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A model-based analysis of the future capacity expansion for German biogas plants under different legal frameworks

D. Balussou[a,*], R. McKenna[a], D. Möst[b], W. Fichtner[a]

[a] Karlsruhe Institute of Technology, Chair for Energy Economics, Hertzstr. 16, 76187 Karlsruhe, Germany
[b] Dresden University of Technology, Chair for Energy Economics, Münchner Platz 3, 01069 Dresden, Germany

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ABSTRACT

As for other renewable energy sources in Germany like wind or photovoltaics, biogas has rapidly expanded in the past fifteen years. The installed electricity capacity for German biogas plants increased from 0.2 GW_{el} in 2001 up to about 4.2 GW_{el} by the end of the year 2016. This expansion has been supported in particular by the Renewable Energy Sources Act (EEG) through electricity Feed-In-Tariffs (FITs). However, major uncertainties are linked to the future capacity expansion in particular due to volatile electricity and energy crops prices. Taking into account this situation this paper analyzes possible future developments of the German biogas plant capacity up to 2030. For this purpose, a regional optimization model is employed, with the objective of determining the optimal economic development of the future biogas plants under different legal framework conditions. The base scenario with a constant energy crops cost evolution shows that the EEG 2012 framework -if maintained- would have fostered the development of agricultural plants, especially co-digestion plants valorizing energy crops and manure. The new EEG 2014 stops the expansion of energy crops mono-digestion plants, which will no longer be built due to an unprofitable situation. The German biogas market will thus face a paradigm shift and move towards the increase of biowaste and small-scale manure plants. Further scenarios quantify the impact of a strong variation of three main fundamental drivers, namely the energy crop costs, the EPEX-Peak electricity price and the biowaste valorization revenues, on future capacity developments. Based on the model results recommendations in direction of plant operators and policy-makers are formulated aiming at a more sustainable electricity production from biogas. Further work should consist in integrating the present analysis in national bioenergy models under the EEG 2017 legal framework.

1. Introduction

In the past fifteen years the German biogas sector has been driven by a strong expansion. By the end of the year 2016 the installed electric capacity in this country was estimated at about 4.2 GW_{el} [1] This represents more than 40% of the European total which has been estimated at about 10 GW_{el} by the end of the year 2016 [2]. This capacity development has been supported by several federal governmental incentives and in particular by the Renewable Energy Sources Act (EEG) with the help of electricity Feed-In-Tariffs (FITs). Following the plan for a nuclear phase out after the Fukushima Daiichi's disaster in 2011, the German Federal Government has launched a transformation of its energy system with the ambitious aim of 80% renewable energy sources in the national gross electricity consumption for the year 2050 [3]. Bioenergy, especially biogas, should contribute in that context to a regional value generation at the scale of municipalities and in the rural sector [4]. New jobs could thereby be locally created and regional biomass feedstock markets emerge in each Federal State in the framework of circular bio-economies.

Since the year 2014 the German biogas sector had to cope with major structural changes however. The Renewable Energy Sources Act 2014, proposed by the Federal Government and starting on the 1st of August 2014, symbolizes a paradigm shift for German biogas plants. Indeed, a major cut in the subsidies attributed to biogas plants is proposed by the legislator in particular for agricultural plants valorizing energy crops. For this plant type the specific subsidies dedicated to energy crops valorization have been removed [5]. This subsidies cut has been carried out for two main reasons. The first one consists of lowering the relatively high end-user electricity prices, especially for residential customers. In the residential sector the electricity price including taxes increased from 14 ct/kWh_{el} in year 2000 up to 29 ct/kWh_{el} in 2014 [6]. By giving the priority to the development of more profitable renewable

* Corresponding author.
E-mail address: davidbalussou@hotmail.com (D. Balussou).

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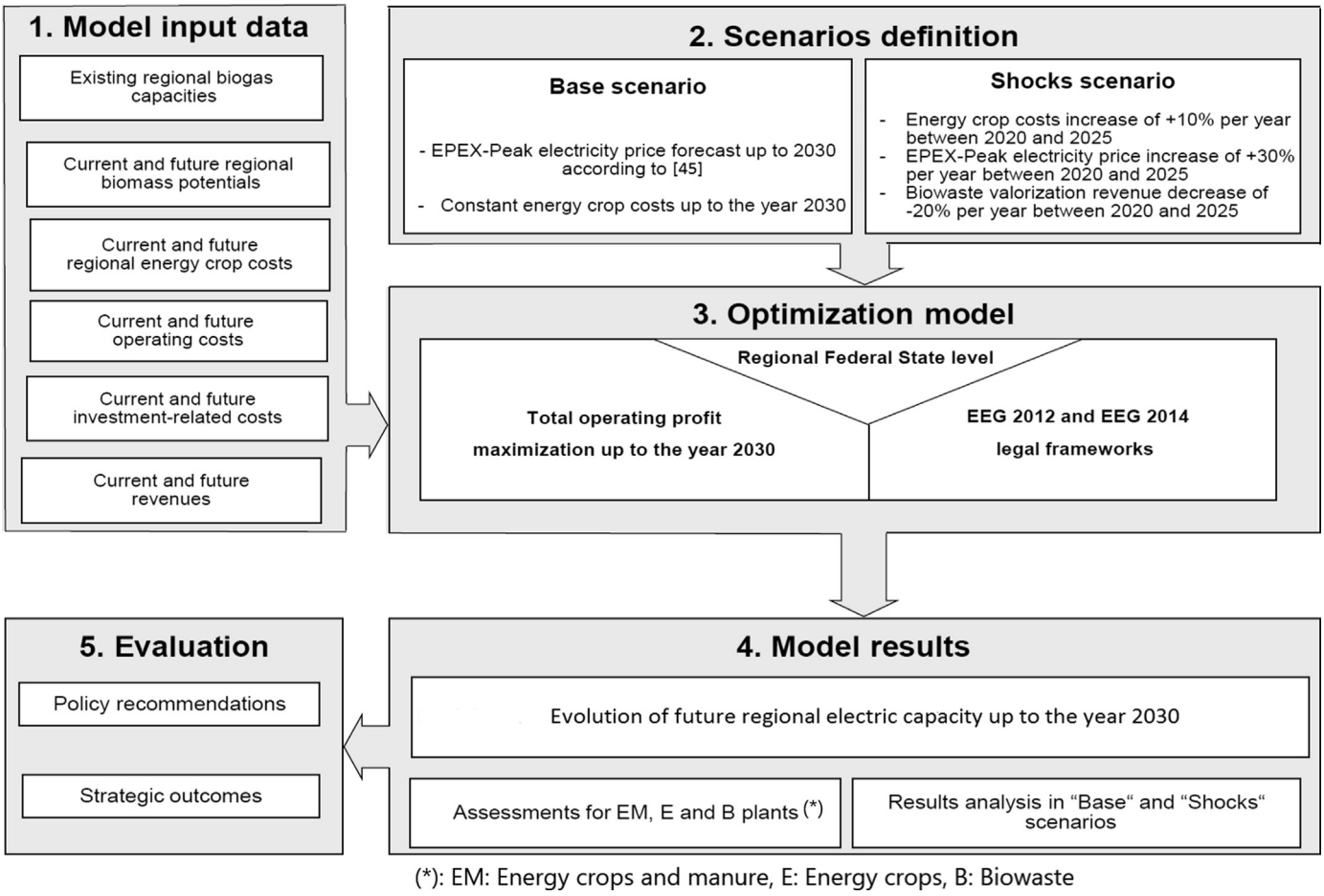

Fig. 1. General employed methodology (author's own representation).

energy conversion technologies, like wind energy or photovoltaic, the Federal Government thus intends to lower the electricity bills for end customers. With an average electricity production cost at about 18 ct/kWh_{el} for agricultural plants, biogas remains one of the most expensive renewable energy technologies [7,8]. Another reason for this cut concerns the past competition between energy and food value chains regarding biomass resources and surface area. The priority was given in the past fifteen years to the valorization of energy crops due to their high energy content and their high hectare yields in comparison with other feedstocks. This led to exclusive cultivation of certain agricultural plants, so called monocultures, like maize silage or rape. In addition, fertilizers and pesticides were intensively used for yield improvements. These aspects negatively impacted the agricultural sector and generated ecological risks including the degradation of humus balance and biodiversity, risks of soils erosion, reduction of the ground-water formation, landscape modifications and loss of ecologically valuable surface areas. The subsidies for biogas plants valorizing energy crops created tensions on maize and wheat markets and have led to a fuel vs food debate. This induced competition resulted in a general negative acceptability for biogas in Germany [9]. Since EEG 2012 German biogas plant operators have the possibility to directly self-market the produced electricity in the framework of the so called "electricity direct marketing" [10]. In addition to the revenues from the sale of the electricity, plant operators receive a supplement i.e. the "market premium". The market premium corresponds to the difference between the plant specific EEG-subsidies and the revenues from the electricity sales on the Exchange market (average EPEX values of the hourly contracts traded on the EPEX Spot Exchange). The objective of the direct marketing model is to better integrate biogas into the German electricity system, through a market-oriented and flexible electricity production. In order to develop a demand-oriented electricity production from biogas a flexibility premium has been further set in the framework of EEG 2012. This premium creates investment incentives for plant operators in supplementary biogas storage and combined heat and power systems (CHPs). The electricity direct marketing model applied to biogas gains more and more relevance in the total bioelectricity mix. In the middle of the year 2015 a total biogas plant electric capacity of about 2650 MW_{el}, was subjected to this new regime. This corresponds to about 66% of the total installed electric capacity at this time (4018 MW_{el}) [11]. However, volatile energy crop and electricity prices, combined with continuously evolving framework conditions, are a source of uncertainty for German plant operators. In this context investment decision making for biogas plant projects is a difficult task that requires the development of decision support tools. Taking into account all these aspects, it is the aim of this paper to analyze, with the help of an optimization model, the future evolution of the German biogas plant capacity. The general methodological approach of this paper is presented in the next section and can be divided into three main parts: the model input data determination, the description of the optimization model structure and finally the analysis and discussion of results and methodology. The input data, model structure and results analysis are described in detail in Sections 3, 4 and 5 respectively. In Section 6 a synthesis of results and a critique of the methodology are formulated. In Section 7 a conclusion as well as recommendations and future challenges are addressed in direction of the German biogas industry.

2. General methodological approach

The main objective of German biogas plant operators is to run and