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From dung to smoke

There are several indications that power plants may help solve a waste problem in the agricultural sector and at the same time obtain better operation of their own plants. It has been proved that adding the fibre fraction from animal manure can solve problems with slagging and corrosion, and the dried fibres have almost the same calorific value as straw.

By Lasse Tobiasen, Jacob N. Knudsen and Henrik B. Møller.

Elsam, Energi E2 and a number of project partners are studying the feasibility of procuring cheap additives to solve corrosion and slagging problems in biomass boilers.

The build-up of large amounts of slag in straw-fired CHP plants is a well-known problem, which may entail increased boiler cleaning costs and associated production losses, when the boiler is not in operation. The problems vary considerably from one year to another, as the chlorine and alkali contents of the straw vary a lot.

The use of additives has been known for a long time, and there are several commercial products on the market known to have the desired effect. Some of these are clay minerals, lime and calcium phosphates. However, most additives are rather expensive, and at the moment the extra boiler cleaning costs remain lower than the cost of buying and using commercial additives.

Alternative additives

Through the Alternative Additives (Alternative Additiver) project, which has received PSO (Public Service Obligation) funds, a group of researchers have studied the feasibility of various cheap residual products from the industrial and agricultural sectors as alternative additives. These are:

- the fibre fraction from animal manure
- mash from beer production

▶

- molasses from sugar production
- fly ash from other power plants
- fractions of clay or sand
- lime.

In most cases, the residual products cannot be used unprocessed, but need pre-treatment before they can be used in power plants. Furthermore, it is necessary to ensure proper firing of the boiler, and finally the relevant environmental problems need to be tackled. It is for instance necessary to ensure that the additives do not create increased emissions or residual products that are harmful to the environment.

Several factors determine whether a particular residual product is suitable as an additive. The amount and composition of the ash are particularly important, as the active substances of the additive ash must react with the fuel ash at the correct ratio. In addition, accessibility and price play a considerable part, and it may also be of some importance whether the additive represents a calorific value, or whether it is necessary to add extra energy due to a relatively high moisture content.

Full-scale tests

In the initial phase of the project, tests have been carried out at the CHP plant in Slagelse (Slagelse Kraftvarmeværk) with e.g. the fibre fraction from degassed animal manure - also known as humus, i.e. liquid manure which has been through a biogas plant and subsequently been dewatered in a decanter centrifuge. The centrifuge separates the manure into a liquid fraction and a fibre fraction with high contents of dry matter, phosphor and organic nitrogen.

The tests at the CHP plant in Slagelse suggest that adding 10-20 per cent dry humus to straw reduces the risk of slagging in the boiler plant. This may seem surprising at first, because combustion of 100 per cent animal manure is known to cause problematic phosphate deposits. In smaller amounts, however, phosphor in animal manure binds potassium from straw into less corrosive compounds such as $K_2CaP_2O_7$ and $KCaPO_4$, which are relatively easy to remove by means of ordinary soot blowing.

photo: torben skøtt/biopress

The tests with addition of humus were carried out at the straw-fired CHP plant in Slagelse.

These results have become particularly interesting after a vast majority in the Danish parliament has decided to pass legislation that will make it possible to use the fibre fraction from degassed biomass as fuel.

Assessment of additives

When short-term tests are used to assess whether an additive has had the desired effect, researchers often use a deposits probe, which is placed inside the boiler. The probe is exposed for a couple of hours and then analysed for the following:

photo: energi e2

For practical reasons, the fibre fraction was dried and pelleted before it was fired into the boiler.

- the amount of deposits
- whether the deposits have sintered, i.e. are "brittle" deposits that are easy to remove
- the content of water-soluble alkali, which indicates ash with a low melting point
- the content of chloride, which increases the risk of corrosion

In connection with the tests with humus at the CHP plant in Slagelse, the visual impression was especially promising in relation to reduced slagging.

Residual products

Naturally, the use of additives should not increase the strain on the environment. Normally, the slag from biomass plants is returned to the agricultural sector, where it is spread in the fields. The fly ash, on the other hand, is often deposited or sent to Kommunekemi (a treatment plant for hazardous waste), because it contains certain heavy metals, e.g. cadmium.

Using animal manure as an additive is not expected to cause problems in

relation to residual products - on the contrary. The phosphor content increases the fertilization value of the bottom ash, and the increased amount of ash reduces the concentration of heavy metals in the fly ash. As shown in figure 1, the phosphor content of the bottom ash is thus more than doubled when 20 per cent dry humus is added to the straw.

Figure 2 shows the effect of adding humus on the cadmium content of fly ash and bottom ash. As the figure shows, the cadmium content of humus is considerably lower than that of straw. The cadmium content of the fly ash is, however, higher than the limit value for phosphor, which means that this fraction has to be deposited.

In connection with the additives project, a more thorough analysis of the value of the ash products as fertilizers, including the accessibility of phosphor, has been initiated. The results will be published later.

Further development

The Alternative Additives project will run until 2007, and during that time several full-scale tests will be carried out with additives other than animal manure. Tests are thus planned at the Ensted plant (Enstedværket) near Aabenraa and the CHP plant in Køge (Køge Kraftvarmeværk), which uses wood chip as fuel. What will be tested here is primarily the corrosion-preventing effect of the additives.

photo: energi e2

Lasse Tobiasen and Kaj Sørensen from Energi E2 inspect the deposits probe at the CHP plant in Slagelse.

Furthermore, a long-term test will be carried out, which within the budget of the project corresponds to 50 hours addition of additives, just as the test results from the above-mentioned plants will be applied to large dust-fired plants.

Whether the power plants may help solve a waste problem in the agricultural sector in the future and at the same time obtain better operation of their own plants is yet unknown. The fact is that from a technological point of view, animal manure seems to constitute a promising alternative to commercial additives. When the necessary legislation on combustion of the fibre fraction from animal manure has been passed, there will also be a financial incentive to use animal manure, and the road from "dung to smoke" will be paved.

The project has received funds from Elkraft's PSO scheme for 2004.

Lasse Tobiasen is an engineer in the process department at Energi E2. Jacob N. Knudsen is also an engineer, employed at Elsam Engineering, Chemistry and Materials. Henrik B. Møller is a centre researcher at the Danish Institute of Agricultural Sciences. The other participants in the project are from Risø, the Geological Survey of Denmark and Greenland and the Institute for Mechanics, Energy and Construction at the Technical University of Denmark. Lasse Holst Sørensen, Reatech, who tragically and very unexpectedly died on 18 August this year, has been a key person to the project all along. He will be missed both as a friend and a colleague.

Figure 1. The phosphor content of the biomass before combustion and of the ash products. Humus, which is used as an additive, represents approx. 20 per cent of the total amount of ash.

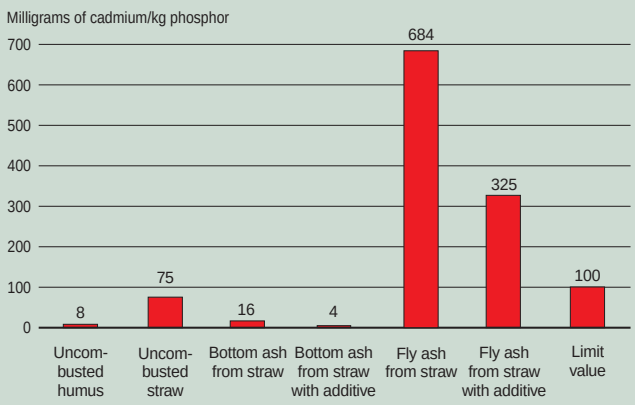


Figure 2. The cadmium content of biomass in relation to phosphor before combustion and in the ash products. Humus, which is used as an additive, represents approx. 20 per cent of the total amount of ash.

We have: money
We need: good ideas

We have money, but we need good ideas. That is the message from a newly established company called EGJ Udvikling A/S to the many entrepreneurs and companies developing new energy technologies.

photo: egj udvikling

The team behind EGJ Udvikling A/S. From the left Tina Andersen, Troels Halken, Pernille Bojsen and Søren Houmøller.

By Torben Skøtt

Denmark needs to dedicate resources to research in order to maintain the basis of our welfare state, and it is therefore necessary for the state to spend more money on research and development, also within the energy area. It is almost impossible to open a newspaper without encountering this message.

It therefore sounds almost heretical when Søren Houmøller, Development Manager of a new company called EGJ Udvikling A/S, states that what is needed is not money but good ideas.

- Our task is to find new energy technologies to invest in. People often approach us with projects, but unfortunately we far too often find that the quality is not good enough, says Søren Houmøller.

- There is a need for entrepreneurs, good ideas, highly qualified researchers and a lot of hard work if new energy technologies are to become commercial successes, says the Development Manager.

EGJ Udvikling A/S was established by DONG and the Municipality of Herning in February with a total capital of DKK 55 million, which will now be invested in new energy technologies aimed at commercialisation. DONG wishes to focus on the development of new energy technologies, while the Municipality of Herning wishes to strengthen its position as a leader in the energy area and create business development and job opportunities in the municipality.

> *"We focus on four things: Technology, market, viability and the people behind the project. In other words: Can it be produced, will it sell, will it pay off and can the idea be realised if we support it?*
>
> *Søren Houmøller*

What is a good idea?

According to Søren Houmøller, it is quite simple to get hold of some of the many millions available through EGJ Udvikling A/S:

- We focus on four things: Technology, market, viability and the people behind the project. In other words: Can it be produced, will it sell, will it pay off and can the idea be realised if we support it?, explains Søren Houmøller.

The time frame is typically between one and six years from EGJ Udvikling A/S invests in a project until the good idea starts to pay off. This is the reason why new companies should try to bring in investors like EGJ Udvikling A/S.

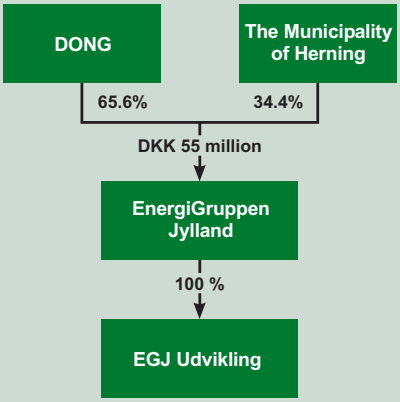
- Without an external investor who knows the market and can contribute with funds and knowledge about business development, you often end up owning 100 per cent of nothing. Several international studies have shown that the companies that bring in investors have far better chances of success and profits than companies that do not. An investor simply increases the size of the cake. When a company brings us in as an investor, it may only retain 60 per cent ownership, but this is no big deal because the larger cake ends up providing increased earnings, explains Søren Houmøller

Future investments

EGJ Udvikling A/S is about to invest in the first technologies, and its focus is on Danish companies with unique technologies. Søren Houmøller does not want to reveal which companies and technologies are involved, but he does not disguise that they involve renewable energy, and he is visibly proud when explaining:

- The projects that we have in the pipeline would have been likely to fail

EGJ Udvikling A/S



EGJ Udvikling A/S was founded on 24 February 2005 with an equity of DKK 55 million, which in the coming years will be invested in new energy technologies.

Development Manager Søren Houmøller, who is a graduate engineer and holds an Executive MBA, is in charge of the day-to-day management of EGJ Udvikling A/S.

The board of the company includes Palle Nørgaard, Managing Director at Siemens Wind Power, who is Chairman of the company, Lars Krarup, Mayor of Herning, and Anders Eldrup, Managing Director of DONG.

because of a lack of funds had we not stepped in. No research and development programmes can fund marketing, production control and business development, so many projects founder simply because of a lack of resources for such things, which are of course at least as important as developing the technology.

For those sitting on a goldmine but lacking money, Søren Houmøller has a very simple piece of advice before they contact a professional investor:

- You need to do your homework and prepare a business plan. Companies like ours receive more than 100 proposals annually, and those that have not considered for instance market and viability are quickly discarded. In addition, you need to be honest and base your proposal on facts. If you believe the market is going to increase by 50 per cent, you have to document why, the Manager explains.

EGJ Udvikling A/S is located in Herning as a subsidiary of EnergiGruppen Jylland. Apart from the Development Manager, the core of the company consists of three business developers. You can find EGJ Udvikling A/S at www.egjudvikling.dk. ■

How to proceed

If you wish to attract funds from an investor such as EGJ Udvikling A/S, you need to prepare a business plan with a description of:

- **The technology,** including advantages and disadvantages and what stage your technology is at.
- **The market,** including customer group, why they would want to buy and how to reach them. What influences the market, who are the competitors and whether there are competing technologies.
- **Finances,** including budgets for the first 5-7 years, generated cash flow, ownership shares and capital requirements.
- **The people behind the project,** including the competences held and needed.

You can find information on the preparation of business plans at the following websites:

www.connectdenmark.dk
www.vf.dk
www.gate2growth.com
www.startguiden.dk

Gasification of the fibre fraction from biogas plants

The biogas industry expects the politicians' decision to allow combustion of the fibre fraction from biogas plants to give the industry a necessary lift, but it might be better to use the fibre fraction in gasification plants.

Tests at the Technical University Denmark suggest that it might be sensible to use the fibre fraction at gasification plants instead of combusting it directly in a power plant boiler. The company behind the tests is Danish Fluid Bed Technology, which has developed a so-called fluid bed gasifier suitable for gasification of unmanageable types of biomass.

Researchers have previously carried out tests with straw with an extremely high chlorine content, dried pig manure and now also the fibre fraction from a biogas plant.

- On Friday 9 September at half past midnight, we opened a bottle of champagne to celebrate 60 hours of uninterrupted testing of gasification of the fibre fraction from a biogas plant, says Peder Stoholm, Managing Director of Danish Fluid Bed Technology.

- Almost 90 per cent of the test worked as expected. A large part of the fibre mass had been pelleted in advance, and everything worked perfectly with this part. However, when we started feeding the fibre fraction directly, we had to reduce the load by just under 50 per cent, says Peder Stoholm. He, however, expects this to be a relatively trivial problem, which can be solved by mounting a more powerful infeed screw.

The ash fraction that remains when the biomass has been gasified contains considerable amounts of phosphor, which there is every reason to believe can be used to produce fertilizer. Initially, the ash will, however, become part of a new test at the Ensted plant (Enstedværket) near Aabenraa, where it will be used as an additive in a biomass-fired boiler. As phosphor is capable of "passivising" the aggressive potassium in the biomass, researchers hope to be able to reduce the corrosion risk in this way.

Peder Stoholm expects the gasification plant to be capable of gasifying practically all types of biomass, including household waste and sewage sludge. The only condition is that the material is comminuted to particles of 2-5 mm. *TS*

Gasification plant with unmanned operation

A development company called BioSynergi Proces has now demonstrated that its gasification technology can work unmanned at a district heating plant. This makes it possible for small CHP plants to replace expensive natural gas with far cheaper forest chips when the plants are renovated.

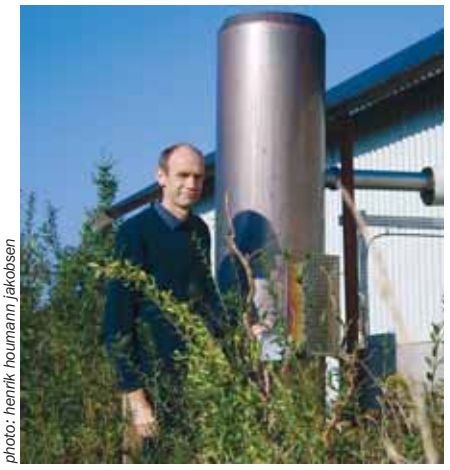


photo: henrik houmann jakobsen

Henrik Houmann Jakobsen at the gas flare of the plant.

By Henrik Houmann Jakobsen

The district heating plants' opportunities to replace natural gas with biofuels have been reduced considerably during the past few years. As a principal rule, the plants cannot replace the gas with biofuels if they produce heat alone, while a plant with combined heat and power production can obtain permission from the authorities.

The only problem is that establishing small biomass-fired CHP plants based on well-known technologies such as steam turbines is not profitable. If the plants are to become viable, they need a technology which can convert the biofuels to gas that can then be used in an engine/generator installation.

With funds from among others the Danish Energy Authority, BioSynergi Proces ApS has developed and established a complete CHP plant using wood chip as fuel. The plant, which is based on gasification of ordinary forest chips, has been mounted at the district heating plant in Græsted (Græsted Fjernvarmeværk) on North Zealand, which buys the entire heat production, while the electricity is distributed via the grid.

BioSynergi Proces is responsible for the operation of the plant and has therefore gained a thorough understanding of its properties. The most important experiences from the operation of the demonstration plant will be described in the following.

Heating with bottled gas

A crucial requirement in connection with gasification of wood chip is minimising the tar content of the produced gas. If the gasification takes place at a temperature that is too low, the gas is bound to contain tar.

To start and heat up the cold plant, we have therefore chosen to use bottled gas to power the gas motor and get the drying installation up and running. We use charcoal, which produces only small amounts of tar, to heat the gas generator.

The start-up procedure is based on the drying installation having sufficient dry wood chip ready when the gas generator reaches a temperature that makes it possible to change from charcoal to wood chip. As long as the plant is in the start-up phase, the produced gas is burned as a gas flare. The gas is not used in the engine until the water circuit and the gas pipes are sufficiently hot.

The calculation worked out

One of the most important questions was whether the energy circuit calculation would work out. As shown in figure 1, the exhaust heat of the engine is used to dry the wood chip. In theory, there should be sufficient energy for the drying process, but would this be the case in practice, and would it be possible to control the plant so that the

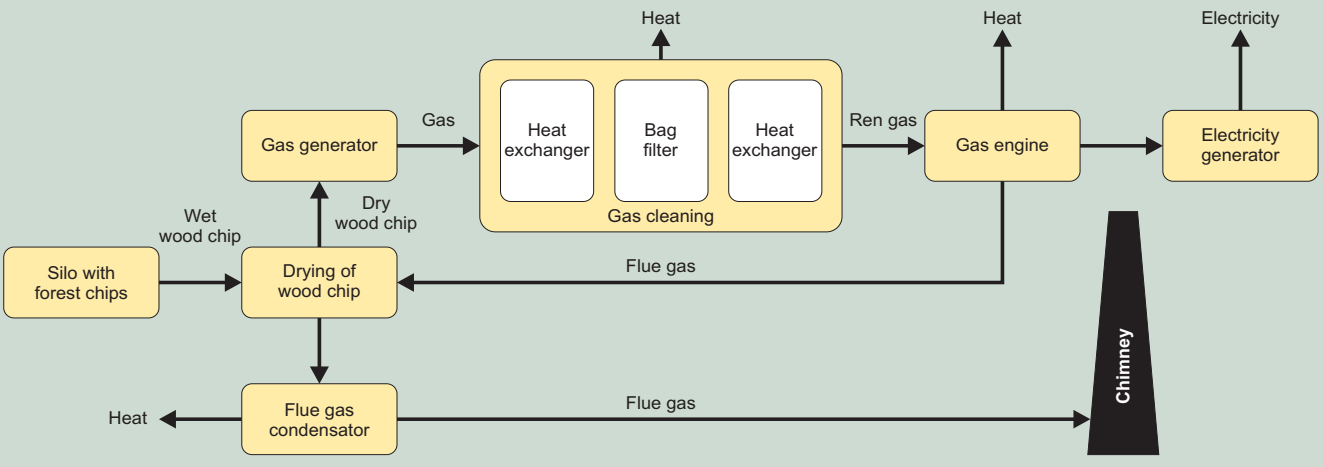


Figure 1. The principle behind BioSynergi's CHP plant. The plant is dimensioned for a fired effect of 425 kW, an electricity effect of 98 kW and a heat effect of 219 kW. This corresponds to 23 per cent of the fired energy being converted to electricity.

drying process would always keep up with the wood chip consumption of the gas generator?

The testing soon provided the first positive answers to the questions. As long as the water content of the fuel was under 50 per cent, there was not only sufficient energy to dry the wood chip for the gas generator. It was also possible to produce a stock of dry wood chip with a water content of approx. 20 per cent.

The maximum water content of the wood chip was discovered in the winter. A container with wood chip with a water content of 50 per cent was covered by drifting snow, so that the water content increased to 52 per cent. When 24-hour frost set in at the same time in February, the drying installation not only had to cope with very wet but also frozen wood chip.

That was the limit. In order to produce enough wood chip for the gas generator, we had to compromise and accept that the water content was only reduced to 30 per cent. Although the gas generator did work with the high water content, its stability was affected and the need for manual observation increased.

Later on, we learned that the operation with frozen wood chip could be sustained by adding a few per cent wood pellets to the wood chip. In the long run, however, storing the wood chip in a frost-free place or increasing the capacity of the drying installation would be more expedient.

Unmanned operation

When the testing was initiated, the control system had not been fully developed. This development took place during the project and it gradually became possible to test unmanned operation. The finished control system is now capable of monitoring the operation and safely closing down the plant no matter which type of failure occurs. The plant may therefore be put into operation and left. In the case of operating failure, the control system raises the alarm over the telephone while a complete shutdown takes place automatically without the presence of the operating staff.

Compared to natural gas, the calorific value of the gas is quite low, 4.5-5 MJ/ Nm3, but in spite of this it has been possible to reach the engine's rated capacity of 75 kW electricity. The composition of the gas is typical of gas generators of the downdraught type as shown in figure 2.

The testing continues

So far, the development and testing of the plant have been subsidised with funds from the Danish Energy Authority's Development Programme for Renewable Energy (the UVE programme). This has led to approx. 550 hours' operation with the gas generator, including 250 hours' engine operation.

BioSynergi Proces has recently entered into an agreement with Eltra A/S to carry through two PSO (Public Service Obligation) funded projects in order to continue the development of the plant.

One of the projects focuses on improving and documenting the ability of the plant to vary the electricity and heat yields. In addition, automatisation of the start/stop procedures will be tested.

The other project relates to optimisation of the energy conversion and various minor improvements to reduce the need for manual attendance. Interested readers can follow the development at www. BioSynergi.dk.

photo: henrik houmann jakobsen

The gas engine is an old Deutz V8 of 75 kW electricity. It is possible to alternate between operation using bottled gas and gasification gas. The exhaust manifolds are isolated, as the heat is used for drying wood chip.

Henrik Houmann Jakobsen is a Bachelor of Engineering and Managing Director of BioSynergi Proces ApS.

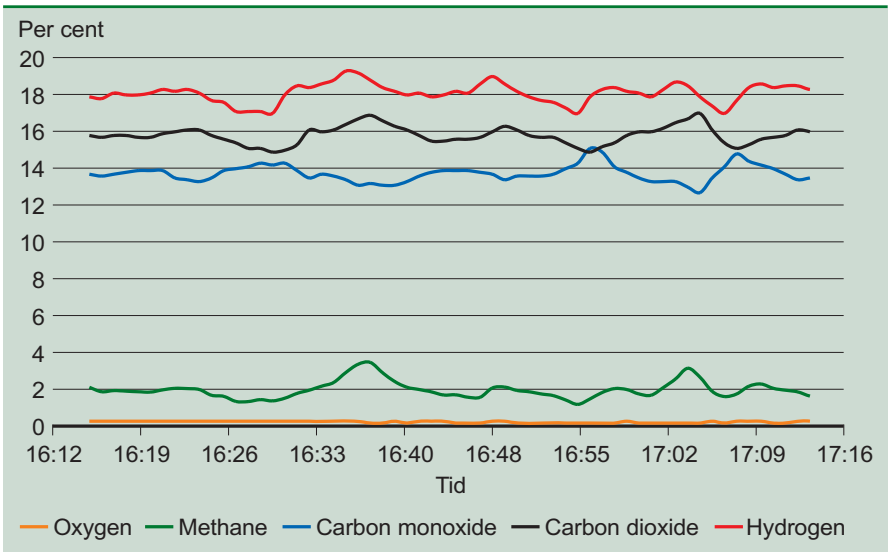


Figure 2. The combustible parts of the gas typically consist of 18 per cent hydrogen, 14 per cent carbon monoxide and two per cent methane. The rest is primarily carbon dioxide and oxygen. The lower calorific value is approx. 4.5-5 MJ/Nm^3.

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Inauguration of ethanol projekt

photo: torben skøtt/biopress

Elsam has upgraded the ethanol plant at the Funen plant (Fynsværket) by a factor of ten, so that it has become capable of treating one ton of straw an hour. This is a large step forward in the process of converting straw to ethanol and fuel for the power plants.

There was a lot of straw, enormous amounts of advanced hardware and a tent full of prominent guests when Elsam inaugurated the upgrade of the advanced ethanol plant at the end of August.

The plant, which has received significant EU research funding, is likely to become a model for the international development within the area. The fundamental idea is that cheap biomass fractions such as straw and waste should be processed into for instance ethanol and solid fuel through a concept using the excess heat from a power plant.

Before the turn of the year, the board of Elsam needs to decide whether they wish to establish a commercial plant in connection with one of the company's power plants. Initially, the process will be based on known technology involving the fermentation of grain, while the more advanced process will not be integrated until later.

The possibility of turning the research project into commercial plants was altogether an important subject to many of the speakers at the inauguration.

- Denmark is a leader within research into and development of ethanol with some of the best basic research on the subject. All the technical conditions are in place, but we lack political support. It is not only necessary to support projects in the initial phase - the politicians also need to provide the framework required for the results to be exploited commercially, said Peder Holk Nielsen, Executive Vice President of Novozymes.

The EU Agricultural Commissioner, Mariann Fischer Boel, who officially inaugurated the plant, was not impressed with the efforts of the Danish Government either.

- It may be fine to set a realistic objective, but the Danish Government's objective of zero per cent for introducing bioethanol is untenable, said Mariann Fischer Boel. She urged the Government to pull itself together and set a more ambitious objective for the years to come.