Third volume
12th issue
February 2006

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New research strategies

The last few months have seen no less than three new research strategies: A strategy from the Advisory Energy Research Committee set up by the Minister for Transport and Energy, a biotechnological research strategy and a new strategy for agriculture.

Denmark needs to prepare to meet the challenges of globalisation. Therefore, the government is focusing on making the Danish society
a leader as regards growth, knowledge and entrepreneurship.

In this connection, the Advisory Energy Research Committee (REFU) has submitted a new research strategy for consultation, the emphasis being on:

- Demonstration of completed technologies.
- Consortiums of businesses and research institutions that are able to handle large projects and contribute to funding.
- Research projects with commercial potential.

For decades, development work in Denmark has created significant core strengths and competences in the energy area, but we now have to make a greater effort to maintain and develop these positions, according to the paper from REFU.

The potential of new energy technologies is huge. The International Energy Agency estimates the requirement for global investments in the energy sector at USD 17,000 billion up to 2030, the equivalent of nearly DKK 4,000 billion a year.

The increasingly strained energy markets and the need to reduce the environmental and climatic effects particularly encourages the demand for renewable energy plants and increased efficiency in the exploitation of the energy sources.

Today, the energy sector contributes significantly to Denmark's economic growth and employment. Exports of Danish energy technology measured in current prices have risen from about

DKK 17 billion in 1996 to just over DKK 32 billion in 2005. From 2002 to 2005 alone, energy technology exports grew by 30 per cent, or 10 times as much as other exports.

According to the statement from REFU, the focus on research and development is not enough, however. It is also vital that other means such as duties and framework conditions support the required development, and thereby contribute to making it attractive for investors to join at an early stage of the development.

The latest evaluation of Denmark's Energy Research Programme estimates that the programme meets its objectives and has been contributory to maintaining the Danish core strengths as regards research and business within the energy area. However, the development has also tended towards a smaller degree of commercial exploitation of the research efforts. It is also stated that the co-funding by businesses and particularly the energy companies has fallen during the project period and is now lower than in the earlier programme periods. These conclusions constitute a special challenge to the future organisation of research efforts.

The strategic public research funding in the energy area now consists of four programmes. Three of the programmes belong under the Ministry of Transport and Energy. They are the Energy Research Programme and the two Public Service Obligation programmes for environmentally friendly electricity production technologies and efficient use of electricity respectively. The fourth programme is the Energy and Environment programme under the Danish Council for Strategic Research. It belongs under the Ministry of Science, Technology and Innovation and covers broadly the same area as the programmes under the Ministry of Transport and Energy. Together, the four programmes have more than DKK 300 million a year to spend the next four years.

The strategy for research, development and demonstration in the energy area can be downloaded from www.ens.dk.

The agricultural research strategy

photo: torben skøtt/biopress

New three-year research strategy from the agricultural sector focuses on energy crops and the use of waste products for energy purposes.

Danish cropping is to contribute significantly to the economy. It is also envisaged to help ensure that the cultural landscape and the environment is managed most appropriately, and finally it is to provide farmers with a sound profit.

This is the ambition behind the Strategy for research and development in crop farming, which is prepared in a joint effort by the Danish Royal Veterinary and Agricultural University, the Danish Institute of Agricultural Sciences and the Danish Agricultural Advisory Service.

One of the focus areas of the new three-year strategy is the production of energy crops. This field needs to find ways of producing with multifunctional output, which, put together, can contribute to a positive operating and national economy. An example could be positive environmental effects such as reducing CO_2 emissions.

The research strategy suggests that there is a need for optimising the production of energy crops, and also that the possibilities of adjusting the existing cultivation systems and crops in harmony with new crops should be looked into. For instance, grain can be used to produce ethanol with well-known techniques, rape can be used to produce biodiesel, and maize can be utilised in biogas plants. Bioenergy production can be integrated with the production of food, feed and non-food products and contribute to value generation by utilising by-products and waste from food production.

"Strategy for research and development in crop farming" can be downloaded from the National Centre's website at www.lr.dk.

Biotechnological research strategy

"Value added and a better environment" is the title of a biotechnological research strategy by the Danish advisory committee on food research".

The overall objective of the strategy is to identify promising action areas where biotechnological research can contribute to new and improved non-food and feed products.

The report contains an overall strategy and seven subareas including one on bioenergy. Here, biogas and bioethanol are singled out as primary action areas. The committee states, among other things, that biotechnological processing can create significantly more value from the biomass than simple combustion. In this connection, development of integrated utilisation of the biomass for the production of food, feed, bioenergy and non-food products is an interesting possibility.

The research strategy "Value added and an improved environment" can be downloaded from www.dffe.dk.

Humidification of combustion air

Humidification of combustion air in biomass-fired district heating plants can increase plant efficiency by 10-15 per cent. The technique is particularly suitable for large plants that provide a high return temperature in the district heating network.

By Jens Dall Bentzen

The possibilities of optimising the biomass-fired heating plants by humidification of the combustion air are good. This is the outcome of a recent project carried out by COWI A/S in cooperation with Simatek A/S and Air Fröhlich ApS.

The purpose of the study was to find solutions for lowering the heating prices from the Danish district heating plants as well as improving environmental conditions.

The study received support from the Danish District Heating Association's R&D funds. The whole project report can be downloaded from the association's website.

The humidification principle

In Denmark, the flue gas at condensing woodchip plants is cooled using the return water from the district heating grid. This means that the flue gas leaves the plant at a temperature, which is 3-5°C higher than the return water.

The humidification technique includes an additional unit after the condenser, which transfers heat and moisture from the flue gas to the combustion air. This cools the flue gas by another 15-20°C, which results in a 10-15 per cent increase in plant efficiency (see table 1).

The basis of the project is a so-called optinox rotor, a special rotating exchanger, which absorbs and releases moisture.

Air Fröhlich has developed the rotor for gas-fired heating plants, where it is

photo: cowi a/s

Scrubber tower for cooling of flue gas and humidification of combustion air at the wood-fired Allö plant in Kristianstad, Sweden.

Water content in fuel	55 %	45 %	15 %
Without humidification:			
Flue gas temperature	55°C	55°C	120°C
Total efficiency	108 %	102 %	90 %
With humidification:			
Flue gas temperature	33°C	33°C	33°C
Total efficiency	119 %	113 %	103 %
Increase in efficiency	11 %	11 %	13 %

Table 1: Data for woodchip plant with a return temperature of approximately 50°C with and without humidification. The efficiency of dry fuel (15 per cent moisture) is set at 90 per cent, as these plants do not use condensing operation.

photo: cowi a/s

Stack and holding silo at the wood-fired Allö plant in Kristianstad, Sweden. Note the smoke plume, which is almost invisible, as a very large part of the water vapour is expelled by humidification of the combustion air.

capable of increasing efficiency to 109 per cent. At the same time, NO_x emissions are reduced by approximately 75 per cent because the moisture content of the combustion air decreases the flame temperature.

Several techniques

The first part of the project was to study Danish and international experience. At this early stage, it became clear that the humidification techniques is widespread in several countries, including Sweden. Field trips to Sweden were therefore made, and several suppliers, consultants and plants were visited.

The final project report includes descriptions of five Swedish plants, as well as a review of the following methods of moisture transfer between flue gas and combustion air:

Plants with rotors

There are several variants of the rotor solution. Some are made in plastic, others in stainless steel. At several plants, particles are removed from the flue gas before the condenser, which provides a very clean condensate. In other plants the condenser functions both as a scrubber and a heat recovery unit. The common feature is a continuous spraying of the rotors.

Plants with towers

Cooling of flue gas and humidification of combustion air can be achieved by means of towers/scrubbers in which the flue gas is first cooled with condensate that has been cooled with district heating water. Subsequently, the flue gas is cooled further with water that has been cooled with combustion air. Normally, two scrubber towers are used (see figure 2), but there are also examples where the two towers are integrated into one tall tower (see the picture on page 4).

Combination with wet electrostatic precipitator

The company SRE has developed a technique in which the combustion air is heated and humidified in a wet electrostatic precipitator. This provides other advantages. For example, there is no leakage between flue gas and air, and the electrostatic precipitator not only collects dust, but also a considerable share of salts.

Profitability

Economic analyses show that the profitability is highest in plants with a high return temperature, and also, of course,

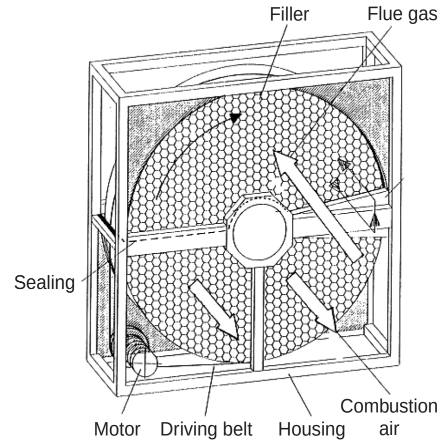

Figure 1: The principle of the optinox rotor.

that profitability improves with plant size and the number of operating hours. Only small plants supplying the district heating network with a low return temperature are not likely to benefit from humidification systems.

The conclusions based on the project are as follows:

- The humidification technique when using woodchip is well-known and well-tested. Several Swedish suppliers have expressed an interest in the Danish market.
- The profitability of humidification plants looks promising for large woodchip-fired plants, especially where the district heating return temperature is relatively high (45-50°C).

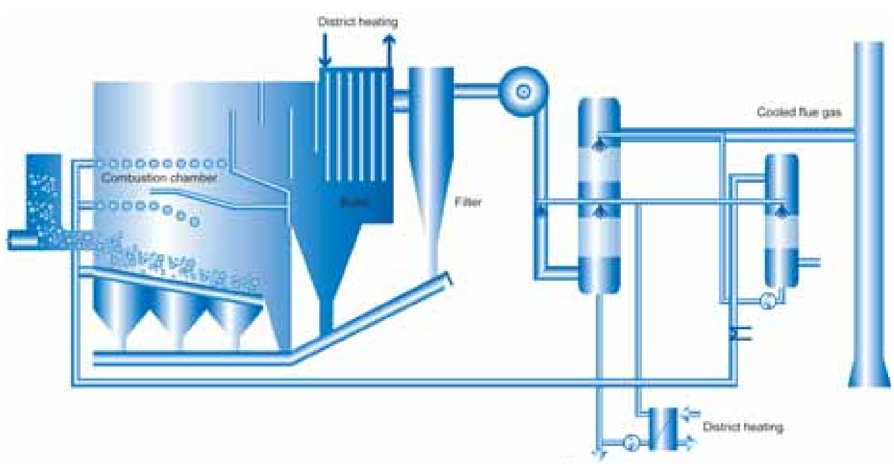

Figure 2: Schematic diagram of a scrubber-based humidification system Fresh air is heated and humidified by a partial stream of condensate whereby it is cooled. The condensate is subsequently used to cool the flue gas, thus separating more condensate from the flue gas.

- The humidification technique can increase the efficiency of wood-chip-fired plants by approximately 10 per cent. The efficiency increase is highest when the return temperature is high.
- The capacity of individual plants increases by approximately 10 per cent, provided the water content of the fuel is below 55 per cent.
- In connection with water contents above approximately 55 per cent, the combustion chamber temperature will often be too low to utilize humidification, and the humidification system should then be bypassed.
- The humidification technique reduces the temperature on the grate, which leads to a smaller risk of slagging.
- Removal of particles, for example by using an electrostatic precipitator or bag filter before the condenser, improves the operation of the condenser and humidifier and requires only simple or no water treatment.
- Using a wet electrostatic precipitator after the condenser can remove part of the salts in the gas.
- NO_x emissions are not reduced considerably by humidification because the most important source of NO_x is nitrogen in the fuel.

Based on the study, it is recommended to establish a full-scale demonstration plant in Denmark, which can function as a Danish reference. Furthermore, it is recommended to look into the technical and profitability potential of applying condensing and humidification at biomass-fired plants, which are not using condensing operation at present. Such plants are mainly straw and pellet-fired district heating plants.

The article has previously been published in the Danish District Heating Association's magazine, "Fjernvarmen" (District Heating), issue 2-2006.

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photo: forskningscenter foulum

The Foulum Research Centre will be supplying manure for the new test plant.

Large biogas test plant

The Danish Institute of Agricultural Sciences is establishing the world's largest operation and research plant for biogas in Foulum, Denmark, at a value of DKK 25 million. Xergi A/S is building the plant, which is expected to be in operation by the end of 2006.

"The biogas plant is an important element in placing Denmark on the world map as a market leader within biogas and environmental technology," says Søren Mikkelsen, Assistant General Manager of the Danish Institute of Agricultural Sciences.

For a number of years, the biogas field has needed a focus and sustained development in order to find the optimal solutions that provide a vital breakthrough in the field.

"With a plant this size we can carry out tests using different techniques and types of biomass. The plant is to be used in research and development projects. It will provide new development possibilities for regional and national businesses," says Søren Mikkelsen.

At the Danish Institute of Agricultural Sciences, the new biogas plant will also be attached to the new technology centre, Centre of Bioenergy and Environmental Technology Innovation, which has just been established at the Agro Business Park. The Danish Institute of Agricultural Sciences is one of six participants of the centre, which, among others, includes the Technical University of Denmark, the Engineering College of Aarhus and Agro Business Park.

"If we are to have a high animal production, we need to develop new environmental technologies that can handle the manure. And I am not just talking about biogas from manure, but environmental technology in general," says Søren Mikkelsen.

The biogas plant will be a full-scale research plant, which will handle manure from the livestock at the Danish Institute of Agricultural Sciences.

The plant is intended to be so flexible that single components can be taken out of the plant, enabling scientists and businesses to test single components and various processes. This allows unbiased documentation of the companies' products.

"With this plant the biogas industry has got a much wanted test station for full-scale tests and documentation similar to the wind turbine industry's test station for wind turbines", states Xergi's Managing Director, Frank Rosager.

He looks forward to being able to document the great optimisation potential of the biogas plants, for example by combining different types of pre-treatment with the use of energy crops such as maize, beet and various species of grass.

A total of four biogas reactors and a complete operation plant will be made available for scientists, students and businesses.

When operating, the plant will be able to produce 850,000 cubic metres of methane a year, enough to supply 800 households with power and 200 households with heating.

Higher gas yield from manure

Tests at the Danish Institute of Agricultural Sciences show that the gas yield from a biogas plant can be increased significantly if the degassed biomass is separated and the fibre fraction subsequently redigested. If lime is added, the yield can be increased even further, but this solution is less attractive due to the costs of lime.

By Henrik B. Møller

Until now, it has been difficult to make enough profit at biogas plants when they only treat manure. Therefore, it has been necessary in the vast majority of cases to secure profitability by adding easily convertible industrial waste.

There is, however, a large unexploited energy potential in manure, which requires special initiatives. Manure contains large amounts of hardly convertible dry matter, which is not converted in traditional biogas plants. Today, only 40 and 60 per cent of the energy content of cattle and pig manure respectively are converted in a biogas plant.

There are various possibilities of increasing the gas production in continuous reactors. Thus, it has been shown that the gas yield can be increased if the solid retention time of the hardly convertible parts of the manure is longer than the hydraulic retention time.

There are several more or less sophisticated ways of increasing the retention time of the hardly convertible parts of the manure. They may, for example, be subsequent mechanical separation and redigestion of the solid fraction, or they may be simple methods such as sedimentation prior to being pumped out.

Higher yields

The Danish Institute of Agricultural Sciences has performed a number of tests with separation of degassed biomass and redigestion of the degassed fibres from a decanter centrifuge with or without chemical treatment.

Yields from redigestion of fibres without chemical treatment vary, depending on the biogas plant and the biomass used, from 94 litres of CH_4/kg organic dry matter to 208 litres of CH_4/kg organic dry matter (figure 1). If up to 70 kg of lime/tonne of fibre is added, it is possible to increase the total yield to 179-291 CH_4/kg organic dry matter.

Figure 2 shows how the increased yield depends on the amounts of burned lime (CaO) and NaOH. The effect of burned lime is apparently better than NaOH, and since burned lime is also cheaper, this solution is, of course, preferable.

The increase in yield ranges from 5-90 per cent depending on dosage. However, at the higher dosages, a certain degree of inhibition is seen at the beginning of the tests, especially when using NaOH.

Lime is expensive

The tests of redigestion of degassed fibres have shown that an increased gas production can be achieved, and that adding of increased amounts of burned lime increases the extra yield.

The use of lime does, however, add appreciably to the costs. In figure 3, the costs are listed per m^3 of methane produced at a lime price of DKK 1.20 per kg.

		Common plant		Farm plant	
	Unit	**Without lime**	**With lime**	**Without lime**	**With lime**
Amount of manure	tonnes/year	150,000	150,000	20,000	20,000
Dry matter content	per cent	7	7	5	5
Biogas yield manure	l/kg organic dry matter	300	300	300	300
Biogas yield	Nm^3/year	2,520,000	2,520,000	240,000	240,000
Amount of lime	per cent	0	4	0	0.7
Biogas yield of degassed fibre	l/kg organic dry matter	208	291	94	117
Extra gas yield	Nm^3/year	419,328	586,656	18,048	22,464
Value extra gas	DKK/year	1,257,984	1,759,968	54,144	67,392
Cost of lime	DKK/year	0	720,000	0	42,000
Net gain	**DKK/year**	**1,257,984**	**1,039,968**	**54,144**	**50,592**
Net gain including separation cost	**DKK/year**	**507,984**	**289,968**	**- 45,856**	**- 49,408**

Table 1: Calculations of the consequences of separation and the subsequent redigestion of the fibre fraction with and without lime. It is assumed that the value of methane is DKK 3.00/m³, and the cost of lime is DKK 1.20/kg. The plant is a common plant with a high residual gas potential in the fibre fraction; the farm plant, however, has a low residual gas potential in the fibre fraction.

In most cases a price of DKK 2.00/m³ of methane will be acceptable. This means that it may be an economic advantage to add 40 grams of CaO per kg separated fibre in a common plant such as Fangel, while it will hardly be an economic advantage to add more than 7 grams per kg of separated fibre for a farm plant (Præstø). This has to do with the fact that the gas potential is far greater in the fibre fraction from the common plant than from the farm plant.

Unfortunately, no tests have been carried out with smaller amounts of lime for fibres from Fangel, but it is possible that smaller dosages will be more profitable.

Best for common plants

Table 1 sums up the consequences of redigestion of the fibre fraction with and without adding lime for a common plant and a farm plant respectively. The table shows that there is a considerable net gain from redigestion of the fibre, provided that separation occurs in advance and is paid for by the involved farmers' advantages as regards fertilizer.

If the separation cost is included, it will not be an economic advantage for plants with a low residual gas potential in the fibre, but it will still be reasonable for common plants with a high residual gas potential. Furthermore, the extra gas production resulting from the addition of lime cannot pay for the additional cost of purchasing lime. It is, however, possible that derived effects in the form of small amounts of fibre and a high lime content in the fibre fraction may contribute positively to the calculations.

For some plants, the value of methane may represent a higher value than DKK 3.00/m³, and in some connections it will be possible to purchase lime at under DKK 1.20/kg. Both will make it more attractive to add lime.

The economic gain of redigestion is, however, primarily dependent on the gas potential in the fibre fraction, and on whether or not the separation cost is included.

Redigestion of fibre is, naturally, only possible if the plant can handle the increased dry matter content in the reactor.

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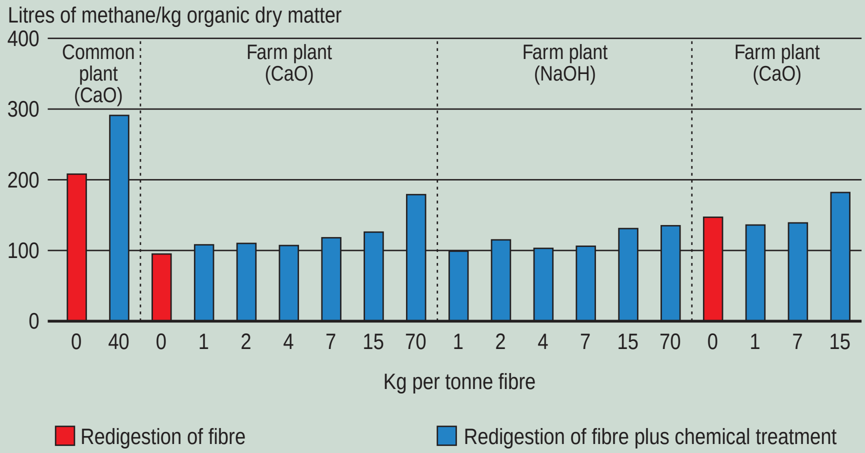

Figure 1: Methane yield by separation and subsequent redigestion of the fibre fraction with and without chemical treatment for 14 days. The tests are laboratory tests using mesophilic batch digestion at 35°C and a retention time of 105 days. The three types of fibre tested come from Fangel (common plant), Præstø (farm plant) and Bygholm (pilot plant).

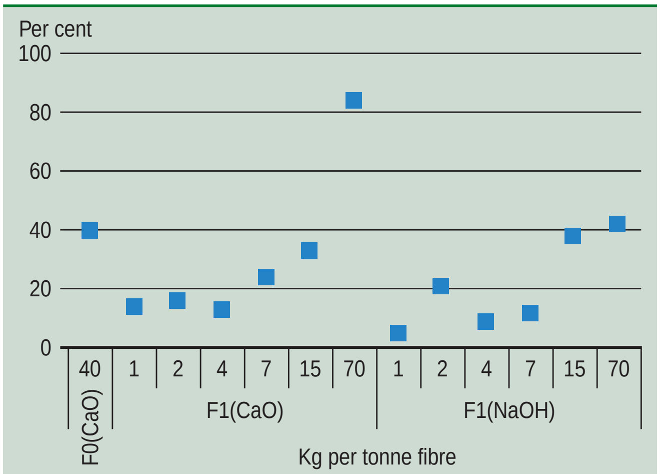

Figure 2: Increased yield in per cent at varying amounts of burned lime (CaO) and NaOH in kg/tonne. F0 is fibre from the biogas common plant in Fangel, while F1 is fibre from the farm plant at Præstø.

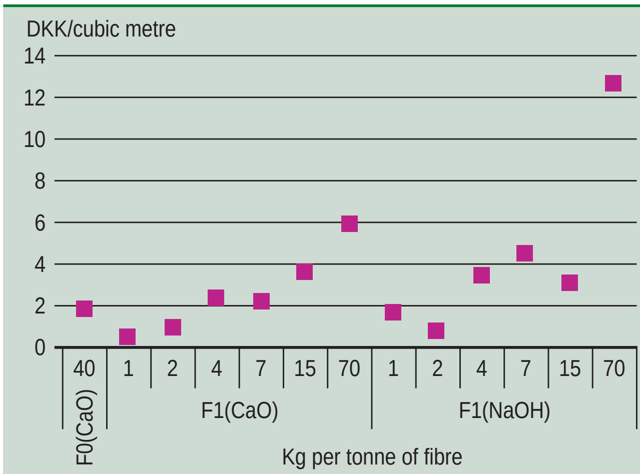

Figure 3: The cost of CaO/NaOH per m³ of increased production of methane compared to no redigestion of the fibre. It is assumed that the value of methane is DKK 3.00/m³ and the cost of lime is DKK 1.20/kg.

Odour nuisances from biogas plants

photo: torben skøtt/biopress

Renovation of biofilter for air cleaning at a plant at V. Hjermitslev.

A new project is to focus on odour nuisances from biogas plants and suggest how inconvenience to traffic in the locality can be minimised.

The energy production from biogas plants has been increased tenfold from 1990 to 2004, but in recent years this development has almost come to a standstill. In many cases, this is due to the economic conditions, but in other cases the projects have been shelved due to the neighbours' fear of odour nuisances.

A new project supported by the Danish Environmental Protection Agency is to remedy the latter. PlanEnergy, a consulting business specialising, among other things, in biogas, is behind the project. The business has been asked to determine how to effectively prevent odour nuisances from the biogas plants so that the authorities know what to demand from new plants.

The fact is that the neighbours' fear is not unfounded. Over the years, there have been several examples of plants which have caused odour nuisances. On the other hand, it is also a well-known fact that many biogas common plants have demonstrated how to completely avoid odour by means of different technical solutions and cleaning methods. The purpose of the project is therefore to collect the existing knowledge in the area and give an account of which technical solutions have proved more effective.

Biogas plants can smell for many reasons. Undersized or faulty air extraction systems can be an explanation. In other cases it can be tank covers that are not tight or displaced air from pretanks when unloading the biomass.

Over the years, a number of systems have been developed to prevent odour nuisances from the plants. In the beginning, the air was often led through bark filters. Later, several plants started burning the air in gas boilers, but today the focus is increasingly on more advanced solutions such as biofilters and chemical scrubbers. These systems have proved very effective, but relatively costly.

The air cleaning project is to be completed on 1 June this year. Apart from solutions to prevent odour nuisances, the project should also contain examples of how to minimise inconvenience to traffic in the area around the biogas plant by choosing the right location. *TS*

FiB – Bioenergy Research is published with support from Denmark's Energy Research Programme, Elsam and Energi E2. 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 supplied as an insert in the Danish magazine, Dansk BioEnergi. Further copies of the Danish version can be ordered from BioPress, via the following e-mail address: biopress@biopress.dk, or telephone number +45 86 17 34 07.

Editor responsible: Torben Skøtt

ISSN: 1604-6358

Production:
BioPress
Vestre Skovvej 8
DK-8240 Risskov
Telephone +45 8617 3407
Telefax +45 8617 8507
E-mail: biopress@biopress.dk
Homepage: www.biopress.dk

Photo on the front page:
BioPress and COWI A/S

Copies printed: 4,000

Print: CS Grafisk. The magazine has been printed on environment-friendly offset paper.

Reproduction of articles or illustrations has to be accepted by BioPress. It is allowed to quote articles if the source is clearly indicated.

Next issue:
to be published in the middle of April 2006. The deadline for articles is 15 March 2006.