus, it is not necessary to clean the scrubber water and the content of hydrochloric and sulphuric acid in the exhaust gas is removed.

In the fall of 2006, a measuring programme was carried out on the facility, which documented that it is living up to the expectations. The smoke is efficiently cleaned for particles, hydrochloric and sulphuric acid, and the condensate from the scrubber is clean and neutralised.

Last but not least, the efficiency of the straw-burning boiler has been increased by approx. ten percent, and thus, the plant can expect to save a bit more than DKK 320,000 on fuel a year.

photo: jens dall bentzen/cowi

The plant manager at the district heating plant in Øster Toreby with a sample of the water from the scrubber tower.

Perspectives

Experience from the district heating plant in Øster Toreby has shown that it is possible to install systems for exhaust gas condensation on straw-burning district heating systems that can ensure efficient cleaning of the smoke and increase the efficiency by about ten percent at the same time.

However, a precondition for installing this type of system is that the return temperature of the district heating water is low. In Øster Toreby, the temperature is all the way down to 38 °C, and therefore, it has been possible to cool down the exhaust gas to about 43 °C. If the temperature of the return water is between 40 °C and 50 °C, it is usually necessary to install a system for humidifying the combustion air to be able to install a system like the one in Øster Toreby.

Apart from the savings on fuel, the facility may be able to prevent expenses for sulphur charges amounting to 150,000 a year. However, it is still not certain whether this would be possible in practice, as the authorities require installation of equipment that can continuously measure the sulphur content of the smoke, which could turn out to be a significant expense for the district heating plant.

The project regarding exhaust gas condensation in Øster Toreby receives support from the Danish District Heating Association and the Energy Research Programme, which is administered by the Danish Energy Authority.

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Biogas and natural gas for transport

photo: torben skøtt/biopress

Natural gas and biogas are obvious possibilities as fuel for the transport sector. The Swedes have already figured this out, and they expect biogas to cover one and a half percent of the energy needs of the transport sector in 2010.

The Swedes are putting a lot of effort into getting biofuels to cover a significant part of the energy needs of the transport sector, and in 2010 at the latest, all gas stations are supposed to be able to offer customers either bioethanol or fordonsgas, which is the collective name for natural gas and biogas. Today, more than 8,000 cars run on fordonsgas, and several transport authorities are aiming to make gas the preferred fuel for busses within the next 5-10 years.

In Denmark, we have a single city bus in Copenhagen that is running on natural gas as a trial, and at no time have we considered selling biogas at the gas stations. Therefore, there were not many Danish presentations at a seminar about biogas in traffic which was held by Biogas Forum at the Technical University of Denmark on the 1st of February.

But there are actually several good arguments for using biogas in cars and busses. According to Bruno Sander Nielsen from the Danish Biogas Association, we have enough animal manure in Denmark to produce 40 PJ of biogas a year, but at the moment, we are only utilising about 4 PJ. The remaining 36 PJ could cover 20- 25 percent of the energy consumption in the transport sector, and the costs of reducing the release of greenhouse gases in this way would amount to DKK 200-400/ton of CO_2. This is significantly less expensive than for liquid fuels, where the reduction costs are typically around DKK 1,000/ton of CO_2.

But it is probably even better to use the biogas in decentralised CHP stations, as is the case today. Here, the biogas can replace natural gas directly, whereas it would have to be cleaned of carbon dioxide to be used for transport.

And that is not an inexpensive solution. Experience from Sweden shows that systems for cleaning biogas usually cost the same as building the actual biogas facility. In Denmark, it would therefore be an obvious solution to use biogas for combined heat and power and natural gas for transport.

The situation is different in Sweden. There, CHP stations fired by natural gas are relatively unknown, so in many cases, sale to the transport sector is the only possibility. *TS*