Second volume
Ninth issue
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FiB
Bioenergy research



Grants for energy research

Friday 30 September is the final date to apply for grants for energy research, development or demonstration plants. The deadline applies to the expected funds for 2006 as well as the unspent funds for 2005.

Grants for energy research, development and demonstration are provided by various programmes, each with a different focus. These are:

- Denmark's Energy Research Programme (DKK 72 million).
- The PSO scheme for environmentally friendly electricity production technologies (DKK 130 million).
- The PSO scheme for efficient use of electricity (DKK 25 million).
- The Danish Council for Strategic Research's pool for energy and environment (DKK 65 million).

The figures in the parentheses apply to 2005. At this point, most of the funds available for 2005 have been allocated, but there are still unspent funds under the PSO schemes and the Danish Council for Strategic Research's pool for energy and environment.

Denmark's Energy Research Programme is administered by the Danish Energy Authority, while the PSO schemes are administered by Energinet.dk and ELFOR. The Danish Council for Strategic Research's pool for energy and environment is administered by the Programme Commission on Energy and Environment, which has its secretariat at the premises of the Danish Research Agency.

The administration of the various programmes is coordinated with regard to areas to be promoted, information activities, deadlines etc. This year, the deadline for all programmes is thus 30 September, and furthermore a common information meeting will be held on Tuesday 30 August at the conference centre of the Danish Society of Engineers.

Further information on the mentioned grant programmes may be found at www.energiforskning.dk, which is a common portal for the Danish authorities that work with energy research. ■

photo: torben skøtt/biopress

Biogas reactors in series may yield up to 15 per cent more gas

Serial operation of reactors may help optimise the gas yield of biogas plants which primarily treat manure with up to 15 per cent. This is the conclusion of a series of new tests carried out at the Department of Environment & Resources at the Technical University of Denmark.

From the mid-1990s, it became common to cover the after-storage tanks of the plants in order to recover additional amounts of biogas. The conversion time in after-storage tanks, however, is typically very long, which limits the efficiency of such solutions.

By Rena Angelidaki & Lars Ellegaard

The primary costs of a biogas plant are to do with transportation and heating, pumping and agitation of the biomass. A larger gas yield may thus improve the financial situation of a biogas plant considerably and constitute an important factor in the development of plants that can compete with other technologies and have a smaller need for addition of easily convertible organic waste.

Apart from the small buffer or hygienisation tanks that have been established for veterinary reasons, most of the 20 common biogas plants that are in operation in Denmark have been established as simple single-stage plants with fully agitated tanks.

From the mid-1990s, it became common to cover the after-storage tanks of the plants, where the degassed biomass is normally kept for 3-7 days, in order to recover additional amounts of biogas. The conversion time in after-storage tanks tends, however, to be fairly long as a result of the low temperature, which means that the efficiency of such solutions is limited. In the instances where after-storage tanks have yielded considerable amounts of gas, the reason is normally a poor process in the main reactor, an unusually long retention time or a high temperature level in the storage tanks.

Serial configuration

During the past few years, it has been documented that dividing the primary digestion process into several stages at a controlled process temperature may

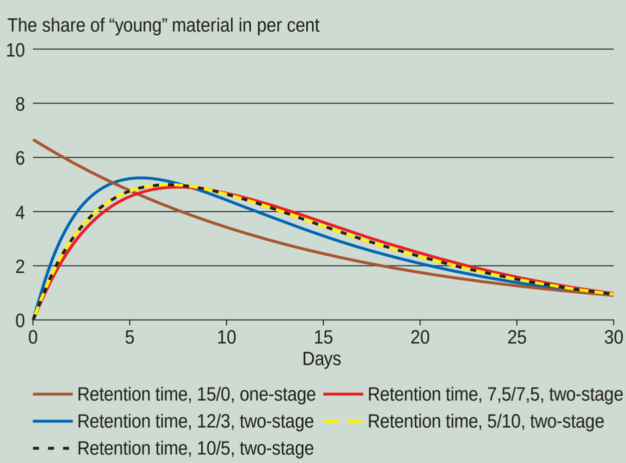

Figure 1. Theoretical calculations of "age profiles" for serially connected reactors with a total retention time of 15 days and varying parts of the total volume at stage 2.

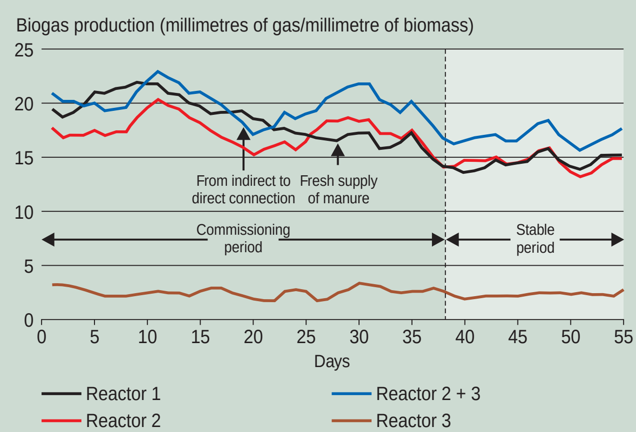

Figure 2. Specific daily gas production of three test reactors. Cattle manure was used, and the tests were carried out at a process temperature of 55°C.

be better, especially when the biomass used consists mainly of undissolved material, as is the case with e.g. manure. Apart from that, recovering gas from after-storage tanks may of course still be relevant, as this normally does not require large investments. A number of years ago, tests were carried out with at two-stage processor to optimise the process conditions by dividing the biogas process into a fairly small "acid stage" and a subsequent "methane stage". This made it possible to maintain optimal process conditions in the two stages, but in practice it also proved difficult to document a higher gas yield, just as it was difficult to maintain a stable process in the initial "acid stage", which was easily overloaded.

The new configuration aims to optimise the process in order to minimise the loss of unconverted or only partially converted biomass. Typically, this theory leads to a two-stage process with a relatively large main reactor and a somewhat smaller post-gasification tank, operating at the same temperature as the main reactor. There are no stability problems with a small after-gasification stage, as it receives biomass already containing an active biogas culture.

Age profile

The explanation of the advantages that are experienced when a process is divided into two stages is to be found in the "age profile" of the pumped out material. In a traditional single-stage process, part of the pumped out material consists of undissolved particles, which have only been in the reactor for a relatively short period of time - considerably shorter than the average retention time - and which is therefore only partly converted. The material of course also contains undissolved particles, which have been in the reactor considerably longer, and which are therefore better converted.

What is crucial is that the loss of a particle, which has only been in the reactor for a short period of time, is larger than the loss of a particle, which has been in the reactor for longer.

The optimal solution would be the same retention time for all undissolved material. This is what is aimed at in connection with serial connection as illustrated in figure 1 in the form of theoretical calculations of age profiles for pumped out material.

As is evident from the figure, the difference in the age profiles of single-stage and two-stage connections is considerable, whereas the difference between the various degrees of serial connection is fairly insignificant.

The amount of relatively "young" material, i.e. material that has not been in the reactor for very long, is smaller in connection with serial connection, and the main part of the age profile is moved towards the average hydraulic retention time. Theoretically, optimal conversion of particles is achieved at an even distribution between stage one and stage two, but this is not necessarily the optimal solution when dissolved nutrient medium is taken into consideration.

A prerequisite for obtaining the advantage of serial connection is that the stage one process is stable and capable of establishing the active bacterial culture, on which stage two is dependent. Therefore, we recommend a serial distribution, where a maximum of 10-20 per cent of the total volume is serially connected. More precisely, what is needed is an adequate retention time at stage one in order to ensure a stable main process. An adequate retention time is approx. 12 days for a thermophilic process and approx. 18 days for a mesophilic process. If you work with a longer total retention time, it will probably be optimal to increase the length of stage two.

Test results

At the Department of Environment & Resources at the Technical University of Denmark, a series of tests have been carried out where serial and parallel operation of biogas reactors have been compared.

Three reactors were used. Reactor 1 had a retention time of 15 days, and was used as a single-stage reactor. Reactor 2 was serially connected with reactor 3 and had a retention time of re-

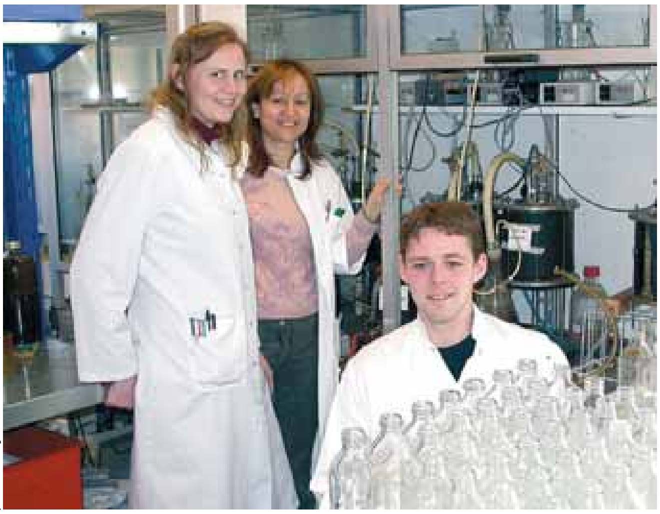

photo: miljø & ressourcer, danmarks tekniske universitet

The biogas laboratory at the Department of Environment & Resources at the Technical University of Denmark. It is Rena Angelidaki in the middle of the picture.

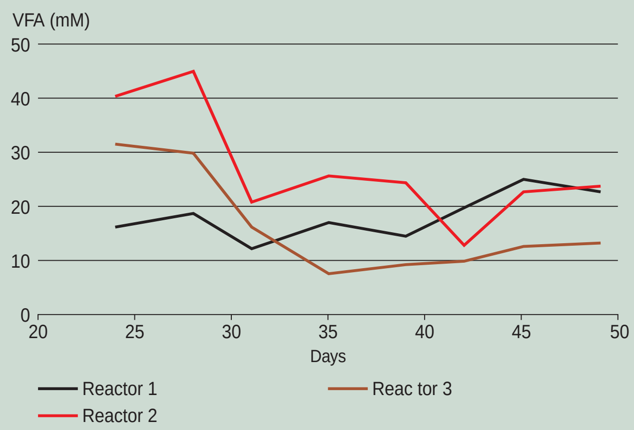

Figure 3. The VFA concentration of three test reactors. Cattle manure was used, and the tests were carried out at a process temperature of 55°C.

spectively 12 and 3 days. Cattle manure from the biogas plant in Vegger was used, and the tests were carried out at a process temperature of 55°C.

Figure 2 shows the daily biogas production of the reactors. In a stable period after the commissioning, the biogas production of the two-stage process was approx. 15 per cent higher than that of the single-stage process. In the commissioning period, the connection between reactor 2 and 3 was indirect, meaning that the biomass from reactor 2 was led to reactor 3 via an intermediate storage. However, it proved important to establish a direct connection between the two stages to avoid activity loss at temporary temperature reductions.

The gas production levels of reactors 1 and 2 turned out to be almost identical in spite of differences in retention times, which indicates that 15 days' retention time is more than enough to ensure a stable process. Extra retention time is therefore best used for serial connection in order to obtain a better distribution of the retention time.

Measurements of the acid levels of the biomass (VFA) also indicate a more efficient two-stage process. After stabilisation, the VFA concentration of reactor 3 thus proved significantly lower than that of the single-stage process (figure 3), and the loss in the form of acid was also lower.

Apart from the general advantages of serial connection mentioned above, other tests have proved that a serially connected process entails an improved yield at varying organic or hydraulic loads. This is due to the time delay of a serially connected system, where stage two can set right a conversion imbalance that has occurred in stage one, rather than allow the imbalance to increase pump-out losses.

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Research and development meeting

Tuesday 30 August 2005

On Tuesday 30 August at 9 am to 4.30 pm, Energinet.dk will host an information meeting on research and development, which will take place at the conference centre of the Danish Society of Engineers, Kalvebod Brygge 31-33, Copenhagen. The meeting is arranged in cooperation with the Danish Energy Authority and ELFOR.

The information meeting especially targets decision makers, researchers and project employees from companies and institutions that work with energy issues and research and development in the energy area.

In the morning, focus will be on the overall objectives of and strategies for Danish energy research, and furthermore there will be speeches about the interplay between private and public efforts. Finally, there will be speeches about the work that the companies responsible for the system carry out to fit environmentally friendly electricity production technologies into the electricity system. The afternoon themes are prioritised promotion areas, application procedures and assessment criteria for applications. See the detailed programme at www.elkraft-system.dk or www.eltra.dk. The final date for registration for the information day is 15 August with:

Mette Fruergaard
mfr@eltra.dk • fax +45 7556 4510

Remember to state your company name, your own name, your company address, your direct e-mail address and your direct telephone number.

Energy research conference

Thursday 15 September 2005

On Thursday 15 September from 9 am to 4 pm, the Danish Energy Authority and the Advisory Energy Research Committee (REFU) will host a conference on energy research of the future. The conference, which will be held at the premises of the Confederation of Danish Industries at H. C. Andersens Boulevard in Copenhagen, will follow up on the research and business perspectives of Energistrategi 2025 (energy strategy 2025) and will focus on development, innovation and growth within Danish energy technology.

The conference will result in specific recommendations for the use of public energy research funds. The number of participants is limited, and to begin with each company may thus only register 1-2 participants. See the detailed programme at the website of the Danish Energy Authority at www.ens.dk/sw26732.asp.

The price of the conference is DKK 750, which includes breakfast, lunch and afternoon coffee. Registration with and payment to:

The Danish Energy Authority • Amaliegade 44 • 1256 Copenhagen K
Att.: Kirsten Sloth o ksl@ens.dk.

Mark the envelope "F&U konference". Remember to state your company name, your own name, your company address, your direct e-mail address and your direct telephone number. Your registration does not become valid until you have paid in your participants fee to the following account in Jyske Bank: 8109 10 05 43-9. Mark your payment "F&U konference".

Pre-treatment of manure fibres can yield up to 60 per cent more biogas

Manure separation with a mobile decanter centrifuge from TechRas Miljø. The main part of the phosphor content and most of the biogas potential are found in the solid fraction.

New tests from the Danish Institute of Agricultural Sciences indicate that the gas yield from digestion of animal manure may be increased considerably by means of pressure-cooking and chemical pre-treatment of manure fibres. In some of the tests, the gas yield was increased by up to 64 per cent, but the pre-treatment costs are significant and thus constitute a limiting factor.

By Henrik B. Møller and Chitra S. Raju

In the future - to a larger extent than today - biogas plants must be designed to make ends meet primarily by treating animal manure. In that connection, it is important to find out how gas yields may be increased, e.g. by pre-treating the manure.

Lately, there has been a lot of focus on manure separation, as this may help solve local problems with excess phosphor. The main part of the phosphor content is found in the solid fraction, which also contains most of the biogas potential. By separating the manure at the individual farms and transporting the solid fraction to a common biogas plant, it becomes easier to spread out the excess amount of phosphor, and the biogas plant receives biomass with a considerably higher gas potential than that of untreated manure.

The solid fraction may be used as a supplement to ordinary raw manure just like organic industrial waste, or the plant may be operated solely on the solid fraction from separated manure and recirculated process water. This is especially advantageous if the transport distances to the biogas plant are long.

If the manure is separated before gasification, pre-treatment is interesting in order to increase the gas yield. In this way, the biogas yield can be increased considerably, but the high dry matter content of the solid fraction will necessitate a change of the reactor design. Tests are currently carried out in this respect in connection with an Energy Research Programme project on biogas plants of the future.

Decanting of manure

During the past few years, a number of tests have been carried out with decanter centrifugation of manure, and most recently TechRas Miljø and the Danish Institute of Agricultural Sciences have cooperated to perform a series of tests to assess the effect of the adjustment of the centrifuge on the separation.

In that connection, the effect of the G-force among other things has been studied with a Pieralisi Jumbo 3 decanter mounted on a mobile trailer. The speed varied between 2,000 and 3,130 revolutions per minute, which corresponds to 1,440 and 2,558 G. The separation results in relation to the G-force are shown in figure 1. From this figure, it appears that increased amounts of nutrients have been transferred at increased G-force.

Autoclave plant at GreenFarmEnergy in Over Løjstrup. Here the biomass was pressure-cooked at a temperature of 147°C for half an hour to an hour, and 4-7 per cent burned lime were added.

Manure from fatteners with a dry matter content of respectively 6.9 per cent (type 1) and 8.9 per cent (type 2) was used for the tests. With manure type 1, the amount of nutrients that was separated was increased until 2,196 G, while no effect was registered form increasing the G-force beyond 2,047 G in connection with type 2. Other parameters such as liquid radius, hydraulic load etc. were also studied.

Pressure-cooking and chemical treatment

The Danish Institute of Agricultural Sciences, GreenFarmEnergy and TechRas Miljø have performed a series of tests with decanting of manure followed by pressure-cooking in practice as well as in the laboratory in order to study the possibilities of increasing the gas yield.

In the practical tests, the biomass was pressure-cooked at a temperature of 147°C for half an hour to an hour where 4-7 per cent burned lime were added, and furthermore tests were performed without lime. The results of the relatively few tests that were carried out are shown in figure 2. From this figure, it appears that the untreated fibres yield 236 litres of methane/kg organic dry matter, while the pressure-cooked fibres yield between 297 and 342 litres of methane, which corresponds to an increase of 26-44 per cent. The thin pig manure in the diagram has been included because it was used to flush out the fibres from the autoclave after ended treatment and thus formed part of the biomass that was digested, and for which adjustments were subsequently made.

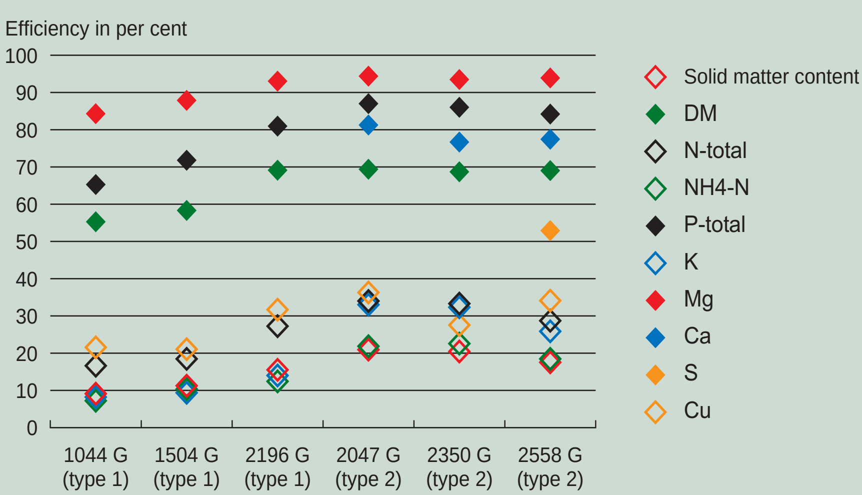

Figure 1. The effect of the G-force on the efficiency of separation with a decanter centrifuge. Manure types 1 and 2 are fattener manure with a dry matter content of respectively 6.9 and 8.9 per cent.

In the laboratory tests, a number of combinations of temperature, time and additions of burned lime were tested as shown in figure 3. Here, the untreated fibres yielded 162 litres of methane/kg organic dry matter, while the treated fibres yielded between 194 and 265 litres of methane, which corresponds to an increase of 20-64 per cent.

No significant statistical difference was found between the various forms of treatment. It is also notable that long periods of treatment with burned lime seem to produce an effect similar to that of pressure-cooking. However, this needs to be further documented through further testing.

The yield level of the laboratory tests was generally lower than that of the practical tests. The reason for this is unknown, but there are indications that the bacterial culture in the laboratory was inhibited in the beginning of the tests. Furthermore, the fact that the ammonia level was reduced in the practical tests, because steam was let out during the process, may have had an influence.

Profitability

The tests indicate that considerable increases in the yield in the order of 50-100 litres of methane/ kg organic dry matter may be obtained by treating fibres from a decanter centrifuge. The organic dry matter content of the fibres is typically around 25 per cent, which means that increased yields of 12-25 Nm^3 of methane/ton of fibres may be obtained.

At a methane value of e.g. DKK 2.50/m^3, this corresponds to DKK 30-75/ton of fibres. But the costs of treating the fibres are considerable, and if it were necessary to add e.g. 4 per cent lime, that alone would cost DKK 30/ton of fibres. On the other hand, some of the lime would have a certain value in connection with its subsequent use for agricultural purposes, and in connection with pressure-cooking it would be possible to recover the ammonia content to benefit the subsequent process. This would be especially relevant in connection with treatment of deep bedding from chickens and similar solid products with a high content of ammonia. In order to assess the perspectives, it is necessary to determine the optimal amounts of lime to be used in the process more precisely.

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Chitra S. Raju has written a thesis on environmental technology at the University of Aalborg and the Danish Institute of Agricultural Sciences. Her study is part of the Energy Research Programme project called Fremtidens biogas (Biogas of the future). ■

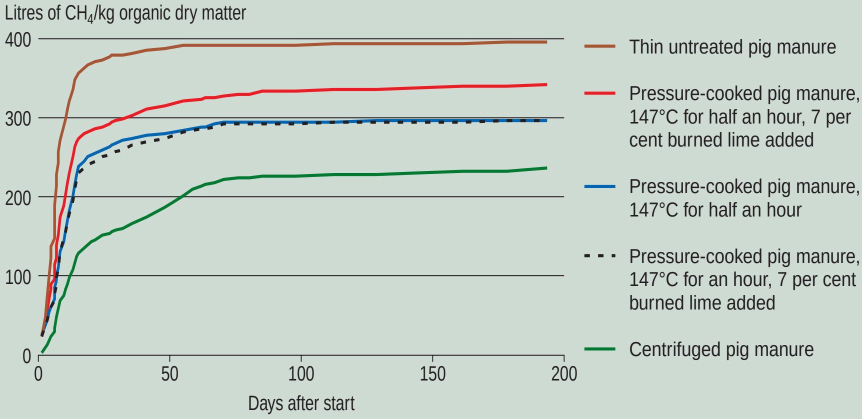

Figure 2. Results from full-scale testing of digestion of untreated manure fibres and pressure-cooked material with and without addition of burned lime.

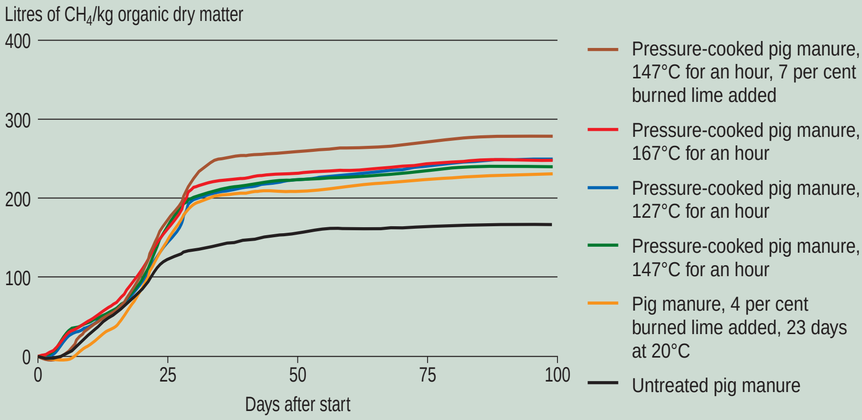

Figure 3. Results of laboratory testing of digestion of untreated manure fibres and pressure-cooked material with and without addition of burned lime.

New EU grants

22 December is the final date to apply for grants for renewable energy plants under the EU's 6th framework programme. A total of EUR 125 million will be available to projects that help promote sustainable energy supplies. The grants, which will be the last under the 6th framework programme, will focus on demonstration plants and development of technologies close to commercialisation. 35 per cent grants for establishment of demonstration plants and 50 per cent grants for research and development projects may be obtained. You can find further information at www.eurocenter.info.

Generally, Denmark has good experience in obtaining EU grants for energy projects. Elsam's ambitious ethanol project has thus received a substantial grant from the EU, and the Technical University of Denmark and RISØ have also obtained grants for various projects. ■

Award for Novozymes

On 25 July, Novozymes received Frost & Sullivans consultants' award for technological leadership within alternative fuels. The award was presented to Novozymes for its research into how the costs of enzymes for the production of ethanol from biomass may be reduced.

This spring, Novozymes made an announcement to the bioenergy industry that it had now reduced the price of enzymes for ethanol production with factor 30. This means that the price of enzymes is no longer the most important barrier to converting by-products such as straw, wood chip and organic waste into ethanol.

Novozymes has been working on developing enzymes since 2001. Back then, the company together with the American National Renewable Energy Laboratory, received a little more than USD 16 million from the American Ministry of Energy for a research project, which would make it possible to produce ethanol on the basis of maize waste. In practice, this cooperation has led to a reduction of the price per gallon of enzymes from USD 5 to USD 0.10-0.18 at laboratory level. ■

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to be published in the middle of October 2005. The deadline for articles is 15 September 2005.

Straw and gas at Fynsværket

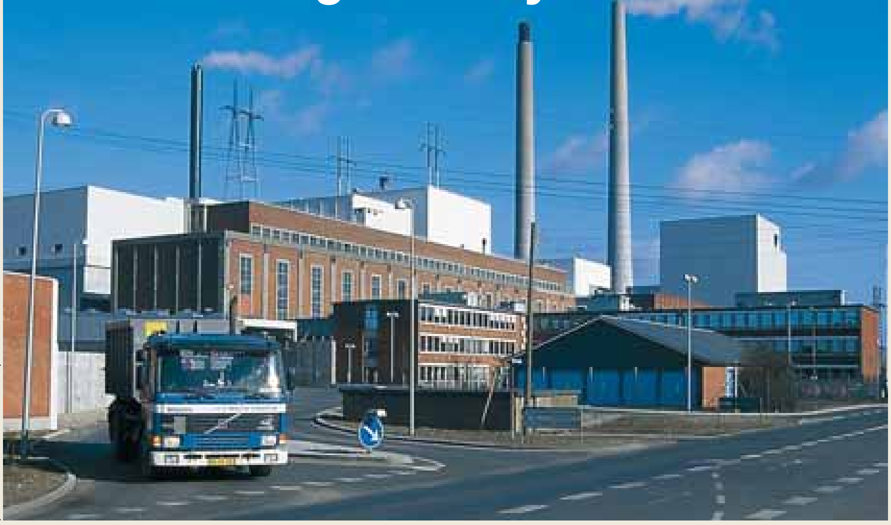

photo: torben skøtt/biopress

While the power plants have gained good experience in burning straw and coal in the same boiler, it is far more difficult to add straw to a natural gas-fired boiler. This is the conclusion of a research project carried out with funds from the PSO scheme.

In cooperation with Burmeister & Wain Energy, a group of researchers have studied the possibilities to add straw to a natural gas-fired power plant block at Fynsværket.

Originally, the project was very extensive with six different tasks, but only a smaller number of the activities were carried through. This has to do with the fact that the initial firing tests led to severe deposits on the heating surfaces of the boiler.

The conclusion of the project is that adding straw at Fynsværket's block 3 will only be partially possible after extensive alteration of the boiler combined with a reduction of the yield of the plant to 63 per cent of the yield of pure gas-firing and a reduction of the steam temperatures from 535°C to 480°C. This, however, is not a good solution, as it would probably entail problems in the turbine.

In connection with the project, addition of a host of additives in connection with straw-firing has been studied, but no additive has been found that can reduce the risk of deposits on the heating surfaces considerably.

Furthermore, a so-called CFD model of the boiler has been prepared. Calculations with the model show that there are problems with complete combustion of the large straw particles, and that the at fuel temperature is higher at the back of the boiler in connection with straw-firing compared to pure gas-firing.

No sensible explanation has been found as to why and how the problems with deposits occur. A possible explanation is that in connection with a former alteration of the boiler it was not possible to create space for a "nose". Such a nose ensures that the upper part of the combustion chamber is used efficiently and prevents uncombusted particles from floating to this part of the boiler. An altered boiler at Asnæsværket (the Asnæs plant), which has had considerable problems with slagging in connection with coal-firing, has the same defect.

Source: Miljøvenlig elproduktion 2005, Eltra 2005.