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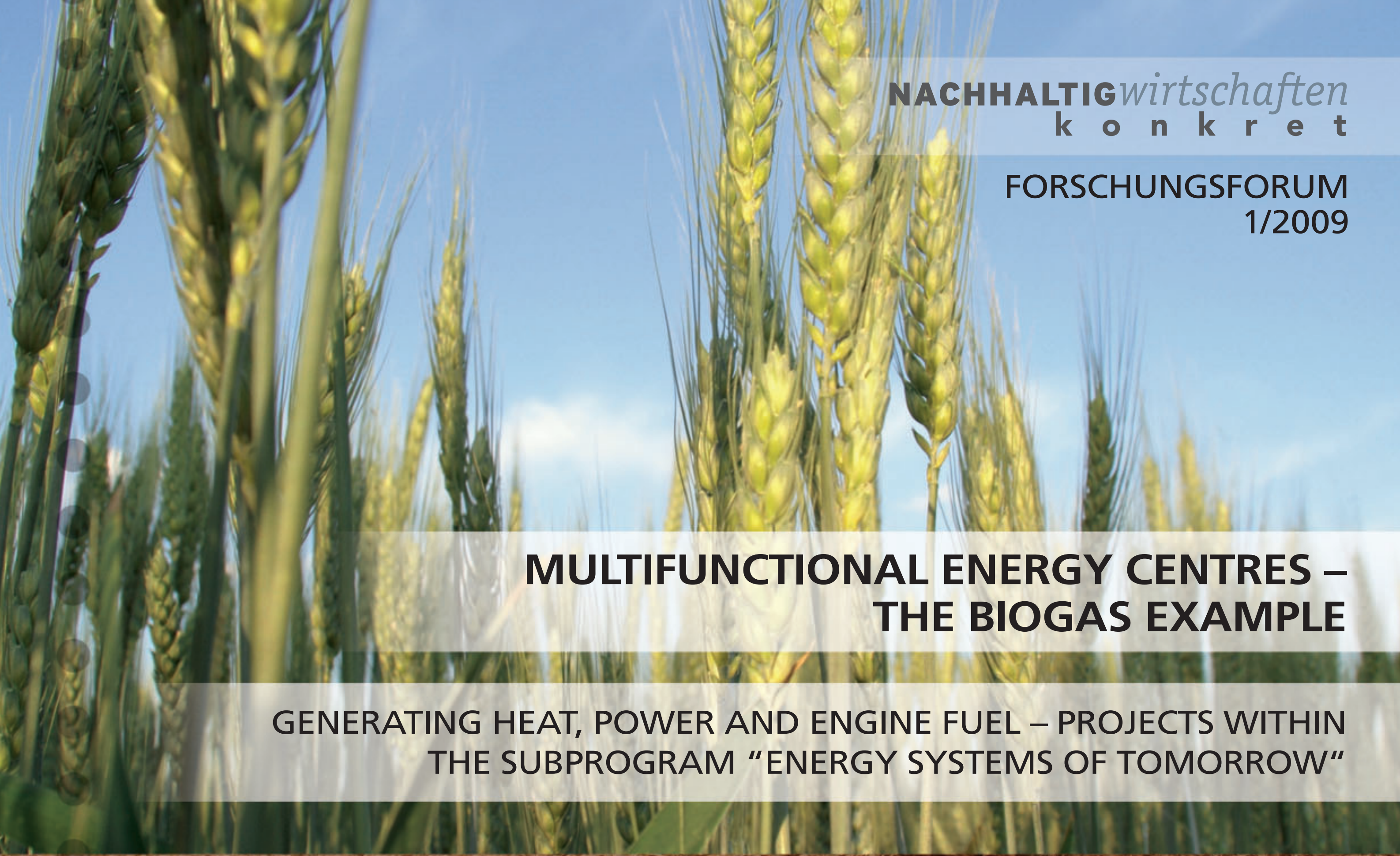
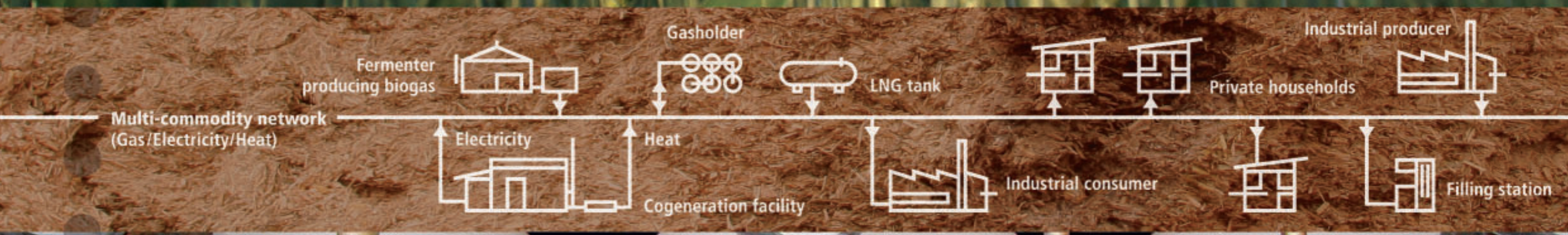


MULTIFUNCTIONAL ENERGY CENTRES – THE BIOGAS EXAMPLE

GENERATING HEAT, POWER AND ENGINE FUEL – PROJECTS WITHIN THE SUBPROGRAM "ENERGY SYSTEMS OF TOMORROW"



bmvit
Austrian Federal Ministry of Transport,
Innovation and Technology

TOPIC

MODEL SYSTEMS FOR MULTIFUNCTIONAL ENERGY CENTRES

As long ago as 1999 the Austrian Federal Ministry of Transport, Innovation and Technology (bmvit) launched the "Sustainable Development" research and technology program, aimed at effectively supporting the process of restructuring towards sustainability. Since then both R & D projects and demonstration and diffusion activities that lend new impetus to innovation in Austria's economy have received support within the scope of a number of subprograms. The "Energy Systems of Tomorrow" subprogram is aimed at developing technologies and concepts for a flexible, energy-efficient energy system based on using renewable energy sources and capable of safeguarding our energy requirements long-term. System issues, approaches and technologies are researched and developed within the subprogram, as are implementation strategies.

The expression "multifunctional energy centre" refers to a synergetic combination of technologies to provide and use renewable sources of energy at community level. Facilities of this kind utilize local or regional resources to deliver heat/refrigeration, electricity and fuels, and are well integrated in their local/regional surroundings. Since the facility is close to the consumers, the process can be very efficient. The multi-commodity approach makes the energy system flexible, particularly as regards storage and control arrangements. Research work in this field is concerned with developing innovative components and system solutions, thus achieving the prerequisites for setting up demonstration projects. In this connexion the question of tailor-made organizational structures for operating the facility is important; here local stakeholders (including consumers) should be involved. From the point of view of energy efficiency and cost-effectiveness multifunctional energy centres can achieve significant improvements in exploiting renewable sources of energy, and should therefore be developed into a mainstay of regional energy supply in future.

Biogas has the potential to play a key role in the sustainable use of biomass as a source of energy. Several advanced technologies have been developed in Austria for processing biogas and using it to generate electricity and heat, and also as fuel. For instance, Jenbacher gas engine technology makes it possible to run engines in the range 0.25 to 3 MW on natural gas, biogas or various special gases. As a high-grade gaseous form of energy, biogas can be used in various different ways: to generate electricity and heat, to be fed into existing natural-gas grids, as an engine fuel and to be distributed in local networks. Alongside energy crops from sustainable cultivation, other substrates can be utilized in cascading processes.

Currently 340 biogas plants with a total capacity of around 86 MW are in operation in Austria, generating roughly 500 GWh of electricity per year from renewable sources (source: Energie-Control 2008). As the feed-in tariff for electricity generated from renewable sources is regulated by statute in Austria (Ökostromgesetz), biogas plants can cover their costs; however, their future is threatened by fluctuations in price and by increases in the cost of substrates. New , economically attractive ways of exploiting biogas are therefore needed.

Expanding a biogas plant into a "multifunctional energy centre" offers a good chance of the facility generating more value locally long-term. There is additional potential in purifying part of the biogas produced to natural-gas (engine fuel) standard and supplying it straight to the consumer, without feeding it into an existing grid.

Several different R&D projects concerned with the technologies required, the layout of "multifunctional energy centres" and implementation in demonstration projects and pilot regions have been carried out within the "Energy Systems of Tomorrow" subprogram.

Multifunktionale Energiezentrale Margarethen am Moos (Multifunctional energy centre in Margarethen am Moos)

A demonstration project within the subprogram, set up by the operators of the associated biogas plant "Margarethen Energy Supply" in cooperation with the Vienna University of Technology.

Effiziente Biogasaufbereitung mit Membrantechnik (Processing biogas efficiently with membrane technology)

At the Vienna University of Technology an innovative process has been developed to purify biogas to natural-gas standard straightforwardly and at low cost.

Agrarische Rohstoffbasis zur Biogaserzeugung (Agricultural feedstock basis for generating biogas)

At the Vienna University of Natural Resources and Applied Life Sciences several tasks concerned with improving the various stages of producing and processing substrates and boosting efficiency have been carried out.

P R O J E C T

GENERATING HEAT, POWER AND ENGINE FUEL
THE BIOGAS PLANT IN MARGARETHEN AM MOOS

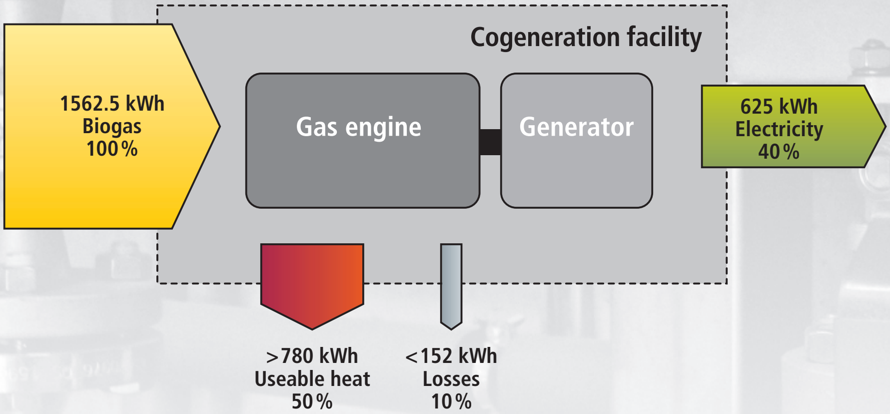
The biogas facility in Margarethen am Moos is operated by a cooperative called EVM (“Energy Supply Margarethen”) and made up of 15 farmers who run a district heating facility for 120 households. In 2004 the cooperative took the decision to set up a 500 kW_{el} biogas plant to generate electricity and heat.

To supply this facility around 10 000 t of renewable raw material are needed per year; this is grown on an area of roughly 200 ha around the plant. Since precipitation in the region in question is limited (600 mm per year), plants that cope well with dry conditions are used, mainly sorghum and sudan grass; the cover crop in winter is rye. Lucerne, grass and clover can also be used. High energy yields can be achieved if the substrate for fermentation is chosen intelligently and state-of-the-art fermentation technology and special additives (see below) are employed.

In the course of the last few years the facility was fine-tuned and enlarged. To make it more energy-efficient, the exhaust gas losses were reduced and power-generating capacity increased to 625 kW_{el}; this was simply a matter of modifying the Jenbacher 316 engine. In a standard cogeneration facility around 20% of the energy content supplied is lost, owing to the exhaust-gas temperature (roughly 200 °C) and radiant heat lost from the engine. Here these losses were cut to 10 %, by designing the exhaust gas heat exchanger for 100 °C and lowering the stack temperature to 100 °C. To cope with peaks in demand and as a standby in emergencies, a 900 kW Wolf boiler is on hand; with a dual-fuel burner, it can run on biogas or biodiesel. This combination of cogeneration facility and boiler can deliver up to 1.6 MW of heat, thus ensuring adequate heating even at extremely low outdoor temperatures.

To increase the value to the local community further, some of the biogas is purified to engine fuel standard and sold on the spot, rather than being fed into a grid; this started in 2007. With

Energy efficiency of the 625 kW Cogeneration facility in Margarethen am Moos



Source: HEI Consulting GmbH

the right technology biogas can be processed to match natural gas for purity, and then used to fuel motor vehicles; in contrast to generating electricity from biogas, this processing involves not energetic conversion but an increase in energy density – incombustible CO_2 is separated from energy-rich CH_4. The purified biogas contains up to 98 % CH_4, the residue less than 2 %. So as not to emit any CH_4 into the atmosphere, the residue is fed back into the cogeneration facility, i.e. used to generate electricity. This means that practically no energy is wasted in purification – efficiency is almost 100 %. A liquid desulphurizing agent (Deuto Sulfo Clear, commercially available) containing trace elements and minerals is added to the substrate to be fermented; it prevents stench and protects the micro-organisms against toxic gases. As a result the biogas produced contains less than 10 ppm hydrogen sulphide (H_2S) and can thus be processed into engine fuel without further desulphurization.

In Austria a statutory order defines the quality standard applying to gaseous fuels. The main considerations are the methane content and the relative density. The biogas facility produces around 25 kg/h of purified biogas, equivalent to roughly 35 l/h of petrol. Sold under the brand name “methaPUR”, it contains more than 95 % methane and complies with international standards for gaseous engine fuels as regards calorific value, Wobbe index and density.

After purification, a high-pressure compressor compresses the biogas to 300 bar and stores it in a high-pressure storage vessel – part of the biogas filling station that started operation in December 2007. The fuel facility functions on the supply-on-demand principle, utilizing the high-pressure storage vessel as a buffer element. The filling station is not open to the general public; customers are required to register with the cooperative first of all.

They then receive a key tag with a built-in chip to activate the filling system. The filling station is self-service; the customer pays by debit card or credit card. "methaPUR" costs no more than the natural gas sold at public filling stations.

In the business case for the facility in Margarethen am Moos a payback period of 6 years is planned for the investment (around 440 000 Euro) in fuel production. By then 200 cars with an average fuel consumption of 5 kg gas per 100 km, travelling 15 000 km per year on average, should be using the filling station regularly. The business case is based on a price of 90 Euro per t of substrate for the biogas facility.

Factbox
Biogas facility in Margarethen am Moos

- ***Nawaro biogas facility, generating capacity 625 kW***
- ***2 digesters (2200 m^3 each)***
- ***Fermenter temperature 40° C***
- ***Sealed storage vessel (4500 m^3) plus open storage tank (5500 m^3)***
- ***Final residue is separated off so that water can be returned to process***
- ***Residue cake is sold to some extent***
- ***Heat is supplied via a district heating grid 3.5 km long***
- ***Heat users: residential area, farms, stately home, council kindergarten***
- ***Connected load (heat): 1.2 MW***
- ***Fuel production: 25 kg/h biogenic CNG***

Producing and using biogenic CNG as an engine fuel has various positive aspects:

- Biogenic CNG is produced locally from renewable resources.
- The entire chain of value creation – making and processing biogas, selling the fuel and using it – is located in the region in question (substrate suppliers, facility operator, fuel consumers ...).
- Production and sale are not dependent on a gas grid, so biogenic CNG can in principle be produced in any biogas facility, regardless of location.
- The fuel is largely climate neutral; in use it releases scarcely any pollutants, such as incompletely combusted hydrocarbons or particulates.
- Producing biogenic CNG can be economically attractive as a supplement/alternative to generating electricity from biogas.

The purchase price of a car running on natural gas is currently close to that of a comparable diesel-engined car and around 20 % above the price of a comparable petrol-engined car. At the moment there are somewhat more than 3000 cars running on natural gas in Austria, with around 140 filling stations selling natural gas. From 2008 on the approach successfully pioneered in Margarethen am Moos should be copied elsewhere; it is planned to implement 20 to 25 more biogas filling stations along these lines.

PROJECT

PROCESSING BIOGAS EFFICIENTLY WITH MEMBRANE TECHNOLOGY

In Margarethen am Moos biogas is purified to engine-fuel standard by means of a membrane process developed in Austria (Institute of Chemical Engineering at Vienna University of Technology; cf. Forschungsforum 2/2006). The process was first successfully tested in a pilot plant in Markt St. Martin in Burgenland, where it was shown that the process works, and that it can achieve the degree of purity required for supply to a grid or for use as CNG fuel.

Biogas from grass and energy crops is a mixture made up of the following gases: 50 to 75 % methane (CH_4), 25 to 48 % carbon dioxide (CO_2), up to approx. 2 % hydrogen (H_2), traces of hydrogen sulphide (H_2S) and ammonia (NH_3). The mixture is saturated with water vapour.

To achieve natural-gas purity from this starting-point, the following steps are necessary:

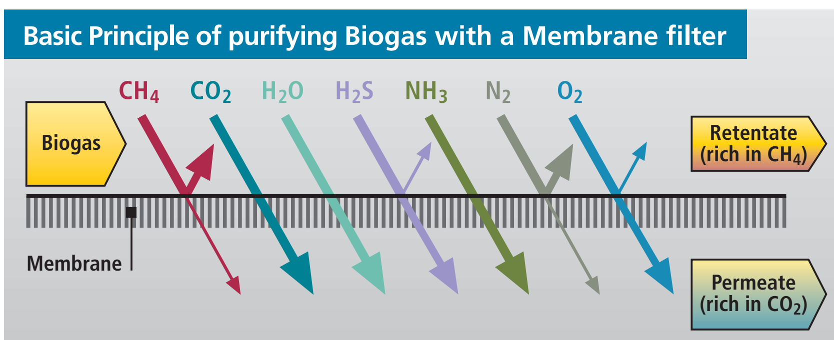
- a purification process to remove biogas constituents that might be harmful to facility components, gas-related equipment, gas-using devices or consumers;
- a methane-enrichment (upgrading) process in which Wobbe index, calorific value and other parameters are set so as to fulfil the quaility requirements for biogenic CNG consistently (as laid down in ÖVGW G31/G33).

A key technology here is gas permeation, in which the selective permeability of polymer membrane materials is utilized to filter out unwanted constituents from biogas. Polymers that can be used for this (cellulose acetate, aromatic polyimides) are much more permeable to CO_2, H_2O, NH_3 and H_2S than to CH_4; the separation process makes use of this. The product gas can be dried and unwanted CO_2 removed in a single step – the subsequent drying stage needed in other processes is superfluous here.

The main elements involved in the process are:

- gas compression, to achieve the operating pressure needed in the membrane unit and to transport the purified gas on
- gas pretreatment (condenser, H_2S adsorber) to remove impurities that could impair the working of the permeation unit
- permeation (membrane module using hollow-fibre or flat membranes)
- control facilities to regulate pressures, temperatures and flowrates, so as to comply with the product specification

In the **project "biogenic CNG filling station in Margarethen am Moos"** a biogas processing train and a biogenic CNG filling station were added to an existing biogas facility. Here sulphur-bonding agents are fed into the fermenter to minimize the amount of H_2S in the biogas produced (see above). The biogas stream to be processed is



first compressed to around 8 bar, and then cooled to roughly 7° C by stages; at this temperature it is dried. Most of the water vapour present is discharged as a stream of water; any traces of ammonia present are also removed at this stage. Next the biogas is reheated to the right temperature for the subsequent steps, and iron-oxide pellets adsorb the remaining H_2S.

Then carbon dioxide and water are removed from the biogas in a single-stage permeation unit; the methane

constituent is retained under pressure and passes to the high-pressure compressor at the filling station. The proportion of methane and carbon dioxide in the gas delivered („methaPUR") is ontinuously analysed online, with feedback to the process. Provided that gas purity is up to standard, the biogenic methane stream is compressed to up to 300 bar for sale at the CNG pump. The biogas processing unit plus biogenic CNG filling station in Margarethen am Moos is the first facility of its kind anywhere in the world. Its simple, compact design has advantages both for operation and economically. Unit power consumption to process 1 m^3 raw biogas is less than 0.2 kWh, so more than 90 % of the biogas' primary energy content reaches the CNG tank.

PROJECT

THE AGRICULTURAL RAW-MATERIAL BASE FOR PRODUCING BIOGAS

Requirements in the production of biogas from agricultural substrates make it necessary to improve methods of producing and processing these raw materials and make them more efficient. At the Vienna University of Natural Resources and Applied Life Sciences several tasks with this aim have been carried out as part of the “Energy Systems of Tomorrow” subprogram. A project by the Division of Agricultural Engineering is concerned both with cultivation issues and with aspects of fermenting substrate mixes from energy crops. As part of this, numerous varieties of the most important energy crops have been sown in several different locations in Austria, and their yields in terms of biomass and methane investigated. The project team has developed ecologically balanced crop-rotation systems and fertilization programs adapted to local conditions for three areas of small-scale production in Austria. Key process parameters for fermenting energy crops in combination with residues from the food and feed industries have been evaluated in the laboratory and in a biogas facility in Bruck an der Leitha.

Maize, sorghum and sugar beet achieved the highest methane yields; sunflowers and cereals revealed their potential as preceding, catch and subsequent crops. In the course of working out crop rotation sequences adapted to local conditions in the regions investigated (Marchfeld, Grieskirchen/Kremsmünster and the hill country of eastern Styria) and with a balanced dosage of fertilizers, methane yields ranging between 1300 and 1750 m^3 at s.t.p. (in organic farming) and between 1680 and 3870 m^3 at s.t.p. (in conventional farming) per hectare and year were recorded.

Under laboratory conditions the sequence of events in fermentation in biogas facilities was simulated, and the most satisfactory volumetric load and the unit yield of methane were ascertained. Adding co-substrates (rapeseed cake, lecithin) and/or enzymes made gas composition more stable. Monitoring the biogas facility in Bruck an der Leitha provided a comparison between two parallel fermentation trains (conventional and organic) – a particularly valuable aspect.

The data obtained in this project provide a basis for further research and development work on a methane energy-value model and on evaluating energy cropping in ecological and economic terms.

FIGURES/DATA/FACTS

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