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From straw to gas

Danish Fluid Bed Technology is far ahead with the development of a new technology in order to transform the more difficult types of biomass into combustible gas. This makes it possible to choose between several different types of fuel and also to reduce the maintenance costs at the major power plants.

By Torben Skøtt

Gasification is not a new invention, but not until recently have researchers found out how to treat the more unmanageable fuels such as straw and livestock manure.

It is the company Danish Fluid Bed Technology which spearheads the development of the technology. For a number of years, they have moved from laboratory scale to a 50 kW test plant and on to a 500 kW plant, which was recently tested very successfully at the Technical University of Denmark.

Since 1999, the development of the technology has been supported by a grant of DKK 10 million from the Danish Energy Authority, and the part of the PSO programme administered by Eltra. Apart from Danish Fluid Bed Technology, researchers from the Technical University of Denmark, as well as Danish energy companies Elsam, Force and Rica Tec, have taken part in developing this new technology.

The gasification plant is based on a so-called circulating fluid bed, which works at relatively low temperatures of around 700°C. There are two chambers in the plant: In the first chamber, the straw is heated up to 650°C; As there is no oxygen inside, the straw does not burst into flames, but is instead transformed into 80 percent gas and 20 percent ash-containing particles of coke. In the next chamber, the coke particles are transformed to gas, leaving a small amount of ash, which may partly be reused as fertilizer. Both chambers contain sand that circulates between them, which thus helps secure a stable temperature level.

photo: danish fluid bed technology

The gasification plant during preparations at the Technical University of Denmark.

photo: danish fluid bed technology

The gasification plant during testing at the Technical University of Denmark.

The gasification plant produces a hot, tarry gas, which is suitable for large power plant boilers, where coating and corrosion often pose problems when the biomass is combusted directly in the boiler. The gas, however, cannot directly be used for engine fuel because of the high tar contents. The so-called two-step gasifier, which we mentioned in the latest issue of Bioenergy Research, is more suitable for this job.

If the gasifier is to be used for engines, it is necessary to remove the high tar contents from the gas. This is not a simple process, but it is technically possible. In small engines, the two-step gasifier will probably be more suitable, whereas for engines of several MW, the fluid bed gasifier will be the more obvious choice, as it is easier to increase in scale.

The worst straw in the world

For the past few months, researchers have carried out two tests using straw in the 500 kW plant and at the moment, they are planning to carry out a series of tests using livestock manure as fuel.

"We chose the worst straw in the world for the two tests, and it still went well," says Peder Stoholm, managing director of Danish Fluid Bed Technology.

"The tests were carried out using bales of straw from Kolindsund on Djursland. Here, the soil contains a lot of salt and consequently, a high content of alkaline salts, including chlorine, which will normally make a boiler plant corrode within a short period of time. Furthermore, the straw from Kolindsund has an ash content of 12 percent, whereas straw from other parts of the country normally contain only 4-5 percent ash."

"We have consciously chosen the worst possible fuel. Power plants cannot analyse every load of fuel they receive, so they must be sure the plant will function using a wide range of different fuels," explains Peder Stoholm.

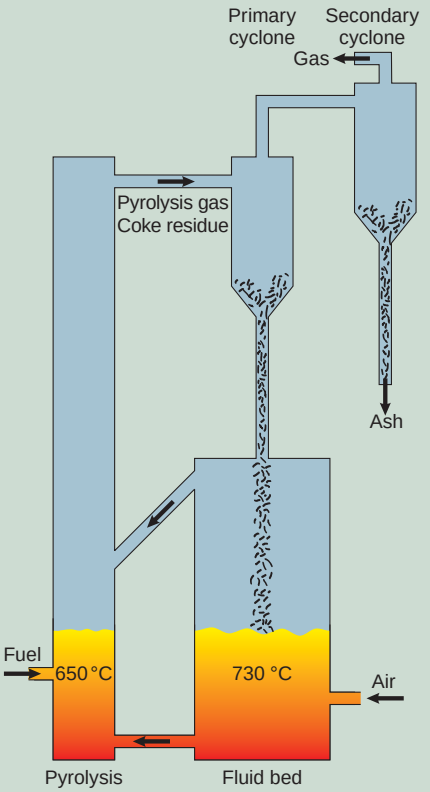
At the smaller 50 kW plant, they have successfully degassed both straw, wood, chicken manure and pig manure. However, wood has only been the subject for one trial, as it may be utilized more easily in many other energy plants.

Many advantages

At first, it may seem troublesome to first transform the fuel to gas and then burn it in a boiler, instead of burning the fuel directly in the boiler.

But there is a purpose to all this. Firstly, you avoid problems with slagging, corrosion and ruined environment plants, which cost the power

How the gasifier works



Pulverized fuel is added to the bottom of the pyrolysis chamber, where it is heated up to 650°C. As there is no oxygen inside, the straw does not burst into flames, but is transformed into 80 percent pyrolysis gas and 20 percent coke. A stream of circulating sand particles takes the coke particles with it, after which they are separated by a primary cyclone and recirculated to the bottom of the pyrolysis chamber through a reactor, which transforms coke to gas.

By gasifying the coke in a separate chamber it is possible to keep process temperatures low, so the ash does not melt. The ash, including alkaline salts and phosphor, can then be separated, resulting in a gas which does not cause slagging and corrosion. The nutritious ash may then be reused as fertilizer and probably also as a source of potassium and phosphor in the production of fertilizer.

plants a lot of money every year. Secondly, you can utilize different and thus also cheaper fuels, such as grain residue and sewage. Thirdly, the gasification technology will make it easier to reuse the ash from the power plants, instead of burning coal and straw in the same boiler as it is done today.

According to Peder Stoholm, the gasification plant may also be a cheap alternative to the many biogas plants, because nearly the entire process takes place within a few seconds instead of weeks. He imagines that the manure is separated at the farms, after which the solid fraction is transported to a communal gasification plant. The transport costs will be limited, as only the solid fraction will be transported, and it will be possible to reuse the contents of phosphor and potash of the manure, which are concentrated in the ash.

However, biological gasification also offers a number of advantages, so another possibility is to only gasify the phosphor-containing fibre residue from the biogas plants.

Existing legislation does not allow the burning of livestock manure. Recently, however, an interdepartmental committee has been set up, which, by 1 June, must present a draft on whether this legislation is to be changed, including whether the duties on burning are to be reduced or removed altogether.

photo: danish fluid bed technology

The 50 kW plant at the Technical University of Denmark. At this plant, tests on the gasification of wood chips, straw, pig manure and chicken manure have been performed.

Great export opportunities

Following the successful tests, researchers have now started planning an upgrade to 5-10 MW. The gasifier is to be upgraded to a size of 100 MW, allowing it to supply gas for an entire power plant block.

Peder Stoholm predicts that the technology may open up the possibility of a considerable export of both know-how and plants. Many of the world's resources of biomass are difficult to utilize, especially for the production of electricity. This is the case with rice straw and cotton waste; and the increasing problems with livestock manure and sewage are definitely not just a Danish phenomenon. In many cases, the fuels simply lie and rot, and are thus contributing to the greenhouse effect as well polluting the water environment. ■

BioNorm concluded

The EU-financed research project BioNorm has now been concluded. Originally, it was the idea that the BioNorm results were to be used in connection with upgrading the technical standards to European standards after three years. Already today, many of the results are being used in the technical standards which have just been published, or will be soon.

However, there are still quite a few loose ends. There are areas which require further research and there are areas which have not been discussed in BioNorm. Therefore, an application for a new project, BioNorm II, has been submitted.

Source: Dansk Standard, no. 1-2005. For further information, please contact Charlotte Vincent Fischer, cv@ds.dk

Liquid biofuels

In December 2002, the European Committee for Standardization, CEN, appointed a task group, BT/WG 149, to introduce the need for standardization of alternative liquids and gaseous fuels. The task group has just published a report which concludes that there is a need for standardization in this field. This applies to fuels for motorized vehicles as well as stationary plants.

Denmark is one of the few countries in the EU that does not use liquid biofuels as engine fuel. Limited amounts of biodiesel are used for heating, though.

Source: Dansk Standard, no. 1-2005. For further information, please contact Charlotte Vincent Fischer, cv@ds.dk

Solid biofuels

The Danish standardization committee for solid biofuels has been very active within the European work on standardization, and has influenced many exisisting and future standards.

The European task group for the standardization of solid biofuels, CEN/TC 335, has a total of 30 subject matters. The first standards have now been published. Among these are standards concerning definitions of solid biofuels, as well as standards for defining water and ash contents.

Source: Dansk Standard, no. 1-2005. For further information, please contact Charlotte Vincent Fischer, cv@ds.dk

Biomass-fired CHP plants - in theory and in practice

photo: torben skøtt/biopress

Researchers still have problems explaining the various operational problems at biomass-fired CHP plants. A better understanding of the physical and chemical conditions in a biomass-fired power plant boiler is needed, as is an improved exchange of know-how between power plants in the eastern and western parts of Denmark.

The CHP plant on Masnedø has far fewer slagging problems than the plant in Maribo-Sakskøbing, even though the two plants are practically identical.

By Torben Kvist Jensen

Since the end of the 1980s, Danish energy companies Elsam and ENERGI E2 have been building and running CHP plants based on biomass combustion, and currently, large amounts of biomass are introduced to central plants. During the whole course the technology has been developed and research and development projects have taken place. Together with Danish energy company Elkraft System, the two companies have started a project to gather the development activities that have already been carried out, and to promote the continued technical development in the field by focusing and qualifying future research and development efforts.

As part of these efforts, Elsam and ENERGI E2 held a seminar on biomass combustion on 14 March. The objective of the seminar was to promote dialogue between the production staff and the technical development staff working at the head offices.

The seminar was a mixture of lectures and discussions. The lectures described E2's operational experiences from decentralized biomass plants and the Avedøre plant, as well as Elsam's experiences with the straw boiler at the Ensted plant and adding straw to coal at the Studstrup plant. Furthermore, speeches from the Technical University of Denmark on research in boiler slagging and corrosion conditions were given. Finally, Aalborg University presented their work with modelling in connection with biomass combustion.

1.4 million tonnes of biomass

The rapid development of biomass fuel combustion over the past many years can be seen in figure 1, which shows the amount of biomass used at Danish power plants.

The oldest straw-fired plant is Haslev CHP plant, established in 1989. It is a so-called cigar-fired plant, where combustion takes place directly at the end of straw bales. The plant has an electrical output capacity of 5.0 MW and burns approx. 25,000 tonnes of straw per year.

At the other end of the scale is the boiler fired by wood pellets at the Avedøre plant. The wood pellets are not fed directly into the boiler, but are ground in three wooden mills and then blown into the boiler as roughly 2 mm particles. The plant produces up to 560 MW of electricity, and is able to burn approx. 300,000 tonnes of wood pellets per year. Apart from wood pellets, they also burn around 150,000 tonnes of straw in a separate grate-fired boiler at the Avedøre plant. With the latest biomass-fired plants at the Studstrup plant and the Amager plant, an installed capacity with the equivalent of around 1.5 million tonnes of biomass functions at Danish CHP plants today.

The biggest problems with the biomass-fired plants stem from handling and pre-processing the fuel. This is the case with both the small grate-fired plants and the large suspension-fired plants, in which the fuel is burnt while floating up through the boiler.

Operational problems

As a measure of what poses operational problems, the number of call-ins to decentralized biomass-fired plants manned during the daytime only was used. These statistics show that problems with straw transports and the combustion plant are generally the reasons why the staff has to work outside standard hours. In addition, problems with heat surface slagging as well as wear and tear were mentioned.

By comparing operational data from various plants, it turns out that there are great differences in the CO emission from E2's straw-fired plants.

Slagelse Kraftvarmeværk, a CHP plant, is a grate-fired plant which uses a push-grate. This means that the layer of straw on the grate is steadily pushed down over the grate, as opposed to plants with a vibration-grate, where the layer on the grate is vibrated at intervals causing great peaks in the CO emission.

One would therefore expect the CO emission for the plant in Slagelse to be low, but this is not the case. The CO emission is actually considerably higher than for E2's other straw-fired plants.

At Haslev Kraftvarmeværk, another CHP plant, the NOx emission was expected to be high because of the highly concentrated combustion, a result of the cigar-fuelling principle. However, operational data show that the NOx emission from Haslev does not differ greatly from other small de-centralized plants.

At Maribo-Sakskøbing there have been problems with boiler wall slagging, which has not been registered at Masnedø, despite the similarity of the two boilers. There are few differences in the version of the boiler, and at Masnedø they sometimes fire up to 25 percent wood chips. Apparently, the wood chips do not make a difference,

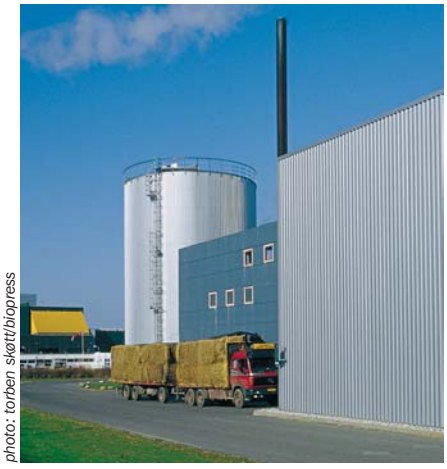


photo: torben skøtt/biopress

The straw-fired CHP plant in Slagelse has a substantially higher CO emission than the other straw-fired plants.

as the plant has considerably fewer slagging problems when firing with straw than at the plant in Maribo-Sakskøbing.

Need for better models

Several projects have developed models for describing the combustion of biomass in grate-fired plants. If these models were able to explain why the conditions are so different, as the examples from Slagelse, Haslev og Maribo-Sakskøbing show, we would have a good tool. It would be possible to reduce emissions and the number of boiler stoppages because of poor heating intake. But before we can describe these conditions by using models, we need to better understand the physical and chemical conditions.

Apart from the concrete examples from E2's straw-fired plants, a number of other subjects were mentioned, which require extra research and development efforts. As an example, we can mention the use of additives for slagging reduction and the reutilization of biomass ash.

Another result of the seminar was that both Elsam's and E2's operational staff became aware of the fact that they have the same problems on both sides of the Danish Great Belt, and that there may help at hand from each other. There was consensus that we must continue our work, and that we should establish a forum for the exchange of operational experiences within biomass combustion.

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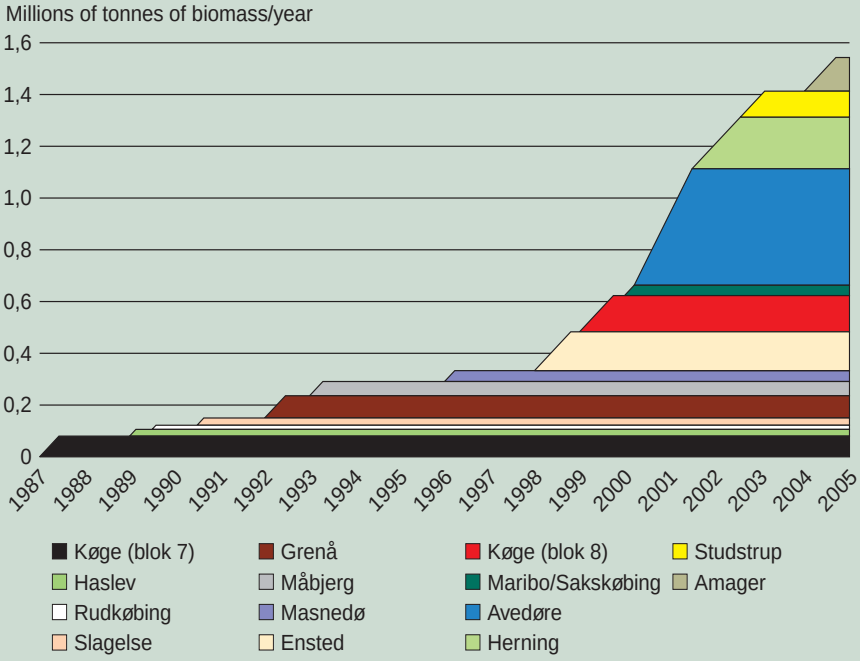


Figure 1: Installed capacity for biomass combustion at Danish CHP plants.

The vast majority of common biogas plants has established gas reception from the so-called after-storage tanks. The picture shows the biogas plant at Vaarst-Fjellerad in Northern Jutland, where a third of the gas production comes from the covered storage tanks.

photo: torben skøtt/biopress

Six million cubic metres of biogas are lost

Every year, six million cubic metres of methane gas are lost in Danish common biogas facilities. This equals the production of almost three large common plants with a 100,000-tonne biomass capacity per year.

By Torben Skøtt

There is a great difference between how much gas Danish common biogas facilities are able to extract from livestock manure and organic waste. This is the result of a study at the Environment & Resources department at the Technical University of Denmark.

On average, around 87 percent of the gas potential are exploited for energy production at the common plants, but there are plants capable of exploiting almost 98 percent of the potential, whilst others exploit only 73 percent.

For every cubic metre of biomass treated at the plants, about 4.2 cubic metres of methane are not being exploited. This amounts to six million cubic metres per year, equal to the production at three large common plants with a capacity of 100,000 tonnes of biomass per year.

From a financial point of view, substantial losses are involved. In practice, however, exploiting the entire residual potential is unrealistic, as it would require a considerable expansion of reactor capacity. Many common plants only have the capacity for a retention time of a few weeks, or much less than the two months it would take for the full gas potential to be exploited.

However, many plants will undoubtedly be able to improve their financial status by focusing on the residual potential. The study conducted by the Technical University of Denmark comprises 18 plants. Imagine the poorest half of these plants improving to the average of the best one-third; then the average loss per cubic metre biomass would be halved. This could result in an additional production of around three million cubic metres of methane per year, which equals an annual income of around DKK 10 million.

Further information

The report "Kortlægning og dokumentation af procesforhold på danske biogasanlæg" (Mapping and documentation of process conditions at Danish biogas plants) is prepared by the Environment & Resources department at the Technical University of Denmark.

Rena Angelidaki was responsible for the project, whilst Majbrit Stavn Jensen has been the overall resource person on the project. Anette Hejnfelt was the editor of the report. Several students have participated in the project as well.

The report may be downloaded from BiogasForum Öresund's homepage: www.biogasforum.dk.

Reasons

There may be many reasons why the gas potential is not exploited sufficiently. First and foremost is the question of how long the biomass retention time is in the plant. A short retention time will entail a low gas production per cubic metre of biomass, and if the retention time is shorter than 15 days, a considerable reactor loss will ensue.

In order to extend the retention time, and thus increase the gas yield, most common plants have established gas reception from the storage tanks (so-called after-storage tanks). However, a few plants still do not exploit the gas production from the storage tanks, which of course entails a considerable loss of methane.

Experience shows that the gas production from the after-storage tanks is highly dependent on temperature. After-rotting from thermophilous plants should take place at no less than 30°C. Mesophilous plant temperatures should be at least 25°C. Gasification more or less stops when the temperature drops below 15°C, but as soon as it increases, the methane production is activated immediately.

It is not only the retention time that influences the gas yield. The plants which lose the most methane generally have a lower biomass manure content,

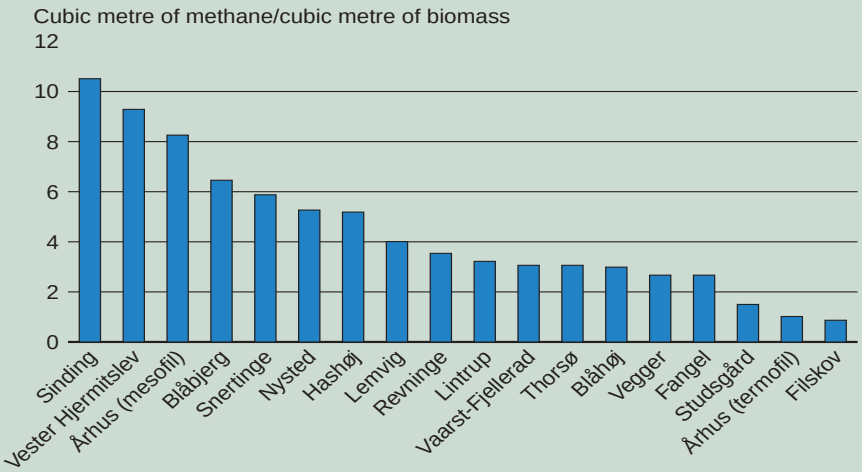
and thus larger contents of organic waste. Generally, they also have a higher VFA level, indicating that the biological process becomes unstable more easily. Finally, mesophilous plants generally lose more methane than thermophilous plants.

Methane leakage from manure storages

One would fear that a poor utilization of methane gas in biogas plants would lead to a considerable leakage of methane from the subsequent manure storages. A greater leakage of methane from storing the partly degassed biomass than from raw manure would thus partly counteract the CO2 advantages which the biogas plant entails.

However, not much indicates that this is the case. As mentioned before, the development of methane nearly stops when the temperature is below 15°C, and as the average temperature in Denmark is only 8°C, the development of methane in the storage tanks is highly limited.

Researchers have calculated that the methane development gained by storing partly degassed biomass makes up a maximum of 10 percent of the residual potential, or approximately 1.2 percent of the potential in raw manure. The study from the Technical University of Denmark does not give a final answer of whether that is more or less than the methane development from raw manure, as they need data concerning methane development from raw manure. In practice, the leakage from raw manure may actually prove higher because of the larger gas potential.



Lost methane gas compared with the amount of biomass processed by the plants. This loss has been calculated after the final step of the process, i.e. after the biomass has been through both reactors and after-storage tanks. For the plant in Århus, the loss has been calculated individually for the mesophilous and the thermophilous lines.

Criticism of new biogas knowledge centre

The Association of Danish Biogas Plants severely criticizes the new centre for livestock manure and manure technology in Foulum. This surfaced at the annual general meeting on 26 February in Bøstrup near Slagelse.

The association is very satisfied that more funds are being made available for research in biogas and manure separation, but is also highly critical of the model chosen by the government. In the future, the vast majority of the funds is to be spent on a newly established centre at the Danish Institute of Agricultural Sciences in Foulum - a detrimental development, according to Aksel Buchholt, chairman of the Association of Danish Biogas Plants) .

"It is a shame that they do not fully utilize the experiences gathered at the many common plants throughout the country. Previously, we could apply for grants to finance concrete development projects, something that contributed greatly to the development."

photo: torben skøtt/biopress

Chairman of Danske Biogasanlæg (Danish Biogas Plants) Aksel Buchholt at the annual general meeting of the association on 26 February.

"This possibility no longer exists. Instead, they have chosen to spend DKK 150 million on a single centre, and it hurts that they do not value our experiences higher," stated Aksel Buchholt at the annual general meeting of the biogas association on 26 February.

He was of the opinion that the centre had been placed in Foulum because the research facility needed a biogas plant to solve the problems with excess manure.

"In January, the centre was presented at a large seminar at the University of Southern Denmark in Odense, but no debate ensued. There were no opportunities to ask questions, and it was all purely one-way communication," stated Aksel Buchholt, who requested far greater openness on the part of the centre. *TS*

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From straw to ethanol

photo: torben skøtt/biopress

Danish energy company Elsam now goes a step further with its big ethanol project, IBUS. Before the summer holidays, a new pilot plant capable of handling one tonne of straw per hour, is to be ready at Danish power plant Fynsværket, and in the middle of May, the board at Elsam must decide whether to establish an ethanol factory based on known technology.

Elsam are still working determinedly to be able to convert straw and waste to ethanol, but now they are also considering starting a more traditional production of ethanol, based on sugar beets or grain. This was stated by Elsam research manager Charles Nielsen at a meeting at Fynsværket on 5 April. The meeting had been arranged by the plant in cooperation with the Danish Knowledge Centre for Livestock Manure and Biomass Technology.

Charles Nielsen is convinced that the transport sector energy consumption will be based increasingly on ethanol, but he also estimates that for the first many years, the more traditional ethanol production will dominate the market. Therefore, Danish energy company Elsam have begun to sort out information in order for the board of directors to be able to make a decision in mid-May on whether the company should establish a traditional ethanol production.

At the same time, technicians are in the process of establishing a pilot plant at Fynsværket, which should be able to convert one tonne of straw per hour into ethanol, fuel or animal feed. The plant, which is a part of the ambitious IBUS project and has been in operation since the summer of 2003, is the further development of a small test plant to process 100 kilos of straw per hour.

The pre-treatment of straw has been the primary job at the test plant . The new plant will especially be used for research in the ethanol process itself, including tests of the bacteria and enzymes necessary for converting raw materials containing cellulose into liquid ethanol.

By combining ethanol production with the production at a power plant, the costs can be reduced significantly. Therefore, Elsam calculates that with a traditional ethanol production, the costs may be reduced by around 20 percent. This will reduce the price of a litre of ethanol to around DKK 2.50, or approx. DKK 0.80 below the European market price. This will give Elsam a clear competitive advantage compared to other producers on the market. *TS*