Can a wastewater treatment plant be a powerplant? A case study

N. Schwarzenbeck, E. Bomball and W. Pfeiffer

ABSTRACT

Today wastewater treatment plants are evaluated not only in terms of their treatment efficiency but also concerning their energy efficiency. Increasing energy efficiency can be realized either through operational optimisation or by realising an already existing potential for energy generation on-site. The main source of energy at a municipal wastewater treatment plant is the biogas produced in the anaerobic sludge digester. Studies indicate excess digester capacities of about 20% in Germany available for co-fermentation of organic substrates other than sewage sludge. This paper presents an example of a municipal wastewater treatment plant going towards an energy self-sufficient operation and even a surplus energy production as the result of an increasing co-fermentation of sludge from grease skimming tanks. In 2005 on average 113% of the electricity consumed for plant operation was generated on-site in gas engines. Co-fermentation of about 30% (related to the total dry residue input) of grease interceptor sludge in the presented case does not only effect a 4-times increased gas yield, but also an intensified 20% higher anaerobic degradation of the organic matter of the sewage sludge and thus having a positive influence not only on the energy and financial balance but also on the anaerobic sludge stabilisation with respect to the degradation degree of the organic fraction.

Key words | co-fermentation, municipal wastewater treatment plants, power generation

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INTRODUCTION

In times of growing concern about the future security of energy supply and growing awareness of the negative impact today's wastage of fossil fuels has on the world climate, the development of alternative sources of energy is becoming more and more important. Although alternative and renewable sources of energy are identified, they have not yet been developed to their maximum possible extent. Their potential in replacing current sources of energy is only reluctantly developed due to real or apparent economical disadvantages. In that context utilizing the potential of already existing installations becomes an interesting option.

Wastewater treatment plants are today benchmarked not only with respect to their treatment efficiency and how well they are able to meet discharge limits, but also in terms of their energy efficiency. Besides the reasonable use of energy on-site, this also includes the evaluation of their potential for energy production. The main source of energy at a municipal wastewater treatment plant is the biogas produced in anaerobic digesters during the process of sludge stabilization. It can be used for powering gas engines, producing electrical and thermal energy for on-site use. Electrical energy is mainly consumed for the operation of aeration tanks (approximately 70% of the total energy consumption). Thermal energy is almost exclusively used for heating purposes (approximately 90% for sludge heating prior and during anaerobic digestion). In terms of costs, electricity contributes to about 80% of the energy costs of a municipal wastewater treatment plant (Pinnekamp 2007). On the other hand only 40% of electrical energy consumption can currently be covered by power generation on-site.

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Taking a look at the available digester volumes at municipal wastewater treatment plants in Germany on the other hand reveals significant excess capacities in terms of installed volume and applicable volumetric loading rate in a range of about 20% (Roos 2007). Reducing the hydraulic retention time in the anaerobic digester slightly from 20d to 18d, having only insignificant influence on the gas yield, would even increase the excess capacities. If those free capacities would be utilized for digesting additional substrates with a high energy content, a step towards energy independency or even surplus energy production could be taken, simultaneously saving energy resources, requiring only minimal additional technical expenditure and realizing cost-effectiveness.

The example of the wastewater treatment plant Grevesmühlen shows how an intensified operation of anaerobic digesters at a municipal wastewater treatment plant through co-fermentation of sludge from grease skimming tanks can result energy independency without negatively affecting the volume and mass of sludge to be disposed subsequent to the sludge treatment. In 2006 energy production was 113% of the energy consumption on-site, energy and financial balance are even.

WASTEWATER TREATMENT PLANT GREVESMÜHLEN

The wastewater treatment plant Grevesmühlen is situated in the northwestern part of Mecklenburg-West Pommerania, Germany, treating the wastewater of approximately 40,000 population equivalents originating from the city of Grevesmühlen and surrounding communities. Pre-treated (aerated mixing tank) wastewater from a dairy contributes about 60% of the daily wastewater influent to the treatment plant, having pollutant concentrations below the level of municipal wastewater. The wastewater treatment plant (Figure 1) comprises mechanical and following biological treatment, i.e. screening (A), aerated grid chamber (B), primary sedimentation (C), anaerobic selector (D) and aeration tanks (E) with pre-denitrification (F) and secondary clarifiers (G). Phosphorus removal is accomplished in terms of enhanced biological phosphorus removal, requiring only a minimum dosage of $FeClSO_4$ at the effluent of the aeration tank. The latter one having a positive influence on the sludge volume index and the H_2S-concentration in the digester gas from the anaerobic sludge treatment (H). The sludge treatment unit comprises two anaerobic digester of 1000 m^3 working volume each, followed by mechanical sludge dewatering.

The treatment unit was built and put into operation between 1994 and 1996, the first anaerobic digester was put into operation in 1996. In 2001 a second digester was put into operation as the result of implementing a centralized sludge treatment concept for the water and wastewater association (Zweckverband) Grevesmühlen. Today raw and excess sludge from the wastewater treatment plant Grevesmühlen as well as the excess sludge from other small treatment plants, being operated by the association, are anaerobically treated together with sludge from grease skimming tanks at the treatment plant Grevesmühlen. The dry residue load in the influent of the anaerobic digester equals 72,000 population equivalents (based on 70 g/(PE·d)), at a dry residue of 5% and 75% ignition loss. Without sludge from grease interceptors, ignition loss would be 72%. The comparably high ignition loss can be

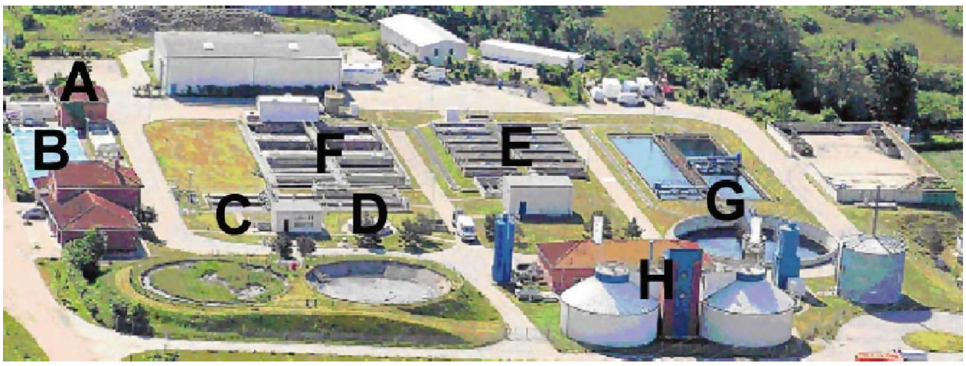

Figure 1 | Aerial photograph of the wastewater treatment plant Grevesmühlen.

attributed to the high content of excess sludge, primary sludge contributes only 10% of the dry residue loading rate. Average hydraulic retention time in the digesters is 17.5 days and would only be 15% higher without sludge from grease skimming tanks. The effluent of the anaerobic digesters shows a dry residue of 2.5% and an ignition loss of 61%, which can be considered as typical for municipal wastewater treatment plants with a high percentage of excess sludge and well established enhanced biological phosphorus removal. Digester gas is almost exclusively used for powering gas engines. The electricity is firstly used on-site and only the excess is fed into the public electricity network. Sludge is disposed in agriculture and landscaping after mechanical sludge dewatering.

OPERATION OF THE ANAEROBIC SLUDGE DIGESTERS

Start-up period and development following the implementation of a centralized sludge treatment concept

In 1997 the implementation of a centralized sludge treatment concept for the water and wastewater association Grevesmühlen at the main treatment plant in Grevesmühlen was decided on. In the course of realizing this concept, an increasing volume of mechanically thickened excess sludge has been delivered from the other treatment plants belonging to the association. Besides economic reasons, it was mainly the better quality of anaerobically stabilized sludge that favoured the decision for a centralized sludge treatment. Starting in 1999 also an increasing volume of sludge from grease skimming tanks of gastronomy has been collected for co-fermentation in the anaerobic digesters at Grevesmühlen wastewater treatment plant. Introduction and start-up of the co-fermentation were prepared and monitored by pilotscale experiments. The results so far indicate and interesting increase in digester gas yield without having a negative effect on the quality of anaerobically stabilized sludge. Even a decreasing mass of dry residue in the effluent of the digesters could be observed due to co-fermentation. Obviously an intensified degradation of solid matter originating from the sewage sludge could be achieved. These results are consistent with other experiments on co-fermentation in the past (Reipa 2003). Figure 2 shows the development of sludge fed into the anaerobic digesters at Grevesmühlen in terms of organic and anorganic dry residue load. Fluctuating masses of sewage sludge (increasing between 1998 and 2000 and decreasing between 2000 and 2002) are due to varying delivery from other surrounding treatment plants not belonging to the association.

Figure 3 shows the relation between sewage sludge and sludge from grease skimming tanks fed into the anaerobic digesters at Grevesmühlen in terms of population equivalents, based on a daily dry residue production of 70 g/(PE·d) and the mass balance from the operational journal

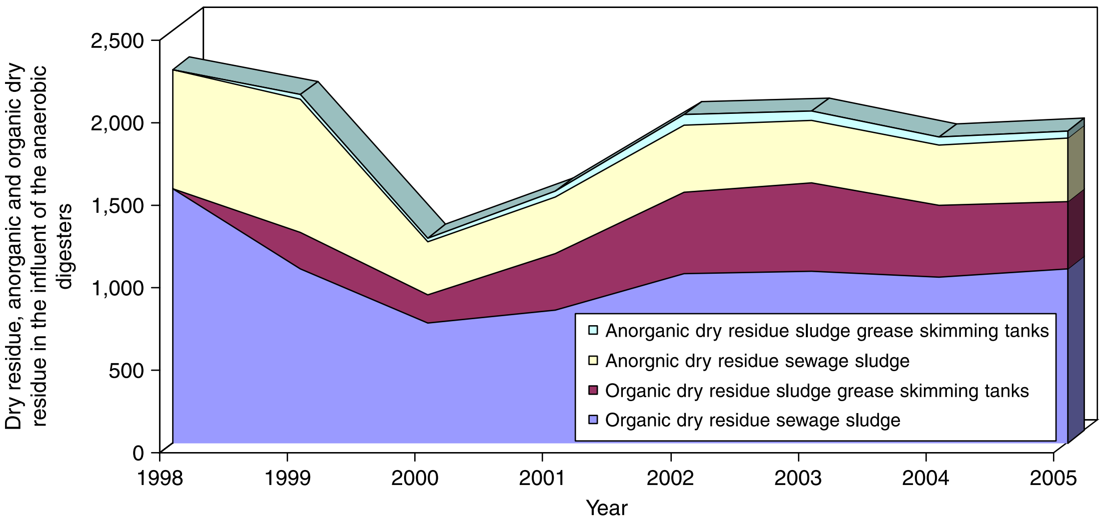

Figure 2 | Development of sludge treated in the anaerobic digesters.

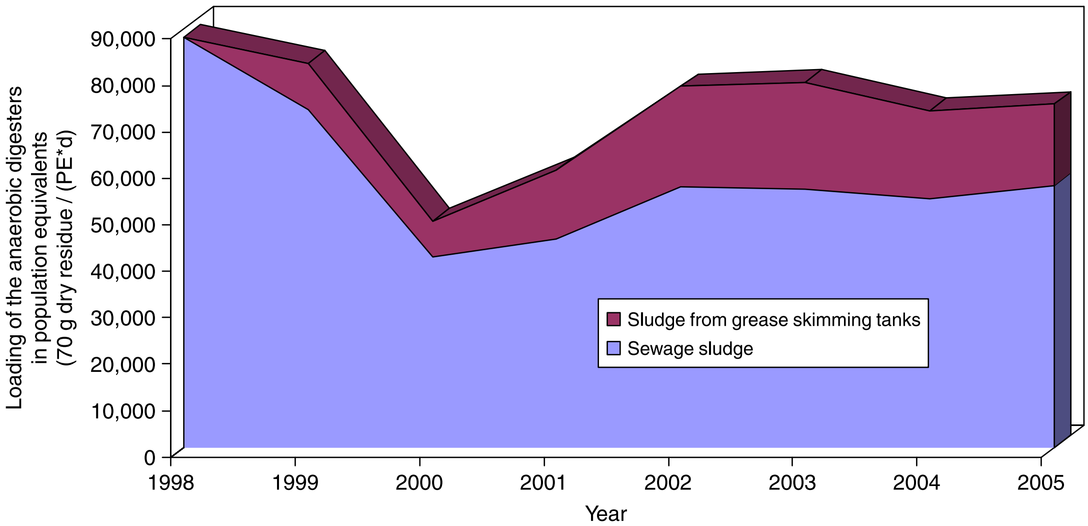

Figure 3 | Development of the loading of the digesters in terms of population equivalents.

of the treatment plant. Again it shows an increasing amount of sludge from grease skimming tanks until 2002 and a rather constant amount of sewage sludge at the same time.

The mass of non-degraded organic dry residue does in contrast to the mass of degraded organic dry residue only fluctuate slightly (Figure 4) and is completely independent of the increasing mass of sludge from grease skimming tanks fed into the digesters (Figure 3). As a result the mass of sludge to be disposed of does not increase, although sludge input increases significantly. The average degradation efficiency between 2002 and 2005 was around 60% concerning organic dry residue and is thus about 20% higher than degradation rates usually measured for anaerobic sludge digestion without co-substrates. The bars in Figure 4 illustrate the mass of anorganic dry residue in the influent and effluent of the anaerobic digesters. Anorganic dry residue in the digested sludge was about 83% of the anorganic dry residue measured in the input sludge. Bearing in mind the difficulties in taking representative

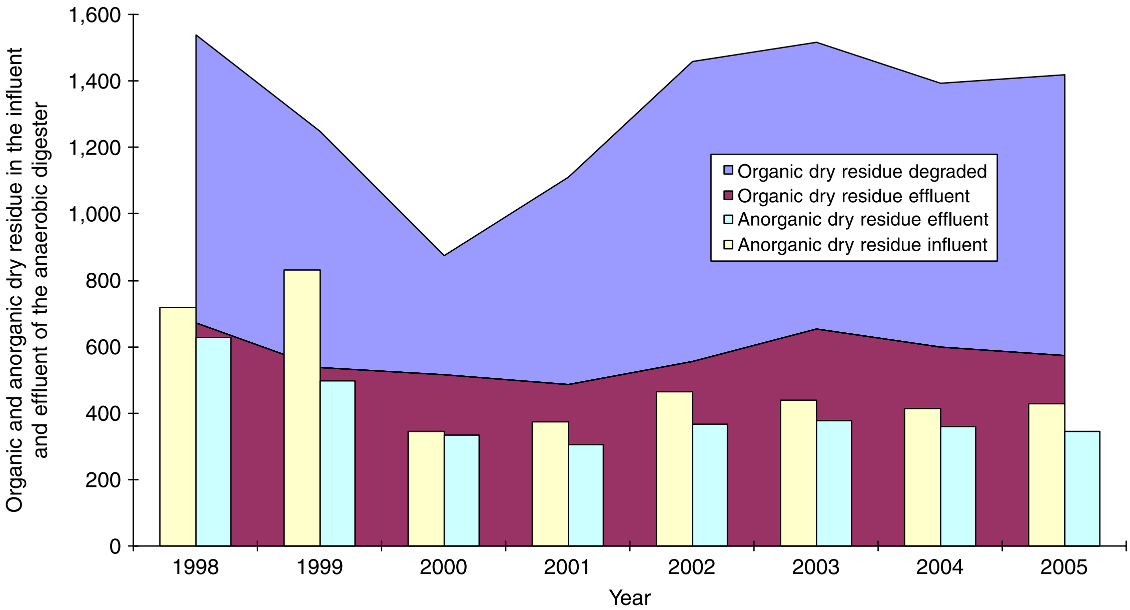

Figure 4 | Development of the loading of the digesters in terms of population equivalents.

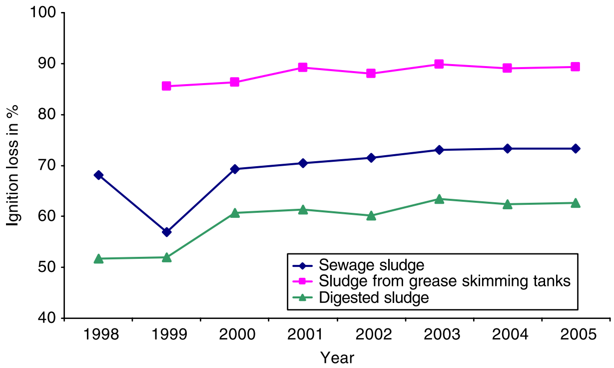

Figure 5 | Ignition loss of sewage, grease interceptor and digested sludge.

samples from large volumes during every day operation the achieved accuracy can be considered a sufficient indicator for the reliability of the available data. A slight overestimation of the input mass of organic dry residue can on the other hand not be excluded completely.

Results from the anaerobic digester operation with increasing co-fermentation of sludge from grease interceptors

Figure 5 shows the ignition loss for sewage, grease interceptor and digested sludge. Ignition loss is around 72% for the sewage sludge, 89% for the sludge from grease skimming tanks and 62% for the digested sludge, neglecting data for 1998 and 1999. These values are not surprising, taking into account the high percentage of excess sludge and the well working enhanced biological phosphorus removal resulting in a minimized use of precipitants.

The dominant impact of co-fermented grease interceptor sludge on the gas yield becomes quite obvious from Figure 6, showing the relation between sludge dry residue mass fed into the digesters and gas yield. Adding an additional 30%–40% of the total annual dry residue load in form of sludge from grease interceptors yields a four fold increase in gas production. In contrast no effect of the heavily fluctuating sewage sludge input on the gas yield can be observed. The specific gas yield between 2002 and 2005 of 600 m^3 gas/(t dry residue added) and 1200 kg gas/(t dry residue degraded) is significantly higher than those for conventional anaerobic sludge digestion. Assuming a normal gas yield and normal organic dry residue degradation rates for sewage sludge an average degradation efficiency of 80% can be calculated for the sludge from grease skimming tanks.

Development of electric energy production

Electric power generation was about 30 kW (based on 8700 hours of operation per year) in 1998 before starting co-fermentation, increasing to 66 kW–103 kW in 1999–2001

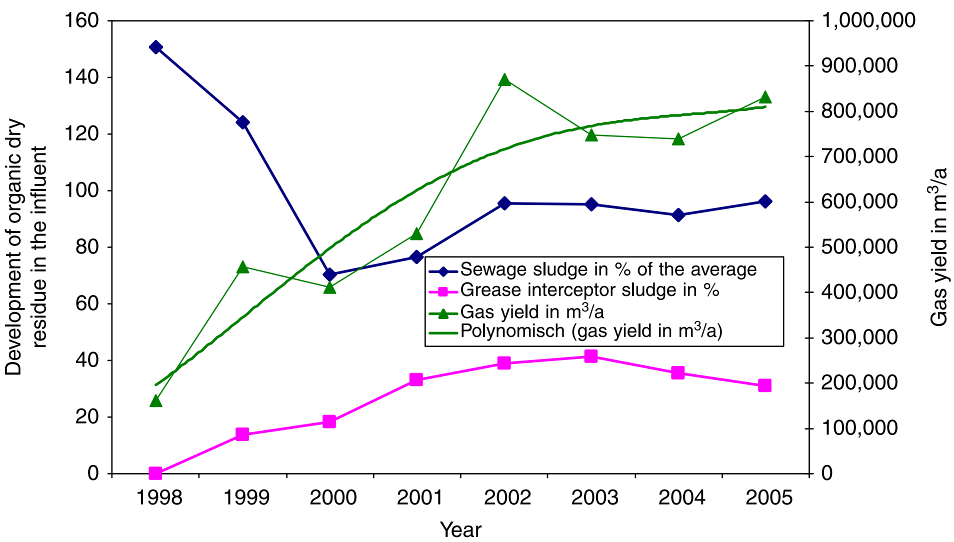

Figure 6 | Relation between digestion of grease interceptor sludge and gas yield.

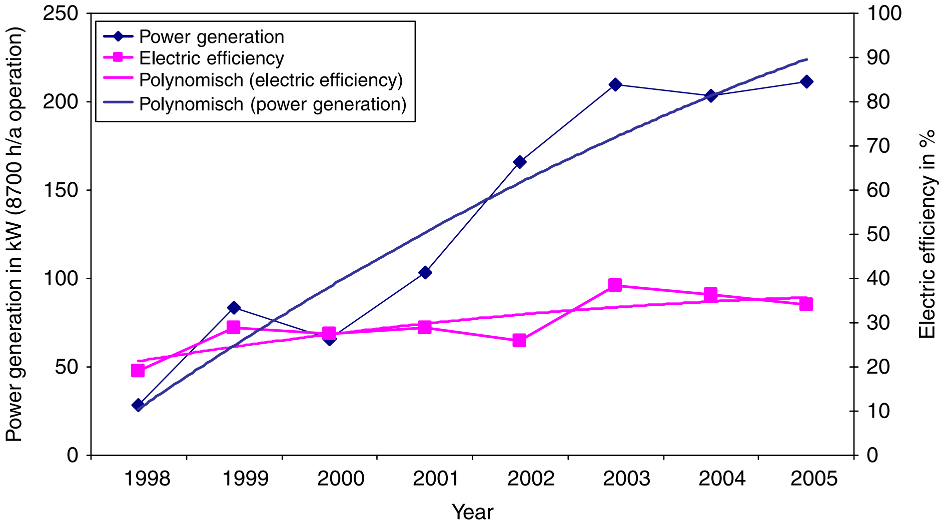

Figure 7 | Development of power generation and efficiency.

due to increasing co-fermentation. In 2001 a second digester and gas engine were put into operation as the result of implementing a centralized sludge treatment concept (see above). Subsequently 210 kW were produced in 2003–2006 and 80% of the installed full load capacities were used. Figure 7 shows the development of electrical power generation together with the achieved electric efficiency.

Figure 8 shows the development of purchase, generation and sale of electric energy at the treatment plant Grevesmühlen. Only about 20% were produced on-site prior to starting co-fermentation and 80% were purchased. Since 2002 almost 100% of the electric energy required for the operation of the treatment plant is being produced on-site and the sale (>20%) of electricity is higher than the purchase (<10%).

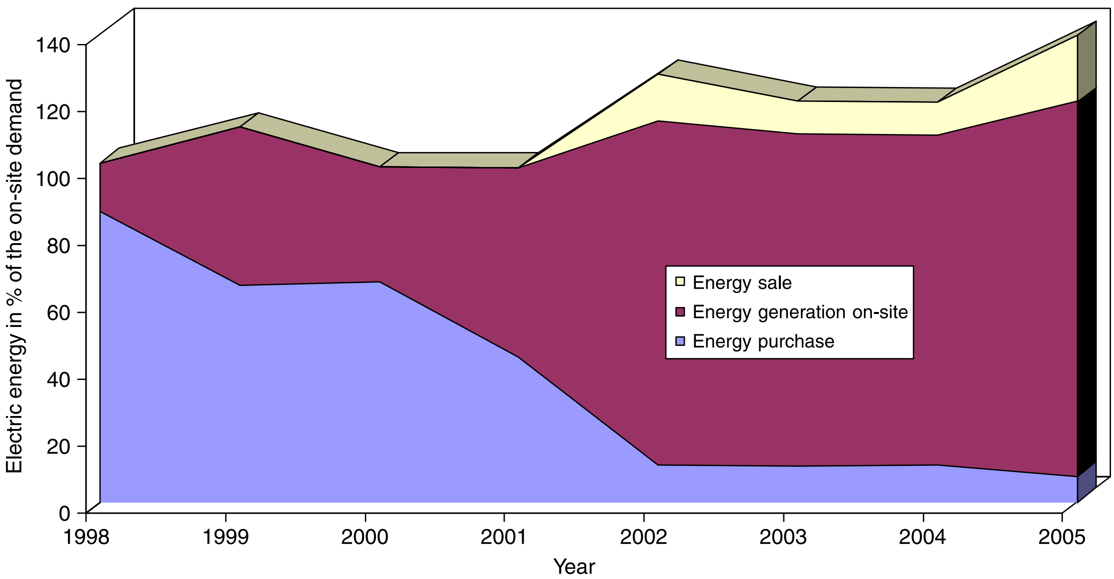

Figure 8 | Development of acquisition, generation and sale of electric energy.

CONCLUSIONS

Additional (up to 30% of the dry residue load) co-fermentation of sludge from grease skimming tanks in the anaerobic digester of a municipal wastewater treatment plant allows:

- a cost-efficient way of utilizing existing excess capacities in the anaerobic digester, saving energy resources and requiring only minimal additional technical installation.
- increasing gas yield and degradation efficiencies through intensified anaerobic digestion, thus not having a negative effect on the mass of digested sludge to be disposed of and the hydraulic retention time in the digester.
- development towards an energy self sufficient operation of a wastewater treatment plant or even a power generating wastewater treatment plant.
- to provide a sustainable and regional disposal option for sludge from grease skimming tanks
- yielding an even energy and financial balance

But this requires:

- ambitious operation and operators of the sludge treatment unit with respect to homogenisation of the co-substrates, even mixing with the sewage sludge, experimental optimisation and monitoring

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