Biogas Utilisation in Berlin

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Sustainable resource management and active climate protection as well as the long-term rise in energy prices determine the decision-making processes of municipal waste service providers. Optimised energy utilisation from waste is is a major priority in the strategy of BSR (Berlin City Cleaning Services). As a result BSR started up an organic waste fermentation plant in 2013. The biogas is processed and transformed into biomethane, which is fed into Berlin‘s gas distribution network and then used as fuel for BSR‘s waste collection vehicles that run on natural gas, thereby replacing about 2.5 million litres of diesel.

1. Conceptual basis

BSR began to segregate domestic organic waste in 1990/91. It was predominantly the inner-city areas with waste collection points with a volume larger than 480 litres per week that were connected to the separate collection system.

Today BSR effects the segregated collection and recycling of around 125,000 tons per annum of organic waste. More than half of this (62,000 tons) comes from locally-sited organic-waste bins. The remainder is derived from the contents of leaf bags and from road leaf collections (60,000 tons), small amounts of tree and shrub trimmings (1,000 tons) and Christmas trees (2,000 tons).

As regards their relative cost effectiveness it now appears that composting and fermentation are edging ever closer. On the one hand the statutory requirements concerning the containment and waste-air purification of composting facilities (Technical Instructions on Air Quality Control) are becoming ever more stringent, on the other hand the revenue situation for the net energy output of fermentation plants is demonstrably more favourable.

With regard to the required capacities and the plant design it is first necessary to ascertain the waste properties with great care. This essentially concerns the content of extraneous materials and the energy-recovery potential of the waste.

The energetic properties of organic waste were investigated for the entire annual cycle. Due to water accounting for around 65 percent of the wet matter content, the average calorific value of Berlin's organic waste is only 3,100 kJ/kg, which means that thermal treatment is not the optimum solution. The situation is different for the relatively dry tree and brush trimmings as well as for wood. These fractions have a calorific value of around 8,000 kJ/kg and they are not suitable for producing appreciable quantities of biogas. This is because, like raked autumn leaves, they are only accessible to anaerobic microbial transformation to a rather limited extent. If we assess the energy required to process garden waste (e.g. electricity and heating, sanitation processes to meet the requirements of the Organic Waste Regulations and for waste-air purification) in a fully encapsulated organic waste fermentation plant, we reach the order of magnitude of the energy potential contained in garden waste. Fermenting garden waste and autumn leaves therefore does not deliver any energetic advantage and is only a sensible ecological option in conjunction with the production of humus.

In the opinion of BSR the biological method of energy utilisation only makes energetic and economic sense if the gas potential is at least eighty normal cubic metres (Nm^3) per megagram of waste. Currently BSR distinguishes between fermentable and less fermentable to non-fermentable wastes. The solid and liquid digestates are recycled after fermentation. The solid digestates are aerobised, graded and used as agricultural soil improvers. The liquid digestates are used as liquid compost with the aim of becoming the ideal fertiliser replacement. The post-treated fermentation residues from the biogas plants have positive ecological properties as soil improvers. In supplying nutrients and organic material, they can make an important contribution to soil fertility, to biodiversity and to protection against soil erosion. By replacing mineral fertilisers, the fermentation residue also helps with climate protection.

The improved energy-related environment – this includes the Combined Heat and Power Act, the Renewable Energy Act, the Renewable Energies Heat Act, the Gas Grid Access Ordinance, the Gas Grid Charges Ordinance, the Incentive Regulation Ordinance and the Electricity Grid Charges Ordinance – offers considerable organisational and cost-accounting benefits in terms of marketing and the feed-in option for processed biogas. The gas system operator is now responsible for the gas pressure measurement and control station, for the connection to the gas grid, for calibration and odorisation as well as for compliance with the regulations of the German Gas and Water Federation (DVGW G685 LPG allowance for alignment with the Wobbe index/calorific value). According to the current interpretation of the wording of the laws, the associated investments in the planned biogas plant must be shared equally between the system operator and the infeed company (BSR). The system operator has sole responsibility for the actual operation.

It is therefore BSR's belief that fermentation of digestible wastes to produce biogas and the agricultural use of the digestate represents the best possible option. In future composting or energy recovery should also continue to be an option for treating the less or non-fermentable wastes.

2. Plant strategy and technical concept

The first phase involved taking a decision in favour of a plant with an annual capacity of 60,000 tons.

Improvements to the cost structure of collection is a key variable for the development of the plant design. That is why an enclosed digestion process was chosen, as this can be implemented in a logistically convenient urban area.

As a result of the new biogas plant, and for the first time in Germany, it has been possible to carry out the entire process chain within a single company:

- Separate collection of organic waste
- Processing of organic waste
- Fermentation and generation of raw biogas
- Cleaning and processing of raw biogas to biomethane quality
- Injection of biomethane into the natural-gas grid via the local gas system operator
- Withdrawal of biomethane energy equivalents via three high-capacity natural-gas filling stations on the company's own land
- Utilisation of biomethane as a diesel substitute for the collection and transportation of local domestic waste

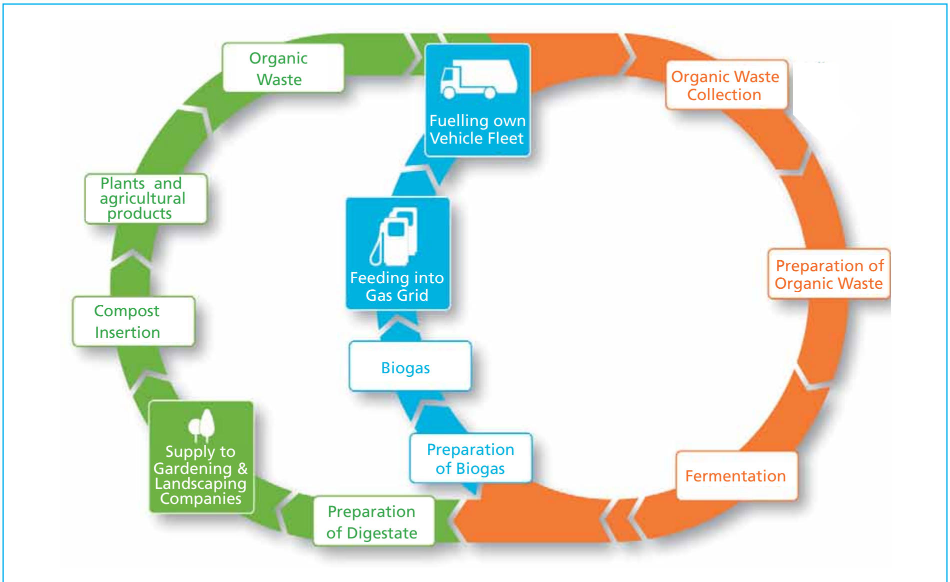


Figure 1: Closed cycles in organic waste disposal

Compared with pure composting, the fermentation of organic waste is much more demanding as regards controlling the biological process and also considerably more elaborate as regards the technical aspects. The anaerobic biological process requires a more sophisticated control (including control of the pH value, organic acids, volume load and temperature) and is more sensitive to faults. Due to the inhomogeneity of organic waste from inner-city areas, the extraneous material content and the fluctuations in quantity and quality that are associated with the annual hydrograph, it is essential from the operator‘s point of view that the plant control equipment is designed to be robust, less vulnerable to faults and to offer redundancy.

A dry fermentation process (dry matter content of the digestate greater than 25 per cent) was chosen. The advantage of dry fermentation lies in its relatively low process-water content and the better processability of unscreenable mineral components and extraneous matter. In the wet fermentation process these components have a strong tendency to settle out, they increase wear and lead to high maintenance requirements. The energy input and maintenance associated with dry methods of organic-waste fermentation is generally less. The treatment concept for the biogas plants provides first for mechanical and then for anaerobic biological processing of the organic waste to generate biogas.

The processing of raw biogas and the injection of biomethane into the natural-gas distribution network offers an interesting alternative for utilising the energy at the site of the biogas plant, certainly since the amendment to the Gas Grid Access Ordinance (GasNZV of 12.04.2008) was published. The processed biogas allows a number of different marketing options to be implemented, for instance the decentralised generation of electricity and heat directly at the site where the heat is required or in the logistics sector as a substitute for fossil fuels.

The question of energy efficiency (energy input/biogas production) throughout the life of the plant was a key element when it came to bid evaluation. Bids with low specific biogas yields therefore only had a small chance of succeeding in Berlin.

Following a Europe-wide tendering process the contract was awarded to the bidding consortium of STRABAG Umweltanlagen GmbH, Dresden, and STRABAG AG, Berlin, in the fourth quarter of 2009.

The planning group consisting of IBA, Ingenieurbüro für Abfallwirtschaft & Energietechnik GmbH, Hanover, in association with Grontmij GmbH, with branches in Berlin and Cologne, and CONVIS Baumanagement & Projektsteuerung GmbH supported BSR during the various project phases.

The plant consists of the following major units: (Figure 2)

- Supply/Pre-processing
- Anaerobic treatment
- Dehydration and aerobisation of solid digestate
- Waste-air treatment
- Gas purification and gas processing

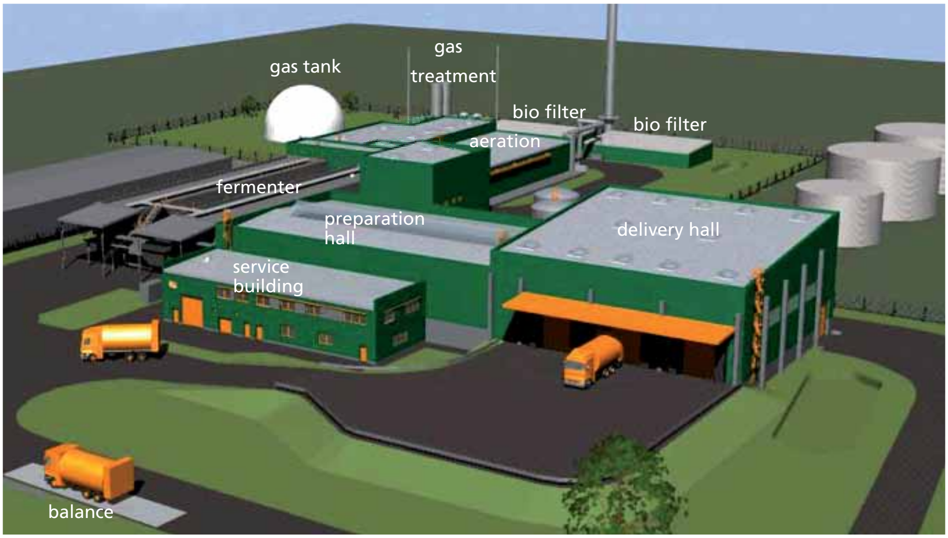


Figure 2: BSR biogas plant

BSR has built a plant with the following features:

- maximisation of biogas and energy compared with other fermentation processes,
- encapsulation of the entire plant (the trapped waste air is filtered through a multi-stage scrubbing process),
- trapping of the waste air via point-source extraction and multiple utilisation of the waste air, and therefore a low total volume of waste air (40,000 m^3 per hour),
- processing of the organic waste by screening, crushing and iron separation,
- short-term intermediate storage of the processed organic waste so that the fermenters can be fed with constant amounts, even on delivery-free days, to optimise the gas yield,
- phase separation of the digestate by full-stream dehydration and separation into solid and liquid digestates,
- fully automated operation even at night, at weekends and during bank holidays,
- fermenter in thermophilic operation (~55 °C) and therefore ensured sanitisation even during the fermentation process,
- biogas collection, cleaning, storage and processing to natural-gas quality Injection into the gas distribution network,
- biogas processing by amine gas treatment (technology with the lowest methane slip),
- rapid aerobisation of the solid digestate via elaborate forced ventilation to minimise odour-relevant and climate-relevant emissions in a separate and encapsulated aerobisation unit,

Mastering the odour situation is of particular significance for the success of the plant. The waste-air system was designed to operate at slightly below atmospheric pressure in all parts of the building. This prevents the waste air from escaping into the environment unchecked. The waste-air stream passes into an acid scrubber, then into a biofilter and finally through a vent stack and into the atmosphere. This meets the most stringent requirements and represents state-of-the-art technology.

3. Biogas utilisation

Laboratory studies conducted by the Technical University of Cottbus determined average gas rates for Berlin‘s organic material at between 104 and 140 Nm^3 per ton, depending on the fermentation process. The tests also showed that the gas rates for the organic material from the leaf bags collected only reach an average of between 20 and 63 Nm^3 per ton, depending on the fermentation process.

At 60,000 ton per year, and assuming 100 Nm^3 raw biogas per ton of organic material, this results in a continuous raw biogas production of 6 million Nm^3. This corresponds to a gross energy content of around 33 million kilowatt hours (kWh). In a block heat and power plant this energy can be converted into approximately nine million kWh of electric current, which requires a connected load of about 1.5 megawatt (MW).

According to a conservative estimate and taking the operating energy and the fermentation process into account, these 60,000 tons or so of organic waste that are available each year to BSR‘s biogas plant correspond to about 1,700 tons of high-quality natural gas (natural gas H, methane content: 87 to 99 percent by volume) or 2.5 million litres diesel equivalents).

Essentially there are four different concepts offering options for the utilisation of this gas.

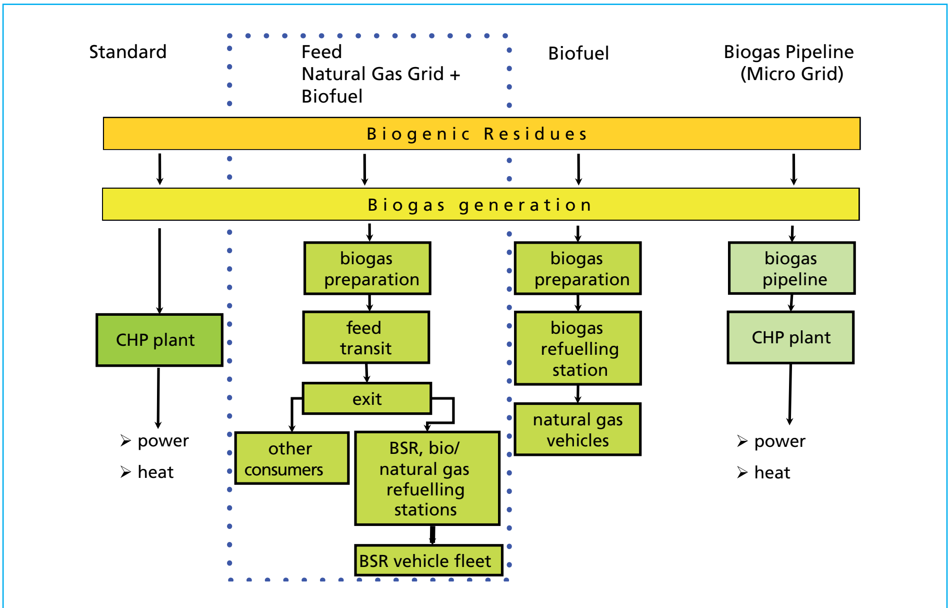


Figure 3: different concepts of biogas utilisation

The processing of raw biogas to produce biomethane has become markedly more relevant in recent years. In contrast to *on-site conversion to electricity*, the processing of biogas to produce biomethane and subsequent injection into natural-gas distribution networks offers several benefits. A key factor is the uncoupling of production usage in terms of place and time. The storage function of the natural-gas distribution network means that biomethane can make a major contribution to the demand-oriented provision of energy. For energy-related purposes biomethane can be used for combined heat and power generation (in block heat and power plants), as a fuel in vehicles that run on natural gas and as a natural-gas substitute in heat-generating natural-gas burners. In addition biomethane can also be used as a raw material in the chemical industry.

With a natural-gas pipeline of suitable capacity running directly along the road next to the property boundary at the site where we were planning to build our fermentation plant, the basic requirements for being able to inject biomethane into the grid were already in place.

GasNZV stipulates certain conditions under which the gas system operators must grant biogas transmission customers access to their networks. Significant regulations for connecting a biogas plant to the networks when injecting biomethane include:

- Priority connection to the network for biomethane injection stations as n obligation for the system operators.
- Cost sharing for connection to the network: 75 percent is met by the system operator, 25 percent by the company utilising the connection, up to a length of ten kilometers for the connecting pipeline. If the connecting pipeline is not more than 1 km in length, the share of the costs to be met by the company utilising the connection is capped at 250,000 EUR.
- Guarantee of network connection being available at least 96 percent of the time must be provided by the system operator.
- The offer of an extended balance-sheet adjustment for the injection and withdrawal of biogas by the company responsible for the marketing area, including 25 percent flexibility over one year.
- The maximum allowable methane emissions into the atmosphere when processing biogas to produce biomethane are limited to 0.2 percent. BSR must ensure that the gas complies with the requirements of DVGW worksheets G 260 and G 262 (published in 2007) at the point of injection. The system operator, on the other hand, is responsible for ensuring that the gas complies with the requirements of the Metering and Calibration Act as reflected in DVGW worksheet G 685 (published in 2007). The system operator also bears the associated costs.

GasNEV (Gas Grid Charges Ordinance) stipulates the method to be used for determining the charges applied for access to the gas pipeline system and the gas distribution networks. According to this BSR currently receives a flat rate of EUR ct 0.7 per fed-in kilowatt hour of biomethane for what is termed avoided network costs. This amount is payable by the system operator into whose network the biomethane is injected. The system operator can apportion these additional costs to all the networks in the network area. The transmission customer (BSR), on the other hand, has to pay a charge for using the network for withdrawing gas.

An important aspect to consider, due to factors such as the raw biogas processing technology selected, is that of the mean calorific value of the natural gas in the gas grid. These H-gas grids, as they are called, which carry gas with a high calorific value, impose stringent requirements on gas processing methods, in particular on the efficiency of CO_2 scrubbing, the permissible oxygen and hydrogen contents and the concentration of trace substances (such as siloxanes and hydrocarbons) in the biomethane. Only if these quality criteria are met can the biomethane be transferred to the relevant system operator. Given our particular circumstances, the biogas processing plant must produce a methane content of at least 96 percent to allow the system operator to adjust the Wobbe index (calorific value) of the very high calorific value that applies to the natural gas in the gas distribution network for Berlin with the aid of propane. In addition the system operator is responsible to odorising the gas, for measuring the gas quality in accordance with the Metering and Calibration Act and for the pressure rating.

4. Biofuel quota

The Biofuel Quota Act is designed to promote the increased generation and use of biofuels.

The biofuel quota allows BSR to generate additional revenue for the project without having to make further investments. The only aspect that needs to be taken into account here, and one that should not be underestimated, is the additional cost associated with administration, manpower and certification.

To ensure that biofuels account for a minimum share of overall fuel consumption, the legislative authority requires companies that market petrol or diesel fuels commercially to meet a specific annual biofuel quota (2013: 7.5 percent of the total quantity of petrol and diesel fuels with an annual increase of 0.25 percent, rising to 8 percent in 2015) in accordance with the Federal Immission Control Act (BImSchG). A penalty is imposed on the obligated company if this quota is not met.

The obligation for meeting this quota may be met by the company concerned (e.g. a company operating in the petroleum industry) or by a third party undertaking to meet this quota (quota transfer), either by adding the minimum amount of biofuels to the fossil fuels of petrol or diesel (E5 and E10 petrol, as applicable) or by marketing a quantity of pure biofuels that corresponds to the minimum share.

This utilisation of biomethane as a natural-gas fuel is then treated under article 37a section 4 subsection 1 BImSchG as if biofuel had been added to a fuel produced from crude oil, so that it can be duly apportioned to the quota.

BSR, which uses sustainable biomethane as a fuel and is itself not required by law to meet a biofuel quota, therefore generates a biofuel quota that can be sold to companies obliged to meet the biofuel quota. This consequently opens up a new business area for BSR in what is called quota trading.

Furthermore, the biogas generated in the BSR plant also has the special feature of being derived solely from organic waste. Under the regulations of article 7 section 1 subsection 36 BImSchV, biofuels derived from waste covered by the provisions of the

Recycling Management and Waste Act count double for the purpose of fulfilling the biofuel quota set out in article 37a BImSchG. They then have a correspondingly greater economic value (termed the double quota system).

Quota trading does not involve the physical sale of a quantity of energy obtained from biomethane, but refers exclusively to the sale of a virtual sustainable quality of the actual biofuel put into the tanks of vehicles and consequently consumed on the road.

According to article 1 section 1 Biokraft-NachV (ordinance regulating the sustainable production of biofuels) compliance with the requirements of the ordinance is a prerequisite for allowing biofuels to be allocated to the quota. Proof of the sustainability requirements having been met and other evidence must be submitted to the *Biofuel Quota* section of the Main Customs Office Frankfurt/O. by 15th April of the following year by completing an annual quota return. Once the Main Customs Office has confirmed the quotas, they can be traded, i.e. transferred to a company required to meet the quotas.

In summary, therefore, the following formal requirements must be met for quota trading:

- Taxation as fuel (marketing)
- Proof of sustainability (from NABISY, the Sustainable Biomass System)
- Biomethane to comply with requirements for fuel according to DIN 51624 (or G260)
- Certification in accordance with the ordinance regulating the sustainable production of biofuels and proof of quantity
- Contractual specification by civil-law contract
- Submitting the return to the Biofuel Quota section in good time

However, the current revenue for the biofuel quota (approx. 1.9 - 2.5 Eurocent/kWh basic quota) justifies the high costs.

The further development of the biofuel quota is uncertain, as starting on 1st January 2015 the biofuel quota will change from a quantity-based target (kWh) to a greenhouse gas-based quota.

5. Emissions/Climate protection

As a municipal waste management enterprise, BSR accepts its responsibilities for climate protection and in spring 2007 the company signed a cooperation agreement with the state of Berlin, which also included BSR undertaking to reduce its CO_2 emissions.

It was known that there was still room for improvement with regard to BSR‘s exploitation of organic-waste recycling, since anaerobic zones can form when waste is composted in open stacks and these zones can lead to significant emissions of the greenhouse gases methane and nitrous oxide. Current measurements [1] taken from open organic-waste composting sites have revealed an average of 1.0 kg methane, 10 g nitrous oxide and 470 g ammonia gas per ton of organic and garden waste. These emissions result in climate pollution of around sixty to one hundred kilograms CO_2-eq per ton input, which causes problems in terms of climate change policy. It is therefore an obvious measure for BSR to cease treating its organic waste in simple open-stack composting sites and instead to opt for fermenting the organic waste and combining this with generating renewable energy and producing high-quality humus and fertiliser.

If the biogas is used as a fuel, the diesel consumption of the collection vehicles can be reduced by almost two thirds and the fleet‘s CO_2 emissions can be reduced by more than 6,000 tons CO_2 per year. Furthermore, the gas-powered vehicles are much quieter. In fact, the reduction of around two decibels (dB) means that the noise level is perceived as being approximately halved. The fine dust emissions are also very low and as a result there will be a noticeable improvement in comparison with existing vehicles.

Material utilisation of the solid and liquid digestates avoids around a further 6,000 tons CO_2 from being released.

All the measures suggested by the German Federal Environmental Agency for improving the climate balance sheet of fermenting plants have been taken into account.

These include:

- biogas processing by amine gas treatment (technology with the lowest methane slip),
- multiple utilisation of the waste air and therefore low total quantity of waste air,
- rapid aerobisation of the solid digestates with the aid of forced ventilation,
- acid scrubber for cleaning the stream of waste air, eliminating the ammonia gas (NH_3) emissions and avoiding newly generating nitrous oxide (N_2O),
- vapour recovery pipeline for containers of liquid digestate,
- thermophilic process, high decomposition rates, therefore very low emissions of residual gas.

6. Conclusion and outlook

Energy production and energy costs are of course important economic parameters for formulating the waste disposal charges applied by BSR. On the one hand BSR is benefitting from increasing revenue for energy derived from waste incineration and landfill gas-operated block heat and power plants, and on the other hand BSR *suffers* from increasing energy costs, especially with regard to diesel fuels.

Against the background of the anticipated development of energy prices, BSR has developed the direct substitution of diesel fuels as the most economical and also the most ecological option. In economic terms the calculation takes rising diesel and gas costs into account and in ecological terms the direct utilisation of biogas results in eliminating all forms of conversion losses.

In December 2012 BSR was nominated for the German Sustainability Award 2012 in the category of *Germany's most sustainable initiative* for its concept of collecting and utilising organic material. Furthermore the fermentation plant, in conjunction with utilising the biogas as a fuel, won a prize in the environment category in October 2013 as an *Excellent place in the land of ideas*.

BSR's concept for a facility that treats organic waste allows us, by reducing transport and diesel procurement costs, to keep increases in our charges to a minimum and at the same time to increase our production of green energy by extending the value chain. This concept – which includes fuelling over 150 waste-collection vehicles with biomethane – is the first one to be implemented in the whole of Germany. In addition we are exploiting measures to reduce greenhouse gases and thereby contribute further to protecting the environment.

BSR had faced the renewed challenge of demonstrating that municipal enterprises are capable of planning, constructing and commissioning technologically presentable facilities – on time and on budget. Once again it has succeeded in this endeavour.

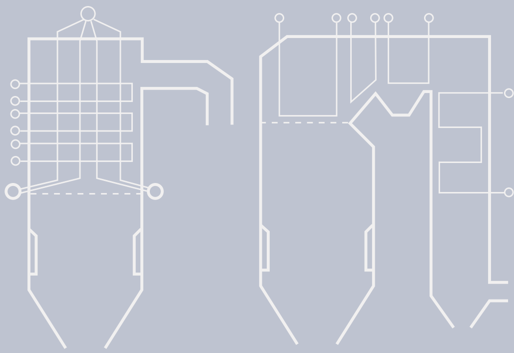
Not only in terms of climate protection, but also in terms of energy efficiency and technology, BSR has created a flagship project for fermentation technology, which, in addition, is also economically justifiable to the ratepayers.

7. Reference

[1] Cuhls, C.; Mähl, B.: (12/2008) Determining the emission situation for the recycling of organic waste, GEWITRA GmbH on behalf of the German Federal Environmental Agency, Dessau (UFO / Environmental Research Plan 206 33 326)

Ersatzbrennstoffe in Kohlekraftwerken

Mitverbrennung von Ersatzbrennstoffen in Kohlekraftwerken



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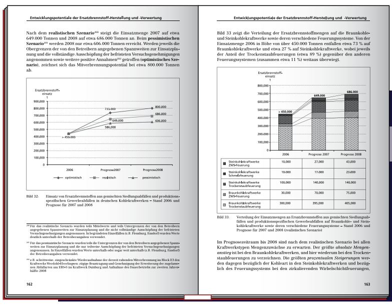
Im Bereich der Kohlekraftwerke bestehen grundsätzlich Potentiale zum Ausbau der Mitverbrennungskapazitäten für Ersatzbrennstoffe und zugleich hohe wirtschaftliche Anreize durch Einsparung von Brennstoffkosten sowie Zuzahlungen der Ersatzbrennstofflieferanten.

Um Ersatzbrennstoffe aus Siedlungsabfällen herzustellen, ist ein enormer aufbereitungstechnischer Aufwand erforderlich. Die Berichte der Kraftwerksbetreiber über Nichteinhaltungen der Spezifikationen machen deutlich, dass hier zum Teil noch erheblicher Optimierungsbedarf besteht.

Zielsetzung dieser Arbeit ist die Untersuchung der Eignung von Ersatzbrennstoffen aus der mechanisch(-biologischen) Abfallbehandlung zur Mitverbrennung in Kohlekraftwerken aus verfahrenstechnischer, ökologischer und wirtschaftlicher Sicht sowie die Identifizierung der wesentlichen Einflussfaktoren und Optimierungsmöglichkeiten.

Hierzu wird zunächst der Stand der mechanisch(-biologischen) Abfallbehandlung in Deutschland hinsichtlich Anzahl, Kapazität und technischer Ausstattung der Anlagen dargestellt. Daran schließt sich eine detaillierte systemtechnische Analyse der Anlagen im Hinblick auf die Verfahrenskonzepte, verfahrenstechnischen Konfigurationen sowie die erzeugten Outputströme und deren Verbleib an.

Im zweiten Teil der Arbeit werden die bislang durchgeführten und derzeit vorbereiteten Projekte zur Mitverbrennung von Ersatzbrennstoffen aus aufbereiteten Siedlungs- und Gewerbeabfällen in deutschen Kohlekraftwerken auf der Grundlage einer Literaturrecherche und der Befragung der Kraftwerksbetreiber untersucht.



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