Assessment of the Cost-Reduction Potential of Different Technology Improvements for a Competitive Biogas Production

Philipp Grundmann
Institut für Agrartechnik Bornim e. V., Potsdam

A substantial reduction of biogas production costs is necessary to reach cost-competitiveness of electricity produced from biogas using energy crops. Cost reduction opportunities are identified for several technological parameters within a sensitivity analysis. The analysed parameters are then evaluated based on theoretically achievable cost reductions. Results show that even under favourable operational, economic and political conditions, the achievement of competitive cost targets for electricity production from biogas using energy crops depends on the development of highly cost efficient methods and concepts, that substantially reduce production costs and increase market shares.

Keywords
Biogas, economy, costs, technology optimisation, strategies

Introduction

Governments in Europe are placing considerable faith in renewable energy technologies for reducing energy related environmental problems [1, 2, 3]. Support is focused among others upon so-called "new" biomass technologies, including biogas. One key-issue for future growth of biogas options is its relative cost, since currently electricity production from biogas continues to be more expensive than the least-cost fossil fuel alternative. The potential of biogas technology innovations to reduce electricity production costs to EU stated cost targets is analysed in the following sections.

Approach

The future cost target for electricity produced competitively with biogas using energy crops greatly depends from the expected fossil fuel cost development. Here, the required reduction to achieve cost-competitiveness is deducted from the EU stated cost target for electricity produced with biomass and the present electricity production costs using biogas.

A sensitivity model is used to identify and analyse future cost reduction potentials of different technological improvements in biogas production. The analysed parameters include technological efficiency parameters, as well as fixed and variable cost parameters. Single parameters are varied iteratively under *ceteris paribus* conditions, to compare and evaluate the resulting cost-effects. The assumptions made are based on up-to-date technological and efficiency parameters in biogas production in Europe. The range of variation of the single parameters is determined either by observed parameter ranges in practice or by assumed ranges. Finally, the cost-effects of single parameter changes are aggregated in three scenarios with parameter variations of 10 %, 20 % and 30 %.

Results and discussion

The European Commission plans to double the use of renewable energy sources from actually 6 % to 12 % of total energy consumption by 2010, and to 22 % by 2020 [2]. Simultaneously, the EU states a cost target for electricity production from biomass of 5 Euro-Cent per kilowatt-hour until 2020 [2]. Present electricity production costs with biogas using energy crops range between 9 to 12 Euro-Cent per kilowatt-hour [4, 5, 6, 7]. In view of future expected electricity costs using fossil fuels and the EU stated cost target for electricity using biomass, a total cost reduction of more then 50 % (i.e. 4 to 7 Euro-Cent per kilowatt-hour) is required until 2020 (**Figure 1**). For this to happen, a strong progress in technology development in connection with a rapid market

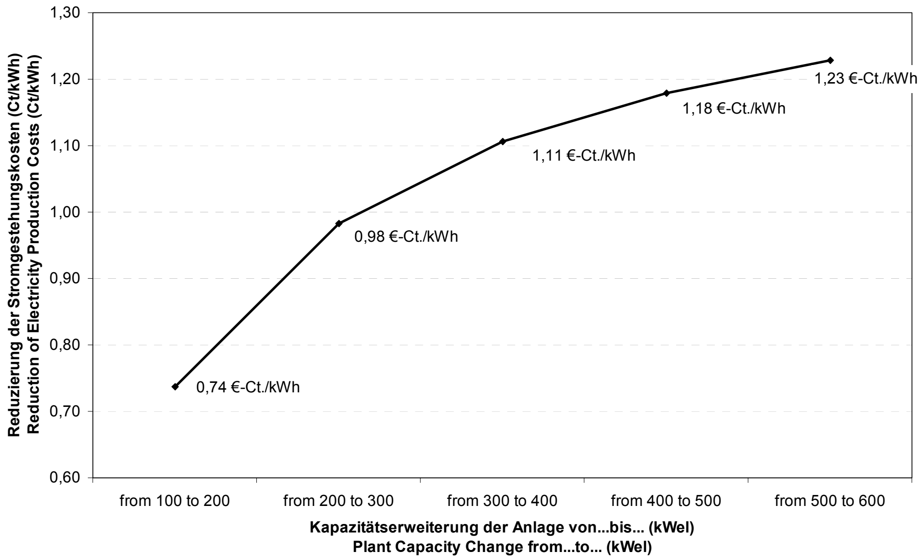

Figure 1: Expected electricity production cost development using biogas compared to fossil energy carrier mix (modified [1, 2, 3])

expansion and a substantial cost reduction is needed.

The relative costs of electricity produced with biogas are partly determined by enterprise specific conditions (e.g. plant size, heat utilization opportunities, etc.), as well as socio-economic and political conditions. Nevertheless, the contribution of technological improvements to reduce production costs is essential to future competitiveness of electricity production using biogas. The main cost determining parameters are the biogas production rate, the specific methane yield, the system workload, the conversion efficiencies and the biomass costs. Beside, the specific investments and the plant lifespan greatly influence total production costs (**Table 1**).

Table 1: Considered parameter variations in the sensibility analysis

Parameters	Variation ranges (from... to ...)
Specific investments - chp	2.000–1.400 €*[$kW_{el.}$]$^{-1}$
Specific investments - reactor	200-140 €*[m³]$^{-1}$
Lifespan technical components	5,0-6,5 a
Biomass yield	10-13 t DM*[ha]$^{-1}$
Conversion-efficiency	30-35 %
CHP - workload (running time)	7.000-8.000 h *[a]$^{-1}$
Methane yield	0,3-0,4 m³CH_4*[kg oDM]$^{-1}$
Biomass costs	75,0-62,5 €*[t DM]$^{-1}$

Plant investments

The plant investments are considered to be a crucial cost-reduction factor due to its high share of total costs and its considerable variability. In practice specific investments can vary within a range of 30 % [5]. Specific investments can be reduced by developing modular and standardized plant technologies [8]. By reducing the relative investment costs for the electricity generator by 10 % under *ceteris paribus* conditions, the electricity production costs fall by 0.64 Euro-Cent per kilowatt-hour. A similar cost reduction is achieved by reducing specific investments for the reactor by 15 % (**Figure 2**).

System workload

The adoption of high-tech solutions from robotics and information technology in biogas production aim at stabilizing the biogas and electricity production process [8]. By doing so, longer generator running times and higher average system workloads are possible. Plants equipped with modern technology usually achieve workloads of 7,000 hours per year [9]. Workloads above 8,000 hours per year are rarely achieved, because of maintenance specific standstill periods. An increase of the generator running time under *ceteris paribus* conditions from 7,000 to 8,000 hours per year results in a reduction of electricity production costs of 1.29 Euro-Cent per kilowatt-hour. This is equivalent to about 20 % of the total cost reduction target of about 6 Euro-Cent per kilowatt-hour (Figure 2).

Lifespan of technical plant components

The lifespan of different plant components varies greatly [9]. The cost-effect of measures that prolong the plant components lifespan is especially high when it comes to cost intensive, short-life technical plant equipment. The average life span of technical plant components is assumed to be 5 years. The cost-effect of increasing the lifespan of technical plant components for one year, e.g. from 5 to 6 years under *ceteris paribus* conditions, is an efficient strategy to reduce electricity production costs by about 0.59 Euro-Cent per kilowatt-hour. This cost-effect is equivalent to 10 % of the total cost reduction target (Figure 2).

Specific methane yield

A significant difference can be observed between the potential methane yields achieved under experimental conditions and methane yields reached in practice [10]. An important task is to reduce this gap, which can amount up to 0.10 cubic

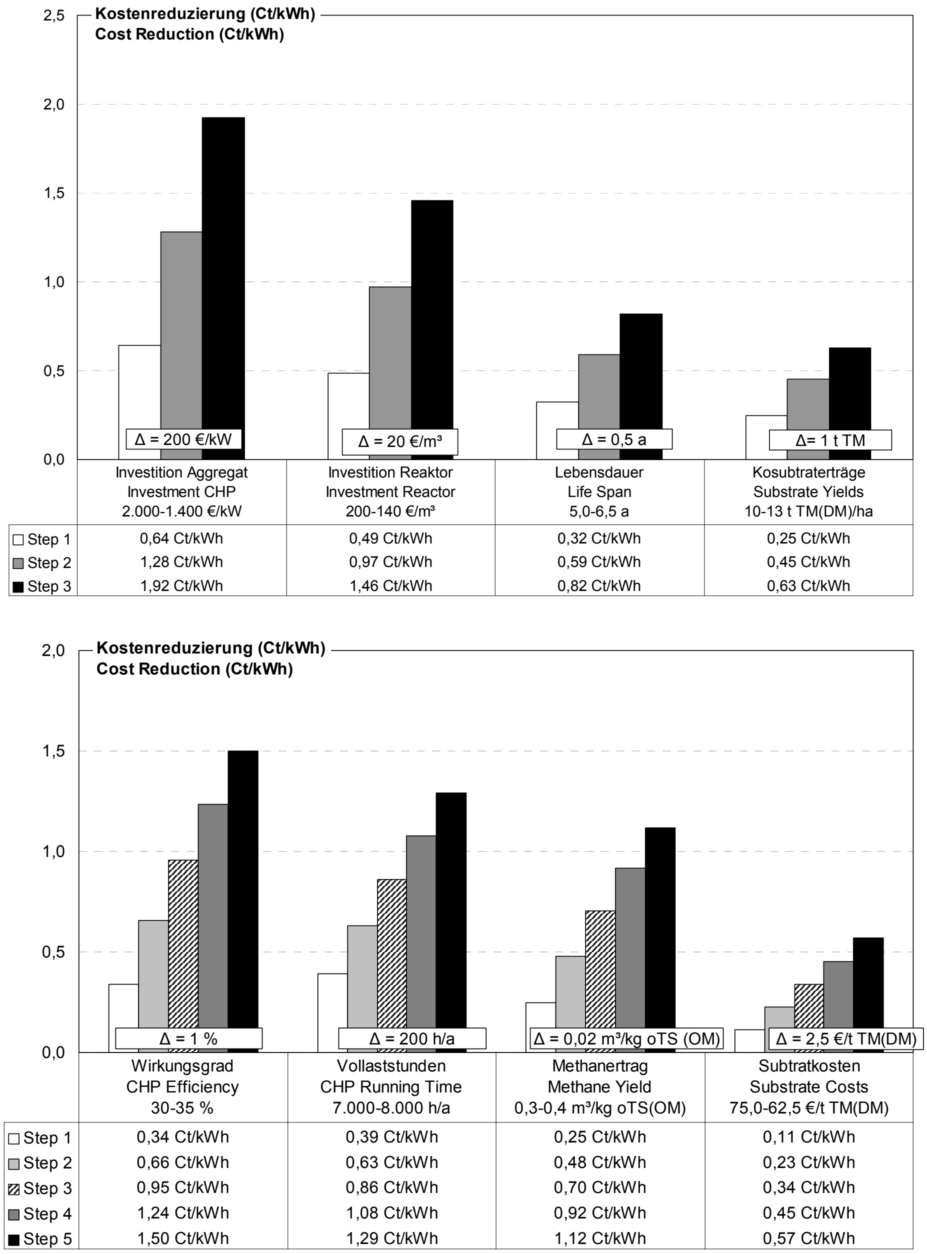

Figure 2: Cost reductions resulting from cost-efficient optimised parameters in biogas production, under ceteris paribus conditions

meters of methane per kilogram organic dry matter. This optimisation potential can contribute significantly to reduce the biogas production costs, since an increase of the specific methane yield from 0.30 to 0.34 cubic meters of methane per kilogram organic dry matter reduces electricity production costs by 0.48 Euro-Cent per kilowatt-hour, under *ceteris paribus* conditions (Figure 2).

Generator efficiency

Much effort is put into developing technologies that substantially increase electricity generation efficiencies. Improving electricity generation efficiencies is possible for example by using biogas in fuel cells [8]. The aim of such technology developments is to increase the conversion efficiencies by 5 % and more. Assuming a baseline average conversion efficiency of 30 %, an efficiency increase under *ceteris paribus* conditions of 10 %, i.e. from 30 % to 33 %, results in an average cost reduction of about 0.95 Euro-Cent per kilowatt-hour within the considered range (Figure 2).

Biomass costs

Biomass related parameters also offer significant cost reduction potentials, since biomass cost variations of 15 Euro per tonne dry matter can be observed in practice [11]. The cost-effect of optimisations that reduce biomass related costs, greatly depends on the quantity and quality of the biomass input [7]. Decreasing biomass supply costs by 5 Euro per tonne dry matter results in a reduction of electricity production costs of 0.23 Euro-Cent per kilowatt-hour, under *ceteris paribus* conditions and assuming average reactor space loads of 3.0 kg organic dry matter per cubic meter reactor space (Figure 2).

Biomass Yields

Increasing biomass yields, while simultaneously keeping biomass supply costs constant, may also reap high cost savings. Augmenting yields for 10 % (e.g. 10 to 11 tonnes of dry matter per hectare) theoretically results in saved costs of about 0.25 Euro-Cent per kilowatt-hour (Figure 2). Nevertheless, one has to keep in mind, that average biomass yields may not increase significantly in future, as a consequence of the promoted expansion of ecological farming practices [3].

Economies of scale

Theoretically, it will be easier for large-scale biogas plants to reach cost competitiveness, due to the cost-effects resulting from economies of scale. A scale-up of the installed CHP capacity, e.g. from 100 to 200 kilowatt under *ceteris paribus* conditions, contributes to a cost reduction of about 0.70 Euro-Cent per kilowatt-hour, which is equivalent to 10 to 15 % of the total cost reduction target. The main cost reduction due to economies of scale effects, is achieved within the range of 100 to 500 kilowatt installed CHP capacity. Accordingly, cost reductions per each additional kilowatt installed CHP capacity decrease significantly within this range (**Figure 3**).

Further options to improve the economic competitiveness of electricity production from biogas are the utilization of the produced heat, trading of CO_2-certificates and manure quality improvements. These options are not further considered in the analysis, since they do not affect directly the electricity production costs.

Scenario Analysis

For further analysing the potential to reach cost competitive levels in biogas production, the cost-effects of the single parameter optimisations are aggregated in scenarios. For the scenario design it is reasonable to differentiate between efficiency parameters and cost parameters in biogas production. Efficiency parameters include the conversion efficiency, the system workload, the methane yields, the biomass costs and the biomass yields. The assumed variation of the efficiency parameters in the scenarios I to III is always 10 % (**Table 2**). In case of the cost parameters, including the specific investments costs for the electricity generator and the biogas reactor, as well as the technical plant components, the assumed variation ranges from 10 % to 30 % in the scenarios I to III. Potential cost-effects resulting from economies of sale are not considered in the chosen scenarios. Further, baseline electricity costs with biogas using energy crops of 10,5 Euro-Cent per kilowatt-hour are assumed for the scenario analysis.

Table 2: Parameter variations in the considered scenarios

	Scenarios		
Parameters	**I**	**II**	**III**
CHP- spec. investments	10 %	20 %	30 %
Reactor- spec. investments	10 %	20 %	30 %
Lifespan technical components	10 %	20 %	30 %
Biomass yield	10 %	10 %	10 %
Conversion-efficiency	10 %	10 %	10 %
CHP - workload (running time)	10 %	10 %	10 %
Methane yield	10 %	10 %	10 %
Biomass costs	10 %	10 %	10 %

The scenario analysis results show a 10 % improvement of all the considered parameters is not sufficient to reach the EU stated cost target of 5 Euro-Cent per kilowatt-hour (**Figure 4**).

Even, it is not enough to achieve cost competitiveness in terms of the EU stated cost target, if cost parameters improve for 20 % and efficiency parameters improve for 10 % only. The scenario III demonstrates, that cost competitiveness in biogas

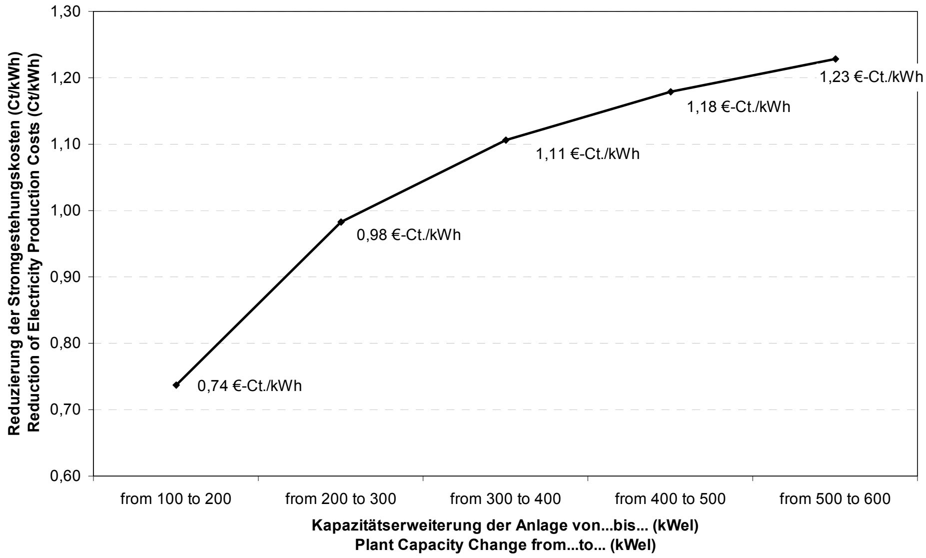

Figure 3: Electricity cost reductions due to economies of scale in biogas production under *ceteris paribus* conditions

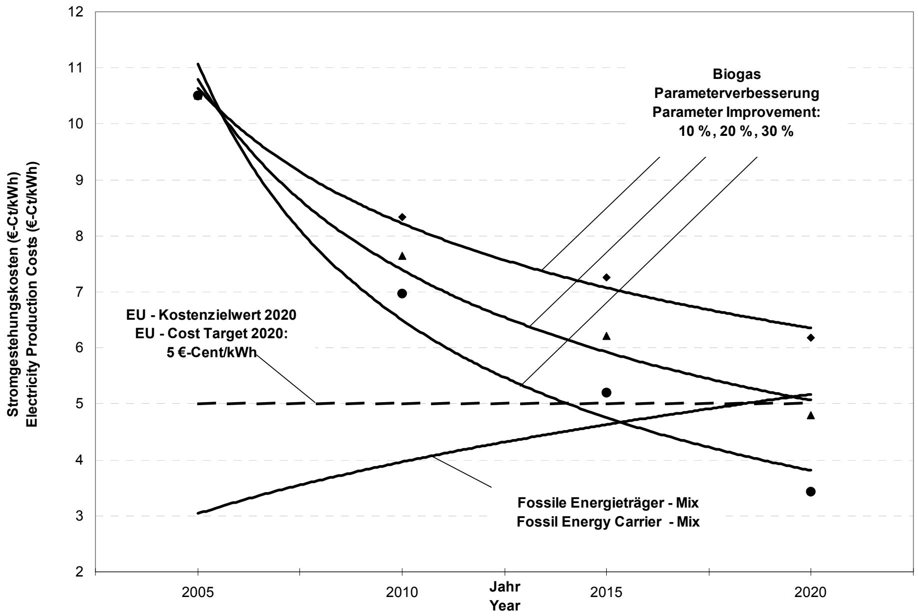

Figure 4: Cost-effect resulting from parameter improvements of 10 %, 20 % and 30 % under *ceteris paribus* conditions

production is possible, if the cost parameters are optimised substantially by more then 20 %, while simultaneously improving all considered efficiency parameters by at least 10 %.

Whether the presented parameter variations and the corresponding cost-effects are fully achieved in practice, will mainly depend, besides from favourable economic conditions, from the optimisation ranges of single parameters, the interactions between the cost-influencing parameters, the cost-efficiencies of different technology improvements and the sectors investment capacity.

Conclusion

Analysis results show that, in the case of biogas using energy crops, the ambitious EU stated cost target for electricity using biomass (i.e. 5 Euro-Cent per kilowatt-hour until 2020) may only be reached by substantially improving all relevant technological parameters. Important cost reductions may be achieved by reducing the specific investments, increasing system workloads and methane yields, as well as improving generator efficiencies. Extending the lifespan of plant components, e.g. by stabilizing the production process, promises further cost reductions, especially when it comes to cost intensive and short-life technical plant components. The cost-effect of improvements in the biomass supply chain mainly depends on the quantity, the yield and the quality of biomass inputs.

Finally, the extent to which single measures and strategies will contribute to total cost reduction in biogas production in future greatly depends from the existing interactions between the considered optimisation measures, as well as the cost-efficiencies of the proposed optimisation strategies and the investment capacities in the biogas sector. The assessment of the cost-efficiencies of technology optimisations is a main target of ongoing research at ATB e.V. for designing cost-efficient technology development strategies in biogas production.

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Author

Dr. Philipp Grundmann
Institute of Agricultural Engineering Bornim (ATB e.V.)
Department of Technology Assessment and Substances Flow
Max-Eyth-Allee 100
14469 Potsdam
Tel.: +49/(0)331/5699-229
Fax: +49/(0)331/5699-849
E-mail: pgrundmann@atb-potsdam.de