Future of anaerobic digestion in Germany

Himanshu Himanshu, Christian Wolf

Manuscript published as chapter of:

Book of Proceedings of STEPsCON 2018

STEPsCON 2018 – International Scientific Conference on Sustainability and Innovation
7 December 2018, Leverkusen, Germany
Future of anaerobic digestion in Germany

Himanshu Himanshu*1, Christian Wolf1
1 Institut für Automation & Industrial IT (AIT), Informatik und Ingenieurwissenschaften, TH Köln

*Correspondence: (Dr. Himanshu, TH Köln, Steinmüller Allee 1, 51643 Gummersbach; Email: himanshu.himanshu@th-koeln.de)

Abstract

The introduction of Feed-in tariffs in the German Renewable Energy Act (EEG) fuelled the growth of anaerobic digestion (AD) industry making Germany the country with highest number of operational AD plants. However, the rapid expansion of AD industry resulted in some unwanted side-effects such as food vs fuel debate, increased prices for electricity and the temporal mismatch between supply and demand of electricity grid. Subsequent amendments in EEG has tried to address some of these issues by reduction in Feed-in tariffs, introduction of a cap on cereal based feedstocks and providing premium for energy production in accordance with market demand. Furthermore, the Feed-in tariffs which were introduced for 20 years are soon going to expire. The changes in legal and political discourse is soon going to introduce some new challenges to the AD industry. This paper has discussed some of these challenges and their potential solutions.

1. Introduction

Anaerobic digestion (AD) is playing a major role in providing renewable energy in European Union especially Germany. Several countries, including Germany, provided subsidies either in the form of feed-in tariffs or through supporting investments to promote renewable energy production from AD [1-4]. The German Renewable Energy Act (EEG) of 2000 obliged energy supply companies to feed electricity generated from renewable sources into the grid at guaranteed tariffs over a period of 20 years [1, 5, 6], while the amendments in 2004 and 2009 set strong incentives for the cultivation of energy crops dedicated to AD [7]. This fuelled the growth of biogas plant construction in Germany making it the country with the highest number of operational AD plants. Most of these AD plants are farm based which utilize energy crops as their primary feedstock and generate electricity as base load power supply.

This rapid growth of AD industry due to the EEG has also resulted in some unforeseen side effects including food vs. fuel debate by occupying land for energy crop cultivation [8], biodiversity loss by converting species-rich grasslands into less diverse arable land [9-11], increase of land rental prices [12] and the increase in energy costs due to feed-in tariffs [7]. Furthermore, the growth of electricity share from renewable has increased the mismatch between supply and demand of the electricity grid especially due to the somewhat
unreliable and non-flexible nature of electricity generation from solar and wind and operation of AD plant as base load power supply.

To address some of the side effects the EEG was amended in 2012, 2014 and 2016/2017 resulting in reduction of Feed-in tariffs, introduction of cap on cereal based crops (an upper limit for new AD plants of 60% from 2014, 50% since 2016 and 44% from 2021), limitation on the annual expansion of the installed electrical capacity, introduction of a premium for flexible biogas [1, 5, 6, 8, 13]. The current AD industry in Germany is going to face some challenges in near future due to introduction of change in legal and political framework. This paper has discussed some of these challenges and their potential solutions.

2. New feedstocks

Cereal based crops are currently the primary feedstocks for AD plants in Germany, however, these crops needs substantial resources and carbon input in the form of fertilizer, machinery etc for production. Furthermore, the land which was previously used for food production is now being used to produce fuel, however, the food demand remains same and probably has to be imported from somewhere else giving raise to the food vs. fuel debate. It is necessary to explore alternative feedstocks which require low carbon input for production and doesn’t compete with food production or change the current agriculture practices. In Italy, a recently developed strategy, Biogasdoneright™, has shown that farm scale AD can be adapted so it doesn’t compete with traditional food and/or feed production on an agricultural farm. In several regions of Italy, only a single crop per year was norm due to lack of markets for the double crop. However as per the new this strategy a double-cropping was adopted where the first crop (traditional crops) was grown to supply the existing food/feed markets while the second or double-crop e.g. winter rye, triticale, forage wheat, or corn silage was grown, harvested, ensiled for year-round operation of AD plants [14-16]. Also, along with energy crops multiple agro-industrial residues were co-digested for biogas production [17-19].

The residues originating from the entire food supply chain (production, processing, distribution, storage, and sale) and organic fraction of municipal solid wastes (OFMSW) (e.g., organic residues from households, kitchens, restaurants, factory lunch rooms and supermarkets, as well as leaves, grass clippings, or yard trimmings), are also valuable feedstocks for AD [20-25]. Currently, in Germany out of 9.8 Million tons of organic household residues, only 20-30% is utilised for AD [8]. However, these feedstocks are highly heterogeneous with temporal and spatial variations in their digestion characteristics [21-25]. On the basis of digestibility, these can be divided in three different fractions, readily digestible fraction e.g. food waste, medium to slowly digestible fraction e.g. grass clippings and inert fraction e.g. plastic bags. The food waste is of special interest for biogas production due to its high methane yield and short digestion time. Furthermore, in Germany, about 15 million tonnes of food waste is generated, of which, about 60% is generated by households and usually discarded in ‘brown bins’[26, 27].
Besides organic residues, biomass from aquatic plants and algae has also been reported as potential feedstocks for biogas production. These feedstocks, generally considered as advanced or third generation feedstock, due to high biomass yield potentials caused by rapid growth and high photosynthetic efficiency, high diversity, no need for fertile agricultural land for cultivation and thus, no direct competition with food production [28-30]. Also, these feedstocks have low lignin concentration which impedes microbial digestion in terrestrial feedstocks. The AD of water based feedstocks is still in infancy and faces many challenges such as economical production and process instability due to high protein, lipid, sulphur, polyphenol, halogen or saline concentrations [28, 31]. Furthermore, the chemical composition and thus the methane potential and optimal harvest time vary with season and location [32].

3. On-demand biogas production

The revision of EEG in 2017 replaced the Feed-in tariff with a tender system and instead of receiving a fixed price for each kilowatt hour fed into electricity grid the supplier can now participate in variable electricity rate determined by the supply and demand of the market [5]. In this scheme, the suppliers have market their electricity themselves and are paid the difference between the feed-in tariff a plant would be entitled to and the average market value of the generated electricity [33]. The premium is designed to motivate the AD plant operators to update their AD facilities from base load supply to flexible energy supply which is determined by the market demand. Furthermore, there are special incentives for acquiring the infrastructure needed for upgrade existing AD plants for flexible energy production. Following approaches can be used for flexible electricity production.

3.1 Biogas storage

3.1.1 On-farm storage

Most of the agriculture AD plants use low or no pressure, single or double layer membrane biogas storage domes which can store biogas for about 4-6 hours [34, 35]. In on-farm storage scenario the AD plant is operated in state of the art manner to constantly produce the biogas, the produced biogas is stored onsite while the electricity from combined heat and power (CHP) is generated only when there is a demand. However, for on-site biogas storage an investment of €10-80 m³ of stored biogas is required [36]. Furthermore, additional cost will be involved to update the AD facility to satisfy the legal requirements posed by the increased amount of biogas storage.

3.1.2 Grid injection

The biogas produced from the AD facility can be further upgraded to biomethane and stored in gas grid which has large storage capacity and this stored biomethane can be used to produce electricity on-demand [37]. This method has gained attention over last few years in Sweden, France, Austria, the Netherlands, Switzerland and Germany [38]. In Germany more than 100 large scale AD facilities are upgrading and injecting the biogas in grid [5]. However,
this approach might not be suitable for smaller AD facilities as the current biogas upgradation technologies are economical for large AD facilities. The cost of gas grid connection has to be covered by both grid operator and AD facility operator which depend on the connection length. The electricity generation from gas grid can result in higher electricity conversion efficiency compared to small decentralized AD facilities as the large gas reservoir from the gas grid can be used to operate natural gas combined cycle gas turbines which electricity conversion efficiencies of more than 60% [39].

3.2 Flexible biogas production

The biogas production from multi-step AD process has been identified as a somewhat robust procedure which can be controlled by varying feeding intervals and changing feed types thus producing biogas on-demand. Following two approaches can be followed to achieve this.

3.2.1 Substrate feeding regime

On-demand biogas production can be achieved by either changing the feeding regime from continuous to pulse or by spiking the slowly digestible feedstock with readily digestible components. Mauky et al. [40] tested different feedstock mixtures in full scale digesters where the feeding interval was altered. Their results show that by flexible substrate feeding, the daily gas production rate can be modulated up to ±50% of the daily average gas production rate. Electricity shutdown up to 3 days was possible with ~ 60% reduction in biogas production. Furthermore, no process instability was observed. Similarly, Mulat et al. [41] tested three feeding frequencies i.e. 2, 24 and 48 h with ‘distiller’s dried grains and reported 14% higher methane yield with 48 h feeding frequency and no adverse effects on the process stability. Feng et al. [42] spiked the AD reactors running on cattle slurry with maize silage and reported peaks of +130% of methane yield and no process instability in short term. This is an attractive option as to achieve flexible biogas production comparatively less additional infrastructure is required and currently in Germany there are grants available to obtain these infrastructure. However, with this approach the microbiome of the AD facility should be resilient enough to cope with rapid changes in feedstock concentrations and the limits of flexible feedings should be well known. Furthermore, a reliable and fast monitoring and control system is also required to control the accumulation of inhibitory substances such as volatile fatty acids (VFA) and ammonia.

3.2.2 Multi stage plant configuration

Another option for flexible gas production is physical the separation of the hydrolysis/acidogenesis steps from the acetogenesis/methanogenesis steps in a two-stage processes. The effluent produced during hydrolysis/acidogenesis stage which is rich in organic acids can be stored and fed in a secondary reactor which will carry out acetogenesis/methanogenesis steps to rapidly produce methane on-demand. Different configurations (Figure 1) of two-stage reactor systems have been suggested for demand-driven biogas production, combining a continuous stirred tank reactor or leach-bed reactor as the first stage with an high-performance reactor such as an upflow anaerobic sludge
blanket or fixed-bed reactor as the second stage [43-45]. However, a two-stage system
requires significant investment due to additional infrastructure.

**Figure 1.** Different configuration of two stage AD reactors used for flexible biogas production. A – Hahn et al.[33]; B – Wall et al.[45]; C and D – Hahn et al.[33]. AF: anaerobic filter, LBR: leach bed reactor.

**Conclusion**

The goal of this study was to identify some of the challenges posed to German AD industry due to recent changes in legal and political situation and potential solutions for these challenges. Based on the review following conclusions can be drawn.

- Due to food vs. fuel debate, expiration of Feed-in tariffs and a cap on cereal based feedstocks, new feedstock options have to be explored. Agro-industrial waste, macro and micro algae, food waste from entire supply chain and OFMSW are promising candidates.
- There is a temporal mismatch between the supply from renewable sources and demand from electricity grid. AD can play a significant role to fill these gaps. Multiple approaches including on-site biogas storage, biomethane storage to gas grid and flexible operation of AD facility can be followed to produce on-demand electricity.
Acknowledgements
This work was funded by Metabolon IIb project.

Conflict of interest
The authors have declared no conflict of interest.

References


