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Biogas in Europe: Food and Beverage (FAB) Waste Potential for Biogas Production

Anna Pazera,*,† Radoslaw Slezak,† Liliana Krzystek,† Stanislaw Ledakowicz,† Guenther Bochmann,‡ Wolfgang Gabauer,‡ Sabine Helm,§ Simon Reitmeier,§ Laure Marley,‖ Francoise Gorga,‖ Laura Farrant,‖ Vaclav Suchan,⊥ and Jaroslav Kara⊥

†Department of Bioprocess Engineering, Lodz University of Technology, Wolczanska 213, 90-924 Lodz, Poland

‡Biogas Research and Consulting, BOKU, Konrad Lorenz 20, 3430 Tulln, Austria

§Kompetenzzentrum für Ernährung (KErn), Am Gereuth 4, 85354 Freising, Germany

‖Association Nationale des Industries Alimentaires (ANIA), Rue Leblanc 21, 75015 Paris, France

⊥Potravinarska Komora Ceske Republiky, Pocernicka 96, 108 03 Praha, Czech Republic

ABSTRACT: The aim of this paper was to give an overview of the biogas market in five countries (Austria, Czech Republic, France, Germany, and Poland) and to compare the potential of renewable energy sources from the food and beverage (FAB) industry waste. The objective included the identification of the production of biogas from organic waste and the untapped potential of organic waste in various industries of FAB and to specify non-technological barriers that hinder development and use of renewable energy potential in each mentioned country. Therefore, an evaluation of the most important FAB waste streams was carried out, to calculate the biogas production potential. The map depicting the existing FAB waste streams was prepared. As the data shows, the biogas market is growing, despite the often unfavorable conditions. Difficulties in obtaining all of the necessary permits and too complex administrative and legal procedures are the main barriers that hamper the development of the biogas market. In fact, the biggest bottlenecks were too many formal requirements and financial barriers. The biggest methane potential of 680 million m^3 of CH_4/year was calculated for FAB waste generated by 13 127 FAB companies in France. The main four branches of FAB industry generating waste being a suitable substrates for biogas production are dairy, meat, brewing, and fruit and vegetable processing industries. As clear from the research, more and more industrial organic waste is used in biogas plants, replacing the most popular but expensive maize silage.

1. INTRODUCTION

The ongoing debate related to Europe 2020 strategy about the availability of sustainable bioenergy resources and the food-or-fuel discussion has revealed the urgency of using untapped waste streams. Anaerobic digestion (AD) of industrial waste provides a promising alternative to standard waste treatment, in particular, of wet waste. The European food and beverage (FAB) industry is the second largest manufacturing sector in the European Union (EU) 27, with a market share of 12.2% in value-added terms. This sector generates a turnover of €917 billion (14.5% of total manufacturing turnover) and employs 4.5 million workers.[1] The amount of residues generated in the manufacturing sector (FAB industry) is 5% of total food production.[2]

Biogas is a renewable energy source that is generated from biomass under anaerobic conditions. Common sources for biogas production are agricultural crops, livestock residues, municipal solid waste, and organic waste, and wastewater from different sectors.

Within the European Community, there is a large heterogeneity regarding utilization of biogas, which is mainly derived from energy crops, agricultural waste, manure, and animal slurry. Austria and Germany are the most advanced, with roughly 4500 plants treating organic wastes. Also, Poland and the Czech Republic are progressing fast. In the Czech Republic, the electricity output from biogas utilization rose by 65% from 2008 to 2010. On the other hand, in most of the other central European countries, the situation is still premature, although the biogas potential is very high, especially in the waste sector.[2]

The surplus of bioenergy generation together with a reduction of greenhouse gas (GHG) emissions perfectly meets the European 2020 targets. Today, FAB companies with combustion installations of a capacity greater than 25 MW taking part in the European Emission Trading System are compulsory. The mobilization and extensive use of organic FAB waste as a renewable source for bioenergy production have high potential and can help secure a safe energy supply in European countries.

The aim of this paper was to evaluate the status of the biogas production out of organic residues from the FAB industry in five countries (Austria, Czech Republic, France, Germany, and Poland) and to localize the untapped potential in different FAB branches. The results were expected to help to estimate the potential of the renewable energy source of FAB industry waste

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and identify the non-technological barriers that hamper using these potentials.

2. METHODOLOGY

To determine the number of existing biogas plants using FAB waste in each mentioned country and indentify waste streams of different FAB industry branches as well as non-technological barriers for biogas projects, two groups have been targeted: FAB producers and current biogas plant operators. Additionally, the data concerning waste streams of different FAB industry branches were collected from administrative units (e.g., Marshal Offices from each voivodship). Existing barriers and bottlenecks for developing biogas production from organic residues in the FAB industry were also identified on the basis of the questionnaires. The methods of collecting data were as follows: (1) interviews with biogas plant operators (Interviews were conducted with the biogas plant operators in each country. All of them were pretty reluctant to communicate by phone and exchange their experience in this field. That is why the direct method was used, the personal meeting.) and (2) survey for FAB producers (The questionnaire was forwarded by e-mail to FAB producers. However, no feedback was received; therefore, a more effective way, telephone poll and personal meetings, was carried out. When sufficient information was not obtained, an Internet research was conducted and existing literature was examined.).

In every mentioned country, the map showing all organic waste biogas plants and, in particular, biogas plants already using residues from the FAB industry was prepared. These are biogas plants located directly at FAB industry sites of waste plants collecting the substrate from their region. Moreover, the kind and amount of used waste from the FAB industry were identified, and the potential energy yields were calculated. Additionally, the data collection showing the arising waste streams in the different branches of the FAB industry in the partner countries was elaborated. The data were expected to show the current way of waste disposal and identify the waste streams most favorable for biogas production. Collected data are presented in a form of a map showing the untapped waste streams for biogas production from FAB branches with most significant potentials. The map was prepared using Microsoft MapPoint Europe 2013 program.

On the basis of the collected data concerning the kind and amount of waste from the FAB industry, the potential for methane production was calculated. The methane potential was determined as

$$Q = \sum_{i=1}^{n} R_i L_i$$

where Q is the methane production potential in the given branch of the FAB industry (m^3 of CH_4/year), R_i is the amount of the ith kind of waste generated in the given branch (tonnes/year), and L_i is the methane production efficiency from the ith kind of waste in a given branch (m^3 of CH_4/tonne).

Theoretically (actual average) from 1 m^3 of biogas, 2.1 kWh electrical energy can be produced.[3]

3. EUROPEAN BIOGAS MARKET

In March 2007, the Heads of States and Governments of the 27 EU member states adopted a binding target of 20% renewable energy from final energy consumption by 2020. In combination with the commitment to increase energy efficiency by 20% by 2020, Europe's political leaders paved the way for a more sustainable energy future for the EU and for future generations. Biogas is seen to be one of the key technologies both to reach EU member state targets for renewable energies in 2020 and to meet their requirements within the European organic waste management directive.

The contribution of renewable energy in total energy production in 2010 and required targets for 2020 for five partner countries are shown in Figure 1.

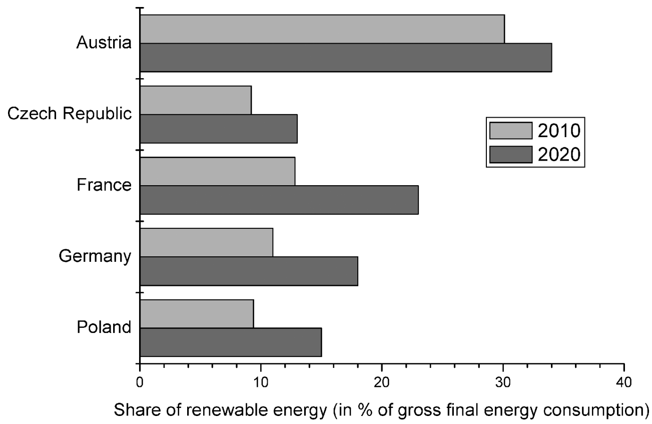

Figure 1. Share of renewable energy in total energy consumption in five EU countries.[4]

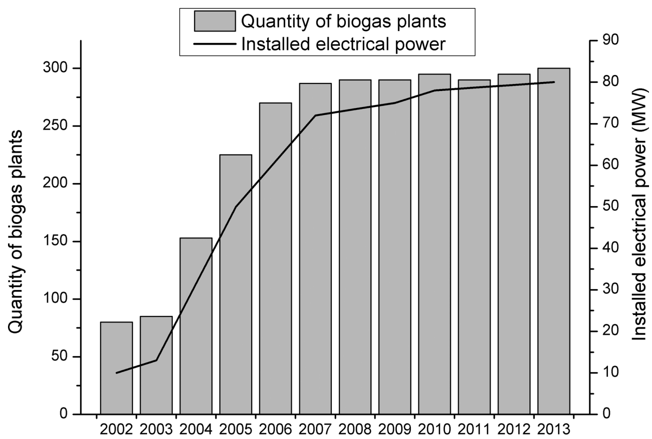

Figure 2. Development of quantity of biogas plants (bars) and the installed electrical power in Austria from the beginning of 2002 to 2013.[5]

Also, the European Landfill Directive sets mandatory targets for a three-step reduction in biodegradable waste going to landfill. Set against a 1995 baseline, it requires a reduction of 25% by 2010, 50% by 2013, and 65% by 2020. Therefore, it is desirable for the EU members to investigate novel solutions based on the use of waste and sub-products from the food industry for renewable energy production. Biogas plants are believed to be enormously advantageous by obtaining biogas from the organic matter contained in agricultural and food waste, which helps the food industry reduce the environmental impact caused by organic waste.

The next sections describe the current status of biogas in five European countries, Austria, Czech Republic, Germany, France, and Poland, to obtain information about diversified scenarios of the biogas market and the use of FAB industry waste.

3.1. Austria. In Austria, the installed electrical power of 15 MW rose to nearly 80 MW within 6 years, from the beginning of 2002, which was the result of the implementation of the first eco-power law (feed-in tariffs) (Figure 2). At the same time, the average installed electric power per biogas plant increased from 0.190 to 0.270 MW.

Until 2013, there were approximately 300 agricultural and industrial biogas plants in Austria, which together produced between 520 and 550 GWh electricity per year. However, there are no adequate data available concerning industrial biogas plants in Austria.

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Table 1. Development of Electrical Power Production from Biogas Plants and Industrial Biogas Plants (Wastewater Treatment Plants) in Czech Republic[a]

	biogas plants			industrial biogas plants (wastewater treatment plants)		
year	number of installations	installed electrical power (MW)	electricity production (TWh)	number of installations	installed electrical power (MW)	electricity production (TWh)
2003	5	1.547	6.519	4	0.886	1.691
2004	7	2.066	7.130	6	0.998	2.001
2005	7	1.954	8.243	5	0.976	2.869
2006	13	6.109	19.21	4	0.940	2.070
2007	19	10.92	43.25	7	1.006	3.292
2008	47	28.95	91.58	9	1.029	4.016
2009	84	53.58	262.6	9	1.499	3.616
2010	112	74.99	447.4	9	1.349	4.971
2011	179	132.9	724.8	9	1.414	6.924
2012	303	254.2	1264	10	1.785	8.517

[a]Includes new biogas plants that have not been through trial operation.

Table 2. Biogas Plants Using Industrial Waste in France, Classified by Regions (80 Agro-industrial Plants, of Which 58 Use FAB Waste)

region	number of installations	methane produced (million m^3/year)	electrical energy production (GWh)
Nord Pas de Calais	12 + 1 under construction	6.742	25.77
Haute Normandie	4	3.016	11.53
Picardie	3	2.495	9.534
Basse Normandie			
Ile de France	1	0.016	0.063
Champagne	2	0.868	3.318
Lorraine			
Alsace	5 + 1 under construction	1.918	7.329
Bretagne	3	1.121	4.284
Pays de la Loire	6	1.203	4.599
Centre	1	1.538	5.880
Bourgogne	3	0.725	2.772
Franche Comté	3	1.401	5.355
Poitou-Charentes	1	1.841	7.035
Limousin	1	1.198	4.578
Auvergne			
Rhône-Alpes	6	0.643	2.457
Aquitaine	9	4.049	15.48
Midi-Pyrenées	9 + 1 under construction	0.742	2.835
Languedoc-Roussillon	2 + 1 under construction	0.604	2.310
Provence-Alpes-Côte d'Azur	6 + 1 under construction	0.187	0.714
Outre Mer	2	2.396	9.156
Corse			
total	80 + 5 under construction	32.70	125.0

There are identified 50 industrial biogas plants using the list of "Approved or Registered Animal Byproducts (ABP) Plants According to Regulation (EC) No. 1069/2009" received from the "ARGE Kompost & Biogas" (representation of interests of Austrian biogas plant operators), but it is impossible to indicate the number of Austrian biogas plants using only FAB industry waste. Initially, the most commonly used substrate was slurry and small amounts of organic waste, while since 2002, 80% of biogas plants have been operating on the basis of co-fermentation of energy crops and manure. Unfortunately, the increase in the prices of energy crops in 2007 caused a significant increase in the cost of production of biogas, and numerous changes of the eco-power law have led to a decline of the feed-in tariffs. The feed-in tariffs for green electricity range between €13.0/MWh (installed electrical power >0.5 MW) and €18.5/MWh (installed electrical power up to 0.25 MW). For biogas plants that use substrates that do not exclusively originate from agriculture (e.g., FAB industry waste), the feed-in tariff for green electricity is reduced by 20%. A gate fee that is charged to the supplier/producer of organic waste should compensate for the reduced feed-in tariff. The consequence was a fewer number of new biogas installations during the last few years, because the cost of green energy production was higher than the feed-in tariffs. Furthermore, the amendment of the green electricity act has caused the deterioration of the framework conditions for renewable energy and stagnation of the whole industry in Austria. Higher prices of energy crops, low feed-in tariffs, and the insufficient usage of waste heat have led to the struggle of numerous biogas plants for their economic existence. To compensate for rising costs of raw materials in Austria, subsidies to substrates were granted in 2008 and the amendment to the green electricity act in 2012

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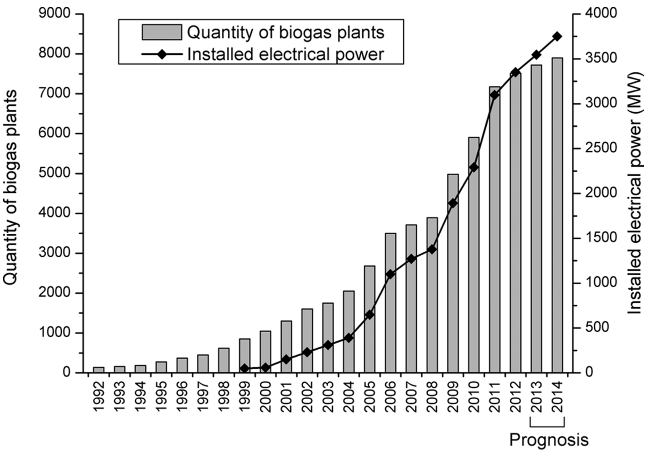

Figure 3. Development of the quantity of biogas plants and installed electrical power in Germany.[6]

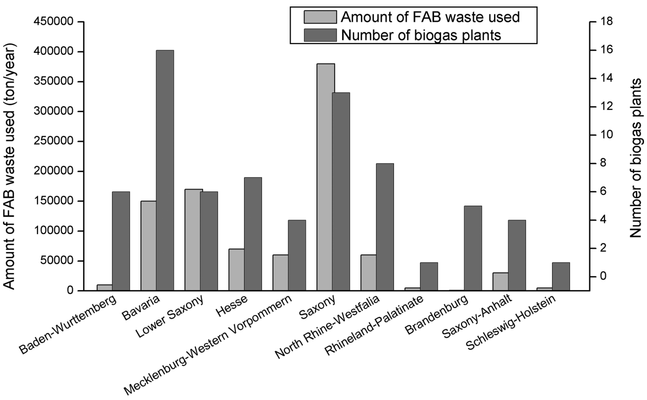

Figure 4. Amount of FAB waste and number of biogas plant classified by federal states in Germany.

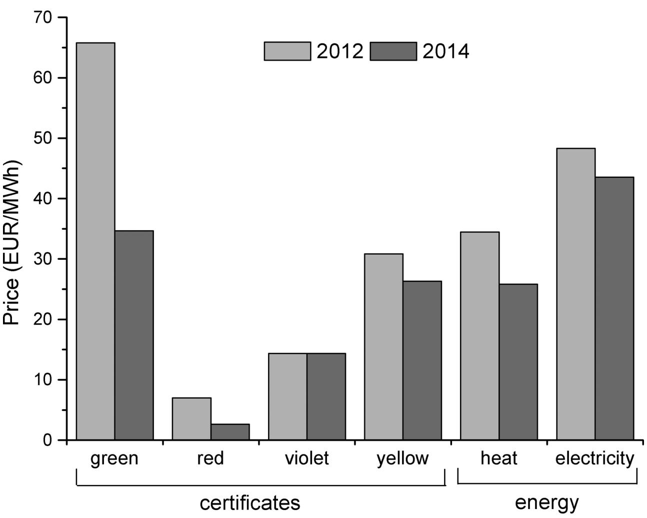

Figure 5. Changes in prices of selected certificates and heat and electricity in 2012 and 2014 in Poland.

was expected to ensure the improvement of framework conditions. In addition, for existing biogas plants, an additional maintenance surcharge, a technology bonus (injection of biomethane into the natural gas grid), and a combined heat and power (CHP) bonus were established.

3.2. Czech Republic. Because of their favorable subsidization schemes, the already established biogas markets in Italy, the United Kingdom, the Czech Republic, and the Netherlands will continue to be among the most important markets in the next 5 years. Electricity production from biogas produced in biogas plants in the Czech Republic was 1264 TWh in 2012 (Table 1).

In the Czech Republic, the main trend in the production of renewable energy is withdrawing biogas from municipal landfills and the use of an anaerobic purification step in wastewater treatment plants. When it comes to the development of biogas plants in the Czech Republic, it is dominated by installations based on agricultural residues and dedicated energy crops. In 2013, in the Czech Republic, there were more than 20 biogas plants, in which biodegradable municipal waste and organic industrial waste are used as substrates. In 2012, there were 13 functional industrial biogas plants (wastewater treatment plants with biogas production); however, only 10 of them generate electricity. Table 1 lists industrial biogas plants in operation. Dobrovice Sugar Mill is the largest biogas producer; it processes wastewater from sugar and alcohol production by means of anaerobic technology. The smallest annual production (about 6000 m^3) of biogas has been reported by Perri Crisps Třemošná, which processes potato chip production waste. Wastewater treatment and the connected biogas production in the sugar industry are rather seasonal, only during the harvest period.

It is planned to build 563 biogas plants, while in 2012, there were 303; however, not all of them have been put into operation. The dynamic development of the biogas market is probably a result of the favorable purchasing price of electric power from agricultural biogas stations and the investment support from the EU structural funds, specifically from the Environment, Entrepreneurship, and Innovations operational programs and the Countryside Development Program, and is also the chief priority of the ECO−ENERGY program established by the Ministry of Industry and Trade (MIT). Because the planned installed output of biogas stations and all renewable energy resources has been achieved in 2013 (including the biogas plants that were issued licenses by the MIT in the course of 2012 and at the beginning of 2013), the investment support for construction and operation support in the form of advantageous electric power purchasing price will be virtually abolished for newly built biogas stations in 2014.

3.3. France. France has on its territory only 80 agro-industrial biogas plants (Table 2). However, the French market for biogas plants is growing like never before. In 2011, the French government has published a number of new initiatives that ensure solid backing for biogas in France. This assistance includes increased support for production of biogas on the basis of waste from cities, industry, and agriculture and the use of biogas for electricity production, heating, and distribution via the natural gas grid. According to a press release from the industry and Ministry of Industry and Energy, up to 2020, support for biogas in France will increase to a total of €500 million a year. The French targets are ambitious. Around 500 new biogas plants with an installed electric capacity of ca. 200 MW will be commissioned by 2020. In this period, both the number of biogas plants and the capacity will triple to 740 facilities and 315 MW, respectively. France is, therefore, the most dynamic market in Europe. Electricity production based on biogas is to be increased 4-fold, and heating based on biogas is to be increased 7-fold, by 2020. It is worth noting that as much as over 70% of mentioned biogas plants in France (58) use FAB industry waste as a substrate (Table 2).

3.4. Germany. Germany is the market leader in biogas technology and is also Europe's biggest biogas producer. More than half of the complete European biogas energy production is of German origin. Thanks to generous subsidies, eco-friendly alternatives have become economically attractive for German power companies and local authorities. Especially the amendment of the German Renewable Energy Act in 2004 and the new version in 2009 supported the expansion of biogas plants.[6] In 2012, around 7515 biogas plants in Germany with an installed electrical power of 3352 MW had been placed. These supplied around 23 000 GWh of electricity to approximately 6.5 million households. For the year 2013, 7720 biogas plants are predicted, and for 2014, a slightly higher number of 7960 biogas plants are predicted, with the quantity of new installations per year clearly declining after 2011 (Figure 3).[6]

However, the German market has slumped dramatically since early 2012, forcing the German biogas industry to internationalize its business strategies. It happened mainly because of the amended Renewable Energy Act, in which compensation rates for biogas were reduced significantly with an added tightening of legal conditions. German plants now have to use at least 60% of their waste heat, and as a consequence, the number of plants constructed per year in the country will decrease from around 1300 in 2011 to 300 in 2012. The major inputs for biogas plants are energy crops with 49% and animal manure and slurry with 43%. Industrial and agricultural residues only account for 1% of the total input (in relation to mass).

Nevertheless, the number of waste biogas plants continually rises. The current situation is estimated to be (economically) favorable for implementing new waste biogas plants. The economic efficiency of individual biogas plants depends upon the amount and quality of the substrate and the utilization of the biogas and the digestate as well as the legal framework conditions. Additionally, favorable is the current, still very moderate interest rate and the feed-in tariff of EEG 2012 for biological waste. Dependent upon the specific gas yield and the size of the plant, it is possible to generate net revenues ranging between €30 and 45 per tonne of input material for electricity out of waste biogas.[7] The advantages of waste biogas plants are the generation of renewable energy in a closed loop (cascade utilization of waste and digestate) and the fact that no agricultural area is required for biogas production.

A total of 71 biogas plants using FAB residues as substrates and 19 anaerobic wastewater plants in the FAB industry were identified in Germany. Most of the biogas plants are co-fermentation plants, which also use other substrates. Only 8 of 71 biogas plants use 100% biowaste from the FAB industry, with inputs of substrate between 4800 and 76 000 tonnes/year. Three of these plants are industrial biogas plants, including two potato processing companies and a slaughterhouse. There are six biogas plants with an input of FAB waste of more than 50 000 tonnes/year. The majority of the plants thus use less than 10 000 tonnes/year.

In Figure 4, you can see the total amount of FAB waste used in the examined biogas plants for each federal state. Lower Saxony has by far the highest input of FAB waste, followed by Bavaria and Brandenburg. The remaining federal states use far fewer amounts of FAB waste for biogas production. Bavaria is the federal state with most of the biogas plants, followed by Lower Saxony and North Rhine-Westphalia.

In addition to the above named biogas plants, 17 anaerobic wastewater treatment plants in the FAB industry were identified. A total of 12 of these industrial plants are integrated into breweries and one each in the beverage-, cheese-, yeast-, and tea-producing industries. By far, most of the wastewater plants are located in Bavaria. The produced biogas is used in the own company to generate process heat and/or electricity. The breweries are thus able to cover around 10–20% of their total heat demand, and the yeast-producing company can cover 72% of the total electricity demand.

3.5. Poland. During the 2001–2005 period, biogas-fueled power plants have been built in Poland only in municipal landfills and wastewater treatment plants with primary objectives to limit unwanted methane emissions from landfills and to reduce the amount of sewage sludge generated by wastewater treatment plants, respectively.[8] The Polish energy sector has also noticed a possibility of biogas production. The importance of biogas as an energy resource in Poland is increasing every year because Poland has a great biogas potential, which is comparable to that of Germany.[9] Poland, as a member of the EU is committed to the diversification of energy sources. By 2020, renewable energy should constitute 15% of final energy consumption in Poland.

The Council of Ministers continues its objective of the construction of 2500 biogas plants in Poland by 2020, with a total electrical power capacity of 980 MW. However, the fact is that, in 2013 in Poland, there were less than 39 agricultural and industrial biogas plants in operation and many projects have been abandoned or suspended because of the collapse of the green certificates support. Agricultural biogas plants in Poland are still mired in crisis, with record losses, and a lot of investment is on hold. The main reasons for this are, among others, the collapse in prices of green certificates (Figure 5), a large reduction in wholesale electricity prices, no yellow certificates from the beginning of 2013, and the lack of the Renewable Energy Sources (RES) Act.

It came even to the fact that there are some already built, ready to run installations, but the owners have not yet started operation, because they would have a loss. On the other hand, in 2013, 10 new biogas plants has already been opened. This is a good result, considering that, at the end of last year, we had a total number of biogas plants less than 30 and, throughout 2012, 12 were put into operation. The rash of new biogas plants based on raw materials and waste from agriculture and agro-food industries this year is the effect of earlier quite good conditions for investment. These conditions consisted of high prices of green certificates, the granting the biogas installation yellow certificates (for energy production from gas co-generation), rising electricity rates, and generous donations, mostly from EU funds, for the construction of such facilities. Among the 39 biogas plants, only 20 use waste from the FAB industry.

Currently, an increasing number of biogas investors are planning to locate their installations in the neighborhood of FAB industry manufacturers (fruit and vegetable processing, dairies, and distilleries) as well as meat producers (slaughterhouses and meat-processing plants), which is believed to ensure a greater variety of substrates and a possibility of receiving all-year-round heat produced in co-generation. The market trends show an increase in the planned power of installed biogas plants. According to the data of the Renewable Energy Institute, around 212 biogas plants have been designed and 37 will be built in the near future.[7]

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Chart 1. Total Production of Waste from the FAB Industry in Five EU Countries

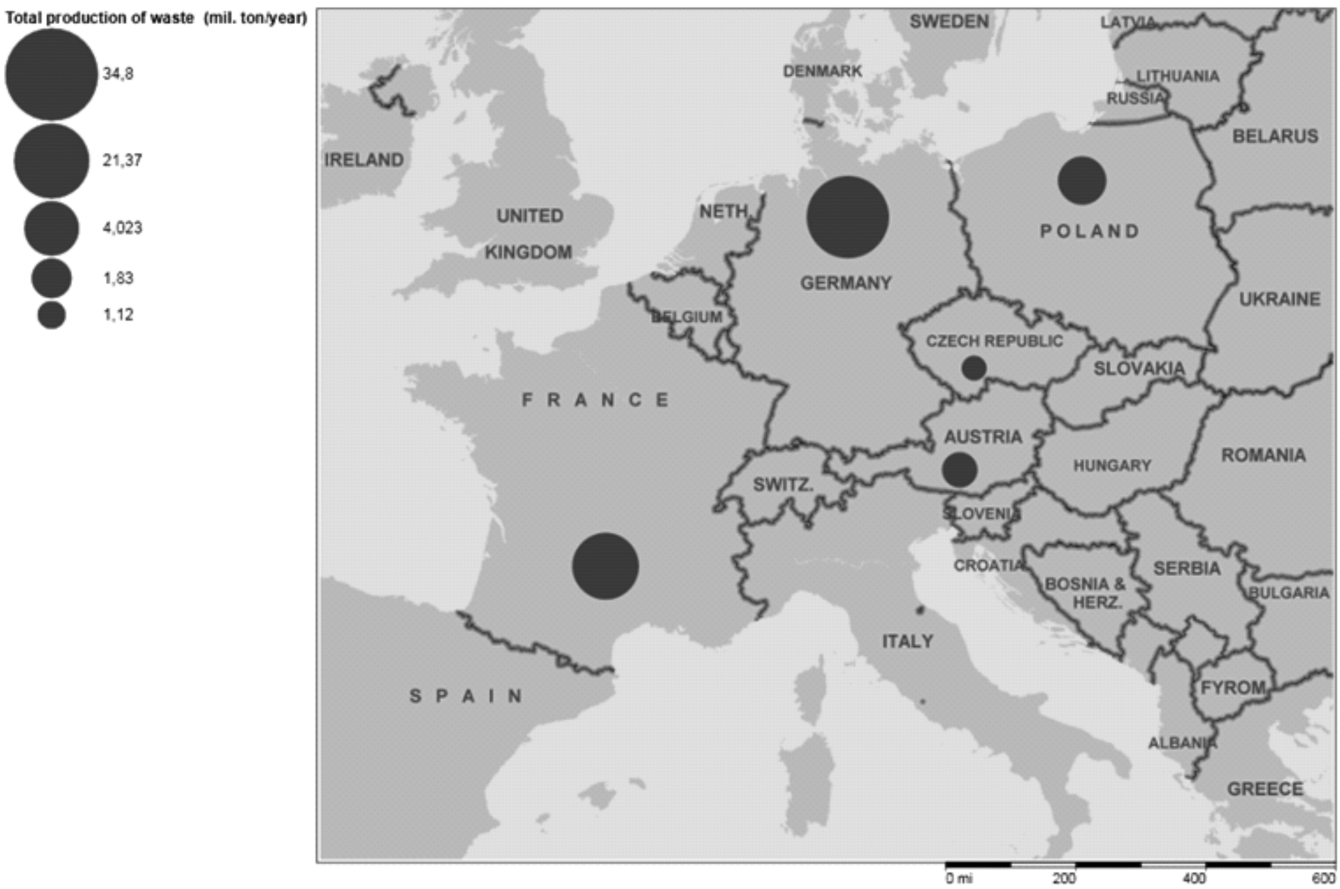

Table 3. Summary of Identified Companies of the FAB Industry in Austria

FAB industry	number of locations/companies	residue/waste stream (million tonnes/year)	methane production potential (million m^3/year)	electric energy production (GWh)
slaughterhouses	47	0.182	10.94	43.32
brewing industry	41	0.186	13.97	55.32
dairy industry	6	0.419	6.670	26.41
milling industry	10	0.061	14.51	57.45
wine industry	5	0.006	1.064	4.213
sugar industry	2	0.240	28.67	113.5

4. FAB INDUSTRY WASTE AS AN ENERGY SOURCE

Over the past decade, greenhouse gas emissions along with climate change have become a predominant topic in policy and, thus, led to framing the European 20-20-20 strategy. The ongoing debate about the availability of renewable energy sources and a possible competition of energy crop cultivation with food production can be overcome by usage of the still untapped potentials of waste streams for the production of electricity, heat, and fuel. AD of industrial waste streams, in particular, from the FAB industry, provides an alternative to the standard waste treatment methods of composting and combustion.

The organic process residues of the FAB industry are still an untapped potential in many countries (e.g., France) throughout the EU, although, by an improved biowaste management, enhanced use of this resource could strongly contribute to reaching the 2020 overall renewable energy target of the EU. Together with the high amount of waste and byproduct output, this turns the FAB industry to a sector that could significantly

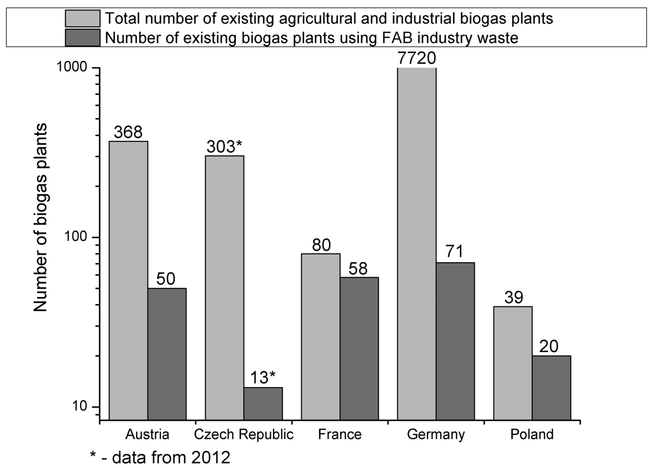

Figure 6. Number of biogas plants in partner countries in 2013.

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Table 4. Main FAB Waste Streams in the Czech Republic

FAB sector	residue/waste stream (million tonnes/year)
meat products	0.161
fruits and vegetables	0.192
sweets/sugar	0.386
dairy products	0.077
bakeries and confectioneries	0.007
drinks/alcohol	0.297
total	1.120

Table 5. Biogas Plants Using FAB Waste in France According to Type of Waste

FAB sector	number of plants
meat products	2
dairy products (cheese, whey, yogurts, and ice cream)	11
sweets/sugar	6
drinks/alcohol (breweries)	7
drinks/alcohol (wineries)	18
drinks/alcohol (distilleries)	4
drinks/alcohol (soft drink)	1
fruits and vegetables	7
starch and food additives	2

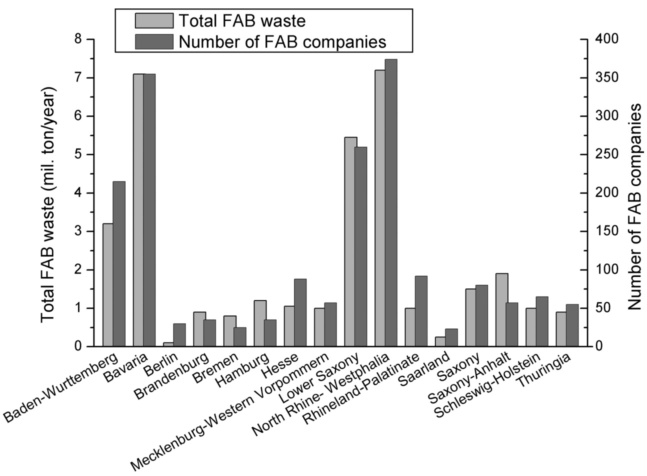

Figure 7. Amount of FAB companies classified by federal states in Germany.

Table 6. Summary of the Potential Biogas Production from Different Stream Waste in Poland

waste stream (tonnes/year)	waste category	number of companies	methane production potential (million m^3/year)
500–2000	fruit and vegetable processing	42	3.040
	dairy industry	18	0.241
	meat-processing industry	92	4.365
	brewing industry	6	0.122
	total	158	7.769
2000–5000	fruit and vegetable processing	43	9.260
	dairy industry	48	2.616
	meat-processing industry	110	15.894
	brewing industry	38	3.528
	total	239	31.299
5000–10000	fruit and vegetable processing	22	9.082
	dairy industry	17	2.296
	meat-processing industry	25	13.061
	brewing industry	13	2.428
	total	77	26.868
above 10000	fruit and vegetable processing	16	13.753
	dairy industry	14	12.235
	meat-processing industry	23	51.253
	brewing industry	36	40.223
	total	89	117.465

benefit from waste management using an AD process for biogas production. Chart 1 shows the total production of FAB waste (in tonnes per year) generated in five EU countries.

4.1. Austria. Most companies of the FAB industry in Austria are breweries (40), dairies (30), and slaughterhouses (20). However, the largest waste stream (0.240 million tonnes/year) and also the greatest potential for biogas production comes from sugar mills (28.67 million m^3/year). Table 3 shows the residue/waste streams of the FAB companies that could be localized and does not show the whole amount/potential. These FAB industry branches show favorable waste streams for biogas production.

As presented in Figure 6, in Austria, the number of biogas plants operating on the basis of waste from the FAB industry is similar to those in Germany and France. It should be noted, however, that the amount of waste streams is incomparably smaller. Among the most significant waste streams in Austria, there are also residue streams of the Austrian food production: grain residues, such as husk and pastry (0.217 million tonnes/year), and expired food (0.065 million tonnes/year). The most important residue streams in the drinks/tobacco industries are from beer, wine, and fruit juice production (0.253 million tonnes/year). However, it can be assumed that the residues of the Austrian food and drinks/tobacco industries are reused as food or as feed. Residues that cannot be used as food or feed are preferably used as substrate in biogas plants or composted. Thermal treatment of residues/waste plays a minor role. All in all, 0.219 million tonnes of animal byproducts are used as substrate in biogas plants. These are mainly kitchen and food waste, dairy waste, former food of animal origin, and small amounts of waste from slaughtering. Hence, the share of industry FAB waste of animal byproducts used as substrate for biogas plants is low. These are the dairy wastes (cheese and butter productions) and slaughtering wastes (slaughter and meat production).

4.2. Czech Republic. Data concerning waste streams in the Czech Republic were collected from two sources: Waste Management Information System (WMIS) operated by the Waste Management Center, which is a part of the T. G. Masaryk Water Research Institute, and the statistical information on the Czech Statistical Office (CSO), which is based on the results acquired through processing of the Annual Waste Statement. The presented data show that the largest percentage (80%) of the total number of waste (1.12 million tonnes/year) is waste materials from primary agricultural and gardening productions (Table 4). The amount of moist livestock excrements generated, estimated on the basis of the

Table 7. Summary of Identified Companies of the FAB Industry in Poland

waste category	number of companies	residue/waste stream (million tonnes/year)	methane production potential (million m^3/year)	electric energy production (GWh)
fruit and vegetable processing	123	0.591	35.14	139.1
dairy industry	97	0.951	17.39	68.86
meat-processing industry	250	1.154	84.57	334.9
brewing industry	93	1.327	46.30	183.4
total	563	4.023	183.4	726.3

number of the kept animals (according to CSO) and average production per head is in the Czech Republic more than 27 million tonnes per year.

The potential for processing the waste by the methane fermentation process is estimated to be about 30% of the theoretical amount. A large percentage of agricultural waste is used by other methods; however, agricultural waste and livestock manure, in particular, are the most important potential sources of substrate for biogas production. The waste from the food industry is another important source of biomass as an appropriate substrate for methane fermentation; about 0.75 million tonnes/year of this biodegradable waste is produced in the Czech Republic every year. However, up to now, only 13 biogas plants use waste from the FAB industry as a substrate. The largest stream of organic waste from industry comes from the production of alcoholic and non-alcoholic beverages (except for coffee, tea, and cocoa) (0.312 million tonnes) and the production and processing of meat, fish, and other foodstuffs of animal origin (0.155 million tonnes). Biodegradable municipal waste also represents a substantial part of the total weight of waste generated and shows significant potential of energy production. These wastes constitute 40% of mixed municipal waste. The Waste Management Plan of the Czech Republic in response to the requirements of Directive 1999/31/EC enforces a gradual reduction of the amount of biodegradable waste disposal in landfills.

4.3. France. Just like in Germany, also in France, because of the competition of companies producing FAB, it is difficult to obtain from them the detailed information on the type of waste generated and their properties. However, there are data concerning waste published by the NAF (French statistical nomenclature for activities). Table 2 shows that waste in France is very diverse in terms of properties (e.g., organic content). The total amount of organic waste generated in France is 21.37 million tonnes/year.

In these two countries, there is a similar number of biogas plants operating on the basis of waste from FAB. However, it seems that, in France, the number of such installations can rapidly grow, because France has started a food waste program to turn organic waste into methane. Since 2012, France requires companies to recycle their organic waste if they produce more than 120 tonnes per year. The largest waste streams come from the food industry (15.56 million tonnes/year), meat-processing industry (2.683 million tonnes/year), and beverage industry (2.394 million tonnes/year). According to the NAF, there exist 13 127 companies in the FAB industry, mainly, processing and preserving meat for butchers' shops, meat processing, production of ready-to-eat meals, and petfood production companies (Table 5).

4.4. Germany. Because of the fact that, in Germany, it is not possible to publish data from any companies without a specific permission because of the high competition among companies in the same branch, the literature data was taken into consideration. Gaida et al.[10] identified 1894 German FAB companies and gathered information from 1767 companies. Altogether they produced approximately 35 million tonnes of fresh waste, which corresponds to more than 13 million tonnes of dry organic waste. In most of the federal states, the dominating waste producers are dairy, fat and oil, starch, and sugar and confectionary companies. In Saarland and Berlin, starch production (including cereal processing) is by far the main contributor to organic waste from FAB industries. Figure 7 shows the number of FAB companies and the amount of produced waste for the federal states. It is remarkable that four states Baden-Wuerttemberg, Bavaria, Lower Saxony, and North Rhine-Westphalia hold by far the most FAB companies and produce the biggest amount of organic waste.

Practically, the entire mass of organic industrial waste generated is managed, and almost nothing is left unused. The largest waste stream as much as 11.8 million tonnes/year comes from the dairy industry, and the second in order of the amount of 6.90 million tonnes/year is from fat and oil production. Significant quantities of waste are generated in Germany by starch production (4.91 million tonnes/year) and the sugar and confectionary industry (4.84 million tonnes/year). Currently, they are used as feed or used thermally. "Other waste" (0.18 million tonnes/year) from the production of condiments, sauces, convenience food, and dietary and other foodstuffs are also believed to have high "redirectable" potential.

4.5. Poland. Directive 1999/31/EC from April 1999 also forces Poland to take up actions aimed at selecting and recycling the organic fraction derived from municipal solid waste. In 2012, Poland began to implement a system of segregation of waste in households. From the point of view of the Polish economy, properly conducted biodegradable fraction management is necessary because, as a result of compliance with the guidelines of the EU countries, landfills are systematically closed because they do not meet EU requirements. In addition, beginning January 1, 2013, prohibition of storage of untreated waste started to be obligatory. Poland, as a member of the EU, has been committed to achieve growth in the share of renewables in final energy consumption to 15% by 2020. As presented in Table 6, Poland has significant potential for production of biogas from waste, because total waste stream amounts to 4.023 million tonnes/year. The total amount of electricity that can be produced from this waste is 726 GWh (Table 7).

The selected organic fraction of municipal waste can be used by the composting process or become a valuable substrate for a biogas production plant. In Poland, the majority of companies (239) generate from 2000 to 5000 tonnes/year of waste. In second place, with the amount of 158, are companies that annually produce 500−2000 tonnes/year of waste. Among all of these waste streams, waste from the processing of meat and dairy waste is the biggest percentage (Table 6).

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5. WASTE MANAGEMENT

The FAB industry is the largest manufacturing sector in the EU.[11] Food-processing wastes are those end products of various food-processing industries that have not been recycled or used for other purposes. Food industry produces large volumes of wastes, both solids and liquid, resulting from the production, preparation, and consumption of food. These wastes pose increasing disposal and potentially severe pollution problems and represent a loss of valuable biomass and nutrients. In general, wastes from the food-processing industry have the following characteristics:[12] (1) large amounts of organic materials, such as proteins, carbohydrates, and lipids, (2) varying amounts of suspended solids depending upon the source, and (3) high biochemical oxygen demand or chemical oxygen demand.

Table 8. Ways of Waste Management in Five European Countries

country	dominant ways of waste management
Austria	feed production
	composting
	waste used as fertilizers
	biogas production
Czech Republic	feed production
	biofuel production
	transfer waste to farmers
France	composting
	application to farmland
	AD
Germany	feed production
	waste used as fertilizers
	biogas production
	thermal use
Poland	transfer waste to farmers
	waste collection by recycling company
	incineration of waste
	waste used as fertilizers

Waste disposal and byproduct management in the food-processing industry pose problems within the areas of environmental protection and sustainability.

The current methods for further utilization of product-specific waste have developed along traditional lines and have been closely bound to the agricultural origins of raw materials themselves. The two general methods of traditional waste utilization have been to use the waste as either animal feed or fertilizer.

Three general methods of waste disposal not associated with agricultural practices are (1) incineration, (2) anaerobic fermentation, and (3) composting.

In every country, there are different ways of waste management (Table 8).

For example, in Germany, the majority of waste from processing of fruits and vegetables, fat and oil and dairy products, or starch are used as feed. Similarly, in Austria, it can be assumed that the residues of the Austrian food and drinks/tobacco industries are reused as food or feed. Those residues that cannot be used as food or feed are substrates in biogas plants, or they are subjected to the composting process. In France, however, organic waste is mainly composted, serves as a fertilizer, or is the substrate for biogas production. In Poland, there are two leading methods of waste management: waste transfer to farmers for feeding animals and paying an external recycling company for organic waste collection.

In summary, the two most popular methods of waste management in these five EU countries are feed production and the use of waste as a fertilizer. Uncommonly, waste is used for biogas production or used thermally. Least often, waste is collected by a recycling company or composted.

6. BARRIERS FOR BIOGAS TECHNOLOGY

Even though there is a favorable legislative framework and state support mechanisms in some partner countries, the biogas market is developing with a slow pace and leaving a considerable part of the existing potential untapped.

Table 9. Most Frequent Barriers for Plant Operators and FAB Manufacturers

country	most frequent barriers for biogas plant operators	most frequent barriers for FAB manufacturers
Austria	barriers in the approval phase of the biogas plant	high price for energy crops
	financial barriers	small amounts of unused waste
	barriers/problems during plant operation	not economically feasible with current legal conditions
	lack of competence of bank employees for waste biogas plants	odor emissions
		not stable material
Czech Republic	complex legislative	accessibility of sources
	complications for obtaining permission	legal constraints
	public opinion (bad smell and heavy traffic)	price
		transport and logistic
France	more lucrative installations	profitability of the facilities
	better access to loans	positive experience feedback
	lighter administrative procedures for new plants	reduction of administrative difficulties
	developing co-digestion with other types of wastes	
Germany	rapid changes in the legal framework	economic aspects
	price of the substrate	problem with legislation
	higher traffic volume	complex authorization of a biogas plant
	odor emissions and noise	
	lack of knowledge	
	missing contact person	
Poland	large number of formal requirements	lack of knowledge
	financial barriers	obtaining all permits
	social acceptance	financial problems

To identify the barriers for the biogas market, surveys among biogas plant operators and FAB producers were conducted in Austria, Czech Republic, France, Germany, and Poland. All survey participants from the FAB industry stated that the permitting procedures represent a barrier for biogas market development. Thereby, the main reason for inefficient permitting procedures seems to be a lack of knowledge and competence of people responsible for administrative procedures. Along with this, changes in the legislation and unstable governmental policies toward the biogas energy signals an instable market and, consequently, a higher risk for investments. Even in the countries that had favorable policy frameworks, such as Germany or Austria, the governmental support has decreased during the past 18 months. This had an

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Table 10. Dominant FAB Waste Streams and Their Methane Potential in Five EU Countries

country	dominant waste streams	total number of companies in FAB industry branches	total production of waste (million tonnes/year)	methane production potential (million m^3/year)	electric energy production (GWh)
Austria	dairy industry	222	1.830	128	507
population = 8414640	sugar industry				
area = 83.86 km^2	brewing industry				
	slaughterhouses				
Czech Republic	waste materials from the sugar industry	2188	1.120	80	317
population = 10513210	brewing industry				
area = 78.87 km^2	meat industry				
	fruit and vegetable industry				
France	beverage industry	13127	21.37	680	2693
population = 66616420	meat industry				
area = 640.7 km^2	fruit and vegetable industry				
	petfood production				
	beet pulp, molasses, and other waste of sugar manufacture				
Germany	meat and fish industry	1767	34.80	2780	11008
population = 80585700	fruit and vegetable industry				
area = 357.0 km^2	breweries and malt production				
	coffee and tea processing				
Poland	fruit and vegetable processing	563	4.023	185	726
population = 38186860	dairy industry				
area = 312.7 km^2	meat processing industry				
	brewing industry				

impact on market development. In Germany, there exist a high number of different legislations that are constantly changing and are, therefore, not adjusted to each other very well. In Austria, the legal and technical requirements are high and the administration process lasts a minimum of 3 months to obtain the approval for realizing biogas projects. Another huge barrier for further biogas implementation is the high prices for crops in relation to the feed-in tariffs. For many years, many biogas plant operators use organic residues from different sources, such as the FAB industry. Only a small amount of organic residues are for new biogas plants available.

In France, potential investors expect easier access to bank loans, because banks now consider biogas investments more risky than investments based on solar or wind energy, and thus, they are reluctant to invest. In addition, the operators of biogas plants in France as one of the major barriers pointed toward complex administrative procedures and lack of positive experiences.

In Poland, the biggest barrier is no social acceptance for biogas investments. This is probably due to the lack or small amount of well-functioning biogas plants, which would be a good example of how tedious waste can be managed with simultaneous energy production. In addition, the intricate legal procedures, long wait for permits, and lack of a proper act promoting renewable energy sources discourage potential investors.

Most frequent barriers for biogas plant operators and FAB manufacturers in five European countries are summarized in Table 9.

7. DISCUSSION AND CONCLUSION

As clear from the data presented above, the driving force behind the development of the biogas market is the use of bioenergy is the Renewable Energy Directive (RED), which

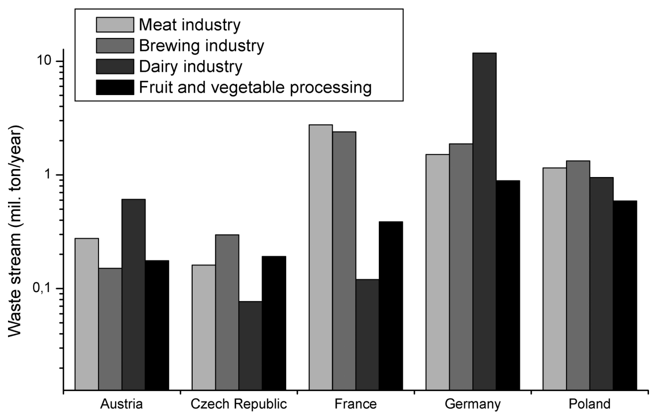

Figure 8. Comparison of the amount of waste streams from the four most significant industries in partner countries.

requires member states to generate 20% of their energy from renewable sources by 2020 and for 10% of transport fuels to be made up of renewable resources. Figure 6 presents the total number of existing agricultural and industrial biogas plants in five countries in 2013 as well as the number of biogas plants using FAB waste.

Biogas production is also increased through various actions supporting and promoting at national and regional levels. An important role is played here by the Renewable Energy Sources Act, which sets the rate of pay for the production of electricity from biogas from, on one hand, the byproducts and wastes and, on the other hand, energy crops. The basis for the cost-effectiveness of energy production is a guarantee of its sales and price. The profitability of projects is also highly dependent upon the use of thermal energy. Therefore, careful consideration and planning solutions of heat usage plays a significant role in the construction of biogas plants.

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In Table 10 and Figure 8, there were collected data showing dominant streams of waste in each country, the total number of companies from the FAB industry, and the total production of waste (in tonnes per year) that they generate. Methane potential of those types of waste was calculated.

Most companies in the food and beverage industry were reported in France (13 127), Germany (1767), and the Czech Republic (2188). These countries generate huge amounts of waste that are characterized by considerable potential for methane production.

Certain food industry sectors (such as alcohols, molasses, starch, whey, and animal oils and greases) have high methanogenic potential and are, therefore, of interest for developing AD. AD is also a viable alternative for liquid wastes, which can be onerous to transport over longer distances, although energy recovery is not currently necessarily very economically interesting.

In France, the recovered energy is generally used directly by the industry, in the form of heat or electricity (boiler or co-generation) because the plants are generally of a modest size. In other European countries, where plants are bigger and the prices at which the energy is purchased are higher, the industry sells the gas for injection in the public gas grid. Biogas production is very slowly being taken up for treatment of effluents, but the pace is very slow because of the economic crisis, which is hindering the industry to invest in waste treatment.

For the industry, in particular, economic aspects play an important role for the choice of the waste utilization. Of course, the revenue that can be obtained from the biowaste is the dominating factor for its utilization. For many waste types, selling them as feed is still the economical best way. If the waste is being used internally, the utilization process must be well-planned and often requires high storage costs to avoid a stop of the production. In particular, the storage of highly perishable goods is difficult and expensive.[10]

The authorization of a biogas plant using biowaste is very complex and often leads to problems. In Germany, there exists a high number of different legislations and norms for biogas plants that are to be considered. These legislations are constantly changing and are, therefore, not adjusted to each other very well. In addition, the implementation of the legislations differs in the federal states, which, for some states, results in different requirements.[13]

To find the best and most suitable solution for waste utilization, it is necessary to conduct case-by-case preliminary feasibility studies that take all of the operational, regional, and ecological characteristics into account.[10]

As the data show, the biogas market is growing, despite the often unfavorable conditions, such as intricate legal procedures, lack of laws supporting renewable sources of energy, or lack of competence of the employees of banks and, hence, the deficiency of financial support for biogas investments. In all countries, however, an increase in the number of biogas installations in recent years is observed. Moreover, in all of the partner countries, considerable waste streams are generated, being ideal substrates for biogas plants. It is satisfactory that more and more industrial organic waste is used in biogas plants, replacing the expensive maize silage.

■ AUTHOR INFORMATION

Corresponding Author

*E-mail: anna.pazera@p.lodz.pl.

Notes

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