Projektinfo **17**/2014

Detailed information on energy research

Organic waste: combining compost and biogas

A liquid extract is separated from the waste from organic waste containers and is used to produce biogas

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A new method improves the energy balance and processing capacity of composting plants. With the usual composting process, considerable energy is consumed to provide the required mechanical ventilation. In the new method, the liquid organic components of the organic waste are separated in advance and are used for producing biogas. This enables energy to be generated in the plants. For the project, a new biofilm digester has been designed which provides cost advantages relative to other digestion processes.

Composting is easy for hobby gardeners. Potato peelings and leaves from the garden are simply thrown onto a pile and, over time, nature transforms this into a nutrient-rich soil. If, however, the organic waste is instead collected and disposed of in organic waste containers, it is then taken to large, centralised composting plants, which requires significantly more effort. The waste is pre-treated, layered, shifted several times during the process, continuously mechanically ventilated and the leachate is collected and fed back into the process. This consumes energy and requires a certain technical expenditure. But this is the only way to create compost of a reliable quality, as is required by agriculture.

In collaboration with the Entsorgungs-Gesellschaft Westmünsterland (EGW) waste disposal company and the Department of Urban Water and Waste Management at Duisburg-Essen University, the Sutco RecyclingTechnik company has developed a new process that combines composting with biogas production: a screw press separates organic matter from the pre-treated, fresh organic waste. The solid content of which the easily degradable organic matter has been removed is then added to the conventional composting process. This pre-pressing creates additional treatment capacity and the plants can process more material with their existing systems. This reduces the specific energy consumption per tonne of organic waste by

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Fig. 1 *The organic waste is initially pulped*

10 to 15 %. The squeezed-out liquid is treated in a new digestion plant, which produces biogas in the digesters. The gas can be used in engines to generate electricity and heat, or fed as biomethane into the natural gas network. Generating biogas from organic waste instead of from renewable resources such as maize, for example, has the advantage that no agricultural land is required.

Making better use of existing capacities

In 2012, approximately nine million tonnes of organic and green waste were produced separately from residual waste ("grey bins") in Germany. The captured volume per resident varies within the federal states from 37 kg in Brandenburg to 151 kg in Lower Saxony. As of 1 January 2015, the amended German Closed Substance Cycle and Waste Management Act requires the separate collection of organic waste nationwide. According to forecasts, the volume will therefore grow by up to 30 %, as a large proportion of the organic waste was previously disposed of together with residual waste. This therefore requires concepts to increase the capacity of the approximately 1,000 German composting plants (2012).
The new composting method with the additional biogas stage (Fig. 2) is intended to be used in as many existing composting plants as possible. This will exploit the energy in the carbon content previously left unutilised during composting before it is converted into CO_2. After pressing out the liquid, organic carbon compounds (organic matter), the organic waste is composted under aerobic conditions as before, whereby the quality of the compost remains almost unchanged. For the treatment of the press water, a biogas process has been selected that is as robust, reliable and economical as possible. This is necessary to limit the operational expenditure and to ensure safe disposal. In addition, the developers want to prevent digestate occurring that has to be disposed of externally. The gas yield is of secondary importance to meet these objectives.

Testing in practice and in the laboratory

The practical test for the combined process is running in the Gescher composting plant belonging to the EGW company. Each year the plant processes about 55,000 tonnes of organic waste that has a low organic matter content when compared nationally. This limits the possible gas yield. Under laboratory conditions, the gas production amounted to 74 Nm^3/t of input in the digestion; in the plant it amounted to an average of

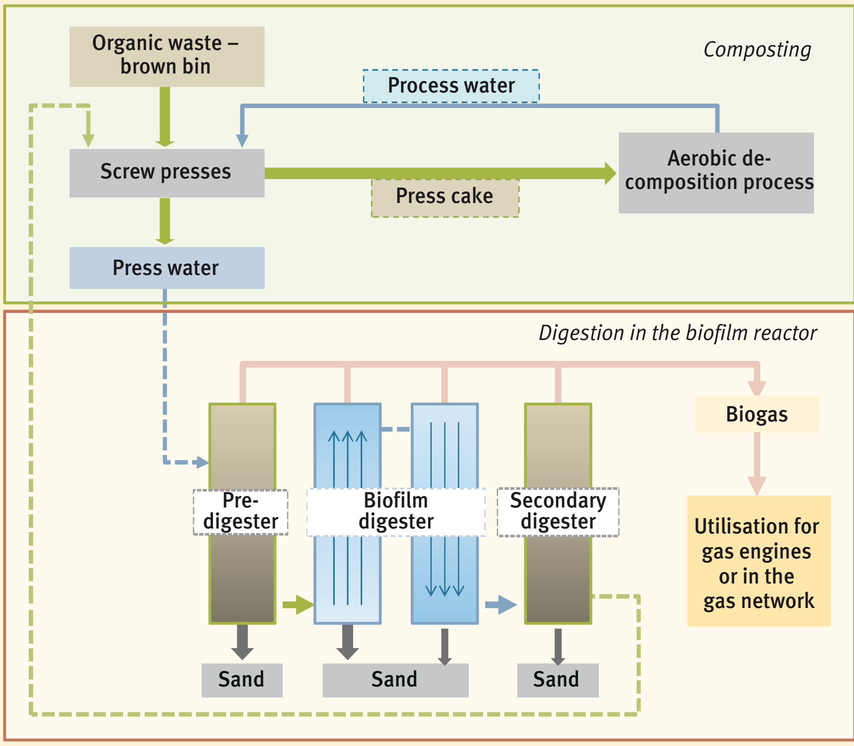

Fig. 2 *The new process is integrated within an existing composting facility. The digestion takes place in four digesters connected in series.*

Organic waste [t]	*Generated volume of press water [m³]*	*Retention time in digester [d]*	*Biogas [m³] per tonne of press water*	*Biogas [m³] per tonne of organic waste*
100	*80*	*8 – 10*	*50*	*40*

Process technology for organic waste and digestion of the press water	*Volume*	*Costs*
Investment costs (estimated)	*60,000 t p.a.*	*~ EUR 2.5 million*
Wear and operating costs incl. presses and CHP plant (estimated)		*~ 88,000 €*
Energy consumption (estimated)	*~ 150,000 kWh p.a.*	*~ EUR 18,000*
Generated biogas	*2.4 million m³ p.a.*	
Possible electricity generation with this gas volume in a CHP plant	*6.67 million kWhel p.a.*	*~ EUR 970,000**

Fig. 3 *Estimated operating costs for a plant with 60,000 tons per year. All figures based on 2014. * German Renewable Energy Sources Act 2014.*

50 m^3. It took about four weeks to convert the plant, which was carried out during normal operation. Two screw presses and two cylindrical and slender digesters connected in series were installed and a continuous stirred-tank reactor (CSTR) was converted into a secondary digester.
A smaller mock-up of the entire plant was built at a laboratory scale at Duisburg-Essen University. Here data is determined that would otherwise be disproportionately difficult to measure in the large system, including the activities, nature and scope of the microbiology on the fixed-bed in the individual stages. The aim of these investigations is to further optimise the process and to speed up the detection of changing operating phases in both qualitative and quantitative terms. One goal is to run the process in the thermophilic range (55 – 60 °C) instead of the previously used mesophilic range (30 – 35 °C). This would be beneficial for sanitising the digestate.

Pressing the organic waste

A screw press separates liquid organic matter from the pulped organic waste (maximum grain size: 80 mm). It works with a pressure of 2 to 5 bar and an electrical output of 37 kW. The squeezed organic waste is then still

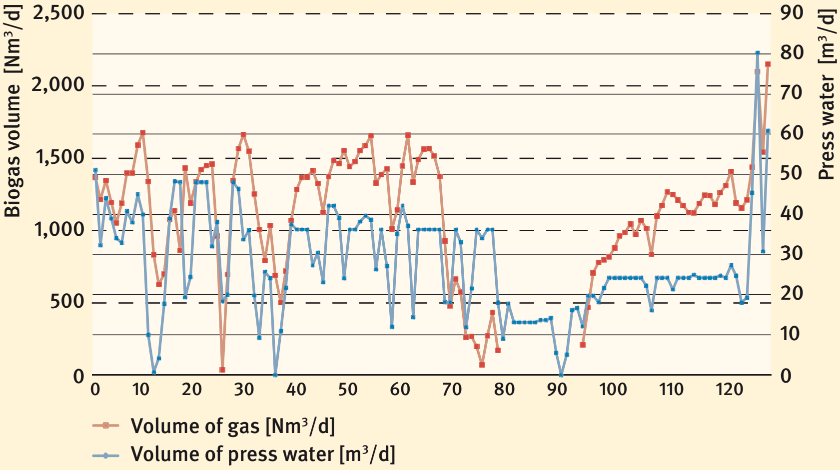

Fig. 4 *The daily biogas production depends on how much press water is fed in. The plant was at a standstill between the 79th and 91st days.*

Fig. 5 *The two biofilm digesters in Gescher are 12.5 metres high with a 3-metre diameter. Left and top right: Digester in Gescher. Below right: The plant in the laboratory.*

sufficiently permeable to air to enable mechanical ventilation during the aerobic composting. If there is excessive compression, the air resistance increases and thus the energy required for the ventilation. After pressing, the material is homogeneously moist and stripped of organic matter, and therefore rots several days quicker. This effect increases the capacity of composting plants by 10 to 15 % for the same energy requirement and without having to expand them.
During pressing, filter baskets with hole sizes from 10 to 20 mm are used. On average Gescher can produce around 45 kg of organic matter from one tonne of organic waste annually. The proportion of dissolved organic carbon in the organic waste varies during the course of the year. It is higher in winter than in summer because then the waste bins are predominantly filled with kitchen waste.

Biofilm promotes gas formation

Wet processes are mostly suitable for digesting press water. The project team decided to use a newly developed biofilm digester with a steep funnel in the base. In this digester (Fig. 5), the microorganisms adhere to a fixed-bed consisting of special textile materials and thus form a large surface area. This creates a biofilm that resembles a layer of slime, whereby only small amounts of bacteria are flushed out of the process. The large surface area makes it possible to shorten the substrate's retention time in the digester, which in turn enables a high throughput in the plant. The method converts up to 86 % of the contained organic matter.
A considerable amount of earth and sand adheres to garden waste. This has to be continuously separated and removed so as not to clog or reduce the filling volume ofrf the digester. For this purpose, collection containers were attached to the bases of each individual digester (Fig. 2) from which the sand can be removed regularly without interrupting the process. Large quantities of sand soon collected in a CSTR digester that was tested at the start of the project. To remove the sand, the process had to be stopped, the substrate drained and the sand then removed mechanically while ensuring occupational safety and providing protection against explosions.
The digestate can be mainly used for washing the fresh organic waste and thus recycled. This avoids external disposal. Otherwise it would have to be sanitised for use as a fertiliser with additional energy expenditure.
The selected biofilm digester meets the aforementioned requirements best of all. Although other dry and wet digestion methods would enable a greater gas yield, they would incur serious disadvantages in terms of the investment, wear and operating costs or the process stability. A film digester available on the market with a tubular fixed-bed was used in the first phase of the project but did not prove to be successful and, following an accident, was replaced with the current system.

Capacities and economic prospects

A plant with an annual throughput of 60,000 tonnes produces about 15 million cubic metres of biogas per year. With a methane content of 60 to 65 %, this corresponds to approximately 9 million m³ of natural gas. Fig. 3 shows an initial estimate of the costs.

Composting and digestion

Dry, solid organic waste materials are more suitable for composting, whereby a sufficient supply of oxygen (aerobic atmosphere) enables the carbon-containing compounds to be converted into CO_2 and heat. This process heat sanitises the compost, enabling it to be used without further heat treatment as fertiliser in agriculture and horticulture.

Liquid or very moist biological waste materials are more suitable for digestion for the purpose of producing biogas. Here, bacteria convert the carbon-containing compounds in the absence of oxygen (anaerobic atmosphere) into biomethane (CH_4). Following gas purification, this can be used in CHP plants or fed into the natural gas network. The remaining digestate from the organic waste can be used as fertiliser in agriculture, provided that it has been sanitised by subsequent heating to between 55 and 70 °C.

Utilising organic waste for generating energy

Irrespective of whether the biogas originates from organic waste treatment plants or agricultural waste materials, it is initially only raw gas. Depending on the starting material, only 50 to 75 % of it consists of the methane gas required for energy production. The rest consists of carbon dioxide and trace gases such as hydrogen sulphide, hydrogen, oxygen and – when using organic waste – long-chain hydrocarbons. Furthermore, it is 100 % saturated with water. During the gas treatment, some of these associated gases are removed when condensing the water vapour, while others have to be removed in a separate purification step. This pre-treatment prevents corrosion and damage to engines and valves, and also enables low-emission combustion. In addition to combined heat and power (CHP) plants that have proven themselves over many years, gas turbines will also in future provide a means for producing energy from biogas. In the long term, the use of biogas in fuel cells is also a technical option.
Biogas is often generated at locations where there is too little local heating demand to be able to operate a CHP plant economically. It then makes sense to feed processed biogas into the natural gas network. The 2010 Gas Network Access Ordinance has paved the way for this. The natural gas network can absorb large amounts of biomethane at any time. According to a report by the German Federal Network Agency to the German federal government, 150 biogas plants fed around 602 million cubic metres of biogas into the gas network in Germany at the end of 2013. A year earlier this figure was 413 million m^3.
As a climate-friendly energy source, biogas therefore helps to secure energy supplies and, in combination with CHP plants, can balance out the fluctuating energy fed into the grid from wind and photovoltaic systems.

Pyrolysis

In addition to the generation of biogas, the research is also focussing on pyrolysis as a further option for the energy-based utilisation of biomass. Here, biomass is carbonised under high temperature and pressure. The resulting biochar can be used not only as fuel; there is also interest for this product from agriculture. There it acts as a soil enhancer and provides a relatively long-term form of carbon sequestration. With funding from the German federal government, a demonstration plant for pyrolysing organic waste commenced operation in Halle-Lochau in 2013.

Project participants

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- **Large-scale plant:** Entsorgungs-Gesellschaft Westmünsterland mbH (EGW), Gescher, Germany, Adolf Kreimer, www.egw.de

Links and literature

- www.energetische-biomassenutzung.de/en/home.html ('Biomass energy use' funding programme)
- www.biogas.org (German Biogas Association)
- www.international.fnr.de (Agency for Renewable Raw Materials – FNR)

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