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Electricity generation potential from biogas produced from organic waste in Mexico

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ABSTRACT

The provision of biogas from organic residues and wastes as well as its use as a renewable source of energy for electricity generation could contribute to a more environmental sound energy supply. Thus, this paper presents a methodology to estimate the theoretical, the technical and the economic potential of electricity generation from biogas of various organic waste sources. Additionally, it includes an assessment of the uncertainties aligned with such potential assessments. The outlined methodological approach comprises a bottom-up resource focused procedure with statistical and spatial analysis for selected organic waste sources. This allows the identification of municipalities/regions where electricity generation from organic waste via the biogas route is most promising. The method is exemplary demonstrated for the given situation in Mexico. The gathered results show that the methodological approach directs to plausible results. These results show also that Mexico has a considerable potential to use biogas from organic residues as a renewable source for electricity generation. Results indicate an average theoretical potential of roughly 167.9 TWh/a (143.5–192.3 TWh/a), a technical potential of circa 10.2 TWh/a (3.6–23.8 TWh/a) and an economic potential of approximately 6.4 TWh/a (2.0–15.2 TWh/a). This later economic potential could be located in around 391 municipalities in Mexico. The methodology proposed here may hold true for other countries with similar conditions and considerable lack of primary data.

Contents

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1. Introduction

In the last decades, the production, collection and use of biogas/sewage gas/landfill gas from organic waste as a renewable source of energy has gain increasing global interest, since it helps to reduce dependency on imported fossil fuels and – in parallel – could contribute to decrease anthropogenic greenhouse gas (GHG) emissions [1,2]. But so far, on a global perspective biogas contributes only little as an energy source [1]. In developing countries, biogas is provided to a very limited extend from small scale fermenters in rural areas. This gas is used mainly for cooking and to limited extends also for heating purpose [1,2]. The same holds true for industrialized countries. Here, biogas from agricultural substrates, from sewage sludge and from landfills contributes likewise only little within the energy system; here more to cover the given electricity and heat demand most likely based on CHP-systems [1,2]. One of the very few exemptions is Germany, where roughly 7800 agricultural biogas plants are operated providing together with landfill and sewage sludge plants around 31 TWh (2014) of electricity and roughly 57 PJ (2014) of heat provided in co-generation [3].

Regardless to this low utilization of biogas on a global scale for the time being, biogas production and use with modern process technology could be a promising option to make use of wet organic waste available basically everywhere at low or zero costs (or even under achievement of waste removal revenues) [1,3]. The produced biogas could be used either for the production of electricity and heat provided by CHP-units (i.e. co-generation) and/or as bio-methane to be used within the transportation sector e.g. in existing CNG-vehicles [1].

Biogas is formed when organic material is decomposed by microorganisms in an oxygen-free environment. This so called anaerobic digestion process occurs naturally in many locations (e.g. within the rumen of ruminant animals, within oxygen-free zones of sediments in lakes or swamps) [2]. From a technical point of view, biogas is produced most promising from wet organic material. Thus, the organic material presented in municipal and industrial waste water (i.e. sewage sludge), the organic fraction of kitchen wastes, the organic waste from the food processing industry (e.g. slaughterhouse waste) as well as livestock manure are typically the most promising and thus most widely used sources for biogas production [4–6]. Beside this, also energy crops (e.g. maize, corn-crop-mix) and/or agricultural residues (e.g. straw, leaves from sugar beet) can be used if (a) surplus agricultural land is available (i.e. no competition with food and feed production) and (b) the economic situation allows for its use as a biogas substrate [3].

In Mexico, the annual electricity generation of to be 137 GWh/a (2012) [5]; biogas from municipal solid waste contributes with 63%, sewage sludge with 29%, industrial organic waste with 6% and by-products from agriculture (e.g. livestock manure) with 2% [5]. Compared to the overall electricity generation this share can be neglected (i.e. in 2012, all over in Mexico around 260.5 TWh/a has been generated; 81.7% from this electricity generation results from fossil fuels, 12% from large hydropower, 3.4% from nuclear and only 2.9% from renewable sources like geothermal, wind and solar [7]).

In the last decades Mexico has implemented legal measures to support the use of renewable sources of energy. For example, the Law on the Use of Renewable Energy and Financing of Energy Transition (LAERFTE, Spanish acronym), approved in 2008, sets an electricity production boundary from fossil fuels of 65% in 2024, 60% in 2035 and 50% in 2050. The General Law on Climate Change (LGCC, Spanish acronym), approved in 2012, sets a target of 35% share of clean generation technologies in 2024 [5,7].

Against this background, the goal of this paper is to provide a methodology to identify the theoretical, technical and economic potential of an electricity generation from biogas provided from organic waste. Additionally the method should allow for assessing the uncertainties associated with these potentials. The results are shown in a spatial context to allow for the identification of municipalities/regions with promising potentials. This methodology is applied exemplary for Mexico and the respective results are discussed below. Beside this, the approach should be applicable also in countries with similar conditions like Mexico (e.g. environmental, social, and geographical) if the necessary data are available.

To achieve this goal, firstly the methodology and selected data for assessing the theoretical, technical and economic electricity generation potentials from biogas are presented. Then, the results and the associated uncertainties achieved with this method for Mexico are shown. For the economic potential, sensitivity analyses are developed focusing on the main influencing parameters. The results are presented in spatial disaggregation maps. Finally, the developed methodology and the results of the biogas potential assessment are critically discussed and conclusions as well as further recommendations are provided.

2. Approach and data

The methodological approach proposed here allows identifying and assessing the theoretical, the technical and the economic electricity generation potential of biogas from different type of organic waste. Therefore, it is based on a bottom-up resource approach with a statistical and spatial analysis of the main organic waste sources. This is true for:

- Landfill gas from municipal landfills and controlled dump sites of municipal solid waste,
- Biogas from municipal and industrial waste water,
- Biogas from livestock manure (i.e. cattle, pig and chicken).

Based on these three organic sources, first the theoretical potential, then the technical potential and finally the economic potential are identified (Fig. 1) [8,9]. The methodological approach for each biomass source is presented below in detail.

The necessary data for this assessment are gathered from literature, statistics, geographical data bases, websites and interviews [10–12]. To validate the data quality, two or more references have been used. Nevertheless, there are still uncertainties within the collected data. Thus, minimum and maximum values are acquired to indicate a range where the "real life" values are most likely to be. In order to develop a clear approach, average values have been used for the subsequent calculations; these average values are not necessarily the arithmetic average of the indicated range due to the available information partly contradicting each other. The uncertainty range of each option is calculated and presented in the final results. For the economic potential, sensitivity analyses are realized in order to identify what (unsecure) parameters might affect significantly the overall assessment.