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Strategy for biogas research

With a tripling of the biogas production before 2005, it has become necessary to prepare a strategy for the biogas research. We need to be in better control of the biological process, and we need to investigate the best way of using the biogas for energy production.

By Torben Skøtt

– Biogas is approaching its second and crucial breakthrough. This may sound a bit pretentious, but nonetheless, that is the truth of the matter, explained the biogas expert from Danish Energy Agency, Søren Tafdrup, at a seminar about biogas research that Energinet.dk and the EUDP secretariat (EUDP = Programme for Energy Technology Development and Demonstration) had invited to at the end of August.

The background for the seminar was not least the latest energy settlement, which proposes an expansion of the biogas production from the current 4 PJ a year to 12 PJ before 2025. In order for this to happen, a determined effort within research and development is required. The reason for this is that the future plants cannot expect to be supplied with industrial waste, but have to operate solely on the more lean livestock manure, and add to this the question of how the increasing amounts of biogas can be used the best for energy purposes.

– With the first breakthrough, we were able to create credibility regarding the biogas. We were able to establish a number of well-functioning plants, but biogas is still the least utilised resource within bioenergy. If we manage to create the second large breakthrough, the way is cleared - not just for a tripling of the gas production, but also for a much more extensive utilisation of the biomass, said Søren Tafdrup to the about 100 participants of the seminar at Energinet.dk.

He made no secret about the fact that it is rather simple plants that are based on digestion of livestock manure and where the gas is used for power and heating that are to create the second large breakthrough.

– We cannot afford more large bad investments, said Søren Tafdrup with reference ot the many high-tech plants, which have almost all been closed and have taken part in giving the biogas business a bad image.

▶

The four main factors

– Farmers, cars, housing and biogas will be in focus in the years to come, said the secretary of Danish Biogas Association, Bruno Sander Nielsen.

– In the future, biogas will be a pivotal technology with regard to the conversion of low-value biomass into high-value energy in the shape of electricity, heat and transport fuel. Biogas can be used for electricity and heat, as is the case today, it can be used for transport, and it can be used in the gas network. It can be used in stationary as well as portable plants, and it can actually also be used in the fuel cells of the future, explained Bruno Sander Nielsen.

According to the Danish Biogas Association, it is particularly necessary to be in better control of the biological process. Today, it is very much up to the plant manager's gut feeling whether the process is managed sensibly, but several plants have experienced that this is not always enough. A system with online measurements that allow you to monitor the process continually is therefore at the top of the wish list.

Photo: torben skøtt/biopress

– Farmers, cars, housing and biogas will be in focus in the years to come, said the secretary of the Danish Biogas Association, Bruno Sander Nielsen.

What should the gas be used for?

In Denmark, two thirds of the total biogas production is used for power and heating. According to the Danish Energy Agency, this is the most optimal solution, and that will probably be the case for the next 10-15 years. Not until after that, there can be a need for finding new applications, is the assessment of the agency.

However, many of the farmer associations that are behind several of the new projects are sceptical towards that strategy. They are worried about being in a poor negotiation position with only one buyer for the gas, and therefore, several have focused their attention on Sweden, where the gas is used almost exclusively for transport and in the natural gas network.

At the seminar about biogas research, Owe Jönsson from the energy company E.ON talked about the Swedish experience with biogas. In Sweden, there are as much as 15,000 cars running on gas, and in 2007, 53 million cubic metres of gas were used in the transport sector. A bit more than half was supplied by the country's biogas plants, while the rest consisted of natural gas.

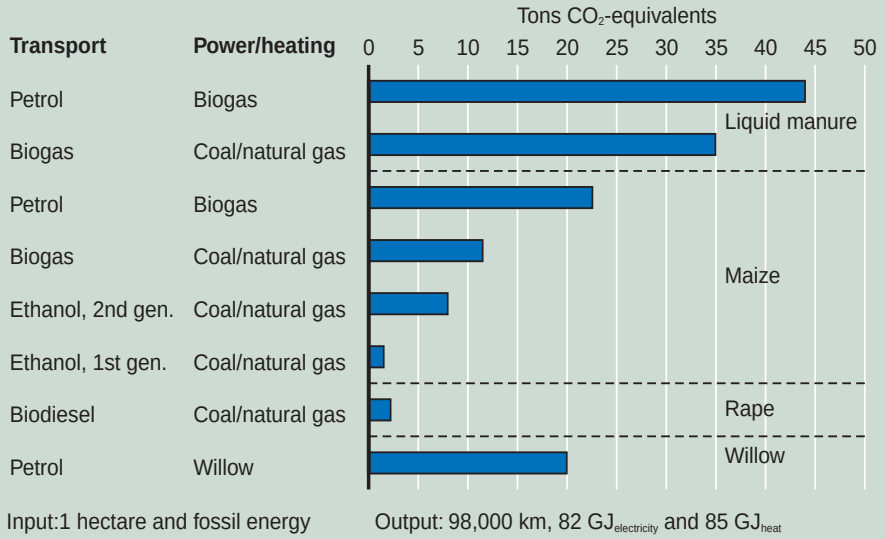
However, hardly any power and heating was produced using biogas. Swedish electricity production is largely based on nuclear power and water power, and the transfer price of biogas electricity has simply been too low for the finances to add up.

On the other hand, there is great financial sense in letting cars run on biogas or use the gas as a replacement for natural gas. Biogas for transport is exempt from duties, and you do not have to pay duties either, if the gas is delivered into the natural gas network and on to a specific customer somewhere in the country.

In order for this to be possible, the gas first has to be purified of sulphur and carbon dioxide. There are 35 such upgrading plants, of which the main part supply gas to the transport sector, while a smaller part send the gas into the natural gas network.

Photo: torben skøtt/biopress

About 100 researchers, corporate managers and industry people participated in the seminar about biogas research at Energinet.dk.



CO_2 reduction by using various types of bioenergy and fossil fuel for transport and combined heat and power. The largest CO_2 reduction by far is achieved by using biogas for combined heat and power and continue using fossil energy for transport. If you use the biogas for transport instead and fossil energy for combined heat and power, the CO_2 emission is not reduced quite as much, but it is still much better than using biomass for biodiesel and ethanol. Source: Wenzel and Thyø.

Up- or downgrading?

At the seminar about biogas research, there was significant interest in developing techniques that can make biogas more competitive compared to natural gas. Today, there are 5-6 different technologies that can purify the biogas of carbon dioxide in order to achieve the same heating value as natural gas, but this is an expensive as well as energy intensive solution. Even though it would probably be possible to reduce operating as well as installation costs through increased research and development, it is difficult to imagine that biogas upgraded to natural gas can become competitive compared to biogas for power and heating.

However, it is worth noting that the Danish natural gas production decreases approx. ten percent a year, which means that already in 8-10 years, we will no longer be self-sufficient with gas from the North Sea. However, the contribution from biogas of 4 PJ is very modest compared to the 191 PJ that come from natural gas today, but all in all, there is a potential in livestock manure of 40 PJ, and add to this the amount of gas that can be produced on the basis of energy crops as well as gasification of wood, straw and waste.

– There is an enormous challenge, but the natural gas network is a potential distribution channel for the future production of gas from biomass, said Jan K. Jensen from Danish Gas Technology Centre at the seminar about biogas research. He explained that the quality of biogas and natural gas is very similar, but that you do not necessarily have to upgrade biogas to natural gas. You can also take another route and downgrade natural gas to biogas instead:

– It is possible to earmark parts of the natural gas network for gas with a lower heating value, which makes it possible to use the biogas directly and supplement with natural gas mixed with air. We have actually had a plant of this type in Revninge on Funen, and that is an area that is worth bringing up again, said Jan K. Jensen.

The main advantage of this model is that you thereby avoid the very extensive costs of operation and establishment of upgrading plants. A plant that can process 300 - 500 cubic metres of biogas per hour costs about DKK ten million, not including the operating costs of DKK 0.80 - 1.80 per cubic metre of gas.

The disadvantage of letting the biogas set the standard is that the installations in the specific households have to be adapted to the lower gas quality. So the goal would be to find an area where the installations are almost worn out anyway or to focus on an entirely new housing area where a gas network could be a sensible solution.

Biogas for transport

In the Danish Biogas Association, they agree with the Danish Energy Agency that biogas should primarily be used for power and heating, but on the other hand, they are not dismissive about using biogas in the natural gas network and in the transport sector.

– At the moment, the use of biogas for power and heating is clearly the least expensive and most efficient solution, but we have to keep in mind that the transport sector has its own reduction goal with regard to CO_2 emission, said Bruno Sander Nielsen and continued:

– In that perspective, biogas can be a sensible fuel for transport, because with regard to reducing the emission of greenhouse gases, biogas is much more efficient than 1st as well as 2nd generation bioethanol.

With regard to reducing the amount of harmful emissions from car exhaust, biogas also has its advantages. Cars running on biogas as well as cars running on natural gas are among the most eco-friendly vehicles. This has been an important argument in Sweden, where they have done a lot to promote gas-powered vehicles in the cities. There, they have often chosen gas for taxis as well as busses.

After the seminar about biogas research, a steering committee has been established for the purpose of formulating a research strategy, which is to be ready during the spring of 2009. The steering committee would be happy to receive constructive contributions on the address biogas@ energinet.dk. ■

Biogas research on new track

Series operation of reactors, online measurements of substances in the biogas reactor, new pre-treatment methods and use of "eco-friendly" crops can open up for a larger biogas yield, estimate scientists at University of Aarhus.

By Flemming Nielsen

At the Faculty of Agricultural Sciences (DJF) at the University of Aarhus, you can now meet quite a bit of optimism among the biogas researchers. With a new state-of-the-art pilot plant in Foulum at Viborg, the researchers believe to have found indication that the biogas yield in the reactor can be increased, and that you can retrieve further energy from the biomass through pre-treatment.

– After the running-in of our pilot plant in Foulum, we are now running several tests that are looking promising, explains Henrik B. Møller, senior researcher at DJF.

The tests are primarily focused on various methods for pre-treatment of the biomass, online measurements of substances in the biogas reactor, series operation of reactors and use of alternative biomass, such as crops, algae and sudd.

Control of the process

A promising research area is online measurements of the biogas process. If you can continually register what takes place in the biogas reactor, you will achieve much better control of the process and thereby achieve a high gas yield.

– We are working on a number of measuring methods called MIMS, NIR and gas chromatography. In that connection, we are investigating whether we can continually register the amount of fatty acids. If we are sufficiently successful, we can get a warning of any imbalance before the process goes sour, explains Henrik B. Møller.

With the monitoring, you can immediately see if any substances such as hydrogen and propionic acid are forming, which are known for inhibiting the biogas production.

Photo: flemming nielsen

- After the running-in of our pilot plant in Foulum, we are now running several tests that are looking promising, explains Henrik B. Møller, senior researcher at DJF, University of Aarhus.

The researchers are also working on simple as well as more high-tech measuring methods in order to investigate the difference between the results from the simple and the more complicated measuring equipment.

Pre-treatment with effect

In the pre-treatment area, the Faculty of Agricultural Sciences has several ongoing activities. In one project, DJF is working together with the companies Xergi and Green Farm Energy on thermochemical pre-treatment. During that process, the biomass is heated to 145 degrees Celsius with a pressure of 4-5 bar with the addition of two percent lime. The goal is to achieve improved yield from deep litter from chickens and cattle. Preliminary results provide increased energy yield of between 20 and 30 percent when using that kind of not easily convertible biomass.

So far, enzymes have only given small effects, but this may be due to the measuring methods themselves, where batch digestion of the material has turned out to be an inadequate method for testing of enzymes.

– Actually, the effect of enzymes can only be identified through continual tests. In that connection, it is often problematic with the many repetitions that are necessary in order to identify the many different combinations of enzymes and biomass that can be relevant.

– Therefore, the use of enzymes is basically uncharted area. With the rather limited effect we have seen so far, the current price of enzymes is one of the largest obstacles, says Henrik B. Møller.

However, he does point out a few positive indications.

– We have carried out tests with liquid cattle manure, where we experienced a

Photo: torben skøtt/biopress

It was called the world's largest biogas pilot plant when the biogas plant in Foulum was inaugurated last autumn. Now, the scientists are working on demonstrating what it can be used for.

positive effect, but it is very difficult to prove statistically, concludes Henrik B. Møller.

Naturally, they are also working on more conventional optimisations, such as choice of temperature and feeding speed.

– During the late summer, we have worked on series operation, where we divide the processes into five days of thermophilic pre-hydrolysis and 15 days of retention time - and reversely 15 days of thermophilic digestion and five days of thermophilic post-digestion. This means that we create an additional thermophilic step, says Henrik B. Møller.

Other combinations, including pre-hydrolysis at 70 ºC, will be tested in the time to come.

The results from the various operating strategies will be published within the next year.

This is how the biogas process is monitored

The researchers at the Faculty of Agricultural Sciences (DJF) are continuously working on developing simple as well as more advanced measuring methods that can be used for monitoring the biogas process. These methods for example include:

Titration, which is a well-known, manual measuring method that is used for about half of the joint plants today. This method can prevent many operating failures, but there is still some uncertainty about how to interpret the results in practice.

Gas chromatography, which is also a well-known method. It is fairly accurate, but the biomass has to be pre-treated first, and it requires quite a bit of expertise to handle the equipment.

MIMS, which is one of the new measuring methods that the researchers expect a lot from. The equipment is able to continually register the accumulation of fatty acids in the gas, which means that you have time to intervene if the process shows signs of imbalance.

NIR, which like MIMS is one of the new methods that there are great expectations for. In this case, there are also online measurements, but instead of measuring the gas quality, you register what takes place in the reactor using infrared radiation.

Plenty of potential

Even though the research is moving forward, there is still a very large theoretical energy potential that is not being utilised with the technology available today.

– We are still extremely bad at utilising the energy of for example liquid manure. We are only able to utilise 50 percent from cattle and 60 percent of the energy content from pig manure. Simply getting that percentage up to 70 would make a huge difference, says Henrik B. Møller.

However, with new research equipment, he is positive regarding the possibilities of making progress.

– With our new pilot plant, which has four separate reactors, we can now prove even small effects of the gas yield when changing various operating parameters with statistical certainty. Furthermore, the reactors are so large that the results can be put directly into practice, which has not always been the case with previous tests at laboraty scale.

Energy crops in waiting position

Within the last year, it has become clear that crops grown directly for energy production have a somewhat lower CO_2 displacement than what was previously assumed, even though biogas is still the technology with the strongest position.

– With the current prices of traditional crops, such as maize, it is often not profitable to produce crops directly for biogas or bioenergy, is the assessment of Henrik B. Møller, but he is keeping one door open:

– The financial advantages are gone, but there can still be significant environmental advantages of replacing traditional cereal growth with perennial crops, such as Jerusalem artichokes and grass. In that connection, the gain is reduced leaching of nutrients, increased carbon accumulation in the ground and reduced consumption of pesticides. With regard to organic plant growth, growing of clover grass for energy may be a method of ensuring nitrogen supply for the other crops. The use of permanent grass from meadows in biogas plants may also be a sensible method of producing energy, caring for the areas and removing a surplus of nutrients, which would otherwise end up in the water environment, emphasises Henrik B. Møller.

At the moment, the Faculty of Agricultural Sciences is carrying out a number of tests with crops for biogas, including Jerusalem artichokes, clover grass, elephant grass, maize and permanent grass.

Photo: flemming nielsen

In the test hall at the biogas pilot plant, researchers from DJF are working with small test reactors. At the other end of the hall, companies and other institutions have their test installations and biogas tests.

Flemming Nielsen is a freelance journalist.

Know the bacteria in your biogas reactor

The production of biogas is a complicated process that the researchers are constantly working on analysing and explaining. The reason for this is that thorough knowledge of how the different bacteria and microorganisms interact is a precondition for a high and stable gas production.

By Rena Angelidaki and Dimitar Karakashev

Photo: torben skøtt/biopress

It can become quite an expensive experience, if the biological process in a biogas reactor loses its balance. Most plants have had this experience. Here is the joint plant in Nysted, which had its last serious breakdown in December 2007.

Within the biogas industry, it is a well-known fact that there are several groups of bacteria in a reactor working together on converting organic material into biogas (see figure 1).

Bacteria use different substrates, produce different products and have different preferences. In the first step, there are the hydrolytic bacteria, which break up long and complex organic molecules into glucose and other smaller molecules. Then come the acid-producing bacteria, which convert glucose into organic acids (VFA) and the acetogenic bacteria, which convert higher VFAs into acetate, hydrogen and carbon dioxide. Finally, there are the methanogens, which belong to a completely separate group of microorganisms (not bacteria) called Archaea. They convert either acetate or hydrogen and carbon dioxide into biogas.

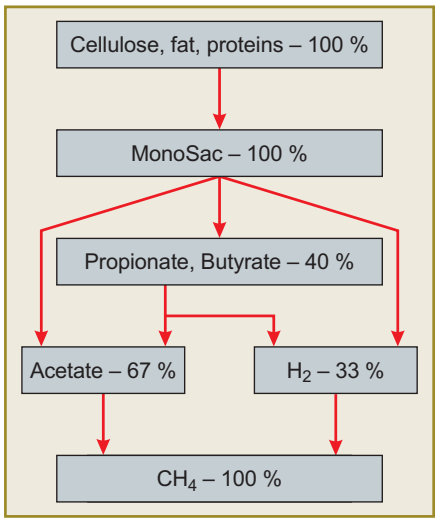


Figure. 1. Biological processes in a reactor where organic material is converted into biogas.

Good interaction

Figure 2 shows a culture where you can see the difference between bacteria and Archaea (methanogens).

In addition to the above-mentioned main groups, there can also be specialised bacteria types that are connected to conversion of special food materials. For instance, fat and oil (lipids) into glyceroles and long-chain fatty acids (LCFA), which are then converted into lower fatty acids (VFA).

The four different main groups have to interact precisely in order for a biogas process to be in balance without bothersome accumulation of intermediate products. Some of the groups are more sensitive and slow-growing than others and are therefore responsible for the process "going awry" and the process being inhibited.

The hydrolysis step is rather slow, particularly for structurally organic materials, such as fibres and tissue. As hydrolysis is a precondition for the subsequent utilisation of the substrate, the hydrolysis step is often the step that limits the yield. Therefore, it is usually necessary to have a rather long retention time for raw materials that primarily consist of undissolved organic dry matter, such as slurry and most types of organic waste.

The acid- and acetate-producing bacteria are relatively robust and can grow and multiply quickly. Conversely, the methanogens, particularly the acetate-consuming ones, are relatively sensitive and slow-growing. Under normal and stable operating conditions, these differences are not significant, as a balance occurs where the concentration of each group is adapted to the conversion requirement.

If there are variations in load or feed composition, differences in growth speed

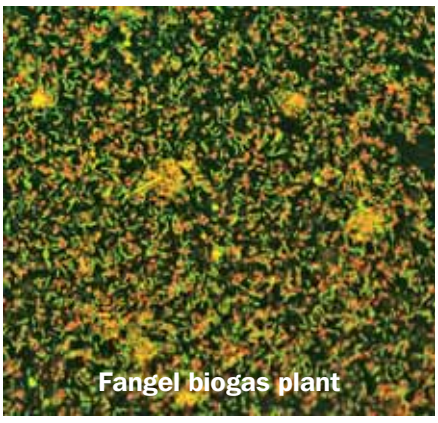


Figure 2. Microbial composition in a reactor where the red microorganisms are methanogens, while the green ones are bacteria.

will result in temporary variations in the concentration of intermediate products, such as VFA, until a balance reoccurs where the conversion capacity of each group is adapted to the requirement. If the variations are too large, accumulation in connection with increasing load can result in concentrations of intermediate products that can have an inhibiting effect on certain groups, after which the process is in danger of breaking down.

Stable operating conditions

This dynamic suggests that you should generally make sure that the operating conditions are as stable as possible and aim for the necessary changes to be carried out gradually. This is particularly the case in connection with the introduction of raw materials that contain new or large concentrations of substances that create inhibiting intermediate products during digestion.

Examples of this are fat and oil, which are also known under the collective name lipids. In slurry, the amount of lipids is limited, but they exist in various types of waste and are rather quickly broken down into for example long-chain fatty acids (LCFA), which can have a particularly inhibiting effect on most conversion steps. However, LCFA can be converted into the more harmless short-chain fatty acids (VFA), but this requires special organisms that are only available in limited concentrations if the process has not been adapted to the specific waste type.

Lipid-containing waste products with a large content of organic solids (VS) can result in a large increase of the production of biogas, but there is a significant risk of foaming and shifting of the pH and CO_2 balance. Therefore, it is particularly important to be careful when introducing these types of waste and otherwise aim for even dosing.

Which organisms are the best?

As the acetate-consuming methanogens are usually the weak link with regard to dynamic adaptation, there has been particular focus on examining the properties of these organisms.

There are two types of methanogens: Methanosarcina, which are round and often bunch together in a structure similar to cauliflower, and Methanosaeta, which are thread-like microorganisms. At the Technical University of Denmark, we have investigated the occurrence of these two types in various Danish biogas plants. We have used some of the newest microbiological methods, where we can identify the various microorganisms by giving them a specific colour. In that connection, we have observed that there can be very different types of methanogens in different biogas plants, but they have the same basic function in the conversion chain, which is conversion of acetate into biogas (see figure 3).

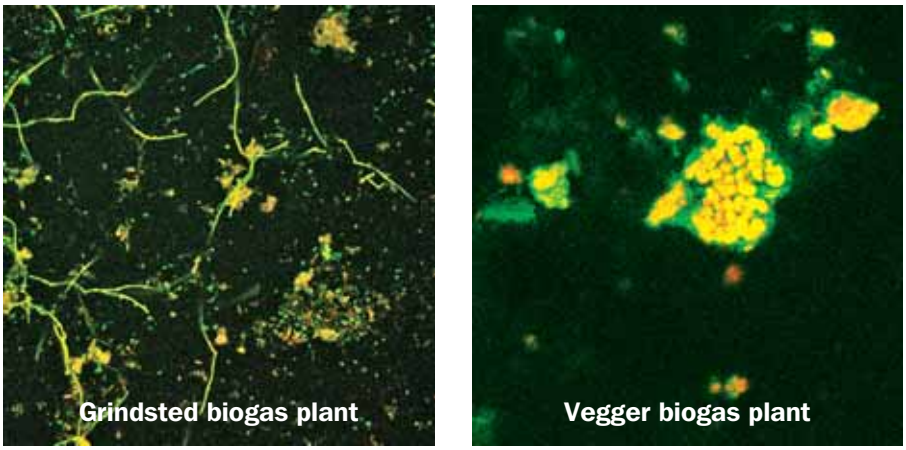


Figure 3. Photo of methanogens in Grindsted and Vegger biogas plants respectively. The green threads are Methanosaeta (Grindsted), while the red, round microorganisms that have a structure similar to cauliflower are Methanosarcina (Vegger).

But what determines which types of methanogens that will establish and dominate in a given reactor, and which types can help ensure a stable process?

In that connection, it has turned out that the Methanosarcinas are very efficient at rather high concentrations of VFA, while they are less efficient at lower concentrations. Furthermore, they are not that good at "eating up". This means that there is a threshold for the concentration of acetate where they no longer grow efficiently. Even though they are not particularly thorough, they are in exchange more robust than their "competitors".

On the other hand, Methanosaeta are good at "eating up" and living off small concentrations, while they under beneficial circumstances - i.e. at high concentrations of acetate - do not grow as quickly.

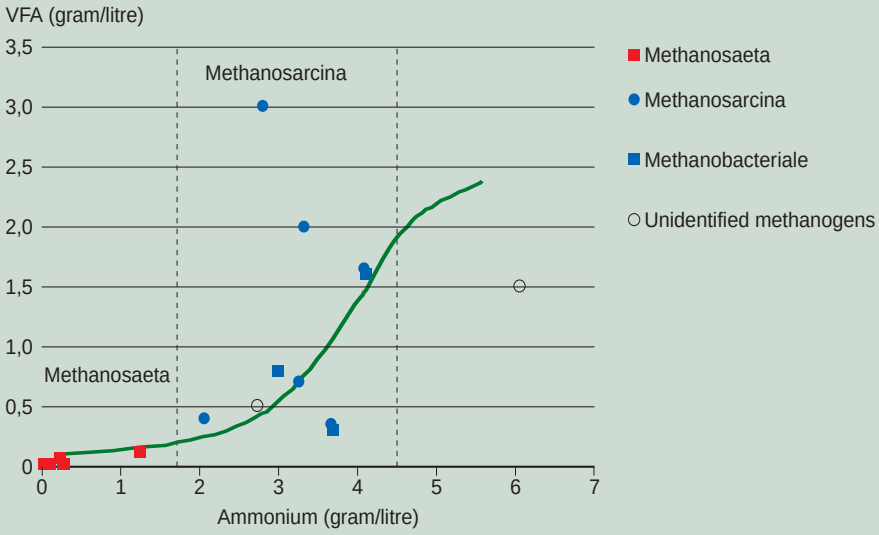


Figure 4. The connection between VFA and ammonium in the reactor from various joint biogas plants in Denmark. The points mark the type of methanogens in the investigated plants. In case of low VFA and ammonium levels, there are mainly Methanosaeta, while there are primarily Methanosarcina at higher concentrations. In a few cases, it has not been possible to identify the methanogens.

It is presumed that it is natural competition that determines which type that dominates. If you are able to keep the VFA concentration low for a long time, Methanosaeta will probably win, while a high and varied VFA concentration will favour Methanosarcina.

From an efficiency viewpoint, low VFA concentration and thereby Methanosaeta would probably be preferable, but with regard to dynamic stability, Methanosarcina would be a better choice. Finally, there is obviously the question of whether you can actually choose, as there are other circumstances that can determine the type of VFA concentration that exists in a plant.

What can we do?

Thus, there is a clear connection between VFA and ammonium level and the methanogenic types that will establish in the reactor (see figure 4).

But can we affect the microbiology in a reactor and thereby the efficiency and dynamic in the reactor? And which role do the grafting materials play when initiating the process?

If you want to establish a specific culture, it is obviously important to have good grafting material that contains large amounts of the type in question. However, that in itself is not enough.

Within certain limits, specific types can maintain their dominance. Thus, here at the Technical University of Denmark, we have managed to keep certain types of methanogens away for longer periods of time through operation under circumstances where you would usually expect other types to establish. But if the process is unfavourable for some microorganisms for longer periods of time, the culture will slowly be replaced - probably within 4-5 months, as there is usually always predisposition for alternative types.

It is still too early to say whether we, in the long term, can develop methods for establishing and maintaining specific methanogenic types or other microorganisms with good process qualities.

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Denmark is getting fewer research funds from the EU

Danish research has to become better in order to get a share of the EU's significant funds for research and technological development. This is established in a new report from the Danish Agency for Science Technology and Innovation, which clarifies Denmark's participation in the EU's 6th framework programme.

The Danish Agency for Science Technology and Innovation has recently made the report: "Tal om Danmarks deltagelse i EU's 6. rammeprogram for forskning og teknologisk udvikling" (Figures regarding Denmark's participation in the EU's 6th framework programme for research and technological development). Among other things, this report states that 2.2 percent of all the researchers that participated in the EU's 6th framework programme were from Denmark. It also states that the Danish research environments were provided with 2.4 percent of all funds.

Thus, the Danish share of the funds was above average, and compared to the other countries that participated, Denmark accounted for the 12th-largest contribution. Measured per inhabitant, the contribution for Denmark was the second-largest.

But this does not mean that Denmark is doing as well as it could. Actually, our share of the funds from the EU framework programmes is dropping. The drop started during the 5th framework programme and that tendency continued during the 6th framework programme.

– It is a serious problem that Denmark's participation in the EU's framework programmes for research and development has been falling. Therefore, the government has taken a number of initiatives to strengthen the researchers' possibilities and motivation for achieving co-financing from the EU. Our research institutions and companies are to participate in more and larger EU projects if we are to achieve the government's goal of doubling the return on the Danish participation in the current 7th framework programme, says the Danish Minister for Science, Technology and Innovation, Helge Sander.

The EU pre-project scheme, the network funds, START funds and the coordinator pool make it possible for Danish researchers and companies to achieve subsidies for preparing applications and contract negotiations. Furthermore, the Danish Ministry of Science, Technology and Innovation supports Danish participation in the EU's 7th framework programme through information, instruction and assistance in connection with applications and project completion. Furthermore, the Danish Ministry of Science, Technology and Innovation has established a special Danish office, DANRO, in Brussels, that collects knowledge about the EU's research programmes and passes on this information to Danish companies and research institutions.

The printed report can be requested by sending an e-mail to eurocenter@fi.dk. The electronic version can be downloaded on www.fi.dk *TS*

Photo: torben skøtt/biopress

The IBUS project, where straw is converted into fuel, feed and ethanol, is one of the projects that has received significant support from the EU's framework programme.

New technique is to optimise the production of biodiesel

Photo: daka biodiesel

Daka's manufacturing plant south of Horsens, where they produce 55 million litres of biodiesel per year on the basis of slaughterhouse waste and dead animals.

Online measurements using laser light at Daka Biodiesel is supposed to improve the production of the green oil.

The parties of the innovation consortium Waste-2-Value have started a number of tests in cooperation with RSP Systems in Odense, Denmark, that are to determine whether it is possible to develop equipment that can monitor the production of biodiesel. This has now resulted in an innovative solution that is based on a technique called Raman-spectroscopy. This makes it possible to gather information all the way down at molecular level using laser light.

The new monitoring equipment makes it possible to observe the production process of biodiesel very closely. Using a fibre-optic light guide, you can use laser light to take samples of the process during its progression. Through the fibre-optic connection to the Raman device, you can get very detailed knowledge of the actual production process, which you can use to adjust and optimise the production of biodiesel. In the long term, this kind of measurement of the process can shorten the production time and make it more profitable to make biodiesel, is the assessment of the people behind the Waste-2-Value consortium.

RSP Systems is a relatively newly started research-based company specialised in the production of tailored Raman devices for various applications. Waste-2-Value includes Daka, Grundfos, the oil company OK, Dinex Emission Technology, Danish Technological Institute and Technical University of Denmark. The purpose of the consortium, which was established in 2007, is to develop 2nd-generation biodiesel for the transport sector. This type of biodiesel is to be extracted from waste products from for example slaughterhouses and farming.

The first project of Waste-2-Value was really made headway with the opening of the factory Daka Biodiesel south of Horsens, which can produce 50 million tons of biodiesel per year. The raw materials are mainly slaughterhouse waste and dead animals from farming.

At Grundfos, which is part of the Waste-2-Value consortium, they are working on developing a technology where you use a supercritical process to convert sewage sludge into biodiesel.

The consumption of diesel oil for road transport has increased significantly since 2002, and almost half the amount of energy used for road transport in Denmark is base don diesel.

The conversion of animal fat from slaughterhouses and farming into biodiesel constitutes a source of at least 100,000 tons per year, which corresponds to 3.8 PJ. Add to this the amount of sewage sludge, which can currently contribute with 2.7 PJ. As the annual consumption of diesel for road transport is almost 80 PJ, these two sources would thus be able to cover about 8 percent of Denmark's diesel consumption for road transport. *TS*

Daka received environmental award for development of biodiesel

On Tuesday the 10th of June 2008, the Danish Minister for the Environment, Troels Lund Poulsen, gave the political party Venstre's environmental award 2008 to Daka Biodiesel.

Photo: waste-2-value

Daka's 2nd-generation biodiesel is now being tested.

Among other things, the minister acknowledged Daka's work on the development of 2nd-generation biodiesel made from slaughterhouse waste. Daka's managing director, N. C. Leth Nielsen, was happy and proud to finally be able to collect the environmental award.

One week earlier, the oil company OK started, as the first in Denmark, letting the company's tankers run on a mix of Daka biodiesel and ordinary diesel oil.

– At first, we will start by having three tankers run on fuel that is mixed with five percent Daka biodiesel made from waste, and during the summer and autumn, we will then expand the number of trucks, explains the head of secretariat Svend Lykkemark from OK.

In the beginning of August, it was the employees' turn to test the new fuel. At OK's main office in Viby, the employees can now fill up with biodiesel and have the engines checked at Danish Technological Institute before and after the test period.

However, other drivers will have to be patient. It is going to be a while yet before Daka's biodiesel is available at ordinary gas stations. ■

Danes love their wood-burning stoves

Danes love their wood-burning stoves - primarily because they give a cosy atmosphere, but also because they help save money. A majority would in principle like to make an effort for the environment, but do not always know what this means. And then there is the minority that, roughly speaking, fire with what they please and disregard the environment.

Photo: torben skott/biopress

It is mainly the cosy atmosphere and a lower heating bill that makes people choose a wood-burning stove. Only five percent buy a wood-burning stove for the sake of the climate.

Forget about environmental considerations and climate campaigns. What really counts for Danes when they choose a wood-burning stove instead of other heat sources is mainly cosiness and finances. For others, the goal is to get a more pleasant type of heat or simply to get enough heat. Only five percent say that they have a wood-burning stove for the sake of the CO_2 balance.

These are the results of a new survey that senior researcher Lars Kjerulf Petersen from the Danish National Environmental Research Institute at University of Aarhus has headed. On the basis of the survey, the researchers have divided users of wood-burning stoves into four types, shown with the most frequent first:

1. The aesthetic-sensuous:
Bodily well-being
Ideals of a good home
Original heat source
2. The pragmatics:
Finances
Best available heat source
3. The ones who want to make their own decisions:
Independence from other heat supply
Making a home according to own preferences
4. Environmental idealists:
CO_2 balance.

The majority by far is in the first group, while the last group only includes 5 percent, as mentioned (see figure 1).

According to the survey, several people have said that they might have taken finances into consideration, but in the end, it was because of the cosy atmosphere that they chose a wood-burning stove, or as expressed by one of the people interviewed:

"It is the cosiest piece of industrial design ever made - it is better than the box (the TV)."

Another of the people interviewed takes it one step further and compares the wood-burning stove with therapy:

"Most of all, it is therapeutic. Being able to sit and look into the flames. It is distressing and it works. To me, it has never been about an inexpensive heat source."

Every third neighbour is bothered

The researchers have also asked the Danes to what extent they feel bothered by smoke and/or smell from wood-burning stoves. Nearly half of users as well as non-users do to some degree – from a little to severely – feel bothered by firewood smoke. However, when it comes to being more than just a little bothered, the viewpoints separate into two groups. Only six percent of the users feel "bothered", "very bothered" or "severely bothered", while the corresponding share of their neighbours without wood burning is 33 percent.

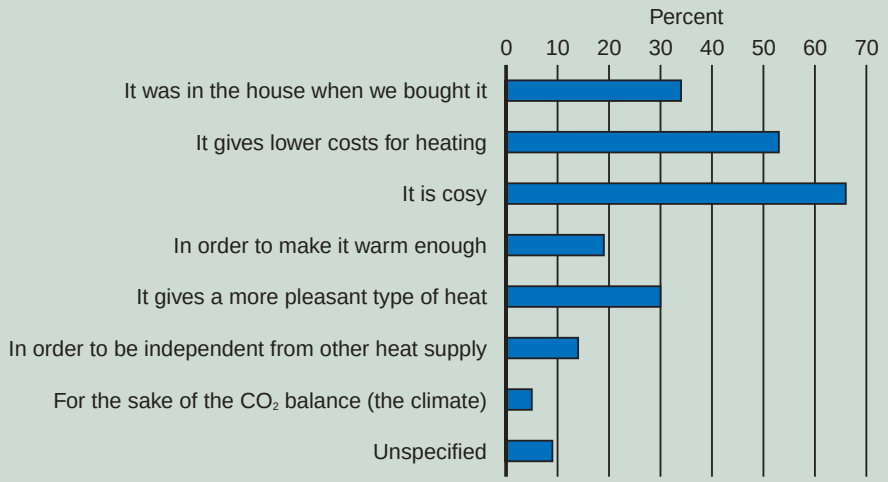
While almost half the interviewed people feel bothered to some degree by smoke from wood-burning stoves, as much as 62 percent feel that something should be done about air pollution from wood burning. However, particularly the more non-committal initiatives, such as information campaigns, gain support, while initiatives that impose additional costs on the consumers do not receive much support. Thus, only 30 percent are willing to pay for the costs of reducing pollution from wood burning, and most households will not pay any more than DKK 800 per year.

The other people make the mess

The majority of the people interviewed state that they fire with clean and dry wood, but 21 percent state that they "occasionally" fire with other types of wood, such as pallets, wood from demolition, furniture and the like. Furthermore, the typical scenario is that almost everyone can tell stories of other people firing with all kinds of junk. The researchers quote one of the interviewed people saying the following about an acquaintance:

"I once worked for someone who fired with car tires. He cut the car tires in pieces and then used them in the stove. He nearly killed his neighbour - because he had bad lungs."

Earlier surveys from Danish National Environmental Research Institute have shown that a few owners of wood-burning



This is why Danes choose a wood-burning stove or furnace. Overview of replys from 361 people in Herlev and Værløse to the question: Why do you have a wood-burning stove/furnace? Source: www.dmu.dk

stoves are responsible for a very large part of he air pollution. Actually, the pollution from a wood-burning stove can vary with factor 100 or more from the cleanest to the blackest smoke. Therefore, the objective is to get to everyone, but according to the researchers, the aforementioned owners of wood-burning stoves will not be receptive to campaigns and good advice. In that connection, only a prohibition helps, which the municipalities are actually authorised to issue, for example by prohibiting certain types of fuel, such as pallets, milk cartons and the like.

The survey "Brændefyring i hjemmet - praksis, holdninger og regulering" (wood burning in the home – practice, attitudes and regulation) is part of an integrated research project, Wooduse, about environmental and health effects and societal aspects of wood burning as house heating. The project has received support from the Danish Council for Strategic Research. *TS*

Development of better wood-burning stoves

The Danish Ministry of the Environment uses a new subsidy scheme to provide a cash injection for the work on developing technologies that can solve the problem of air pollution from wood-burning stoves and furnaces.

At the end of June, the Danish Ministry of the Environment announced that now, more than DKK seven million will be earmarked for development, testing and demonstration of technologies that can contribute to lowering the pollution from wood burning in private homes.

– Wood-burning stove provide renewable, CO_2-neutral energy. There is just the problem that they also pollute the air - particularly if you do not fire in the correct way. We have to do something about that, so we can enjoy the advantages of wood-burning stoves with a clean conscience. Therefore, we need to develop and test new technologies in the area, says the Danish Minister for the Environment, Troels Lund Poulsen (V).

As part of the scheme, up to DKK 800,000 have been earmarked for the establishment of an innovation partnership for environmentally friendly wood burning, which is to strengthen the cooperation between the industry, the knowledge institutions and the authorities.

Examples of projects that can get support are development of intelligent wood-burning stoves that can control their own air supply to keep the wood burning clean and systems that warn the users if they are not firing correctly. Furthermore, the Ministry of the Environment has started a large demonstration project where filtres and similar technologies for post-mounting on existing wood-burning stoves and furnaces are to be tested in practice. *TS*

Discount on knowledge

The Danish Council for Technology and Innovation (RTI) now offers small and medium-sized companies coupons for purchase of knowledge or research.

– The new offer for small and medium-sized companies is efficient and unbureaucratic. The discount is given right away, and hopefully, this can give many small and medium-sized companies the courage to start cooperating with the knowledge institutions, says the Danish Minister for Science, Technology and Innovation, Helge Sander.

– Many small companies do not have any experience using the resources that are available at the knowledge institutions, and therefore experience it as a major challenge. These companies can benefit from a gentle push, when they are considering leaving well-known and safe methods. They are now given that push, says Lars Mikkelgaard-Jensen, chairman of the Council for Technology and Innovation.

The offer includes two types of discounts tailored for two types of companies: Knowledge Coupons, which are aimed at small and medium-sized companies that have few or no research and development activities, as well as Research Coupons, that are more suitable for companies with research potential. Both types of coupons give the companies a discount on the cost of entering into a qualified partnership with a knowledge institution.

The Danish Council for Technology and Innovation has earmarked DKK 40 million for knowledge coupons and DKK 30 million for research coupons in 2008 and 2009. A knowledge coupon can have a value of up to DKK 100,000, while a research coupon can have a value of up to DKK 1.5 million.

The Danish Agency for Science, Technology and Innovation will be issuing coupons according to the principle "first come, first served". The applicants have to live up to simple application criteria, which are available upon request from the agency.

Source: www.fi.dk

Construction start for ethanol factory

The 5th of September was the official first day of construction for DONG's ethanol factory in Kalundborg. The factory, which is to be ready for the Copenhagen Climate Summit, will be one of the world's first plants that can produce fuel on the basis of straw and other residual products from farming.

By Torben Skøtt

Photo: inbicon

The managing director of Inbicon, Niels Henriksen, explains to the Danish Minister for Climate and Energy, Connie Hedegaard, what the finished plant will look like.

– A 2nd-generation plant like this one is not based on food products, which means that it does not take the bread out of the mouths of the world's population. This is a positive contribution for the battle against climate changes, said the Danish Minister for Climate and Energy, Connie Hedegaard, at the official construction start of what is very quickly supposed to be one of the world's first straw-based ethanol plants.

It is DONG's subsidiary Inbicon that is supposed to handle the establishment and operation of the advanced plant. The company has been promised support from the EUDP pool of almost DKK 77 million out of a total fixed asset investment of DKK 300 million.

The people behind Inbicon do not make a secret of the fact that they are going to be very busy until the Climate Summit in December 2009, where they are hoping to be able to drive many of the foreign delegations to and from the Bella Center in cars running on straw-based bioethanol. Therefore, it was also necessary to "jump the gun" with regard to the construction, just as they are continuing developing the technology at a pilot plant in Skærbæk while the factory in Kalundborg is being built.

Started at the plant Fynsværket

The new plant in Kalundborg has roots back to the IBUS project, which DONG (previously Elsam) headed during the period 2002 - 2006. It was an extensive EU project for DKK 100 million, the purpose of which was to integrate the power and heat production at a power plant with a plant that could produce bioethanol and feed for farming. During the project, a pilot plant was established at the plant called Fynsværket, which was later moved to DONG's headquarters in Skærbæk, where it is still being used for research and development.

Today, the plant in Skærbæk can handle one ton of straw per hour, and it is the experience from this plant that has been used to design the plant in Kalundborg. Here, the capacity has to be increased to four tons of straw per hour, which will result in an annual production of 5.4 million litres of ethanol, about 8,000 tons of fuel and 11,000 tons of feed pellets.

The location in Kalundborg has been chosen because it makes it possible to use some of the surplus heat from the coal-fired Asnæs plant. According to DONG's calculations, this will result in an additional plus on the CO_2 account of 10,000 tons per year, because the alternative would have been to direct the heat into the ocean. Furthermore, the ethanol plant can supply fuel pellets that have been cleaned of alkali, unlike untreated straw. Thus, you avoid corrosion problems at the power plant, even when using rather large amounts of biomass.

Focus on pre-treatment

Even though DONG now has six years of experience with development of 2nd-generation plants for production of bioethanol, they still consider the technology to be so complicated that it is necessary to focus the development on specific areas.

– Our core area is a pressurised pre-treatment of the biomass. It is quite a challenge to get bales of straw into a pipe where there is a pressure of about 20 bar, explains Jan Larsen from Inbicon. He emphasises that they obviously have the whole process under control, but that they have chosen specific focus areas, which they now have a patent on.

– There is a remarkable number of areas that you have to be in control of when upscaling a plant, which means that it would not be realistic to have experts in all areas. We have chosen pre-treatment because it is an area that we can also use in other connections, and furthermore, we have developed a special technology that makes us capable of hydrolysing biomass with a dry matter content of more than 25 percent – nobody else has been able to do that, explains Jan Larsen.

According to the calculations of Inbicon, bioethanol can reduce the CO_2 emission by 84 percent compared to traditional fuel. If ten percent of the petrol consumption in Denmark is replaced by bioethanol, it would result in an annual CO_2 reduction of 600,000 tons. If you include the production of biofuel and feed, you achieve an additional reduction of 400,000 tons of CO_2 per year. ■

Catalysts in bioboilers

Title:	6533 – Deactivation of SCR catalysts of additives
Responsible:	DTU, Dep. of Chemical and Biochemical Engineering, Anker Degn Jensen, ✆ +45 4525 2841
Grant:	PSO – DKK 2,734,000

The project has investigated whether the addition of fuel additives in biomass-fired power plants poison DeNOx catalysts. For that purpose, tests have been carried out at laboratory and pilot scale with additives based on calcium and phosphorous for binding of potassium. The results indicate that potassium is bound strongly in the compounds formed through reaction between potassium, calcium and phosphorous, and no potassium deactivation was observed in the tests. However, in case of too high addition of additives, deactivation caused by phosphorous can potentially be a problem. All in all, the additives seem promising from the perspective of the DeNOx catalyst.

Ash fractions from alternative biofuels

Title:	6356 – Utilisation of ash fractions from alternative biofuels used in power plants
Responsible:	Danish Technological Institute, Frank Elefsen, ✆ +45 7220 1250
Grant:	PSO – DKK 1,200,000

The purpose of the project has been to find a way to utilise various ash fractions from alternative biofuels that have been found suitable as power plant fuel. Utilisation of the ash products has been assessed on the basis of processing and reutilisation, the limit values of the executive order regarding sludge as well as the new EU directive on disposal.

Incorporation of a two-step gasifier in an energy system

Title:	6528 – Incorporation of two-step gasifier in an energy system
Responsible:	MEK-DTU, Ulrik Henriksen, ✆ +45 4525 4309
Grant:	PSO – DKK 2,700,000

The purpose has been to investigate the safety condition of the Viking gasifier and to develop and implement a new control system that is to make it possible to ensure a more flexible power and heat production. During this project, a number of components have continually been improved, and long-term tests of almost 4,000 hours have been carried out, of which the majority have been related to engine operation. The tests showed that the plant has good regulation capabilities, and it was stated that the amount of non-incinerated carbon in the ash varies from 0.1 to 6 percent depending on the fuel being used. The experience from the project will be used in connection with the upscaling of the Viking gasifier at Weiss A/S (project 6529).

Optimisation of the biogas process

Title:	6356 – Use of online fatty acid sensor to control and optimise the anaerobe process for low-cost biogas from the liquid manure
Responsible:	Environment and Resources – DTU, Irina Angelidaki, ✆ +45 4525 1429
Grant:	PSO – DKK 1,661,000

The purpose of the project has been to test a system than can continually register the amount of fatty acids in a biogas plant. In this way, works managers at biogas plants are given a better chance of intervening in time if the process shows signs of an imbalance. The system has been test at a laboratory plant and a pilot plant.

Biogasol is applying for support for ethanol factory

Biogasol is aiming to be ready with a plant for production of 2nd-generation bioethanol for the Climate Summit next year.

Photo: bo jarmer, danmarks tekniske universitet

Biogasol's plant on Bornholm is to be based on the Maxi-fuels plant that has been developed at the Technical University of Denmark.

On the 5th of September, Biogasol has applied for support for an ethanol factory on Bornholm from the EUDP pool that the Danish Energy Agency is administering. Biogasol also applied in the spring, but back then, the entire pool went to DONG's project in Kalundborg. This caused quite a bit of debate, which several politicians took active part in, and the result was that the finance committee of the Danish parliament decided in June to move forward the pool for 2009, which means that it became possible to carry out a new application round in September.

Furthermore, Biogasol chose to complain to the Energy Board of Appeal about the decision of the EUDP committee in the spring, but the board did not agree with the complaint.

According to the managing director of Biogasol, Birgitte K. Ahring, a future plant on Bornholm will be based on a technology that differs from others through the fact that it efficiently converts all biomass into valuable energy products, such as bioethanol, biogas and solid fuel while recycling the process water. The reason for this is an efficient pre-treatment technology as well as a very special microorganism that converts all sugar in the biomass into ethanol. The special microorganism is the result of long-running biotechnological development work and is one of the key technologies for efficient production of 2nd-generation bioethanol.

If BioGasol achieves support from EUDP, the plant on Bornholm will be ready for operation at the Climate Summit in November 2009. *TS*

Selective hydrolysis of sludge - phase 1

Title:	6515 – Selective hydrolysis of sludge – phase 1
Responsible:	Eurotec West A/S, Preben Jensen, ✆ +45 8672 1422
Grant:	PSO – DKK 1,200,000

This project has included a cost-benefit analysis of the possibilities of using selective hydrolysis of sludge at the sewage treatment plant Esbjerg Renseanlæg Vest. In this way, it will be possible to increase power and heat production from biogas and reduce the energy costs of handling nitrogen and sludge.

Among other things, the analysis is based on laboratory tests at Risø- DTU, and it shows that it is possible to achieve a simple payback time on the investment of about five years, if you use primary sludge and denitrification and incorporate the value of the sanitation system. On this basis, a test plant will be established at the sewage treatment plant (project 7570).

Optimisation of biomass-based energy production

Title:	4114 – Modelling and optimisation of biomass-based energy production
Responsible:	DONG Energy, Tommy Mølbak, ✆ +45 7923 3030
Grant:	PSO – DKK 4,330,000

The project has improved the process and method knowledge about dynamic operation and stability of biomass-fired boiler plants. The need for high regulation-ability means that the focus of the project was adjusted along the way to include all wood-fired units that can contribute to improving the stability of the system.

The project has created increased understanding of low-load operation of dust-fired boilers. On the process side, modelling and analysis of vaporiser stability, and the model has been built along with the closest process parts in a dynamic model. The results are promising, and there is basis for continuing the work in the area.

Photo: energi e2

The project about optimisation of biomass-based energy production has created understanding of low-load operation of dust-fired boilers. Here is a dust-fired biomass boiler at the Avedøre plant.

Upscaling and demonstration of the Viking gasifier

Title:	6529 – Upscaling and demonstration of the two-step process
Responsible:	Weiss A/S, Bjarne Skyum, ✆ +45 9652 0444
Grant:	PSO – DKK 6,502,813

The purpose of the project has been to establish a gasification plant for wood chips with a capacity of 600 kW heat input. The plant is an upscaled version of the Viking gasifier, which has been developed at the Technical University of Denmark.

In connection with the establishment, various considerations have been made regarding design choice, just as a number of valuable experiences have been gathered, which can be used at the establishment of future plants. In a subsequent ongoing project 6325, the plant is implemented, and problems are solved continually.

Photo: torben skøtt/biopress

The wood chip-fired gasification plant at Weiss is an upscaled version of the Viking gasifier, which has been developed at the Technical University of Denmark.

Production of bioethanol

Title:	33031-0058 – Socio- og company-economic analysis of bioethanol production in Denmark combined with power/heat and biogas. Phase 2: Bioethanol production in Denmark combined with power/heat and biogas
Responsible:	National Laboratory for Sustainable Energy , Lars Henrik Nielsen, ✆ +45 4677 5110
Grant:	EFP – DKK 964,000

The project, which is divided into two phases, will analyse three different plant types for production of ethanol based on raw materials that for example include straw, cereals, liquid manure and waste. Phase II is consistent with the preconditions in phase I of the project, which is financed through EFP-2005.

The primary focus is on two promising new plant concepts, where Denmark has special preconditions and qualifications, while existing plant concepts based on cereals have been used as reference. The two new plant concepts are characterised by the fact that they produce ethanol in connection with a CHP plant (IBUS concept) and produce bioethanol combined with heat/power and biogas (Risø-DTU concept) respectively. The raw material basis of the ethanol production is straw/whole crop as well as residual biomass, waste etc.

Measuring equipment for waste-fired plants

Title:	5727 – Advanced measuring equipment for improved operation of waste-fired plants - phase 2
Responsible:	DONG Energy, Tommy Mølbak, ✆ +45 7923 3030
Grant:	PSO – DKK 1,984,600

The purpose of the system has been to develop a system for online optimisation of incineration of waste.

Phase 2 has included work on putting together a measuring programme at the CHP plant in Haderslev to determine the main characteristics of the incineration process. Based on camera information and existing measurements, it has been possible to describe important conditions in the boiler room. Parts of the concept have been tested in Haderslev, and with regard to the ongoing phase 3 (project 7336), the concept is tested in Haderslev as well as at Reno Nord.

Renewable energy and micro CHP plants

Title:	Micro-CHeaP
Responsible:	FORCE Technology, Jesper Cramer, ✆ +45 7215 7750
Grant:	EFP – DKK 787,000

The project has been part of a larger EU project with 26 partners, where the purpose was to investigate how renewable energy sources, including biomass, can be combined with micro CHP plants. However, after a well-founded accusation of fraud, the coordinator of the project went bankrupt in the beginning of 2007. After this, the 26 parties have suggested a new coordinator, who has negotiated with the Commission regarding the further progress of the project, but at the end of February 2008, the Commission decided to end the project completely. Therefore, there is no conclusive report or the like about the results of the project.

Grate firing - emissions and residual products

Title:	3339 – Grate firing - emissions and residual products
Responsible:	DONG Energy, Bo Sander, ✆ +45 7923 3325
Grant:	PSO – DKK 7.000.000

The current project is about the production of liquid potassium fertiliser from straw fly ash. A pilot plant has been established at the straw-fired boiler at the Ensted plant, and in 2007, stable production was achieved at the plant. It has been demonstrated that it is possible to produce a liquid product with 10 percent potassium by weight and a very low content of heavy metals. The product was delivered to farmers, who mixed it with liquid manure.

However, the process is not financially competitive compared to other technologies for ash treatment, which means that no commercial plant has been established subsequently.

Co-firing with biomass at power plants

Title:	4105 – Co-firing with biomass in suspension-fired power plants
Responsible:	DONG Energy, Charles Nielsen, ✆ +45 7923 3333
Grant:	PSO – DKK 4,522,000

This Danish-American partnership has resulted in two Ph.D dissertations as well as a model for biomass incineration in power plants. At the University of Aalborg, a model has been established and tested for measuring of the flow around the torch head. Subsequently, the model has been compared to CFD calculations for pure coal firing and coal firing with the addition of straw. Studies have been made of how the ash is formed and how deposits occur in the boiler under varying conditions. The work has been continued in project 4881, which will result in a complete report on the topic.

Photo: torben skøtt/biopress

The project about co-firing with biomass at power plants has resulted in two Ph.D. dissertations and a model of biomass incineration in power plants. The work has been continued in project 4881, which will result in a complete report on the topic.

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Torben Skøtt, Inbicon and Volvo

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– to be published in the middle of December 2008. The deadline for articles is 15 November 2008.

Trucks are to run on DME

Photo: volvo

The Danish company Haldor Topsø and Swedish Chemrec will be working together on building the world's first factory for production of DME on the basis of biomass. The factory, which will be established in the north of Sweden, is to be able to supply 4-5 tons of DME per day.

In one and a half years, 14 trucks should be running on DME extracted from biomass in northern Sweden

Haldor Topsø's qualifications within catalysts that can convert gas into liquid fuel will now be utilised in the European BioDME project, which Volvo is responsible for. Here, the whole chain from biomass to utilisation of the diesel-like fuel DME is to be tested. An important piece of the puzzle will be the establishment of a factory in Piteå in northern Sweden, where black liquor, which is a waste product from the paper industry, will be gasified and converted into DME.

DME stands for Di-Methyl-Ether and is today primarily used as propellant in spray cans and as replacement of LPG gas for cooking. Many consider it to be the fuel of the future for the transport sector, which is due to the high energy efficiency, the low CO_2 emission and a very pure combustion compared to for example diesel oil.

The disadvantage is that the engines have to be modified in order to run on DME, but truck manufacturers like Volvo are ready to accept that challenge. They call DME "the preferred fuel" – unlike other car manufacturers, who are more inclined to use biodiesel and ethanol.

The consortium behind the BioDME project consists of a number of European partners. The Swedish company Chemrec is to build the plant that can produce gas on the basis of black liquor, and Haldor Topsø is, as mentioned, supposed to supply the catalysts that can convert the gas into DME. The company Preem is supposed to be responsible for the distribution of DME and build four gas stations in that connection, and finally, Volvo is supposed to supply 14 DME-driven trucks.

Haldor Topsø has previously supplied equipment for China where coal is converted into DME, but the project in northern Sweden will be the most advanced and efficient plant so far.

BioDME has received support from the EU's 7th framework programme as well as the Swedish Energy Agency. The total budget amounts to EUR 28 million or about DKK 200 million. *TS*