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ENERGY PRODUCTION FROM RESIDUES: ECONOMIC ASSESSMENT OF BIOGAS INSTALLATIONS - DEVELOPMENT OF A CALCULATION TOOL

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ABSTRACT
The changing situation in Germany with the future limitation of funding by the EEG (Erneuerbare Energien Gesetz - Renewable Energies Act) (EEG 7/21/2014) has resulted in the situation whereby solutions for the operation of biogas plants lacking public funding need to be evaluated more precisely. The economics of biogas plants, powered exclusively by residues such as biowaste or municipal solid waste should be investigated with a focus on economic and business factors.
The economic assessment approach applied here examines business opportunities for regional biogas operations in different European countries. A calculation tool was developed that shows the profitability of biogas plants and considers main and typical characteristics to provide a reliable basis for a future business case analysis. The main purpose of this tool is to estimate the profitability of future biogas installations at the project planning stage; consequently, application of this tool should minimize the economic risks for investors prior to undertaking the main investment. As biogas plant lifetime is typically assumed to be 20 years, the model allows the creation of profitability models over the same period of time.

1. INTRODUCTION

Anaerobic digestion is a well-established method for energy production from biomasses. The biogas production technology has been implemented to varying degrees in accordance with the EU policies for green and sustainable energy supply (Ahrens et al. 2017a).

In 2013 9,200 biogas plants were in operation in Germany (GreenGasGrids, n.d.) and more than 12,000 biogas plants worldwide (incl. Germany) (ecoprog, 2016). Currently an installed capacity of approx. 7,000 MW_{el} exists (ecoprog, 2016). According to the European Commission greenhouse gas emissions should be reduced by 20% (compared to 1990) and the share of renewable energies increased up to 20% of the total energy demand by the year 2020 (European Commission, n.d.). Therefore, additional biogas plants with an overall installed capacity of about 2,600 MWel will be built worldwide up until 2025. Although the German market has declined sharply Europe is still the undisputed leader in the field of biogas technology (ecoprog GmbH 2016).

In comparison with other European countries, biogas technology in Germany is well established. The question therefore arises whether the technology applied in Germany could be transferred to other countries or - if not - which changes and adjustments would be required. Apart from technical adaptions, the crucial question of economy and feasibility of the process under different European conditions is considered. Consequently, this study illustrates an appropriate method for use in forecasting the economic situation of a biogas plant installation in line with a series of critical economic parameters (such as tariffs or operating costs) and legislation (funding).

Although the field of anaerobic digestion has been widely investigated, the FNR (Fachagentur Nachwachsende Rohstoffe, Germany) has highlighted a need for further research following the development of technology, and particularly due to changes in market conditions (FNR, 2012).

The changing situation in Germany with the future limitation of funding by the EEG (EEG 7/21/2014) has resulted in the situation whereby solutions for the operation of biogas plants which are not reliant on public funding should be identified. The changes made to this legislation provide plant operators with less positive prospects than before. Therefore, operators of already existing biogas plants and especially new biogas plants will be forced to find new

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business opportunities.

While this new situation in Germany has been caused by modifications to the legislation, and therefore public funding, most European countries have no access to this kind of funding . The profitability of biogas plant operations devoid of public funding is therefore a crucial requirement to be taken into account on opting to implement this energy producing technology with a view to the future. A calculation tool that takes into account aspects relating to both current and future conditions has been developed and will be presented here.

2. USER-ORIENTED APPROACH

To date no studies have been undertaken to assess the economic feasibility and business opportuntites provided by biogas plants powered exclusively by residues (biowaste, municipal solid waste etc.) and crucially, not supported by public funding,. The economic assessment approach illustrated here intends to close this knowledge gap by examining (in addition to various input factors, such as availability of substrates, funding or operating costs) the regional opportunities for biogas business case studies in different European countries.

For the first time targeted assessments of the economy will be revealed, which provide significant decisional support not only for operators.

Consideration of the profitability of biogas plant operations is affected by numerous factors, including high costs or the generation of significant income.

First, substrates for the process need to be carefully considered and selected. The use of waste materials (organic residues from industrial or agricultural production processes, as well as for example, biowaste from households or other sources) represents the focus of the present paper. The use of these waste materials for the production of energy (particularly biogas) provides the possibility to avoid disposal and produces a positive effect on the profitability of planned business operations.

Present discussion on the widespread use of agricultural areas for maize cultivation (especially in Germany) underlines that the current situation needs to be changed, and alternatives such as the use of biogenic residues encouraged. In this context, the question arises whether it is economical to use waste-based materials as substrates for energy production in biogas plants.

An additional highly important factor impacting on the profitability of biogas plants is the feed-in tariff that can be obtained for the energy produced, which may be biogas itself or electricity and heat.

These aspects underpin the development of a comprehensive calculation tool for feasibility and profitability analysis. The economic aspects are based on a widespread data research of different operated biogas plants in Germany and Sweden (Abowe, 2014), as well as literature data and country-specific data from Lithuania and Estonia (Abowe, 2013). Moreover, all impacts on the economy such as legislation, country-specific aspects, technology and others, have influenced this study

All these investigations have led to the development of the calculation tool, capable of creating profitability models for the implementation of biogas technology over a period of 20 years.

Technology aspects, such as operation modes of biogas plants (wet/dry digestion, plug flow or garage fermenter) in particular, are likewise crucial in the consideration of profitability. Experiences and results from several lab tests, supervision of operating large-scale biogas plants as well as pilot plant tests (especially during the ABOWE project) were taken into consideration.

All the above-mentioned aspects were taken into account for the development of the calculation tool, which allows estimation of the profitability of a series of different biogas business cases.

The standard method for the execution of company evaluations is the discounted cash flow method. This method is based on calculating the value of future cash flows by discounting to the valuation date and deduction of the initial net investment (Schacht, Fackler 2009). The discounted cash flow method provided the basis for the developed profitability calculation tool.

The widely adaptable applicability for conditions to be found in different countries makes the tool and the background considerations an outstanding one.

The major objective underlying development of the calculation tool was to identify a means of demonstrating the profitability of biogas plants by means of a model taking into account the main typical characteristics, thus providing a reliable basis for a future business case analysis. The developed model has been successfully implemented and tested in several scientific applications in different European regions (Sweden, Lithuania, Estonia, Finland, Germany) – corresponding results have been published by ABOWE (2013, 2014), and Ahrens et al. (2017b), Ahrens et al. (2016).

The main aim of this study was to develop a calculation tool to enable the user to ascertain whether investment in a biogas plant would be profitable or not. The singular feature of this tool should be the consideration of operative cash flows over a lengthy period of time, ease of handling with readily available data and, a crucial factor, transferability to other European countries and – as a very far-sighted aim – application to other technologies.

A calculation model aimed at helping potential plant installers to determine profitability may represent a useful instrument, particularly when applicable to various types of input materials and design. In particular, application of the model in a European context constitutes the goal of this work.

A general model that takes into account all these potential issues provides an important tool, especially for less developed European countries in the field of biogas technology, to implement the EU Directive, and promote the establishment of biogas plants to improve the living conditions of the population.

All considered influence variables will be taken into consideration in the economic calculation. On the basis of this widespread approach a selection of the best and most profitable technologies is yielded.

Ostfalia University of Applied Sciences operates a series of pilot plants (plug flow fermenter for wet or dry fermentation as well as garage fermenter) for the production of biogas. In these pilot plants, test runs verify the results provided by theoretical calculations. Data determined by these tests form the basis for biogas potentials and therefore possible obtainable revenues.

On the basis of the results of the pilot plant tests the calculation tool was applied to large-scale projects and - with the aid of these tests - improved and advanced (Abowe 2013, 2014).

The EU-funded project ABOWE (Implementing Advanced Concepts for Biological Utilization of Waste) was fundamental in the preparation of this work and in determination of the necessary data. One objective of the ABOWE project was to promote investment decisions by performing pilot plant tests and related activities. The results were applied to evaluate cash flow calculations.

Figure 1 shows a simplified presentation of the necessary data and sequence to be adhered to in using the calculation tool. This flow chart represents the frame of the tool. After entering data relating to available substrates and selecting the operating mode and gas use, tariffs for the sale of the products should be chosen. Calculations and necessary data, which run in the background, are not shown here. Following this data entry, the cash flow over a time period of 20 years is obtained.

In performing the calculation a series of aspects (including necessary replacements of parts of the biogas plant, country specific aspects) were considered and different key values (e.g. investment costs, operating costs, energy demand, substrate data) were taken into account. Depending on the scenarios and the region all variables influencing economy or economic feasibility can easily be changed and adapted to ensure the calculation model provides an impression of the profitability of a planned biogas implementation project.

3. CASE STUDY - RESULTS OF THE ASSESSMENT

The following case study shows an example of assessment of biogas plant operations.

Two scenarios have been calculated: biogas plant projects with plug flow fermenter and CHP-unit (combined heat and power unit) for the production of electricity and heat, which only differed in the chosen tariffs for electricity.

In this easy example the costs for investment, maintenance and others - such as personnel or transport - were based on average data acquisition for biogas plants under different operating modes (mainly from literature studies and according to information from plant operators). These data were used as an operational background in the calculation tool and are not presented here. However, the tool provides the opportunity to vary crucial input parameters and allows the identification of different perspectives towards variation of resulting impacts on plant feasibility in line with variation of different cost parameters.

The calculated and verified economic key value data, used as a background in this tool, are based on the above-mentioned widespread data search.

Table 1 shows some of the assumptions made in the case of 2,004 tons of biowaste (methane potential 102 Nm^3 CH_4/Mg FM) (FNR 2017) and 680 tons of corn silage (methane potential 104 Nm^3 CH_4/Mg FM) (FNR 2017) being used as input materials for a biogas plant per year, yielding production of a theoretical amount of approx. 250,000 Nm^3 CH_4.

In these case studies, the produced electricity was assumed to be sold at a feed-in tariff of 0.247 €/kWh_{el} (a possible electricity rate currently paid by customers in Germany (Stadtwerke Wolfenbüttel, 2017)) and that the feed-in tariff for heat is 0.03 €/kWh_{th} (Ahrens 2017). Further assumptions related to an income from biowaste collection and utilization of 40 €/ton and expenses for corn of 30 €/ton. The results of the cash flow calculation are reported in Figure 2 (cumulative discounted cash flows, initial value = investment costs). The result of the calculation represents the possible profit after a defined period of time.

The second scenario proceeded based on the assumption that the feed-in tariff was much lower as the plant op-

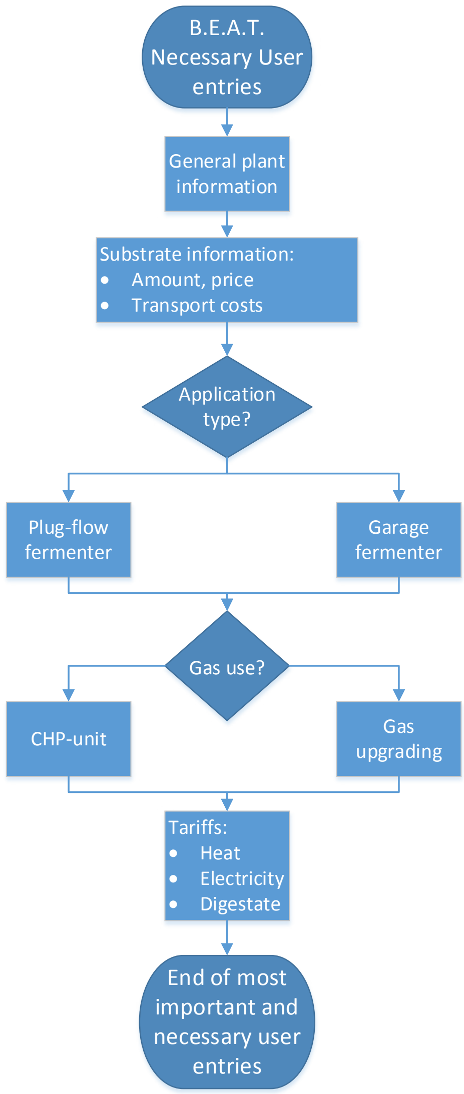

FIGURE 1: Flow chart of the calculation tool B.E.A.T. (Biogas installations Economic Assessment Tool).

TABLE 1: Tariffs and further background assumptions (extract of all used data).

	Tariffs			
	Costs		Income	
	Case 1	Case 2	Case 1	Case 2
Substrates: Biowaste Corn silage	30 €/Mg FM	30 €/Mg FM	40 €/Mg FM	40 €/Mg FM
Electricity	-	Grid charge and taxes: 0.169 €/kWh$_{el}$	0.247 €/kWh$_{el}$	0.078 €/kWh$_{el}$
Heat	-	-	0.03 €/kWh$_{th}$	0.03 €/kWh$_{th}$
Produced energy	984,518 kWhel/year and 984,518 kWhth/year; efficiency rate of the CHP-unit: η = 40%			
Biogas plant: Plug flow fermenter system, investment costs (average amount depending on size of biogas plant (per kW installed electrical capacity)) plus 30% for waste hygienisation (assumption)				
Sale of electricity and heat (minus own demand); handling of digestate was not considered in this example				

erator was obliged to pay grid charges and taxes, implying a total lack of financial gain. In this case the feed-in tariff was taken as 0.078 €/kWh$_{el}$.

Figure 2 shows the possible result of an assessment made with regard to biogas plant operations using biowaste and corn silage.

Here the two case studies demonstrate the influence of the feed-in tariff for electricity. In case 2 the operator was obliged to pay grid fees and taxes, consequently the curve will not reach the zero line within 20 years.

4. RESULTS AND DISCUSSION

Wide-ranging experiences and investigations have resulted in the development of the calculation tool, which has enhanced the calculation of profitability estimates for a series of different biogas business cases.

The calculation provides the basis for a decision-making process relating to the financial implementation of advanced digestion technologies, particularly in the absence of public funding. Particular focus is placed on the potential demands of implementers and investors and the production of renewable energy throughout the EU member states. Data relating to influencing factors such as operating costs, market prices or substrate characteristics are continuously collected from existing biogas plants, and therefore the future results of the tool can be verified against real data. The particular aim in developing this tool was ease of handling with only a small amount of necessary input data.

The two case studies are intended to provide a rough idea of the purpose of the calculation tool and illustrate the strong dependency on important input factors such as feed-in tariffs. Therefore, the paper contains only an excerpt of all acquired data and assumptions required during calculations.

An approximation of the profitability of planned biogas projects is provided. Detailed calculations and estimates may only be obtained by applying models of real systems. The assumptions given are not intended for generalized use, but relate to scenario-specific aspects chosen for the examples presented here.

Applicability of this tool to new biogas concepts such as a demand-driven operations (Ahrens et al., 2016) and

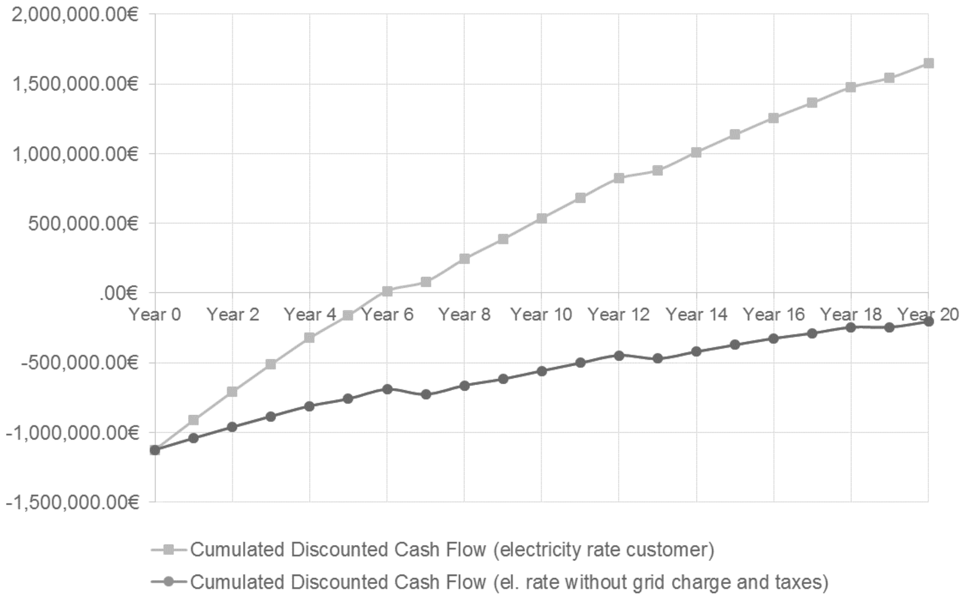

FIGURE 2: Cumulative discounted cash flows of two scenarios.

use of a series of CHP-units (combined heat and power plants) should results in a greatly enhance user-convenience, possibility of assessing existing large-scale plants, as well as the implementation of additional key data.

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