Political Power-Play at its best – the case study of biomethane in Germany

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Abstract

Biomethane is a gaseous and biogenic energy carrier, chemically identical to natural gas. When used as natural gas substitute, it can contribute to significant GHG savings depending on substrate utilization, cross compliance and system operation. Being an important part of Germanys climate protection program the development of a national biomethane market was pushed by several incentives via energy and climate policies and led to a rapid growth in biomethane producing facilities. Recent adaptions of the installed support schemes no longer guarantee sufficient compensation for the production of renewable energy. A system dynamics model was developed to evaluate future policies on their environmental and economic efficiency. Market participants want to shift from biomethane use in combined heat and power plants to new markets. The model will be able to simulate future energy and climate policies, estimate their success in terms of sustainable capacity development to support policy makers for the development of efficient support schemes that incite a further sustainable and economic efficient biomethane market development.

Keywords: biomethane, renewable energy, energy system, policy analysis

1. Introduction

Biomethane is biogenic methane chemically identical to natural gas. It is produced either via an upgrading process of raw-biogas or upgrading of synthetic natural gas. Raw-Biogas is produced through anaerobic digestion (AD) of several feedstocks like energy crops, manure, sewage, plant residues or organic waste. Synthetic natural gas is produced via thermochemical gasification of lignin-rich biomass like straw and wood. Whereas the production of raw-biogas through AD and the following upgrading process to biomethane is widely applied worldwide the thermochemical pathway to produce biomethane (often called bio-SNG) is not yet market-implemented. Being chemical identical to natural gas biomethane as well as bio-SNG can substitute this fossil energy carrier in each application (CHP plants, direct heat and transport sector). When used as natural gas substitute, biomethane as well as bio-SNG can contribute to significant GHG savings (Majer, 2011) ; (Rönsch, 2011). In order to achieve progress on climate protection the German Government relies on a mix of policies and instruments to decarbonize the overall energy system with the aim of greenhouse gas (GHG) emission reduction of at least 40 % till 2020 and 80 % - 95 % till 2050 in comparison to the level of 1990 (Horschig and Szarka, 2015). Biomethane as an opportunity for the decarbonization of the power, heat and transport sector was part of widely applied support schemes to incite R&D efforts and market development. The most important support schemes, the way the government interfered as market creator and the role of market failures as a barrier of the biomethane market development can be looked up in (Horschig and Szarka, 2015). In this paper the focus shall be laid on how system dynamics can help to predict market developments during times of political power-play. Support schemes for biomethane were first installed in 2004. Since then the level of support was changed each two to three years. From 2014 on the support is no longer sufficient for a further capacity development of biomethane. There is huge uncertainty in the market if new support schemes will be installed in not yet widely decarbonized markets like the heat sector, seldom features like the high level of flexible energy supply and storage possibilities will be priced or if a European-wide trade will be established. But there is not only uncertainty among market participants. Possible impacts of new support schemes in terms of capacity development, sustainability, new technologies or to avoid over-compensation have to be considered and estimated. Both, market participants and decision-makers can benefit from system dynamics. With a sound system dynamics model it is possible to derive scenario-driven simulation results on the impact of new governmental market-influences.

Besides the fact that biomethane increases energy security and diversity and represents an option for energy storage the main justification for the support of a market development is the fact that biomethane can contribute to significant greenhouse gas savings depending on the scope of application (where natural gas is substituted) and the supply chain. A comprehensive study of Majer et al. (2011) analyzed several different value chains and determined possible greenhouse gas savings (figure 1). Of course, greenhouse gas emission calculations are strongly dependent on assumptions. Figure 1 displays possible greenhouse gas emission savings of biomethane used in different value chains. Internal energy usage means that internal heat and power, that arises during the energy conversion process is used for the energy provision whereas external heat and power usage means the external supply of energy. Highest savings can be achieved in the combined heat and power supply chains with organic waste as feedstock. Savings of more than 100% can be achieved when organic waste is used for energy provision instead of landfilling it (avoided emissions).

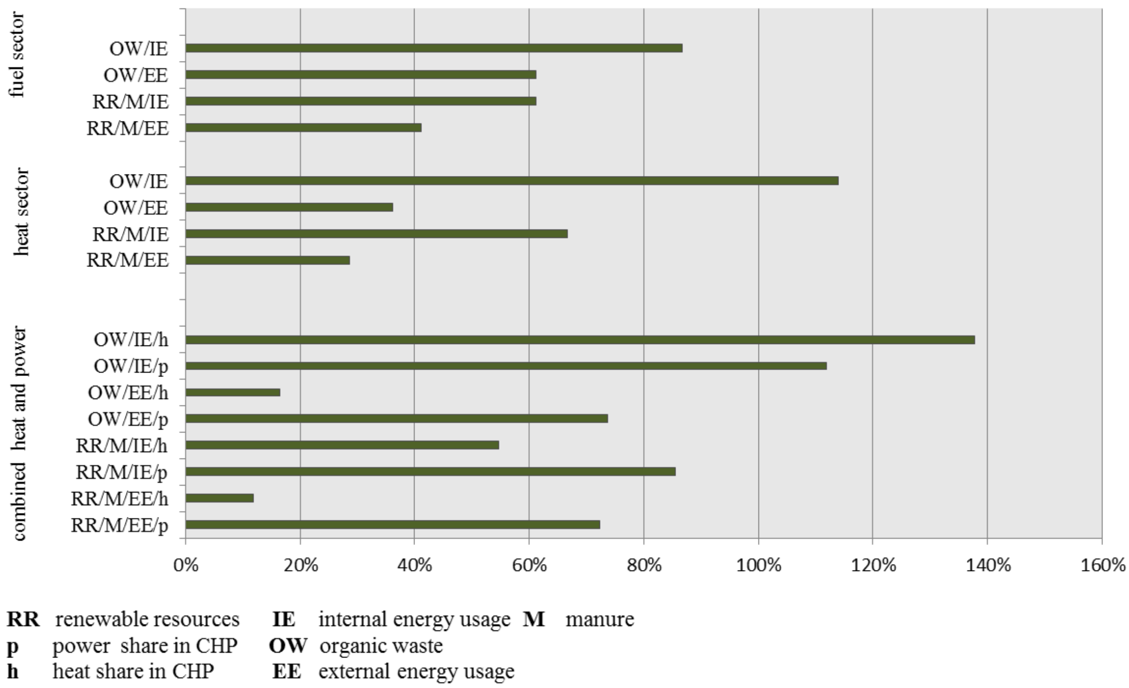

Figure 1 Greenhouse gas emission savings of biomethane against fossil reference in % (following (Majer, 2011))

1.1 Biomethane market

Since 2004 a variety of support schemes (main influence by Renewable-Energy-Source-Act) fostered a biomethane market development. The first biomethane plant went on grid in 2006. In the past ten years more than 180 biomethane plants were constructed feeding-in more than 110,000 Nm³/h (≈ 8 TWhpa). In this way the largest biomethane market worldwide raised. With the argument of too high costs for the power production out of biomethane the main support was decreased in 2014. Compensation which is necessary due to higher costs of biomethane in comparison to natural gas is no longer sufficient. Nonetheless the advantages and possibilities of biomethane for the task of decarbonizing the energy system make it worth to analyze the historic and current market situation, implement upcoming technologies and transfer this into a system dynamics simulation model. In this way it is possible to derive insights into market behavior and scenario-driven simulation results of possible futures for the biomethane market. Results of political power-play can then be simulated and estimated.

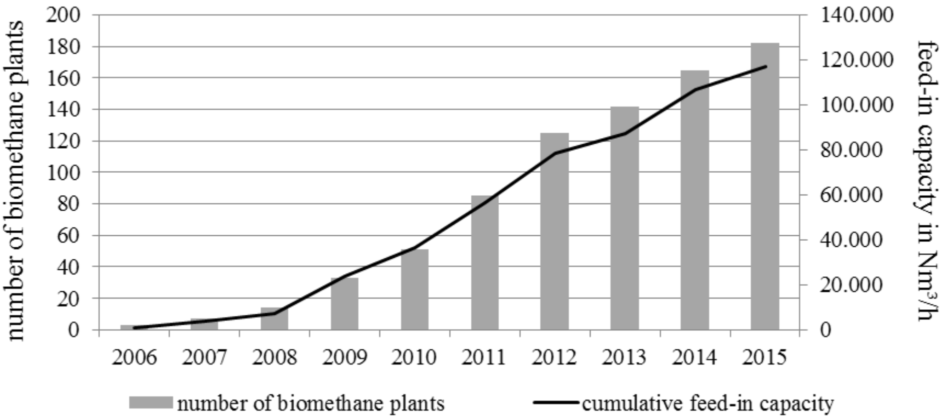

Figure 2 Development of the German biomethane market ("Biogasanlagen zur Biomethan-Produktion FNR-Mediathek," 2015)

1.2 Aims and objectives

It is the aim of this work to analyze the historic market development of biomethane in Germany till the present moment. Results are transferred to a system dynamics simulation model. A future technology, the thermochemical production of biogenic synthetic natural gas (bio-SNG) is implemented via a learning-curve & market adoption sub-model. After completing the model building process scenarios are implemented and simulated. The scenarios are designed in a way to reflect market predictions and hopes of participants. Market shares of biomethane in the heat and transport sector are simulated as well as future shares of bio-SNG under varying boundary conditions. Finally greenhouse gas savings for each scenario are calculated.

1.3 Recent work on the topic

System Dynamics suits well for the task of simulating policies and political power-play in renewable energy markets. Coupling System Dynamics with evaluation tools and methods enables the simulation of medium-term effects of potential futures and the analysis of interactions of economic and environmental interactions and feedbacks (Spyridaki and Flamos, 2014). However, Aslani et al. (2014) stated, only little research has been done using the System Dynamics methodology for dynamic modelling of renewable energy policies involving energy and climate policies (Aslani et al., 2014). Possible explanations are complexities when it comes to combining energy and climate policies and modeling their feedbacks and the limitations of bottom-up approaches concerning the implementation of market failures. SD Activities concerning Renewable Energies were done by Movilla et al, Hsu et al and Barisa et al. ((Barisa et al., 2015; Hsu, 2012; Movilla et al., 2013)). Hsu developed a System Dynamics model to verify renewable energy promoting policies for cost/benefit analysis, CO_2-reduction targets and budget limitations (Hsu, 2012). His simulation results show how the Taiwanese CO_2 mitigation goal can be reached by a proper policy combination. Barisa et al. (2015) developed a System Dynamics model for the dynamic simulation of the Latvian biodiesel market that is facing a new vision of the Latvian government with the plan to end subsidizing the market but increasing the consumption of biofuels (Barisa et al., 2013). Sanches-Pereira & Gómez (2014) used the SD methodology in an analytical framework modeling the Swedish biofuels system (Sanches-Pereira and Gómez, 2014). Their results indicate different pathways for decision makers to reach national renewable fuels goals. Jeffers et al. (2013) developed a SD model to analyze the US bioenergy feedstock market for the biofuels and biopower industries (Jeffers et al., 2013). These are regulated by several policies. They simulated how the market for bioenergy feedstock will react on policy changes. Concluding it can be said that there are several different SD models that include a part of a renewable energy system. Some deal with biofuels others with the generation of renewable power. Renewable heat is the topic of only few research papers. Until now there is no research paper of a dynamic simulation model for the whole renewable energy market. Within the presented approach we will show that it is possible to develop a dynamic simulation model that is capable of simulating policy changes with effects to the three energy sectors power, heat and transport. The German biomethane market will serve as the case example.

1.4 Political Intervention – a double-edged situation

If there was the political will to decarbonize the energy system, including the power and heat supply as well as the transport sector, there are two main options to do so. On the one hand there is the possibility to increase the price for fossil fuels, and hence include the external costs. On the other hand, new technologies can be subsidized by money for R&D or compensation for the production of green energy. One reason for the price difference (in most cases) between fossil fuels and green energy is market failures. More work on this topic has been done by (Brown, 2001; Fisher and Rothkopf, 1991; Jaffe et al., 2005). The current market situation is mainly determined by subsidies. Although there is a mechanism in force that considers external costs for fossil fuels, its impact is comparably low (European Union Emission Trading Scheme). This is because the price for polluting the environment is way too low to foster investment in renewable energy. Therefore, the scenarios used to simulate future developments of the German biomethane market consider both possibilities to intervene in markets.

2. Methods

We developed a system dynamics model of the German biomethane market. The first step was to analyze the existing market, its structure and barriers and drivers. This research was concluded in the set-up of a conceptual model. A research paper including a detailed description as well as a figure of the conceptual model has recently been submitted to a scholarly journal. In the final version of this manuscript, subject to acceptance, we will refer to it. The next step was to transfer the conceptual model to a causal loop diagram. Details of it can be looked up in (Horschig and Szarka, 2015). In the following the causal-loop-diagram was transferred to a stock-and-flow diagram. The model was calibrated with historical data. During the development of the stock-and-flow model several experts in the field of biomethane were consulted to ensure a sound model building process. The learning-curve and market-adoption sub-model of bio-SNG was calibrated with data of an associated PhD project. The system dynamics model will be able to calculate scenario-dependent overall greenhouse gas emission savings. The included natural gas flow sub-model can determine in which scope of application natural gas will be substituted. In this way, the environmental most beneficial scenario can be determined. In addition, the most economic beneficial scenario is measured by avoided greenhouse gas emissions per input of compensation.

2.1. Scenarios

Until now we defined three different scenarios. The first scenario is the *base scenario*, where the current situation is implemented into the model. This scenario was used to calibrate the model. The second scenario is the *green heat scenario*. In this scenario it is simulated which effect a direct subsidy would have to the use of biomethane for heating purposes. The third scenario is the *green transport scenario*. This scenario is defined by a direct subsidy for biomethane in the transport sector. Boundary conditions and main assumptions are equal for all scenarios. The modeled time horizon is 2000-2030.

3. Results

Until now only the base scenario is implemented into the system dynamics model. The simulation results are displayed in figure 3. It has to be mentioned that the compensations for the production of biomethane are guaranteed for 20 years. After expiration of these payments a nearly complete re-investment in the infrastructure (biomethane plant,etc.) is necessary.

However, current compensation schemes are not sufficient to re-finance this re-investment. An ongoing biomethane production cannot be realized.

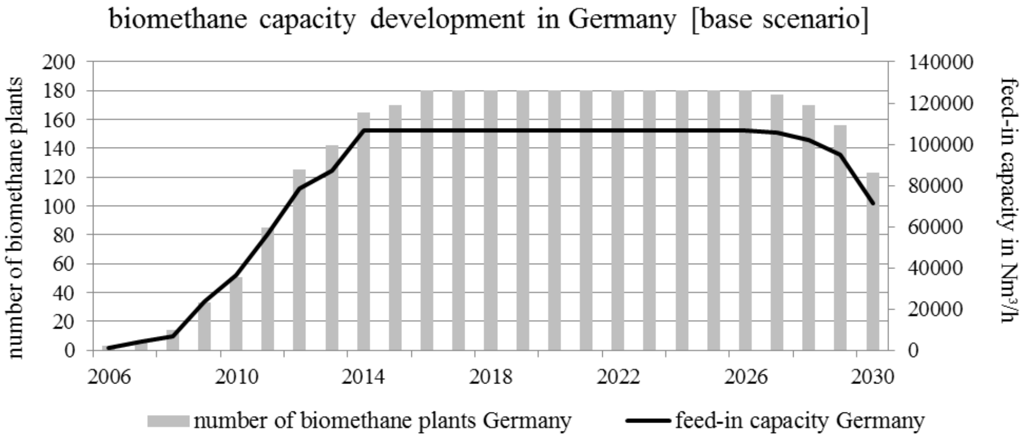

Figure 3 Simulation results of *base scenario*

The simulation results indicate that there will be a gradually decrease of biomethane production plants and thus feed-in capacity. Of course, current greenhouse gas savings of 2,800kt CO_{2eq} per year will decrease, too.

The simulation results of the *green heat scenario* and the *green transport scenario* will be shown at the annual conference in Delft. Furthermore, the final version of this manuscript, subject to acceptance, will include these results. In addition, the simulation results of an adapted emission trading scheme (section 1.4) will be shown at the conference, too.

4. Discussion & Conclusion

The aim of the presented research was to develop a market simulation model for the German biomethane market that is capable of simulating future policies and determine the most environmental and economic beneficial one. This model shall be seen as a step to a renewable energy system model (including the sectors power, heat and transport) that is able to simulate economic and environmental effects of new policies. So far, the presented approach was calibrated with historical data and reproduces them well. The base scenario was implemented and results indicate not the best future for biomethane in Germany. The bio-SNG sub-model works well, too. Simulation results for different future bio-SNG prices and how they affect the biomethane market were summarized in a scholarly paper, recently submitted to a journal. Subject to acceptance, the reference will be in the final version of this paper.

Summarizing it can be said that simulation results of the base scenario indicate that without further support the biomethane market in Germany will disappear in a mid-term period. To be realistic, a future support of biomethane for power production only won`t happen. Bioenergy is too valuable for this purpose and competing renewable power supplying technologies like wind power or solar power are cheaper. Although a comparison of wind power and solar power with bioenergy is not fair because bioenergy can provide energy independently on short-term weather effects. Promising markets for biomethane are seen in the heat and transport sector (Deutsche Energie-Agentur GmbH, 2014). The results of our simulations (green heat scenario and green transport scenario) will show decision makers the amount of support that is needed for a further capacity development and hence an ongoing decarbonization of the heat and transport sector. Biomethane can be an option for the decarbonization of the inner-city heavy duty traffic that cannot be replaced by electric vehicles. Simulation results will be shown at the conference and presented in the final version of this paper, subject to acceptance.

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