Fifth volume
26th issue
December 2008

FiB
Bioenergy research



Energinet.dk about gasification plants:

It is now or never

With a total grant of approximately DKK 18 million, Energinet.dk now wants to have tested whether the gasification technology is viable or not. The money will partly go to a two-stage gasifier at the district heating plant Hadsund Fjernvarme, and partly to the development of a fluid bed gasifier, enabling the power plants to use waste instead of coal to a higher degree.

By Torben Skøtt

It has taken a long time. Too long, many would probably say. Since the first gasification projects were launched in the beginning of the 1990s, about DKK half a million has been used for the development of the technology, but the big breakthrough has still not occurred.

However, a single success story has taken place during those years. In Harboøre, the local district heating plant has had a gasification plant in stable operation since 2003, but it did take ten years to get that far. It took four years to get the gasifier to run optimally, three years to get the plant to produce electricity and another three years before a number of problems with the purification of the waste water had been solved.

There has been no shortage of failures. In the 1990s, a plant in Blære was given up, in 2003, the municipal works in Herning gave up getting a gasification plant in the village Høgild to work, and more recently, a gasification plant in Gjøl in Northern Jutland has been recommended for scrapping before it has even been put to use. In Skive, where they have built a gasification plant for DKK 250 million, they have not given up hope yet, but they are significantly behind schedule according to the original timetable, and the budget has been overrun several times.

It is remarkable that we have actually gotten this far, considering the results of the many research and development projects. Danish researchers have often attracted international attention with regard to development of technologies that can convert biomass into clear gas and with regard to gasi-

photo: torben skøtt/biopress

The gasification plant in Harboøre has now had stable operation since 2003, but apart from this, there have not been many success stories.

fication plants that can use many different types of waste as raw materials. Thus, there are plenty of success stories from laboratories and test plants, but when it comes to upscaling the technology and using it in real life, there is quite a bit of difficulty.

Two-stage gasifier

Energinet.dk, who administers the PSO funds, wants to do something about this. To start with, they have allocated about DKK 18 million for the purpose, and if it is a success, the company is prepared to spend even more money on this area.

– It is now or never. A lot of money has been spent on research and development, and with the passing of the act on renewable energy, the plants can look forward to some reasonable framework conditions, so now we have to test whether it can work in practice, says Kim Behnke, who is a section manager at Energinet.dk.

The majority of the money from Energinet.dk will go to initialisation and demonstration of a so-called two-stage gasifier at the district heating plant Hadsund Fjernvarme. The technology is based on research results from the Technical University of Denmark and experience from a pilot plant at the boiler factory Weiss A/S in Hadsund.

What is special about the plant is that it is capable of producing clear gas that can be used directly in an engine plant. Thereby, you avoid expensive and complicated gas purification, and you get a plant that can produce electricity and heat with a high efficiency. Thus, there is basis for this type of plant to be a worthy replacement for the many small natural gas-fired plants, which often struggle with an overstretched economy.

The plant will have an electricity output of 500 kW and will, for the time being, be using wood chips as fuel. Energinet.dk supports the project with DKK 10 million from the ForskEL programme and DKK 5 million from the ForskVE programme.

Fluid bed gasifier

In addition to the plant in Hadsund, Energinet.dk has granted DKK 3.2 million for the design of a demonstration plant developed by Danish Fluid Bed Technology. The plant, which has been mentioned several times in the magazine, is able to degas organic waste, including manure fibres and other residual products from farming. The technology has been tested thoroughly in pilot scale at the Technical University of Denmark, and now, the plan is to upscale the plant with a factor of ten. However, the support from Energinet.dk only goes to a design study, after which a decision has to be made about the construction of the plant in connection with one of DONG's power plants.

– If the project becomes a success, we will be favourably disposed towards an application for support for an actual demonstration plant, says Kim Behnke. He can see large perspectives in the technology, not least because it gives the power plants good possibilities for replacing part of the coal with waste.

– In the latest energy settlement from February, the power plants were given permission to fire with certain types of waste, so we need to develop a technology that can handle the waste in a sensible way. Here, the fluid bed gasifier can turn out to be a good solution, because it can convert waste into gas, which can subsequently be burned in a power plant boiler, explains Kim Behnke. ■

photo: torben skøtt/biopress

DKK 15 million from the PSO funds of the year will go to the construction of a two-stage gasifier based on research results from the Technical University of Denmark and experience from a pilot plant at the boiler factory Weiss A/S.

DKK 37 million from PSO for bioenergy

photo: torben skøtt/biopress

The biogas plant in Foulum, where the researchers are for example going to start investigating how to optimise the gas output from livestock manure.

Electric cars and fuel cells became the major top scorers at the distribution of PSO funds for funds for 2009, but bioenergy is also nicely represented with a total aid amount of DKK 37 million.

Almost half of the DKK 130 million that the ForskVE programme has at its disposal in 2009 will go to electric cars and fuel cells. A large electric car project on Bornholm will get as much as DKK 32 million and a project for development of fuel cells will get DKK 25 million in aid.

However, bioenergy is also nicely represented in the three research programmes administered by Energinet.dk. From the ForskEL programme, almost DKK 29 million will be going to bioenergy, from the ForskVE programme, it is DKK 5 million from a total limitation of DKK 50 million, and from ForskNG, the entire grant of DKK 3 million will go to a biogas project.

The largest grants have gone to thermal gasification, which is mentioned in the previous article, but aid has also been granted for projects about handling and burning of biomass, and apart from this, four different projects about biogas have received aid.

For instance, a bit more than DKK five million has been granted for development of a technology for thermal pre-treatment, which makes the biomass more homogenous, gives it a higher energy density, makes it easier to reduce and more storage stable.

Within combustion of biomass and waste, two projects have been given a total of DKK 2.3 million in aid. One of the projects can be used to create two-dimensional images of the flue gas in a boiler system, while the other project is to develop a method to assess how much biomass there is in combustible waste.

Biogas projects

Biogas can receive aid from the ForskEL programme as well as the ForskNG programme. Under the first mentioned programme, there has to be an element of environmentally friendly electricity production, while the projects under ForskNG are more about transport and refinement of biogas.

From the ForskEL programme, Energinet.dk has granted a total of DKK 8.1 million in support for three different biogas projects. They are about pre-treatment of the biomass and development of methods for monitoring of the biological process. Furthermore, the research centre Forskningscenter Foulum will get DKK 3 million in aid from the rather new ForskNG programme. The money is to be used for a project that is supposed to optimise the biogas output from livestock manure and investigate whether pre-treatment of the liquid manure can help increase the gas production. *TS*

DKK 8 million from EUDP for biogas

Nordic Bioenergy and Novozymes are going to do research on how to optimise the transport of liquid manure from the farmers to the large centralised biogas plants.

With the latest energy settlement, the ground has been prepared for biogas production to the tripled from the current 4 PJ to 12 PJ per year. A minor part will probably be produced at the large pig farms, but the large majority of the expansion will most likely be based on joint biogas plants receiving liquid manure from the surrounding farms.

New biogas plants cannot expect to be supplied with industrial waste, which means that they have to be prepared for their economy to be based solely on degasification of the more meagre livestock manure. This places significant demands on handling and transport of liquid manure, and this has encouraged the board of the EUDP programme to grant DKK 8 million for development of a technology that can be used to pre-treat liquid manure in order to minimise the transport costs.

The grant has been awarded to Nordic BioEnergy - a newly founded company that is basing its research on the technology developed by Bioscan from 1985 until the company's bankruptcy in February 2007. In co-operation with Novozymes, Nordic BioEnergy is going to develop a plant concept where the manure is separated at the individual farmers. After that, the fibre fraction is to be liquefied using enzymes in order to make it possible to transport it in tank trucks to the nearest biogas plant, while the already liquid fraction remains at the farmer.

– The aim is to concentrate the livestock manure in the least expensive and most effective way. We will not be changing anything about the biogas plant - it is the logistics that need improvement, explains Lars Rohold, who is the manager of Nordic BioEnergy.

The EUDP project is expected to be completed in three years. *TS*

With a newly developed fuel cell for methanol, the action radius of electric cars can be tripled, and as methanol can be distributed in the same way as petrol, the fuel cell can help give the electric cars a crucial breakthrough.

photo: torben skøtt/biopress

At the inauguration of the energy town Frederikshavn, it was possible to test drive the various electrically driven cars.

Methanol can get the sale of electric cars

By Torben Skøtt

It is not many years ago that biofuels were launched as the green, environmentally friendly alternative to petrol and diesel, but since then, there has been a sometimes rather fierce criticism of the "green" oil. NGOs from most of the world are worried that large-scale use of biofuels might affect food safety, and several researchers have presented documentation that the environmental advantages of using biodiesel and bioethanol are very limited.

Conversely, electric cars have had some good fortune lately, for example with a new bill from the minister for climate and energy, Connie Hedegaard (K), who wants the EU to assess cars on the basis of their ability to displace fossil fuels. This will give the electric cars a much better position that the various types of biofuels, for example because an electric engine has a much higher efficiency than a combustion engine.

The sore spot of the electric car is still its range, which is usually 150-200 kilometres. For many people, this would be completely unacceptable, and that is probably one of the main reasons the electric cars have never really made it big.

But why not combine the efficiency of the electric cars with the ability of the biofuels to store energy over a long time? That is the philosophy behind a new concept proposed by the Northern Jutlandic development company SerEnergy. With a newly developed fuel cell, they are able to triple the action radius of the electric car, and as the cell is run by methanol, the trouble of building expensive and complicated infrastructure for hydrogen is avoided.

From biomass and waste to electricity

The new concept was presented on the 3rd of November in connection with the official inauguration of the energy town Frederikshavn. In that town, the city council has decided that the town should be self-sufficient with renewable energy in 2015, and already in September 2009, the first green filling station, where citizens and the home care service can fill up the new environmentally friendly cars, will be opened.

photo: torben skøtt/biopress

Anders Korsgaard from SerEnergy with one of the fuel cells that can give the electric cars a larger action radius.

The idea of combining fuel cells and batteries is not new at all, but it is unique that the town of Frederikshavn has chosen to use a liquid fuel such as methanol, which is converted into hydrogen in a transformer built into the fuel cell. In this way, they avoid having to build an expensive and complicated distribution system, as methanol – unlike hydrogen – can be distributed and stored in the same way as petrol and diesel.

Methanol, which is also called wood alcohol, is currently one of the most frequently used chemicals in the world, and it costs pretty much the same as diesel. Among other things, it is used as antifreeze and solvent, and it is also used in the production of various chemicals. Methanol can be produced on the basis of fossil fuels such as coal and natural gas, but biomass can also be used as raw material.

– Our system builds a bridge between past and future. We can get started today because we use a familiar fuel like methanol, and we can improve the along the way as we become better at producing methanol on the basis of biomass and

Technology	CO_2 Kg/GJ	SO_2 Kg/GJ	NO_x Kg/GJ	Particles Kg/GJ
Conventional diesel	333	0.01	0.62	0.02
Conventional petrol	352	0.01	0.13	0.00
Natural gas	294	0.01	0.10	0.00
Bioethanol (1. gen. E85)	225	0.04	0.57	0.00
Bioethanol (2. gen. E85)	139	0.02	0.27	0.00
Biodiesel (RME)	150	0.01	1.02	0.02
Rape oil	138	0.01	1.03	0.02
Methanol from biomass	80	0.02	0.18	0.00
Hydrogen	402	0.16	0.67	0.00
Electric cars	185	0.07	0.31	0.00
DME	120	0.04	0.74	0.02

Table 1. The environmental impact connected with the use of various technologies in the transport sector in 2025. The environmental impact is stated in Kg/GJ of mechanical energy. Source: Alternative fuels in the transport sector (Alternative drivmidler i transportsektoren), The Danish Energy Agency, January 2008.

waste, explains Anders Korsgaard, who is the manager of SerEnergy. He considers methanol to be a brilliant method of getting more renewable energy into the transport sector. Windmills can charge the car's batteries during periods with excess current, and when the batteries no longer suffice, you can switch to methanol, which supplies energy to the electric engine through a fuel cell.

The Danish Energy Agency backs up the project

In the Danish Energy Agency's report from January 2008, "Alternative fuels in the transport sector", they also point out the many environmental advantages of combining electric cars with fuel cells for methanol. For instance, the CO_2 emission as well as the emission of sulphur and NO_x are significantly lower for methanol than for bioethanol and biodiesel, and methanol is described as a solution with good energy exploitation and great flexibility (see figure 1).

A disadvantage is that it is an expensive solution as long as the production of fuel cells is limited. Once an actual mass production takes place, we can expect to see cars with fuels cells to a greater extent.

Biomass cannot be converted directly into methanol, but it can be converted into gas, and then, the gas can be included in the production of methanol. Subsequently, the methanol has to be converted into hydrogen, which is then turned into electricity through the fuel cell, which means that there is a long line of conversions of energy, which each result in a loss, but this does not concern Anders Korsgaard:

– It may be that, in the end, only a fourth of the biomass is actually converted into mechanical energy, but that is not particularly significant if we can utilise the wind power optimally in this way and get the sale of electric cars going, says the manager of SerEnergy.

Twice as effective

At the official inauguration of the energy town Frederikshavn, the press was shown a number of different electric cars, which will be characterising the townscape in the future. The selection ranged from little two-person city cars through delivery vans to a truck with an open truck bed.

What gathered the most interest was an eight-person electrically driven Fiat, which will be equipped with fuel cells from SerEnergy before long. At the presentation, the car was equipped with an electric 60 kW motor and a number of lithium-ion batteries, but the plan is to mount three fuel cells with a total wattage of a bit more than 13 kW.

Previously, the market has been divided into low- and high-temperature cells, which operate at 60-70 degrees and 600-1,000 degrees respectively, but SerEnergy has chosen to construct a fuel cell where the temperature will usually be at about 160 degrees. Thereby, they have achieved a sturdy construction that is better at enduring that the quality of the fuel varies than the types that are currently on the market.

Anders Korsgaard estimates that the electric car with fuel cells will have a total efficiency of about 50 percent, which means that it will be at least twice as effective as a traditional petrol-driven car. With batteries, the operating costs will be at about DKK 0.75/kWh and almost DKK 1/kWh when using methanol as fuel. ■

Among other things, the working group behind "Alternative fuels in the transport sector" recommend:

"..... that the development effort within thermo-chemical conversion of biomass and waste into biofuel through gasification is strengthened through the national research and development programmes for new energy technology. This technology may involve some fundamental advantages in the shape of better utilisation of energy and increased flexibility compared to biological conversion."

Thomas Hartung from Aarstiderne at the stirling engine, which is going to cover the company's heat requirement and 60 percent of its electricity requirement from now on. In the background, you can see the pyrolysis reactor, which partly supplies gas to the stirling engine and partly supplies coke for soil improvement.

photo: torben skøtt/biopress

Carbon is just as important as energy

The Danish eco-company Aarstiderne has recently inaugurated an advanced gasification plant with an appurtenant stirling engine that is not just going to produce electricity and heat. The aim is for half the fuel to be converted into coke, which Aarstiderne will use to improve the fertility of the soil.

By Torben Skøtt

Is it better to burn straw in the power plants than to plough the straw into the ground? Offhand, most people would probably say yes, but we can no longer ignore that when we use straw in the power plants, we have to deduct the amount of carbon that will be lacking the soil.

The explanation for this is that Denmark, as one of the few countries in the world, has chosen that changes in the soil's carbon balance should be included in the climate balance. This means that we can no longer settle for keeping track of the amount of greenhouse gases that we emit into the atmosphere. In the future, we also have to be able to account for whether we have increased or eaten into the soil's carbon storage.

The reason that the carbon content in the soil can affect the climate balance is that the amount of carbon added to the ground, for example by ploughing down the straw, no longer appears in the atmosphere as CO_2. However, there is actually a constant exchange of carbon between soil and atmosphere, which means that, in practice, it can be difficult to work out the balance, and the fact is that many have criticised the scheme of encouraging creative bookkeeping.

But carbon in the soil is not just about a larger or smaller emission of greenhouse gases. When the soil contains a lot of carbon, it is good at holding on to water and nutrients, and this is of particular significance to organic farmers, who do not have the possibility of supplementing with artificial fertiliser.

The world's first

At Aarstiderne, who supply organic fruit and vegetables to 40,000 families in Denmark, the fertility of the soil is a vital factor. Therefore, it is not surprising that precisely Aarstiderne could recently inaugurate the world's first plant able to convert biomass into energy as well as a product containing coke, which can be used for soil improvement.

The core of the plant is a pyrolysis reactor, where half the biomass is converted into gas and the other half is converted into coke. Subsequently, the gas is burned in a boiler, which partly supplies heat for the company and partly runs a stirling engine, which is connected to an electric power generator. In that way, Aarstiderne can use the new plant to get more fertile soil, cover the entire heat requirement and 60 percent of the electricity requirement.

– It may seem paradoxical that we only convert half the biomass into energy, but for us, it is a matter of a long-term strategy aimed to increase the carbon storage of the soil, explains Thomas Hartung, who is a co-owner of Aarstiderne. He is convinced that the coke fraction from the plant is a much better soil improvement product than the unprocessed biomass.

– If you leave straw on the ground, 95 percent is turns into CO_2, and only 5 percent is retained in the ground. If we choose to convert straw into coke instead, we can store about half of it in the ground, and in this way, we can increase the carbon storage of the soil, explains Thomas Hartung.

The Indians knew it

Using coke to increase the carbon storage of the soil and thereby improve fertility is not a new invention. According to Thomas Hartung, a Dutch researcher named Wim Sombroek discovered some very fertile soil types along the Amazon river in Brazil in the 1950s.

That area is otherwise characterised by exhausted soil, but it turned out that in connection with the Brazilian Indian's settlements along the river, there were areas that consisted of a very dark and very fertile soil.

Further analyses showed that the areas were thousands of years old, and that the black colour was due to supply of some kind of charcoal or coke. Thus, the Indians must have known already back then that charcoal can improve the fertility of the soil significantly.

Serendipity

Serendipity is a term for a situation where you find something interesting while looking for something completely different. For Aarstiderne, this is a recurring phenomenon, and therefore, they have chosen to establish a development company of that name. The first assignment of the company will be to commercialise that ideas and patents contained in the new combined energy and soil improvement plant.

Serendipity works closely together with Stirling Denmark, who have handled the technical installations, and there, they expect that they will be spending the next months to correct various teething troubles in order for the plant to be able to start fully automatic operation at the beginning of the new year.

– This is the first time that we have supplied a plant of that type, explains Lars Jagd, who is the manager of Stirling Denmark. The company, which is based on 15 years of development work, is specialised in the production of stirling engines driven by heat produced outside the engine. This can be heat from a wood chip boiler or a boiler fed with gas from a pyrolysis reactor, which is the case at Aarstiderne.

In connection with pyrolysis, the biomass is heated without the presence of oxygen. In this way, there is a cleavage of the material, creating a gas, which can be used for heating, and coke, which can be used for soil improvement or as solid fuel. Pyrolysis is a type of simple gasification where you only convert part of the material into gas - a technique that is for example used for production of charcoal.

– A major advantage of pyrolysis is that we can use practically all types of biomass and waste, and the temperature is so low that there is no risk that the coke fraction can contain harmful substances, explains Lars Jagd. According to his assessment, there is great potential for that type of plant, as it is possible to work with difficult fuels, which would be particularly attractive in the developing countries. ■

Sustainable biofuels

50 percent of the petrol consumption and 9 percent of the diesel consumption can be covered with biofuels without harming the production of foodstuffs.

In a proposal for directive from January 2008, EU suggests that the production of biofuels should be sustainable if they are to benefit by a tax reduction compared to fossil fuels. This has caused researchers from RISØ and the Technical University of Denmark to compose a report on what it takes for the production of green feels to be described as sustainable.

It appears from the report that forestry and farming with their connected industries can supply significant amounts of raw materials for the production of biofuels without harming the production of foodstuffs. Thus, the resources would be able to cover 50 percent of the petrol consumption and 9 percent of the diesel consumption, and if part of the crop area for feed and foodstuffs is taken over, the potential would be even greater.

– If we are to take over part of the fields for the production of fuel, the crops should also have another function, explains created the report together with Steffen Bertelsen Blume and Erik Steen Jensen.

Thus, it would not be sustainable to base the production of biofuels on crops such as potatoes, maize and sugar beets, which have a large consumption of diesel, fertiliser and pesticides. However, perennial and nitrogen-fixing crops such as lucerne and clover would be a sustainable solution, as their demand for field work, fertiliser and pesticides is minimal.

Many people have pointed out lucerne as the most sustainable crop, and as it also belongs in the better end of the scale with regard to energy output, it would be an obvious choice for the farmers that want to supply raw materials for the production of biofuels. *TS*

Crop	Litres
Maize	7.587
Lucerne	6.805
Sugar beets	6.741
Winter wheat	5.126
Willow	5.000
Spring wheat	2.607

Table 1. Output of biofuels per hectare for select crops.

Source: Calculation of the Danish biomass resource to be used for the production of biofuels for the transport section up to the year 2020, Risø-R-1665.

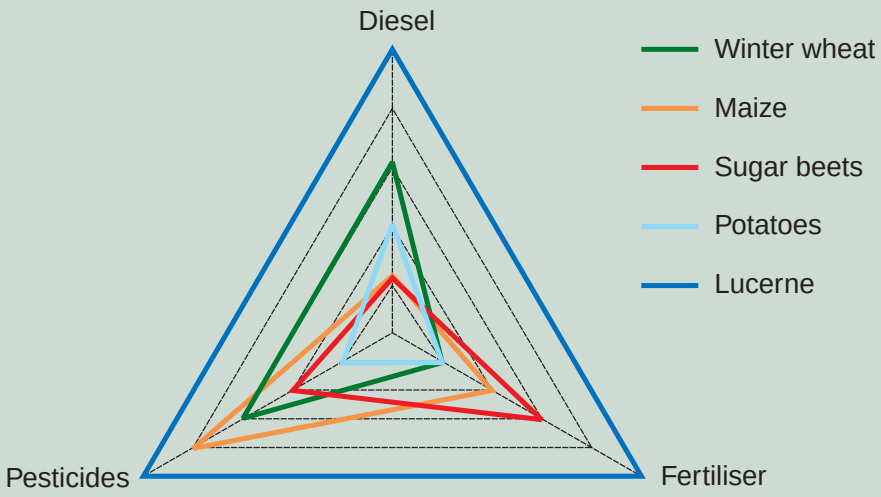

Figure 1. Sustainability of five select crops, based on the consumption of diesel, pesticides and fertiliser. The size of the triangle indicates the sustainability. I.e., crops with the largest triangle are the most sustainable.

photo: det jordbrugsvidenskabelige fakultet/århus universitet

Choose the right crops for the biogas plant

With the right combination of various growing systems, farmers can supply energy crops with a high gas potential for the biogas plants all year round.

By Poul Erik Lærke, Margrethe Askegaard, Henrik B. Møller and Uffe Jørgensen

With the latest energy settlement, which laid the ground for an expansion of the biogas production from the current 4 PJ per year to 12 PJ per year before 2025, there will be competition for the organic waste, which has ensured the finances of most biogas plants so far. Thus, many of the new plants should be prepared to only be supplied with the more meagre livestock manure, possibly supplemented with energy crops, which often have significant gas potential.

A group of researchers under the leadership of the Innovation Centre for Bioenergy and Environmental Technology (CBMI) has therefore chosen to investigate how the farmers can optimise their production of energy crops. In a sandy clay soil at the testing station Foulum Forsøgsstation, they have registered the energy production in 2006/2007 from nine different growing systems, and in that connection, it has turned out that there is a number of different combination that can make it interesting for the farmer to grow crops for the production of biogas.

Fodder beets are the absolute top scorer among the tested energy crops with regard to output as well as energy production.

The combination of crops in the various systems can be seen in figure 1, where the first crop in systems 1 to 6 was established in the autumn of 2006, while the crops in systems 7 to 9 were not established until the 30th of March, 11th of April and 17th of April 2007 respectively. The dates for harvesting can be seen in the figures.

The calculation of energy production from the crops is based on the production of methane in small test plants, which provides a good simulation of the conditions in a full-scale biogas plant. There was the best gas potential in green rye, where the production amounted to 395 m^3 of methane per ton organic matter, and the worst in the tops of Jerusalem artichokes, which only produced 300 m^3 of methane. The other crops had a gas potential of about 350 m^3 of methane per ton of organic matter.

Subsequently, the net energy production has been calculated by subtracting the energy consumption for field work and fertiliser, as well as the consumption of electricity and heat at the biogas plant. Energy consumption connected with transport of the biomass and any need for storage of the crops have not been taken into consideration.

Fodder beets is the top scorer

Fodder beets were the absolute top scorer in the test, with regard to output as well as energy production. This crop produced about 22 tons of dry matter per hectare, which resulted in a net energy production of 250 MJ per hectare.

At the other end, we find system 8 with spring triticale/rye grass, where the production only reached almost 11 tons per hectare, followed by hemp with a production of about 13 tons per hectare. In the other growing systems, the production was between 16 and 18 tons of dry matter per hectare, corresponding to a net energy production of between 150 and 200 MJ per hectare.

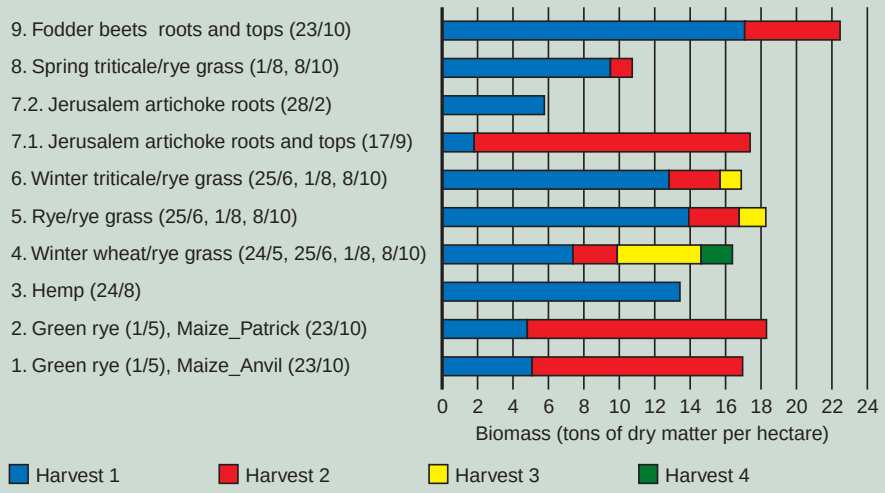

Figure 1. Production of biomass in 9 different growing systems. The dates in parenthesis show the time of harvesting.

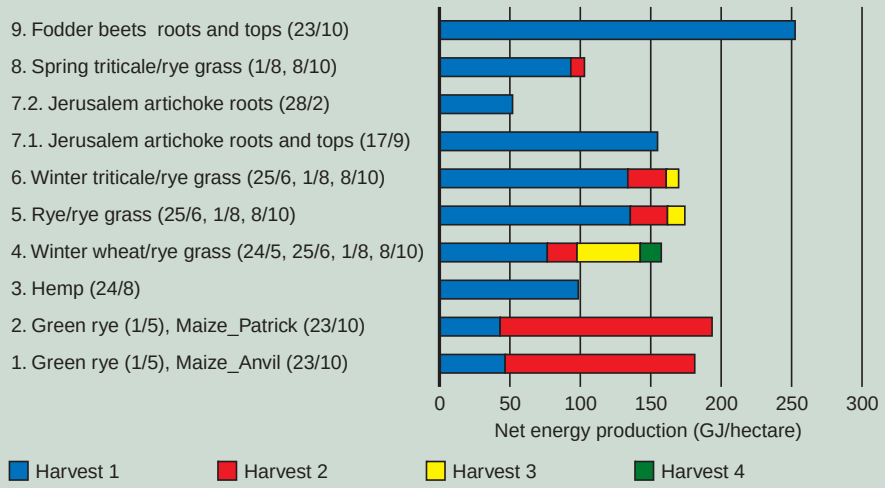

Figure 2. Net production of energy in the 9 growing systems. The dates in parenthesis show the time of harvesting.

The results also showed that the roots of the Jerusalem artichokes contain less than half the amount of dry matter that they can supply after the tops have withered. Therefore, it is necessary to harvest the tops before they wither in order to achieve an acceptable total output from the crop.

Choose more crops

By choosing crops from several different growing systems, it would be possible to reduce the expenses connected with storage of the biomass. This kind of strategy could look like this:

Harvest of green rye in the spring before the sowing of maize, harvest of grass fields throughout the summer, continue with the tops of Jerusalem artichokes followed by beets or maize during the winter. At the end of the winter, you can supplement with the roots from Jerusalem artichokes, if there is a need for thinning out of the roots before the following growth season.

The study "Production of bioenergy and biofuels from biomass" ("Produktion af bioenergi og biobrændsler fra biomasse") has been carried out with support from the Danish Ministry of Science, Technology and Innovation and the Danish Ministry of Food, Agriculture and Fisheries.

Poul Erik Lærke, Margrethe Askegaard, Henrik B. Møller and Uffe Jørgensen are all employed at the Faculty of Agricultural Sciences at Aarhus University, www.agrsci.dk.

Genetic modification is to make bioethanol less expensive

A group of American researchers have genetically modified a bacterium that can reduce the production costs of bioethanol significantly.

Everywhere in the world, researchers are working intensely to develop the so-called 2nd generation technology that is going to make it possible to produce bioethanol on the basis of cellulose-containing residual products, such as straw and wood waste. In that way, you can avoid using raw materials that are normally used for production of foodstuffs, and you get the possibility of using a wide selection of different residual products that would usually be considered to be waste.

So far, the production of bioethanol has taken place with the use of naturally occurring bacteria. When dealing with sugar-containing crops, this has been unproblematic, but when using waste and residual products, it has been necessary to supplement with enzymes, as the bacteria are not able to keep the process going when the temperature exceeds 37 °C.

The new genetically modified bacteria, which has been given the name ALK2, can ferment all the sugar available in the biomass, and it works at temperatures of up to 50 °C. In this way, the supply of expensive enzymes can be reduced significantly. Thus, controlled tests at Darthmouth College in New Hampshire show that the amount of enzymes can be reduced two and a half times by using ALK2 instead of the naturally occurring bacteria.

Another advantage of the genetically modified bacteria is that there is no production of by-products in the shape of organic acid. The only organic product released with ALK2 is pure ethanol.

Source: www.biofuels.com

Online control of the biogas process

photo: torben skøtt/biopress

The biogas plant in Ribe is one of the places where the researchers have carried out full-scale tests.

Control and regulation of biogas plants will be an interesting market in the years to come. In Germany, where there are currently 3,800 biogas plans, monitoring and control of the biogas process is one of the areas that attract significant research funds, and in Denmark, we are also catching up quite well.

By Jens Bo Holm-Nielsen

At the Centre of Bioenergy belonging to University of Aalborg, we are for example working on online control of the biogas process using so-called process-analytical technologies. The work partially takes place at the University of Aalborg's laboratories in Esbjerg, partially at Aarhus University, and finally, a number of full-scale tests have been carried out at the biogas plants in Lintrup and Ribe.

One of the areas that we are focused on is how to extract samples that provide an accurate representation of the composition of the biomass. As we all know, the raw materials are rather non-uniform, as they consist of organic waste as well as livestock manure, and therefore, the aim is to get a representative cross section of the various types of biomass.

Another area that we are working on is online monitoring of the biological process. Production of biogas involves thousands of bacteria groups, and the individual process steps have not yet been described in detail.

Continuous collection of dependable data is vital in order to be able to control the process. This applies to biogas plants as well as the many new biorefineries, which are supposed to be able to supply liquid fuel for the transport sector in the future. Therefore, new research results can easily have a spillover effect on other types of bioenergy, just as the opposite can be the case, of course.

Process-analytical technologies

A necessary precondition for being able to optimise the biogas production is much better monitoring and analysis of the biological process than is the case today.

For that purpose, we are working on developing a number of technologies that give the plant managers of the biogas plants a much better change of intervening quickly in case of imbalances in the process (see figure 1). The methods used today are imprecise as well as slow, and there are countless examples of biogas plants that have suffered great losses because the biological process has gotten out of balance.

A deeper understanding of the dynamics in the process often generates new information that can help optimise the systems in the future. Researchers are currently working intensively on developing process-analytical technologies for the medicine, feed and foodstuff industries, but the biogas sector can definitely take part in that development process.

Tests and sensors

In order to overcome the difficulties of extracting a correct sample of the biomass, a research group at the University of Aalborg has developed a concept where you transform the content of a 3-dimensional bioreactor into a 1-dimension al pump loop (see figure 2). This provides a much better possibility of carrying out a

correct analysis of the biomass in the reactor.

Next, it is vital to choose sensors carefully. We have chosen to work with a so-called near infrared spectroscopy (NIR), where light rays with wave lengths from 780 nm to 2500 nm are used.

This system has turned out to be very useful for characterisation of the organic material in a biogas reactor. In practice, it takes place through the light rays hitting the liquid from the biogas reactor, which causes the molecules that contain organic acid (VFA) to start vibrating. Some of the light is absorbed, while other light rays are thrown back. A lot of information is available from these light spectres, and on the basis of different light bands, you can estimate the content of VFA in the biomass.

Throughout the last decades, NIR spectroscopy has been used to characterise the quality of various foodstuffs and feeds, and today, this is routine at the large laboratories.

Apart from the NIR spectroscopy, we are working on research and development within the mid-infrared spectrum (MIR), where the light rays have a wave length from 2500 nm to 6,000 nm.

Finally, we are working on being able to characterise differences in organic dry matter with acoustic sensors. In practice, this means small accelerators that measure vibration differences of the individual pump-in and pump-out places.

Process-analytical chemometrics

Process-analytical chemometrics are vital in any type of fermentation industry, including the production of biogas. It consists of commercial software programmes that can handle large amounts of data. What is most important is that the information about for example VFA and ammonium exhibits a certain breadth. Because, you need low, medium as well as high values for the development of the models.

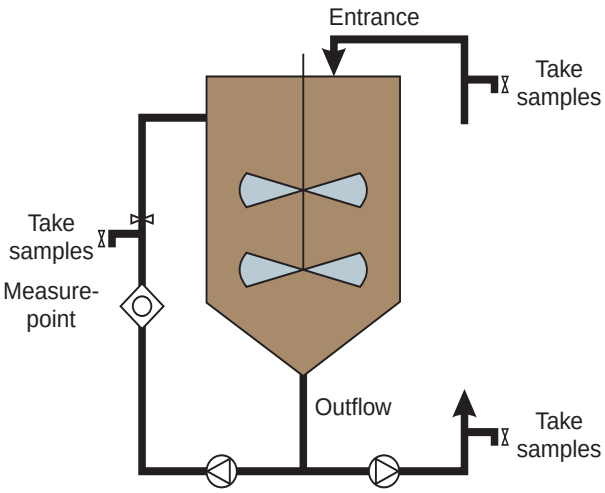

Figure 2. Biogas reactor with location of measuring points and drawing taps for tests. The concept has been developed for full-scale reactors within fermentation industries and biogas plants.

Current results

The researchers have succeeded in making good and sturdy calibration models of all VFA acids, including a strong model for propionate. However, it has not been possible to model organic acids with very low levels in a full-scale plant, where the levels are often between 0 - 1,000 mg per litre.

On the basis of tests at the biogas plant in Lintrup in Southern Jutland, the researchers have been able to create models of total VFA, acetate, propionate and NH4, which are very interesting control parameters that can warn the plant manager of any imbalance in the process.

A critical parameter is that well-functioning biogas plants that do not get near the critical limit for overload cannot get particularly good control models. Thus, there will be a need for follow-up and further development of the tools and not least to make the systems sturdy and simple to handle and maintain.

The main thing is to continuously monitor the VFA level of the biogas plant. Is it increasing, decreasing or stable. Active measures have to be taken if online measurements reach a pre-set level of for example 3,500 mg VFA per litre of biomass.

Jens Bo Holm-Nielsen is employed at the Centre of Bioenergy belonging to the University of Aalborg and made a PhD thesis about online control of the biogas process using process-analytical technologies (PAT). An electronic version of the thesis can be obtained by sending an e-mail to jhn@aaue.dk.

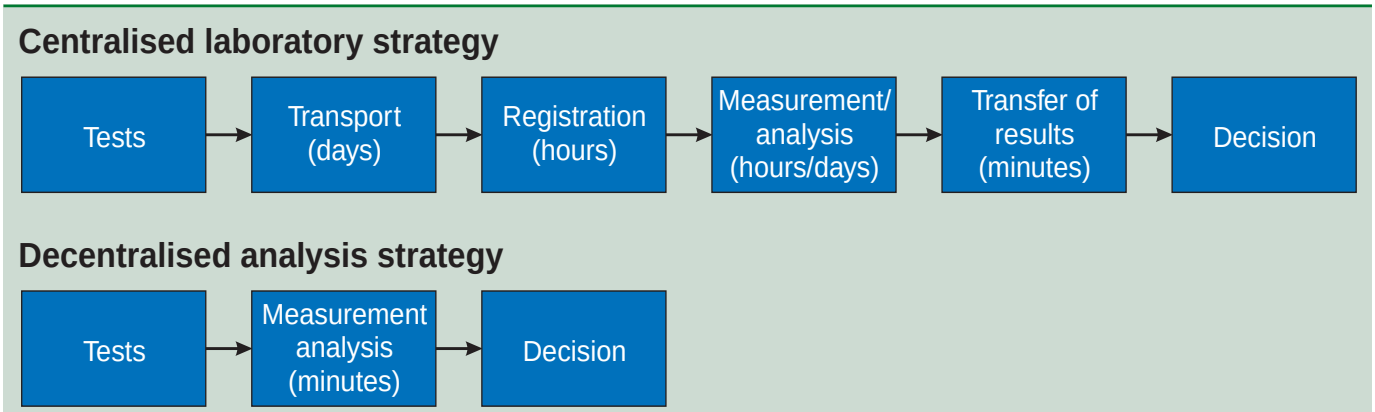

Figure 1. Different strategies for monitoring and control of the biogas process. With the decentralized strategy that the researchers are working on developing, the plant managers will have a much better change of intervening quickly if the process shows signs of an imbalance.

DKK 17 million for biorefinery

Professor Birgitte Ahring, who for many years did research in biofuels at the Technical University of Denmark, but is now employed at the University of Aalborg, has been given DKK 17 million from the Danish Agency for Science, Technology and Innovation. The money is to be used for a biorefinery that is going to produce 2nd generation biofuel, feed, antibiotics as well as additives for feed and foodstuffs. The refinery is supposed to be located in Ballerup.

Apart from being the manager of Biogasol, Birgitte Ahring manages the establishment of the University of Aalborg's centre of bioenergy and bioproducts as well as Washington State University's centre of bioproducts and bioenergy.

Butanol is better than ethanol

Researchers at the Californian Joint BioEnergy Institute have produced a type of yeast that produces the 2nd generation biofuel butanol as part of its metabolism, writes the Danish engineering weekly Ingeniøren.

Butanol is a type of hydrocarbon that is even more suitable for cars than ethanol. It can be used in the existing infrastructure, and the cars will be able to run on up to 85 percent butanol, even without any changes to the car. In an article in the magazine Microbial Cell Factories, the researchers write that they have increased the yeast's ability to produce butanol tenfold, and that they expect to be able to increase the productivity even further.

New application round for the Danish National Advanced Technology Foundation

The 27th of January is the deadline for applications for aid for advanced technological projects and platforms.

The Danish National Advanced Technology Foundations invests in advanced technological projects and platforms where research institutions and companies work together. Since 2005, the foundation has invested DKK 807 million in 60 advanced technological projects and platforms, including projects within energy and environment.

An advanced technological project is outlined and aims determinedly at creating a specific result that increases the parties' possibility of improving their knowledge and market position. Advanced technology projects have a duration of 2-4 years and a total budget of DKK 5-30 million. The investment of the Danish National Advanced Technology Foundation is DKK 2.5-15 million.

An advanced technological platform is a cooperation between research institutions and companies and creates a radically new technology that clears the way for the participating parties to start up to several new commercial activities and has a duration of 3-5 years and a total budget of DKK 30-150 million. The investment of the Danish National Advanced Technology Foundation is DKK 15-75 million.

In 2009, the deadlines for sending in expressions of interest are the 27th of January and the 1st of September. Select applicants are then asked to send in applications before the 30th of March and the 28th of October respectively.

Further information about the Danish National Advance Technology Foundation is available at www.hoejteknologifonden.dk

Højteknologifonden

New application round for EUDP

The deadline for EUDP is the 25th of February 2009. During the autumn of 2009, there will be another application round, but in the autumn round, you can only apply for a maximum of DKK 5 million in aid for each project.

EUDP´s next application round will be carried out already at the beginning of 2009 with deadline on the 25th of February. The notice materials can be retrieved at www.ens.dk/eudp from the middle of January 2009.

It is possible to apply for aid for projects related to all types of energy technologies that meet the objective of the EUDP legislation.

During the fall of 2009, it will also be possible to send in applications for EUDP, but only for aid of no more than DKK 5 million per project. Therefore, application have to be sent in before the 25th of February for projects applying for aid of more than DKK 5 million, if the aid is needed in 2009.

The applications are to be made in English, if the aid applied for is above DKK 3 million.

The assessment of the project applications will entail significant focus on the commercial perspectives in the applications, including that there is a well-founded and clear business plan.

EUDP stands for Energiteknologisk Udviklings- og Demonstrations Program (Energy Technology Development and Demonstration Programme) - see www.ens.dk/eudp. EUDP has an independent board and secretariat in the Danish Energy Agency.

EUDP will invite all potential applications to an information meeting about the spring application round at the end of January 2009. Further information will be put on EUDP's website.

EUDP

Raw materials for biogas plants

Seminar about optimisation of raw materials for biogas plants at the research centre Forskningscenter Foulum 29th of January 2009 at 10 AM to 4 PM

Schedule:

- Welcome and introduction. Michael Støckler, CBMI.
- How large are the potential biomass resources in Denmark for biogas? Uffe Jørgensen, Faculty of Agricultural Sciences, Aarhus University.
- Which financial possibilities does the latest energy settlement provide for biogas production and for payment of new raw materials? Kurt Hjort-Gregersen, Institute of Food and Resource Economics, University of Copenhagen.
- Comparison of dry matter output, biogas convertibility and net energy surplus of various crops for biogas. Poul Erik Lærke, Faculty of Agricultural Sciences, Aarhus University.
- Dry matter output and biogas convertibility of maize and festulolium at various localities and harvest times. Søren Ugilt Larsen, AgroTech.
- Possibilities of optimising the energy content of livestock manure. Henrik B. Møller & Alastair James Ward, Faculty of Agricultural Sciences, Aarhus University.
- Energy utilisation of grass from extensive areas. Lisbeth Nielsen Natur & Landbrug and Henrik B. Møller, Faculty of Agricultural Sciences, Aarhus University.
- How can the convertibility of biomass to biogas or ethanol be increased through pre-treatment, and what will it cost? Hinrich Uellendahl, Centre of Biotechnology & Bioenergi, University of Aalborg Copenhagen
- Is there future potential in decentralised production of ethanol, biogas and feed from beets? Karl Martin Schelde, CBMI.

Price: DKK 100 for students and DKK 300 for others, including lunch.

Registration: No later than the 22nd of January to Mette Toft Christensen, e-mail mtc@cbmi.dk, ✆ +45 8999 2503

CBMI AgroTech

COPENHAGEN INSTITUTE OF TECHNOLOGY
AALBORG UNIVERSITET KØBENHAVN

Gasification plant for waste

Title:	4781 - High-temperature slagging waste gasifier, Phase 1
Responsible:	TK Energi, Thomas Koch, ✆ 4618 9000
Grant:	PSO – DKK 4,194,000

The purpose of the project has been to evaluate a concept for a gasification plant for waste as well as to plan select components for a pilot plant.

The first analysis showed that a so-called entrained flow gasifier would be a sensible choice. The technology has been used commercially for coal, and it appears that the heavy metals from the waste will be encapsulated in the slag, which means that the risk of leaching will be minimal.

The preliminary tests were carried out in a vertical cyclone reactor with dried waste water sludge as fuel. It was possible to get a bit of slag out of the test, but it was not possible to achieve satisfactory control of the gasifier. Therefore, it was decided to construct a new horizontal plant where fuel and oxygen is blown in through one end, while gasification gas and slag comes out the other end. The advantage of that design is that a slag bath is formed at the bottom of the reactor, where large particles are caught. Thus, they get a longer retention time than the gas, which sets lower demands for trituration of the fuel.

Tests with the new plant showed that it is possible to gasify waste water sludge, but that the outlet of the reactor has to be changed. Analyses of the slag showed that the risk of leaching of heavy metals is lower than for slag from Danish waste incineration plants, and that the slag meets the requirements for use as construction material.

In preparation for the construction of the next gasifier, a design study has been made of a number of relevant components, where the focus has for example been on:

– A new technology for pre-treatment of waste at low temperatures.
– A new gasifier design that ensures that the outlet cannot be blocked by slag.
– A new system for purification of the gas.
– A financial study that reviews the finances of a commercial plant

photo: tk energi

Tests with gasification of waste water sludge in a horizontal test reactor at TK Energi.

Optimisation of staged gasification plant

photo: biosynergi proces

A peek into the reactor at the gasification plant in Græsted.

Title:	5729 - Upgrading and optimisation of the plant operation of staged gasification plant (the castor plant in Grædsted)
Responsible:	BioSynergi Proces ApS, Henrik Houmann Jakobsen, ✆ +45 4586 1430
Grant:	PSO – DKK 2,942,000

With aid from the Danish Energy Agency's development programme for renewable energy, BioSynergi Proces ApS finished the establishment of a so-called open core plant for gasification of wood chips in 2003-2004. The gas is used for the production of electricity and heat through a gas engine that is connected to an electric power generator.

The current project has been about further development of the plant, with particular focus on reducing the daily tending tasks and on ensuring stable and unmanned operation of the plant. Furthermore, there has been as special sub-assignment that has consisted of gaining increased insight and achieving practical experience with optimisation of the engine operation. At the start of the project, the plant was only able to supply electricity for the network for about 200 hours, but at the end of the project, 2,500 hours of engine operation on gasification gas had been achieved.

A more detailed description of the project's results is available in the two reports from September 2008, which can be obtained by contacting BioSynergi Proces ApS.

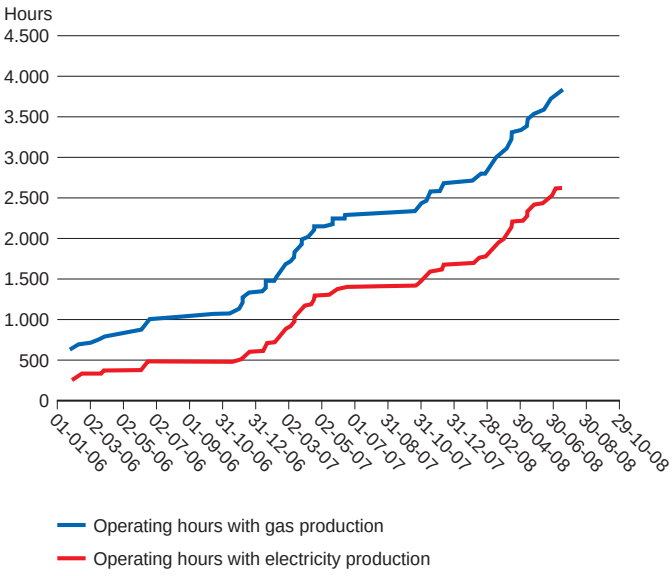

Figure 1. The accumulated number of operating hours with the gasification plant from the 1st of January 2006 until the end of the project in the autumn of 2008.

Optimisation of gas output from biogas plants

Title:	33030-0017 - Methods for optimisation of biogas output of liquid manure-based biogas plants
Responsible:	The Technical University of Denmark, Rena Angelidaki, ✆ +45 45251429
Grant:	EFP – DKK 7,000,000

The purpose of the project has been to investigate the possibilities of increasing the biogas production from liquid manure through serial operation of reactors, change of stirring procedures and post-treatment of fibres.

The results show that when two reactors are series-connected, the gas production can be increased by 11 - 17.8 percent compared to parallel operation. The increase in gas production mainly comes from the second reactor in the series, and it is vital that both reactors operate at the same temperature in order to ensure a stable process. The tests with change of stirring procedures show that the gas production can be increased by 12.5 percent by changing from continuous stirring to only ten minutes of stirring in the reactors each day.

Through post-treatment of degasified fibres, it is possible to achieve improved gas output through aerobe treatment and trituration, while chemical treatment does not result in any significant improvement.

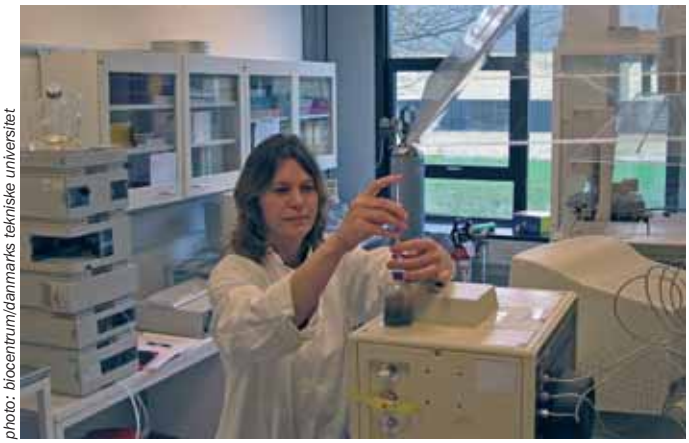

photo: biocentrum/danmarks tekniske universitet

Test at the Technical University of Denmark show that the biogas production can be increased to series operation of reactors, change of stirring procedures as well as post-treatment of fibres.

The market for biofuels

Title:	33032-0146 – REFUEL – Renewable fuels for Europe
Responsible:	COWI, Henrik Duer, ✆ +45 4597 2211
Grant:	EFP – DKK 693,000

Refuel, which stands for "Renewable Fuels for Europe", is a large EU-financed project, where a so-called "road map" describing how the market for biofuels can develop in the EU up to the year 2030 has been developed.

In this project, market opportunities and potentials for biomass resources have been analysed for countries in the EU 27 and Ukraine, and scenarios have been set up for the development up to the year 2030. Furthermore, specific suggestions have been made for framework conditions, and the political means of control have been assessed.

The project has shown that there is enough biomass potential to ensure significant supply of biofuels, but it is vital to accelerate the development of new 2nd generation technologies in order to ensure sustainable development.

X-ray analysis of biofuels

Title:	5773 - X-ray analysis of CO_2-neutral fuels
Responsible:	Danish Technological Institute, Lars Nikolaisen, ✆ 7220 1302
Grant:	PSO – DKK 617,000

The traditional chemical analyses of biofuels and ash from burning of biomass are expensive as well as slow. An obvious alternative could be x-ray analyses, which are less expensive as well as quicker, but experience from this project shows that the results can in some cases deviate from the traditional chemical analyses.

The most conspicuous is a consistently large deviation with regard to the element silicon, but also with regard to the lighter elements, there are large or small variations. For the other substances, there is pretty good consistency between the reference method and the x-ray analyses.

For most fuels, the mass balance of chlorine is very precise with deviation down to 0 percent. This may be connected to the fact that chlorine is mainly in the flue gas and not so much in the ash.

The opposite is the case with sulphur. There, the main part of the element is in the ash and only a minor part is in the flue gas. In several cases, more sulphur was found through the x-ray analysis than through the reference method, while there was good consistency between the two methods in other cases. The reason for the deviating mass balances of sulphur is unknown.

Gasification of biomass for fuel cells

Title:	33030-0113 and 33031-0093 – GreenFuelCell – Integreret forgasnings-brændselscelleanlæg (SOFC)
Responsible:	TK Energi A/S, Thomas Koch ✆ +45 4618 9000
Grant:	ENS – DKK 1,729,000

The purpose of the project has been to develop a scalable staged gasification concept where the gas is so pure that it can be used in a fuel cell.

In this project, two parallel tracks were developed - one at ECN in the Netherlands and one at TK Energi in Køge. At the same time, researchers at the Technical University of Denmark and RISØ worked on removing the tar content of the gas. ICT in the Czech Republic and CEA in France worked on removing inorganic components from the gas. In France, CEA worked together with Dutch ECN on developing the fuel cells, while Force Technology in Denmark handled the system study.

ECN's gasification concept failed, as the system for gas purification generated large amounts of soot. At first, TK Energi succeeded in demonstrating the concept, but in the final version, there were problems with the part of the reactor where the pyrolysis takes place. At the Technical University of Denmark and RISO, the researchers gained new knowledge about how to remove tar from a staged gasification plant, while ICT and CEA did not manage to find new methods for purification of the gas. At ECN and CEA found new limits for how sensitive the fuel cells are to typical pollutants in the gas.

Apart from support from the energy research programme, the project has been given support from the EU's 6th framework programme.

Co-firing of biomass and natural gas

Title:	6526 - Co-firing of biomass with natural gas and NOx formation through biodust firing
Responsible:	DONG Energy, Peter Simonsen, ✆ +45 9955 1111
Grant:	PSO – DKK 4,500,000

The purpose of the project has been to achieve new knowledge about co-firing of biomass and natural gas at power plants using dust firing. In that connection, measurements have been carried out at the plant Avedøre II as well as a minor test plant at the Technical University of Denmark, and a number of valuable experiences have been gained about emission of nitrogen oxide (NO), burnup of wood particles and formation of deposits in power plant boilers.

Among other things, the results show that no matter which combination of fuel you use, the emission of NO can be reduced by dividing the burning into two stages, and at Avedøre II, it is possible to minimise the emission through proper selection of operating parameters. The highest emission was measured at firing with oil. When using wood combined with natural gas, the emission did not depend of the percentage of wood.

The project group has made a detailed description of combustion of wood particles at dust firing. At the Technical University of Denmark, the wood particles were exposed to powerful heating, which resulted in a significant release of pyrolysis products and a low coke fraction of 2-7 percent. In most tests with powerful heating, spherical, very porous coke particle were formed. The tests at the Avedøre plant showed that up to 99.8 percent of the wood burned out at a content of O_2 as low as 1.5 percent.

As we all know, the use of biomass in power plants can cause problems with deposits and corrosion, but at the Avedøre plant, only moderate deposits were found. When wood is burned together with oil or natural gas, alkali metal usually occurs as sulphate in the deposits, while there is hardly any chlorine. When adding fly ash from coal firing, there is an increased content of alkali-Al-silicate in the deposits.

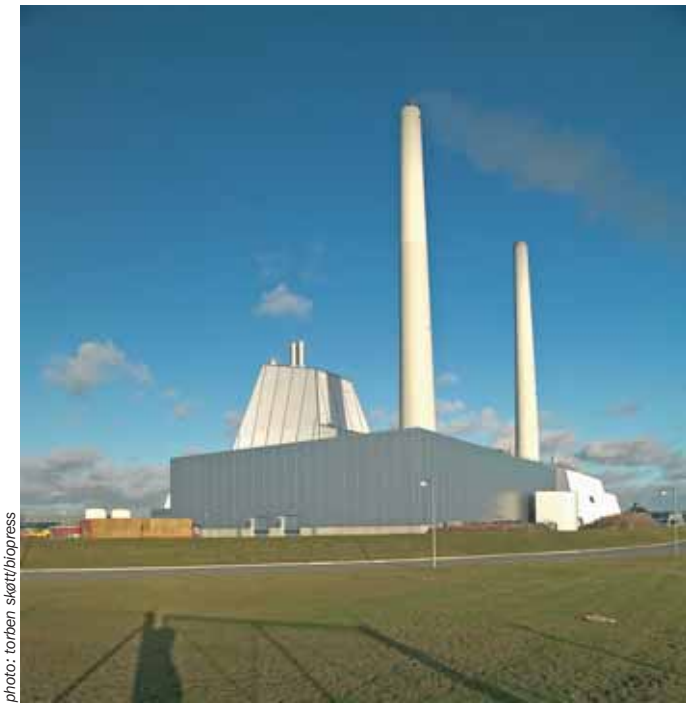

photo: torben skøtt/biopress

At the Avedøre plant in Copenhagen, only moderate deposits were found in the boiler for biomass.

FiB – Bioenergy Research is published with support from Denmark's Energy Research Programme. The newsletter, which is free of charge, is published six times a year both in a Danish and an English version. Both versions can be downloaded from the Internet at the following homepage: www.biopress.dk

The Danish version of the newsletter is also available in a printed version. Further copies of the Danish version can be ordered from BioPress, via the following e-mail address: biopress@ biopress.dk, or telephone nr +45 8617 8507.

Editor responsible:
Torben Skøtt

ISSN: 1604-6358

Production:
BioPress
Vestre Skovvej 8
DK-8240 Risskov
Denmark
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E-mail: biopress@biopress.dk
Homepage: www.biopress.dk

Photo on the front page:
Torben Skøtt and
TK Energy

Next issue:
– to be published in the middle of Marts 2009. The deadline for articles is 15 February 2009.

Historical lift for energy research

photo: torben skøtt/biopress

At the beginning of November, the negotiations about the globalisation funds fell into place. This means that DKK 750 million will be allocated for energy research and development in 2009.

– This is a historically large amount. That much money has never been allocated for energy research before. We have doubled the funds in four years, says the Danish minister for climate and energy, Connie Hedegaard, about the DKK 750 million, of which DKK 43 million are earmarked for climate research.

The responsibility for the grant lies with the settlement parties behind the globalisation funds. This means the Danish government and the parties Dansk Folkeparti, Socialdemokratiet and De Radikale. Together, they have decided that the amount for energy research should increase to DKK one billion in 2010.

– The green technologies are the growth areas of the future, which will create jobs, growth and development in Denmark. But this kind of development does not come from the market alone: The state has to help make sure that the best and most viable technologies are explored, developed and tested, so that they can overcome the transition from idea to market. That is the reason why it is so vital that we prioritise money for research and development, says the Danish minister for climate and energy, Connie Hedegaard (K).

Throughout recent years, the export of Danish energy technology to other countries has been a great success. For instance, technology worth DKK 52 billion was exported in 2007. That is 13 percent more than the year before and ten times more than the growth in the rest of the merchandise export - which only rose by 1.3 percent.

The agreement to spend DKK 750 million on energy and climate research in 2009 is welcomed by many, but several organisations point out that it is far from enough. In a joint press release, the Confederation of Danish Industry, the Danish Metalworkers Union, the Danish energy association and the Danish Society of Engineers have thus asked the politicians to allocate DKK four billion for this area in the year 2020. This is necessary, according to the four organisations, if Denmark is to be able to continue developing its sustainable energy system and reduce the emission of climate gases. *TS*