Biomass for power and heat supply

FACTSHEET

Bundesministerium
für Umwelt, Naturschutz,
Bau und Reaktorsicherheit

Umwelt Bundesamt

INSTYTUT JAGIELLOŃSKI

ECOFYS

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Part I: **Biomass for power and heat supply in Germany – Policy instruments and market developments**

By: Matthias Spöttle (Ecofys)

Part II: **Biomass for power and heat supply in Poland – Policy instruments and market developments**

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Key messages

Part I

By: Matthias Spöttle
(Ecofys)

Bioenergy has grown rapidly in Germany and is currently the country's second largest renewable energy source for electricity. Since 2007 the amount of biogas plants has more than doubled and the respective installed capacity has more than tripled. This growth was also supported by the German Renewable Energy Sources Act (EEG) which provides funding for renewable energy supply.

With the growth of bioenergy, the debate around the impacts of bioenergy on the environment has also grown. There are public and political discussions about using food crops for energy supply and about increasing land-use for bioenergy. In contrast to wind and solar power, the feedstock availability for bioenergy is also limited, while at the same biomass can be used for multiple purposes, i.e. food, feed, energy, and material use.

With the EEG 2017 the German Government has set priorities for the further increase of renewable electricity with an annual increase for biomass auctions of 150 MW until 2019. This prioritization is the outcome of a political agreement. According to the German bioenergy industry, the funding for bioenergy plants in the EEG 2017 are set in a way that makes it difficult for new plants to operate in an economic viable manner. However, existing plants running on waste and residues would still be able to make a profit.[1]

The German Government plans to steer the use of sustainable biomass to purposes that do not have alternative options for decarbonisation and to uses where biomass can be used in the most beneficial way for the energy system, i.e. aviation fuel and shipping fuel as well as material use for insulation. Biomass for power supply should always be generated in a CHP plant to be most efficient. Furthermore, biomass plays an important role as a flexible renewable energy source that balances out fluctuations in wind and solar power.[2]

1. Erste Bewertung des Erneuerbaren-Energien-Gesetzes (EEG 2017), Bioenergie Verbände und Deutscher Bauernverband, July 2016.
2. Impulspapier, Strom 2030, Bundesministerium für Wirtschaft und Energie, September 2016.

Part II

By: Christian Schnell PhD
(Instytut Jagielloński)

Biomass firing is in Poland a main technology for power and heat production by RES with a production of up to 9.5 TWh of electricity annually, however, with a remarkable decrease of production in 2016 to 7.0 TWh due to partly switch off of co-combustion of coal and solid biomass. The power and heat production by biogas amounts to 1.0 TWh of electricity annually, whereas half of this production is generated by agricultural biogas plants. Regulatory uncertainty almost stopped project development a few years ago, although above technologies are most feasible to technically balance weather-dependent RES such as wind farms and PV installations with zero-emissions. Biomass firing and gasification has a large impact on creating jobs mainly in rural areas, and should also stipulate development of high-innovative technology in case of greenfield investments. However, a proper design of the support system is inevitable to stipulate the market.

Furthermore, biomass is crucial for further production of district heating. Poland is obliged to derogate 15 GW of heat capacity in generators with installed heat capacity from 200 to 500 MW by end of 2023 and 10 GW of heat capacity in generators with installed heat capacity from 20 to 200 MW by end of 2022, in case those depreciated mostly coal-fired generators will not be adopted to new best-available-technology emissions standards (BREF). Approximately 13 GW of this installed capacity is currently ordered to produce ditrict heating.

Although EU further implements restriction on the use of wood for energy production, on change of land for crops used for energy production, and additionally limits the amount of municipal waste used for energy production due to EU recycling targets, the available amount of solid biomass for energy production demonstrates the possibility of biomass firing and gasification.

Available liquid biomass might be also used for producing biomethane, which so far is not fed-in into gas networks. This type of use replaces natural gas imports and therefore increases the energy independency of Poland.

Table of contents

Part I:
Biomass for power and heat supply in Germany – Policy instruments and market developments 7

1.1 Policy support 8
1.2 Market overview 10
1.3 Costs 14
1.4 GHG reduction 18
1.5 Sustainability 19

Part II:
Biomass for power and heat supply in Poland – Policy instruments and market developments 20

2.1 Overview 21
2.2 Support scheme for electricity (and heat) production from biomass and biogas 24
2.3 Available solid biomass for electricity and heat production 29
2.4 Methane gas production from liquid biomass 32
2.5 Biogenic waste 33

Part III:
References 35

Part I: Biomass for power and heat supply in Germany – Policy instruments and market developments

By Matthias Spöttle (Ecofys)

1.1 Policy support

In July 2016 the German Government revised the Renewable Energy Sources Act (EEG). The aim of the EEG is to increase the power supply from renewable energy sources.

In July 2016 the German Government revised the Renewable Energy Sources Act (EEG). The aim of the EEG is to increase the power supply from renewable energy sources. Therefore, all figures in the law refer to power supply only. Plant operators that receive funding according to the EEG cannot receive funding in line with combined heat and power act.[3] Due to more funding, biomass plant operators will opt for EEG funding. From 2017 onwards funding for renewable energy technologies will be auctioned. These auctions are expected to cover 80% of new build installations. This means that future rates of funding for renewables will be determined by the market and not by the government. Germany thereby wants to ensure an increase of renewable energy supply at a controlled pace and at low costs.

For bioenergy, 150 MW will be auctioned yearly from 2017 – 2019, increasing to 200 MW in the period from 2020 to 2022. Only new plants generating more than 150 kW and maximum 20 MW can submit a bid. All existing bioenergy installations, also those below 150 kW, can submit a bid as well to enable them to operate their plants after termination of the previous EEG funding. A further requirement for participation is that bioenergy plants need to be able to generate electricity in a flexible, demand-based manner. The use of maize and cereal grain is limited to 50% and decreases to 47% from 2019 onwards.

The different price caps for bids for new plants depending on installed power and feedstock are presented below. The price caps decrease by 1% each year.

KWK Gesetz, §1.3. https://www.gesetze-im-internet.de/bundesrecht/kwkg_2016/gesamt.pdf

Table 1 | **PRICE CAPS FOR BIOENERGY BIDS 2017**
SOURCE: RENEWABLE ENERGY SOURCES ACT (EEG) 2017

FEEDSTOCK / PATHWAY	PRICE CAP	INSTALLED POWER
BIOMASS ACCORDING TO BIOMASS REGULATION	113.32 ct/kWh	≤ 150 kW
	11.49 ct/kWh	≤ 500 kW
	10.29 ct/kWh	≤ 5 MW
	5.71 ct/kWh	≤ 20 MW
FERMENTATION OF WASTE AND RESIDUES	14.88 ct/kWh	≤ 500 kW
	13.05 ct/kWh	≤ 20 MW
FERMENTATION OF SLURRY (MAX. 80% SLURRY)	23.14 ct/kWh	≤ 75 kW

Existing bioenergy plant can receive a maximum of 16.9 ct/kWh funding for their power supply. This provides an opportunity for existing bioenergy plants after the termination of their previous, 20-year EEG funding. Although these 16.9 ct/kWh are higher than the price cap for new bioenergy plants, they are lower than the previous EEG funding. A bioenergy plant that receives funding in line with the 2009 EEG could receive 18-21 ct/kWh, depending on feedstock and installed power.

According to the German bioenergy industry, the maximum price of 14.88 ct/kWh is not sufficient for an economically viable operation, but requires plant operators to explore further sources of income.

In addition, there is a flexibility bonus for biogas plants, which is 40€/kW installed power per year for new plants and 130 €/kW installed power per year for existing plants in operation before August 2014. The flexibility bonus is installed to reward bioenergy plants for down-regulation to avoid over frequency in the system, but also for renewable energy production during times with no wind or sun.

The funding is limited to 50% of the bid price for biogas plants and to 80% for plants processing solid biomass. Bids must be submitted in a sealed envelope to the Bundesnetzagentur, German Agency for Electricity and Gas, by 1 September. The Bundesnetzagentur will sort all applicable bids, starting with the lowest bid until the maximum yearly deployment volume is reached. The successful bidders will receive the funding according to their bid for 20 years.[4] The first auctions for bioenergy will take place in September 2017.

4. Renewable Energy Sources Act, http://www.bgbl.de/xaver/bgbl/start.xav?startbk=Bundesanzeiger_BGBl#__bgbl__%2F%2F*%5B%40attr_id%3D%27bgbl116s2258.pdf%27%5D__1478173518392

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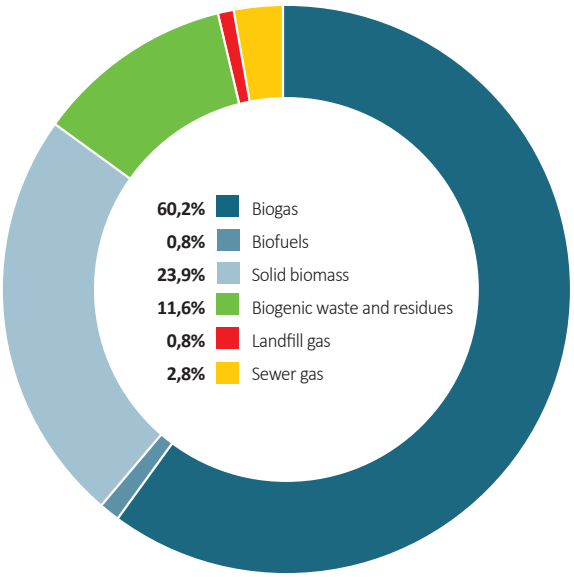
1.2 Market overview

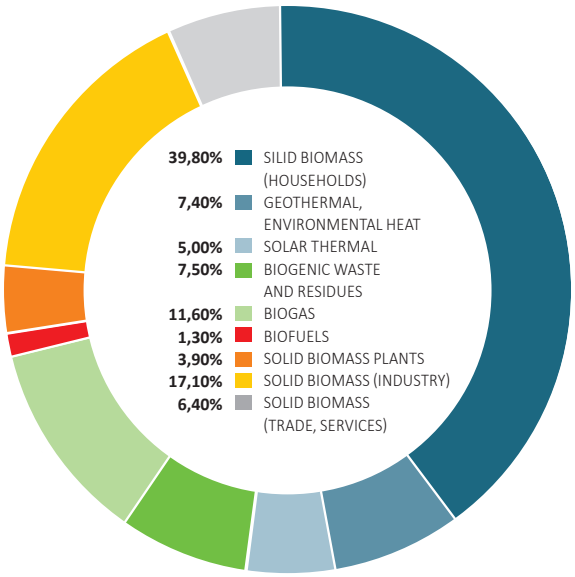
Figure 1 | **ELECTRICITY GENERATION FROM BIOMASS IN GERMANY 2015**
SOURCE: BMWI, AGEE-STAT, FEBRUARY 2016



In 2015 biomass was the second largest renewable energy source in Germany (after wind) with a share of 26.8% of renewable-based electricity totalling to 50.3 TWh5. Most of this bioenergy was produced from biogas.

5. AGEE-Stat 2016. http://www.erneuerbare-energien.de/EE/Redaktion/DE/Bilderstrecken/entwicklung-der-erneuerbaren-energien-in-deutschland-im-jahr-englisch.html

Figure 2 | **HEAT SUPPLY FROM RENEWABLE ENERGY IN GERMANY 2015**
SOURCE: BMWI, AGEE-STAT, FEBRUARY 2016



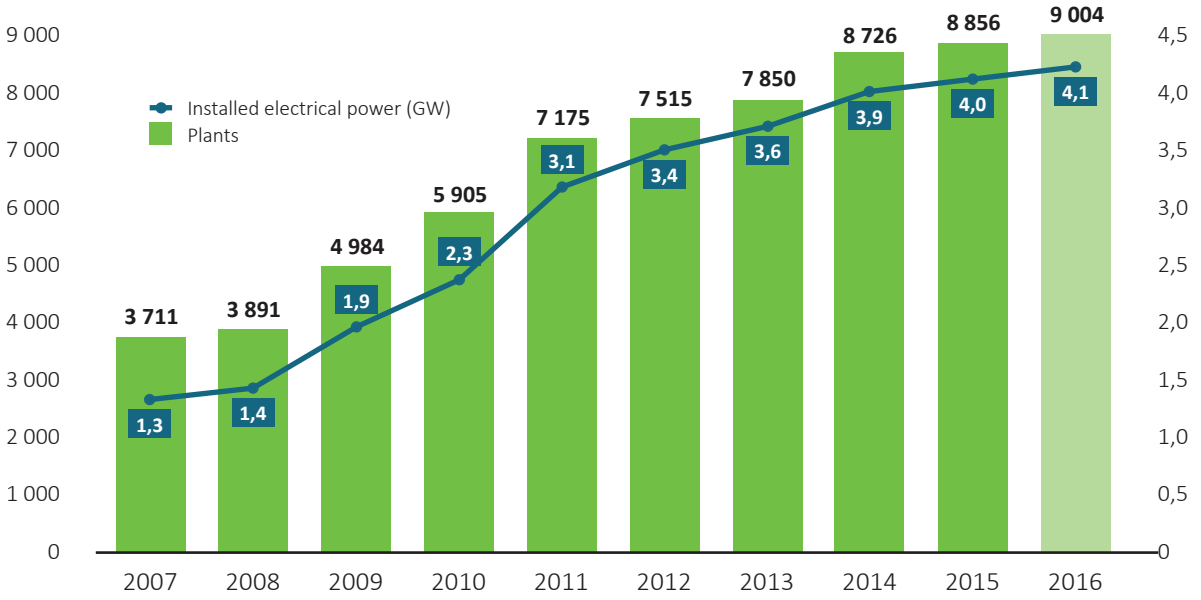
The electricity generation from biogenic waste and residue is quite limited as it only accounts for 11.6%. It is important to note that most agricultural wastes and residues fall into the category of biogas. Cellulosic waste and residues are also often used as compost. Food waste and residues like used cooking oil are mainly used as a feedstock for biodiesel production. (Liquid) biofuels are mostly used in transport as the feedstock costs are also too expensive for electricity generation.

For heat supply, biomass was the dominating renewable energy source with a share of 87.6% in 2015 in Germany. However, the vast majority of the biomass based heat is produced in households using woody biomass and not by dedicated bioenergy plants.

Bioenergy plant supplying heat to third parties accounts for 16.8% out of which biogas plants have the largest share.

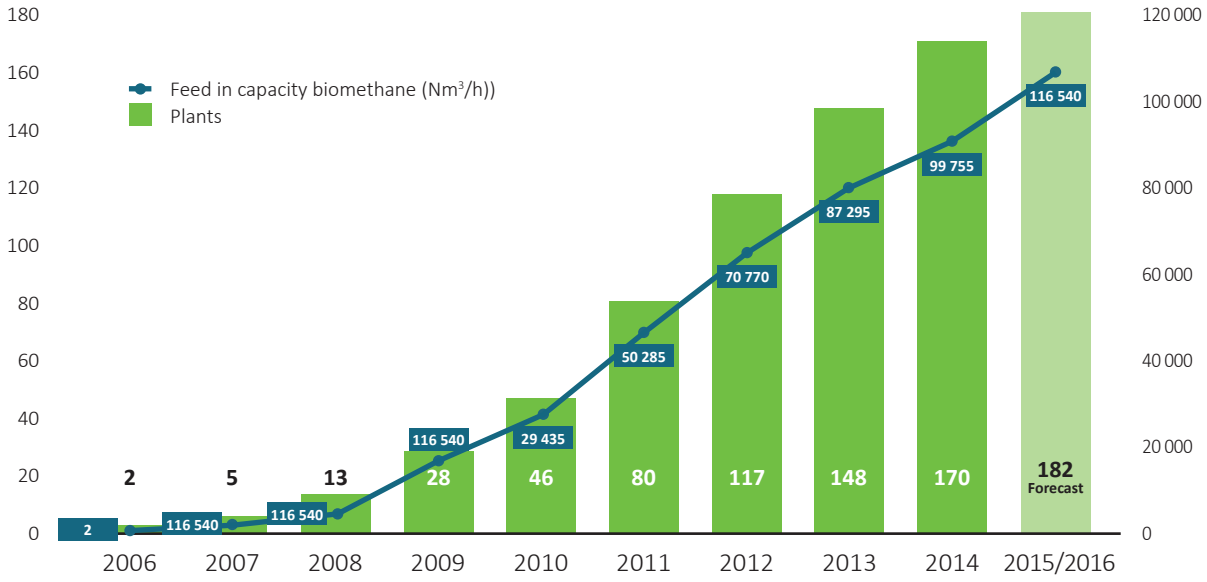
Since 2007 the stock of biogas plants in Germany has more than doubled and the installed power has increased from 1.3 GW to 4.1 GW. The increasing installed power is due to the upscaling of existing biogas plants in order to improve the opportunity for flexible operation. More than 90% of the biogas plants are CHP plant, so they are also engaged in heat production.

Figure 3 | **DEVELOPMENT OF BIOGAS PLANTS IN GERMANY**
SOURCE: FACHVERBAND BIOGAS, 2016



There was also a tremendous increase in biomethane plants from 2 in 2006 to 170 in 2014 and 182 in 2015/16. The difference between biogas and biomethane is explained in detail on page 10.

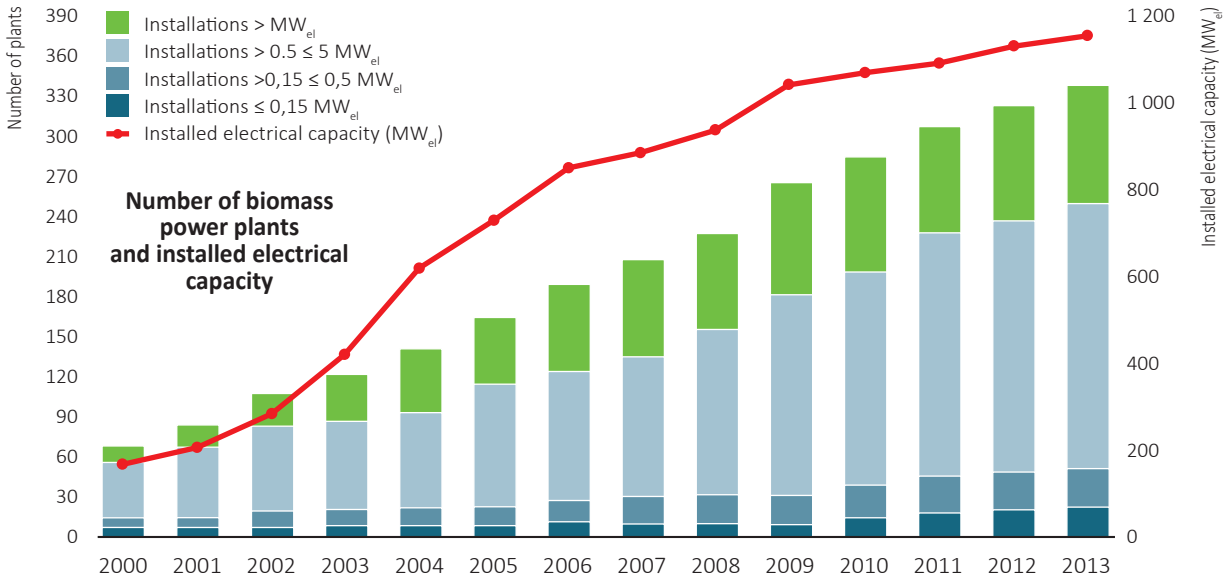
Figure 4 | **DEVELOPMENT OF BIOMETHANE PLANTS IN GERMANY**
SOURCE: FNR, 2015



However, compared the total amount of biogas plant the amount of biomethane plants is quite limited. The increase is driven by the need to access further markets not in the vicinity of the plant. There is no support scheme for biomethane production.

The stock of solid biomass plants increased fivefold from 2000-2013.

Figure 5 | **STOCK SOLID BIOMASS POWER PLANTS**
SOURCE: DBFZ, 2014



1.3 Costs

In this chapter the average investments (CAPEX) as well as operation and maintenance costs (OPEX) covering all operating expenses for biogas plants and solid biomass plants are displayed.

Biogas

The main income for biogas plants in Germany was electricity generation as this guarantees secure revenues due to the Renewable Energy Sources Act. Therefore, the cost of electricity generation per cent in kWh are an important figure to assess the profitability of a biogas plant.

Selling heat is more difficult especially when biogas plants are not in the vicinity of potential customers. Furthermore, the heat demand of customers changes significantly during the year and the surplus heat production of the biogas plant is contrary to this demand. Around 25% of the heat is needed for heating the fermenter (FNR, 2016).

Investments costs for biogas plants

Typical investment costs per KW electricity for a complete biogas plant including combined heat and power decrease with an increase in installed power.

Table 2 | **AVERAGE INVESTMENT COSTS FOR BIOGAS PLANTS IN GERMANY**
SOURCE: FACHVERBAND BIOGAS 2016, *FNR, LEIFADEN BIOGAS, 2016

INSTALLED POWER	PRICE €/KWEL	TOTAL AVERAGE PRICE
75 KW	8,000	600,000 €
150 kW	6,500	975,000 €
500 kW	4,600	2,300,000 €
750 kW	4,000	3,000,000 €
1 MW	3,600	3,600,000 €
400 M³/h (BIOMETHANE)*	n.a.	4,700,000€

Operation and maintenance costs for biogas

For the calculation of operation and maintenance costs (OPEX), model biogas plants are used with a pre-defined feedstock mix. Small biogas plants with 75 kW are typically built by farmers making use of their slurry from animal husbandry, whereas bigger biogas plants process a mix of slurry and silage.[6]

Several assumptions are made in order to calculate the costs of the biogas model plants. The following are the most important to note:

- Biogas plants run 8,000 hours per year.
- The own power consumption of the plant is 6.5-8% of produced power, depending on plant size.
- The efficiency is 38% for small and medium size plants to 42% for big plants.
- 45% of the produced heat can be used externally and 20% of heat in the case that more than 60% of feedstock is slurry.

The OPEX of biogas plants comprise the following:

- **Variable costs**
  - Feedstock costs differ significantly but can equal up to 60% of the total costs of a biogas plant. Slurry is assumed to have no costs, as the biogas plant is usually at the same location as the animal husbandry. The cost for silage varies from 28 €/tonne fresh matter for grass silage, to 31 €/ tonne for cereal silage, and 32 €/tonne for maize silage.
  - Consumables are all materials that are used to operate the plants (power, lubricating oil, diesel, etc).
  - Maintenance and repair costs
  - Laboratory analysis
  - Interest charges
- **Fixed costs**
  - Amortisation
  - Interest loan capital
  - Insurance
  - Staff costs
- Overhead costs

The OPEX of model biogas plants with a determined feedstock mix are presented in Table 3 below. It is important to note that the actual costs for biogas plants could be higher or lower. In particular, the feedstock costs, the full load hours per year, and the efficiency are important levers to reduce the OPEX.

The feedstock costs range from 16% (75 kW plant) to 48% (1 MW plant) of the total costs. Electricity generation costs are above the price caps according the Renewable Energy Source Act 2017 (EEG 2017), so a focus on electricity generation is not profitable. Only existing biogas plants using biogenic waste and residues will be able to operate only with the EEG 2017 remuneration, other plants need to identify further sources of income.

In addition to the remuneration for electricity generation, biogas plant operators can claim a flexibility bonus for demand-driven power supply. The price for heat differs significantly from region to region with 2 ct to 6 ct/kWh.

To be profitable, biogas plants in Germany need to shift from silage to an increased use of biogenic waste and residues.

6. Silage refers to plants which are completely used as a feedstock for biogas production, i.e. grass, maize or cereals.

Table 3 **OPERATION AND MAINTENANCE COSTS OF BIOGAS PLANTS**
SOURCE: FNR, BIOGAS LEITFADEN, 2016

INSTALLED POWER	75 KW 80% SLURRY, 20% SILAGE	150 KW 30% SLURRY, 70% SILAGE	250 KW 20% SLURRY, 80% SILAGE	500 KW 20% SLURRY, 80% SILAGE	750 KW 20% SLURRY, 80% SILAGE	1 MW 100% SILAGE	BIOMETHANE 400M³/H 100% SILAGE
Variable costs							
Feedstock	85,100	85,100	162,530	310,904	458,582	622,413	664,110
Consumables	39,876	39,876	34,201	62,910	103,078	143,683	186,717
Maintenance	48,704	48,704	58,111	84,923	107,522	124,823	103,491
Laboratory analysis	300	300	300	300	300	300	300
Interest charges	579	579	849	1,529	2,231	2,970	3,181
Sub-total	174,559	174,559	255,991	460,566	671,713	894,189	957,799
Fixed costs							
Amortisation	89,336	89,336	104,703	169,242	224,759	261,476	315,168
Interest loan capital	20,102	20,102	29,282	47,755	63,168	73,581	97,785
Insurance	4,885	4,885	7,081	11,479	15,143	17,571	23,546
Staff costs	12,146	12,146	14,331	18,116	20,852	22,962	26,073
Sub-total	126,469	126,469	155,397	246,592	323,922	375,590	462,572
Overhead costs	761	761	2,485	4,982	7,562	10,067	10,560
TOTAL	**301,789**	**301,789**	**413,873**	**712,139**	**1,003,197**	**1,279,846**	**1,430,931**
Electricity generation costs ct/kWh el	29.76	24.19	19,92	17,07	15,81	15,13	Gas generation costs at grid 7.93

Currently sustainable, certified biomethane injected into the grid in one Member State can only be classified as sustainable and as biomethane when used in the respective Member State.

Upgrading to biomethane production

A further opportunity for biogas plants to remain profitable is the shift to biomethane production in order to have a product that can be used for multiple purposes, i.e. heat, power and transport fuels. There is no public incentive for upgrading to biomethane. Due to the possible injection into the gas grid, biomethane can be transported over longer distances, although there are administrative and legal restrictions for cross-border transport. Currently sustainable, certified biomethane injected into the grid in one Member State can only be classified as sustainable and as biomethane when used in the respective Member State. There is no accounting system for chain of custody for (sustainable) biomethane on the EU level to verify that the material is actually (sustainable) biomethane. It is simply considered to be natural gas. In the absence of price regulations for biomethane injected into the gas grid, the price must be negotiated between the producer and the customer.

Biomethane, is a 100% renewable source of energy which is commonly produced by decomposition (called anaerobic digestion, which takes place in the absence of oxygen and the presence of microbes) of organic matters such as plant materials, sewage waste, animal manure, organic waste, industrial waste, etc. The process of decomposition of organic matters in an oxygen-free environment produces biogas, a mixture of methane and carbon dioxide that can further be upgraded to biomethane. The upgrading process includes purification of the biogas to optimise the biomethane yield. One of the most commonly used upgrading technologies is pressure swing adsorption (PSA) which separates CO_2 from biomethane by adsorption on a surface at elevated pressure.

Ecofys calculated the price of biomethane production in Germany, based on average upgrading parameters in Europe. The following parameters were considered for cost calculations for upgrading:

- Biogas price of 0.05 €/KWh (0.25 €/m3)
- Pressure Swing Adsorption was used as the main upgrading technology
- Methane purity in biomethane of at least 97% was sought

Cost calculations for the upgrading of biogas to biomethane were performed using the biomethane-calculator software developed by the Technical University Vienna. Based on the above parameters, the cost of biogas upgrading to biomethane in Germany are calculated to be 0.095 €/kWh of methane (0.946 €/m3 or 1.33 €/kg of methane), taking into account the lower heating value of methane. The total investment costs are estimated to be €1.6 million on average, which include the upgrading unit, the cost of for pipelines, and injection into the grid. Due to economies of scale the price will decrease for large plants.

Solid biomass plants

It is very difficult to estimate the average costs of solid biomass plants due to the variety of technological options and the variety of feedstocks, i.e. waste wood , fresh wood, forestry residues and agricultural residues. Based on interviews with the German Fachverband Holzenergie, the CAPEX and OPEX of two exemplary solid biomass plants are displayed below.

Investments costs for solid biomass plants

In general, a biomass plant processing fresh wood is more expensive than a biomass plant processing waste wood. The cost for a connection to the heating system adds €1,000 / metre of pipeline.

Table 4 | **INVESTMENTS COSTS FOR EXEMPLARY SOLID BIOMASS PLANTS IN GERMANY**
SOURCE: FACHVERBAND HOLZENERGIE, 2016

INSTALLED POWER	FEEDSTOCK	PRICE €/MWEL	TOTAL AVERAGE PRICE
1 MW	Fresh wood	4,000,000	4,000,000
5 MW	Waste wood	3,000,000	15,000,000

Operation and maintenance costs for solid biomass plants

The table below shows the OPEX and estimated turnover of three exemplary solid biomass plants:

1. 5 MW plant running on waste wood with heat supply generating 25,000 MWhel per year
2. 5 MW plant running on waste wood without heat supply generating 36,000 MWel per year
3. 1 MW plant running on fresh wood with heat supply generating 6,000 MWhel per year

Table 5 | **OPEX AND TURNOVER FOR EXEMPLARY SOLID BIOMASS PLANTS**
SOURCE: FACHVERBAND HOLZENERGIE

COST ITEM 1,000€/YEAR	5 MW, WASTE WOOD WITH HEAT SUPPLY	5 MW, WASTE WOOD	1 MW, FRESH WOOD WITH HEAT SUPPLY
Variable costs			
Feedstock	850	750	550
Maintenance	750	450	200
Consumables	450	225	200
Sub-total	2,050	1,425	950
Fixed costs			
Amortisation	1,000	800	250
Staff costs	700	450	200
Rent, insurance, service contracts	450	225	200
Sub-total	2,150	1,475	650
TOTAL Costs	**4,200**	**2,900**	**1,600**
Turnover heat	2,500		1,100
Turnover electricity generation	2,250	3,500	800

These costs are only rough estimates. In reality costs will be highly dependent on feedstock prices, especially if the price of waste wood fluctuates significantly.

In the EEG 2017 there is no remuneration for electricity generated by processing waste wood. Solid biomass plants aiming for funding in line with EEG therefore need to use fresh wood or forestry and agricultural residues.

1.4 GHG reduction

The increasing share of renewable energy in the German power and heat market results in significant greenhouse gas emission (GHG) reductions. In 2015 a total of 156,1 million tonnes of CO_2 equivalent of GHG emissions have been avoided through the use of renewable energy, out of which bioenergy had a 36.5% share. GHG avoidance is assessed by setting the emissions for final energy supply arising from renewable energy against the emissions of the substituted fossil and nuclear energy carriers.

The table below provides a detailed overview of the avoided GHG emissions due to bioenergy in Germany in 2015.

Table 6 | **AVOIDED GHG EMISSION DUE TO BIOENERGY IN GERMANY IN 2015**
SOURCE: FNR

GHG AVOIDANCE IN 1.000 T CO_2-EQ ENERGY CARRIER	POWER	HEAT	TOTAL
Solid Biomass	13,173	33,611	46,784
Liquid biofuels[7]	159	369	528
Biogas	10,418	3,310	13,728
Total	**23,750**	**37,290**	**61,040**

1.5 Sustainability

Currently there are no mandatory sustainability criteria for biomass for heating and electricity generation, but only for biofuels in transport. However, the EC proposal for the revision of the Renewable Energy Directive (RED) from November 2016 aims for extending the sustainability criteria to all biomass energy uses. The sustainability criteria shall be extended in their scope to cover biomass and biogas for heating and cooling and electricity generation. Biogas is removed from the definition of biofuels, but a new category of "biomass fuels" was introduced meaning gaseous and solid fuels produced from biomass. The proposed Art. 26 states that sustainability criteria must apply to installations over 0.5 MW in case of gaseous biomass fuels, but EU member states can implement sustainability criteria also for smaller installations (EC, 2016). This proposal will now be discussed between the European Parliament, the European Commission, and the Council of Ministers, so the final revised RED might be different.

In Germany there is an intensive debate about using food crop-based biomass for energy generation and about the so-called "Vermaisung", i.e. the perception that more and more maize as mono-culture is grown mainly for bioenergy purposes.

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In Germany there is an intensive debate about using food crop-based biomass for energy generation and about the so-called "Vermaisung", i.e. the perception that more and more maize as mono-culture is grown mainly for bioenergy purposes. In 2015 maize was cultivated on 2.6 million hectares out of which 1.7 million hectares were cultivated for animal feed and 0.9 million hectares (35%) for biogas (FNR, 2015). This is a slight increase to 2012 when 31% of the total maize area was used for biogas. Besides the costs aspect (i.e. making biomass more expensive than PV or wind), sustainability is a concern for the German Government as well. At the same time the German Government wants to use the positive aspects of bioenergy, namely the ability to provide flexible, demand-driven energy supply as well as stable energy supply and the variety of feedstocks that can be processed. The EEG 2017 reflects this position by emphasising the use of biogenic waste and residues but also incorporating a flexibility bonus.

7. Predominantly used as transport fuels

Part II:
Biomass for power and heat supply in Poland – Policy instruments and market developments

By Christian Schnell PhD (Instytut Jagiellonski)

2.1 Overview

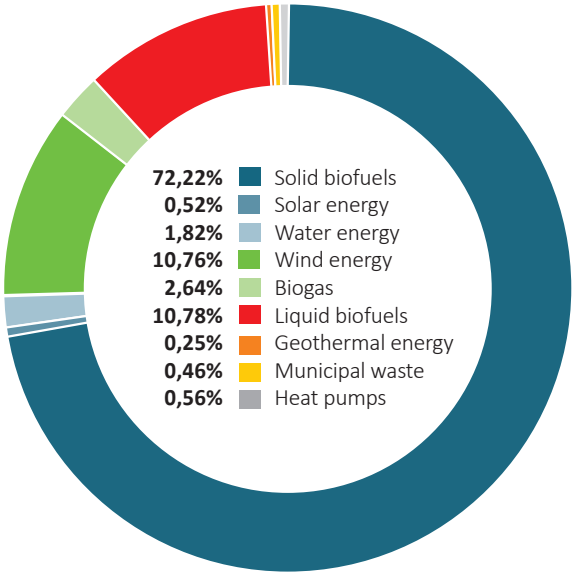
Currently, Poland's RES share in energy production is still based on solid biomass. Bioliquids have the second largest share in RES energy production, i.e. transport fuels, however Poland does not produce second and third generation biofuels – biofuel for transportation is not subject of this fact sheet. The percentage share of energy from biogas is relatively low, e.g. amounting to one tenth of the share of RES energy production from biogas in Germany. The share of energy production from biogenic waste is very low amounting to less than 0.5%.

In 2015 Poland's RES share in energy production is still based on solid biomass.

Table 7 **RES ENERGY GENERATION 2011-2015 BY SOURCES IN PERCENT**
SOURCE: CENTRAL STATISTICAL OFFICE GUS 2016

SPECIFICATION	2011	2012	2013	2014	2015
Solid biofuels	84,89%	82,07%	79,88%	76,14%	72,22%
Solar energy	0,17%	0,17%	0,29%	0,43%	0,52%
Water energy	2,68%	2,06%	2,45%	2,31%	1,82%
Wind energy	3,68%	4,79%	6,03%	8,13%	10,76%
Biogas	1,83%	1,97%	2,12%	2,56%	2,64%
Liquid biofuels	5,76%	7,96%	8,18%	9,18%	10,78%
Geothermal energy	0,17%	0,19%	0,22%	0,25%	0,25%
Municipal waste	0,43%	0,38%	0,39%	0,45%	0,46%
Heat pumps	0,39%	0,41%	0,44%	0,55%	0,56%

Figure 6 **THE STRUCTURE OF ENERGY PRODUCTION FROM RENEWABLE ENERGY SOURCES IN POLAND, BY CARRIERS IN 2015.**
SOURCE: CENTRAL STATISTICAL OFFICE GUS 2016



Most of the energy production from biomass is based on individual households burning wood and also wood waste, which, next to burning low quality coal, causes severe problems to Poland's air quality.

Solid Biomass

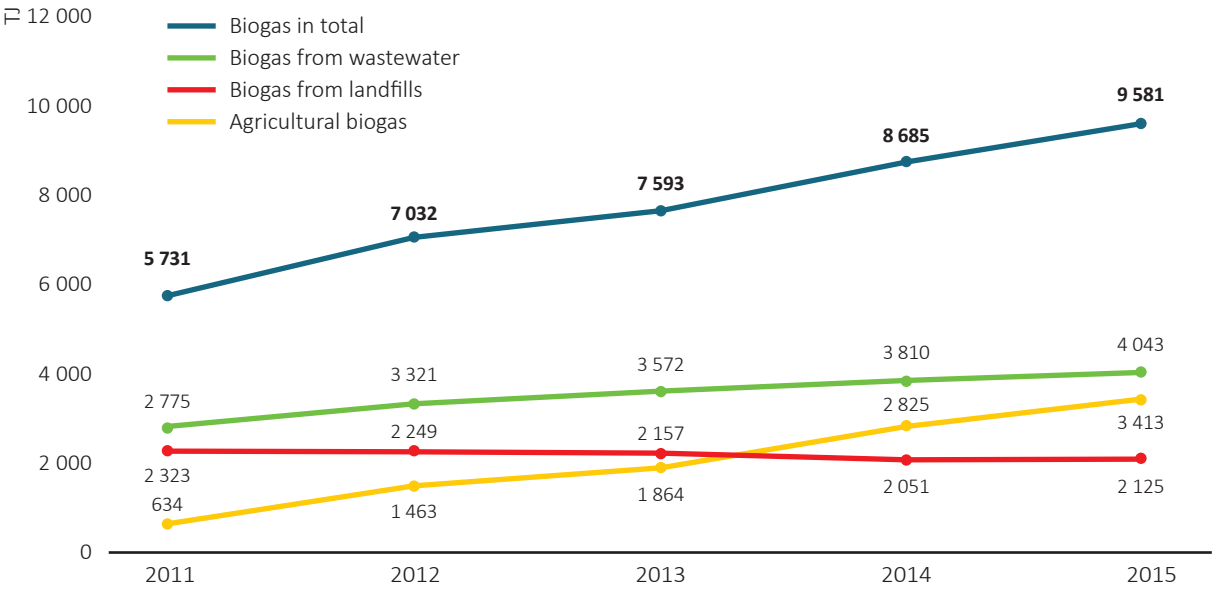
Most of the energy production from biomass is based on individual households burning wood and also wood waste, which, next to burning low quality coal, causes severe problems to Poland's air quality. The GUS Central Statistical Office adds each biomass combusted in Polish households, even wood for fireplace, to the RES target. There is no monitoring system, and the calculations are based on a survey made every three years. The most recent survey was carried out in January 2016 based on ca. 5 thousand respondents (out of nearly 13.6 million households in Poland). However, the share of final consumption of solid biomass (for heating) decreased from 70.38% in 2011 to 66.27% in 2015, whereas the share of solid biomass for energy production in the energy sector increased appropriately.

Currently, Poland produces annually up to 9.5 TWh of electricity from solid biomass, mostly in larger co-combustion (co-firing) plants and larger dedicated biomass power/CHP plants, i.e. refurbished boilers of coal power plants. From 2011 to 2015 the consumption of biomass for energy production increased by 6.7%, whereas the production decreased by 1.3% in this period. In 2015, Poland imported solid biomass amounting to 9.8% of its consumption, whereas 2.5% of the solid biomass production has been exported (mainly wood pellets).

Biogas

Especially biogas production from agricultural biogas plants – amounting to approx. 100 MW – has been steadily increasing by 10-20% each year during the last five years, mainly due to the distribution of investment grants from EU regional operational support programmes. Yearly electricity production by agricultural biogas plants amounts to approx. 0.45 TWh, whereas units that use landfill gas or gas from sewage plants in Poland produce approx. 0.55 TWh.

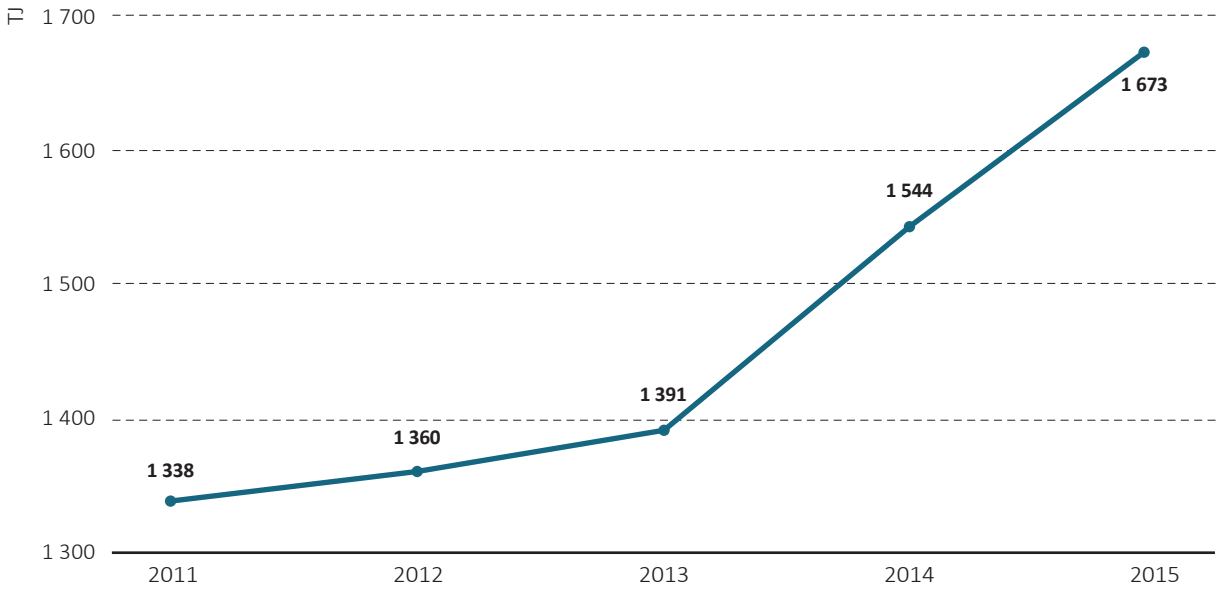
Figure 7 **BIOGAS ELECTRICITY PRODUCTION 2011-2015 IN GWH**
SOURCE: CENTRAL STATISTICAL OFFICE GUS 2016



Biogenic waste

The use of biogenic municipal waste has seen a remarkable increase from 2014 due to a change of the waste ownership, i.e. from 2014 municipalities are owners of the waste and are responsible for waste disposal against a fee paid by the household, and currently amounts to 1,700 GJ.

Figure 8 **BIOGENIC MUNICIPAL WASTE ENERGY CONSUMPTION 2011-2015 IN GJ**
SOURCE: CENTRAL STATISTICAL OFFICE GUS 2016



2.2 Support scheme for electricity (and heat) production from biomass and biogas

The prior RES operative support scheme, a green certificate scheme with a quota obligation on retailers, has been closed by end of the first half of 2016 for new entries, but will continue until the end of a 15-year support period.

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Technology-neutral bidding scheme

According to the original RES Act which entered into force in May 2015 the new auction support system provides a general technology-neutral bidding scheme for (i) contract-for-difference market premiums concerning RES-E generators with at least 500 kW installed capacity or (ii) feed-in tariffs for RES-E generators with 40 kW to 499 kW installed capacity. Micro-installations are promoted by net-metering. However, by 1 July 2016 the Polish Government revised the RES Act before first auctions have been organised. For certain technologies special technology baskets have been introduced, e.g. biogas installations and incineration plants. However, due to the general approach of the EC DG Competition to promote technology-neutral bidding schemes Poland government seems to agree to resign from introducing technology baskets and will come back to the original support system. However, the support system shall be modified in a way, that specific technologies can be limited to its share in each auction basket. RES-E generators can start in four technology-neutral baskets for generators with up to 1 MW installed capacity or more, and for the generators with a smaller and at least a 40% capacity factor, i.e. a production of at least 3,504 MWh/MW installed/year. The capacity factor-threshold has been introduced especially to promote biomass and biogas installations, which are generally not able to compete with onshore wind and PV in auction support schemes based on price per MWh.

Volume and value of auctioned RES electricity and reference prices

Generally, each year until the end of October, the Council of Ministers sets the volume and the value of electricity that can be auctioned in the upcoming calendar year, and also the sequence of the auctions in relevant baskets. However, for the year 2017 this regulation has been so far published only as a draft, whereas the auctioned volume corresponds to 2.3 TWh of RES-E per year. Furthermore, due to EC DG Competition recommendation it is planned to publish a non-binding volume path for each technology for

The prior RES operative support scheme, a green certificate scheme with a quota obligation on retailers, has been closed by end of the first half of 2016 for new entries, but will continue until the end of a 15-year support period. This support system mainly promoted the cheapest RES technologies, i.e. co-firing of solid biomass and coal in power plants, large scale dedicated biomass investments and onshore wind as the cheapest RES technology. All the other RES technologies have been developed only due to an additional investment support mainly from EU grants, e.g. biogas installations, dedicated (co-)firing of solid biomass in CHP plants or PV. The amount of RES production substantially exceeded the required quota, so an oversupply of green certificates lead to a sharp decrease of lead to a sharp decrease of green certificate prices. This development has been also observed with other still operating quota systems, e.g. the comparable Swedish support system. Therefore, investors currently require higher return on investment than in the EU member states with a more stable regulatory environment at a level of 7.5 – 8.0%, and the costs for project finance amount to 5 – 6% p.a. Unfortunately, this provides to relatively higher costs per MWh of green power.

the coming three years in order to provide more transparency of the project developers. Project development of biogas and biomass projects may take 5 to 7 years before the project obtains a building permit, due to restrictions in the planning and environmental law. Only a project with a building permit can prequalify for the auction.

Each year the Minister of Economy sets so called "reference prices" – which are ceiling strike prices for bidders to avoid oversupport. For this purpose each year the Ministry of Economy calculates a LCOE (Levelized Costs of Energy) value. Since LCOE values will be set, a level where most successful projects with BAT (Best Available Technology) are able to win an auction, the reference price is supposed to be substantially higher than the LCOE value. However, in practice, most reference prices are at a low level. For the year 2017 the reference prices set by the appropriate regulation published by the Minister of Energy amount to:

Table 8 **REFERENCES PRICES FOR RES-E 2017**
SOURCE: MINISTRY OF ENERGY

RES-E generator	Reference price as proposed by the Ministry of Energy in PLN/MWh	Corresponding amount in Euro per kWh (FX EUR/PLN 4.35)
Units with an installed capacity < 1MW that use agricultural biogas (incl. slurry and silly crops) for power generation	550	12.64 €c
Units with an installed capacity > 1MW that use agricultural biogas for power generation	550	12.64 €c
Units that use landfill gas	405	9.31 €c
Units that use gas from sewage treatment plants	365	8.39 €c
Units that use "other biogas" than agricultural biogas, landfill gas and gas from sewage treatment plants	355	8.16 €c
Dedicated biomass or hybrid units with ≤ 50 MW capacity for power generation	415	9.54 €c
Dedicated biomass or hybrid units with ≤ 50 MW capacity for high efficient CHP	450	10.35 €c
Dedicated biomass or hybrid units with > 50 MW capacity and a total installed heat capacity of maximum 150 MWth for high efficient CHP	435	10.00 €c
Co-firing of biomass units without size limitation	325	7.47 €c
Waste incineration plants	385	8.85 €c
Units that use bioliquids for power production	475	10.92 €c

However, although Poland has a strong agricultural footprint and an influential agricultural lobby the auction support system is less favorable for electricity production from agricultural biogas. Lacking of support for agricultural biogas led to a situation where in Germany there are 90-times more agricultural biogas installations installed than in Poland – producing 31.3 TWh of RES-E in 2015.

Furthermore, the support for large dedicated or co-firing biomass installations is comparably high – the maximum size of such installations is not capped. According to ARE Energy Agency, dedicated biomass installations produced in 2015 4.6 TWh and co-firing installations 4.5 TWh. Such installations are owned mainly by large Polish and foreign plants with a strong lobby, whereas new dedicated biomass installations are predominantly developed as municipal CHP plants but face difficulties with obtaining a building permit-status if they enter a market with the existing players. Furthermore, in order to partially close a presumably 8 TWh gap to the EU 2020 target the renewal of non-dedicated co-firing in depreciated coal power plants is a solution which is still under discussion. However, the implementation of 2030 targets under the Polish National Energy and Climate Plan according to the new EU Governance regulation may have a negative impact as it requires a permanent increase of RES, also after 2020. Furthermore, renewal of non-dedicated co-firing in power/CHP plants would again lead to a massive import of cheaper biomass from Eastern Europe and Asia – especially wood biomass imported from Eastern Europe costed in 2014-2015 more than 50% less than the Polish wood biomass-, and faces strong opposition from the Ministry of Environment and the State-owned forests.

Due to a change in the support system of non-dedicated co-firing in power plants has been phased out during 2016, and is currently practised mainly in 14 dedicated CHP plants providing for a half of electricity production from co-firing compared to 2015. The table below presents 2016 RES production in GWh based on ARE monthly reports.

Table 9 **RES-E PRODUCTION IN 2016**
SOURCE: ENERGY AGENCY ARE

	2016												**∑ in TWh in 2016**	∑ in TWh in 2015
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII		
Dedicated biomass	469.9	419.7	378.4	344.3	400.5	395.3	391	312.1	354.5	376.5	347.2	397.8	**4.6**	4.6
Co-firing power /CHP plants - only biomass share only	178.9	205.1	244.8	211.4	204.4	220.8	224.4	185.1	152.1	189.4	161.9	173.9	**2.4**	4.5
Biogas	74.0	83.0	80.1	80.6	79.9	77.1	81.0	81.2	81.4	87.2	84.4	91.2	**1.0**	0.9
Onshore wind	1212	1458	830.6	922.4	761.5	640.3	748.2	740.8	665.1	1241	1061	1689	**12.6**	10.9
PV	0.4	3.5	7.6	11.7	17.0	18.4	16.6	16.5	15.1	6.3	3.9	3.6	**0.12**	0.06
Hydro	113.0	220.5	260.3	203.8	191.1	120.9	150.6	139.2	99.1	195.4	206.6	239.5	**2.1**	1.8
∑ in GWh	2049	2390	1802	1774	1654	1473	1612	1475	1367	2096	2224	2595	**22.8**	22.7

The electricity currently produced from biogas goes in line with the National RES Action Plan assumptions for the year 2015, however, the forecast for electricity production from biogas installations in 2020 amounts to more than 4 TWh. Additionally, also the production of electricity from solid biomass in 2015 amounting to 9 TWh goes in line with the National RES Action Plan, however, currently the production is sharply dropping to 7 TWh/year due to a change in the support system for co-firing. Therefore, the government announced that it would especially promote technologies with a high efficiency co-efficient, i.e. biomass and biogas installations in the new contract-for-difference market premium auction support system. Unfortunately, the auction system has not yet been notified by the EU Commission and the Ministry of Energy expects first auctions for new projects no sooner than at the end of 2017. Generally, with the envisaged construction time of 1.5 years after a successful bid for biogas installations and up to than 3 years after a successful bid for larger solid biomass plants or incineration plants, the objections of the National RES Action Plan can hardly be achieved.

The target for Poland is 15% in the gross final consumption of energy. This is the minimum target which Poland is obliged to achieve by 2020.

Poland's 2020 target

The Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing the Directives 2001/77/EC and 2003/30/EC sets out a common framework for the promotion of energy from renewable sources. The target for Poland is 15% in the gross final consumption of energy. This is the minimum target which Poland is obliged to achieve by 2020. According to the National Action Plan for energy from renewable sources drawn-up in 2010, which was agreed and accepted under Article 4 of the Directive by the European Commission, and then supplemented in 2011, Poland is committed to achieve a share of energy from renewable sources of 15.85% in the final consumption of energy in 2020. As regards the method of calculation of the share of energy from RES in each sector, the gross final consumption of electricity from renewable energy sources is calculated as the quantity of electricity generated in RES generators in order to achieve a share of electricity from renewable sources of 19.13% in the final consumption of electricity in 2020. According to the analysis obtained from Instytut Jagiellonski, in 2020 Poland may face a substantial gap between agreed RES-e percentage of electricity consumption amounting to approximately 33 TWh RES-e production and forecasted RES-e production for 2020 amounting to approximately 25 TWh, which results as an amount of the current RES-e production of 22.5 to 23.0 TWh annually and, additionally, a 2 TWh annual production by new installations which will be presumably constructed and connected as a result of 2017/2018 auction for new RES-e installations.

According to the COM (2016) 482 paper (final) agreed between the EU member states, Poland is obliged to reduce its greenhouse gas (GHG) emissions under ETS and non-ETS sectors by 7% compared to 2005 level.

National Energy and Climate Plans and the 2030 GHG reduction target

The set of documents published by the Commission as the 'winter package" generally reshapes the EU Energy Policy including legislative proposals and a range of explanatory and background policy documents.

The main legislative proposals are:

- a revised Directive on the Internal Market for Electricity (the Revised IMED),
- a revised Electricity Market Regulation (the Revised Market Regulation),
- a Regulation on the Governance of the Energy Union (the Governance Regulation),
- a new Regulation on Electricity Sector Risk-Preparedness (the Risk Regulation),
- a recast Regulation on the Agency for the Cooperation of Energy Regulators) (the ACER Regulation),
- a revised Renewable Energy Directive (the Revised RED),
- a Directive amending the existing Energy Efficiency Directive and a Directive amending the existing Energy Performance of Buildings Directive,
- but also a Communication on Accelerating Clean Energy Innovation (the Innovation Communication).

The Governance Regulation is a framework legislation aiming to give credible underpinning to the commitments on climate change that the EU as a whole has made in 2014, under the Paris Agreement and to bridge the gap left by having an EU level 2030 renewables target but no correspondingly increased Member State level targets. It also gives a legislative expression to the EU's Union-level energy and climate targets to be achieved by 2030, which are a binding target of at least 40% domestic reduction in economy-wide greenhouse gas emissions as compared with 1990, a binding target of at least 27% for the share of renewable energy consumed in the EU, a target of at least 27% (increased to 30%) for improving energy efficiency in 2030, to be revised by 2020, having in mind an EU level of 30% and a 15% electricity interconnection target for 2030. According to the COM (2016) 482 paper final agreed between the EU member states, Poland is obliged to reduce its greenhouse gas (GHG) emissions under ETS and non-ETS sectors by 7% compared to 2005 level. Based on this obligation, the EU Commission ordered the recent PRIMES Scenario outlook calculating for each member state its carbon footprint until 2030 and even 2050 in 5-year steps. This scenario has been published in July 2016 and has been thoroughly analysed by the Polish utilities. Generally, this scenario provides for Poland a scenario of reducing GHG emissions kWh to 500g CO_2/kWh until 2030. According to COM(2015) 572 final paper, by March 2017 integrated projections should be submitted to the Commission covering both reference and policy scenarios by each member state. The full plan should be submitted to the EU Commission by the end of 2017, to be consulted within the region in 2018 and notified until the end of 2018.

Every 10 years, starting from 2019, each Member State is to enact an integrated national energy and a climate plan covering a period of ten years, starting from the 2021-2030 period. The plan is to set out, in considerable detail, the information which is required by the relevant Member State, i.e. national objectives and targets, additional policies and measures adopted, and finally its emissions projections going forward to another 10-year period. The achievements have to be reported every two years, and every five years an update is required. The plans are first to be submitted to the Commission for comment one year in advance, in draft, i.e. the first draft by 1 January 2018. Practically, such a plan will be most likely the basis for successful notification of any support mechanism for energy production and energy efficiency measures.

In case if starting from 2021, the agreed percentage of RES production resulting from the 2010 National RES Action Plans is not kept, and starting from 2024 the agreed path for reducing the GHG emissions is not kept, the given member state has to pay a "financial contribution" to a "financing platform" at the EU level which supports RES development in Europe. It is therefore of importance to present a reliable scenario to the EU Commission in order to avoid paying financial contributions at a latter moment.

Support system for heat production from biomass

The current certificate support system for high-efficient cogeneration expires in 2018 – an investment support for heat network is granted in parallel to an operative support for power. Although due to its high efficiency, especially biomass CHP technologies will presumably have a major impact on fulfilling 2020 NAP and 2030 GHG reduction targets, the government has not yet presented any new support system for high-efficient cogeneration.

The current certificate support system for high-efficient cogeneration expires in 2018 – an investment support for heat network is granted in parallel to an operative support for power.

2.3 Available solid biomass for electricity and heat production

Poland has a well-developed agricultural and forest sector. Therefore, the potential for use of forest and agricultural biomass for energy production is comparably high but requires coordinated management of the feedstock. Currently, the energy production potential of solid biomass is not used sufficiently due to a lack of long-term planning for operative support. Nevertheless, during the historic peak of non-dedicated co-firing in power plants in 2012, the potential of solid forest and agricultural biomass for energy production has been already tested, and future installations may benefit from that experience.

According to the information provided by the "Polish Biomass" Association, a member of AEBIOM, the current feedstock of solid agricultural biomass, mainly straw and grass, amounts to more than 10 million tons per year.

Table 10 **STRAW AVAILABLE FOR ENERGY PRODUCTION**
SOURCE: ASSOCIATION POLISH BIOMASS

Voivodship	Million tons of straw / yearly technical potential for energy production
West Pomerania	0.8
Pomerania	0.9
Kuyavien-Pomeranian	1.2
Lubusz	0.2
Greater Poland	1.7
Lower Silesia	0.6
Opole	0.4
Silesia	0.4
Lodz	0.6
Masovia	0.8
Warmian-Masurian	0.8
Podlaskie	0
Lublin	1.5
Swietokrzyskie	0.3
Lesser Poland	0.1
Subcarpathian	0.2
Grass, reed etc.	1.1
TOTAL	**11.6**

However, without a country-wide planning and a logistics concept, according to the "Polish Biomass" approx. 60% of this potential is practically accessible for energy production.

Wood biomass

Furthermore, according to the "Polish Biomass" Association, wood biomass to be used for energy production has also a large technical potential of estimated 11 million tons per year. This potential covers waste from forest industry, forest thinning, pulp and paper industry and self-sown plants in parks and at roads.

However, in 2016 Poland imported 2.5 million tons of wood chips for energy production, mainly from eastern Europe. Generally, the price for imported wood chips from eastern Europe amounts to half the price of wood chips from the Polish forestry industry. However, due to the impact of the LULUCF regulation, the price for imported wood chips will most likely increase in the future. Currently, Polish forests produce up to 2 million cubic meter of wood for energy reasons per year, i.e. up to 1.4 million tons.

Currently used biomass for electricity production

Due to legal restrictions, dedicated biomass firing installations currently use 20% 'agro' (agricultural) biomass and 80% forest biomass, whereas co-firing installations use 80% 'agro' biomass and 20% forest biomass to

Table 11 **CURRENTLY USED BIOMASS FOR ELECTRICITY PRODUCTION**
SOURCE: ARE, OWN CALCULATION

	Annually production forecast in GWh	Efficiency	Biomass in th. GJ	Biomass GJ/ton	Biomass in th. tons	Forest/ percentage	Agro/ percentage	Forest/ th. tons	Agro/ th. tons
Dedicated biomass	4600	28%	59000	10	5900	80	20	4720	1180
Co-firing	2300	32%	26000	12	2150	20	80	430	1720
Total	6900				8050			5150	2900

be mixed with coal – the general energy share of biomass should not amount to less than 15%. The amount of currently used biomass for energy production can be based on the electricity production data of dedicated biomass firing installations and co-firing installations for 10-12/2016. Generally, 1 MWh of electricity corresponds to 10 GJ of chemical energy, whereas 1 ton of straw produces 12 GJ and 1 ton of wood chips (with 50% humidity) produces up to 10 GJ. So, in 2016 almost 3 million tons of 'agro' biomass have been used for power production, whereas according to 2011-2015 data Poland imported from third countries an average of more than 600 thousand tons 'agro' biomass per year for power production. However, due to the phase-out of simple co-combustion the amount of imported 'agro' biomass in 2016 most probably decreased to a level of approx. 500 thousand tons.

Heat production from biomass

According to the Polish Chamber of Heat Producers, currently up to 15 million tons of coal – corresponding to 300 million GJ - produce up to 95% of 32 TWh yearly heat production distributed in district heating systems, partially by 6.5 GW CHP installations.

The Revised Renewable Energy Directive (RED II) as published by the EU Commission at the end of November 2016 prohibits, starting from 2024, "public support for installations converting biomass into electricity" unless they apply high efficiency CHP, if they have a fuel capacity of 20 MW or more. However, this would not require the termination of support that has already been granted to specific projects.

2.4 Methane gas production from liquid biomass

Currently, no biogas plant in Poland is producing biomethane for feed-in to gas network. Although the Polish government strongly promotes e-mobility for public bus transport, in rural areas busses with gas engines are most recommended. Furthermore, trucks and airplanes create additional potential for the use of biomethane in transportation. For the time being Poland does not produce any 2G- or 3G-biofuels, although the EU member states are obliged to introduce a scheme to promote the production of those biofuels. Therefore, we expect that the methane production from liquid biomass will substantially increase.

According to the Poznan University of Life Sciences, Poland's farmers industry is capable to produce 8 billion m3 biomethane solely based on agricultural biomass waste (mainly slurry) – not taking into account use of corn for energy production.

2.5 Biogenic waste

The electricity generation from biogenic waste and residue in Poland is very limited. Food waste and residues like used cooking oil are mainly used as a feedstock for biodiesel production.

The electricity generation from biogenic waste and residue in Poland is very limited. Food waste and residues like used cooking oil are mainly used as a feedstock for biodiesel production. Biogas units that use landfill gas or gas from sewage plants have a visible impact on electricity production. In 2015, those units produced approx. 0.5 TWh electricity in Poland. Currently, biogenic municipal waste in Poland amounts to a total of 2.3 million tons, consisting of kitchen and garden waste - amounting to 29-37% of total municipal waste-, wood – amounting to 0.2-0.7% of municipal waste- and waste from green areas – amounting to 3-5% of municipal waste.

However, according to the planned volume of the 2017 auction – the revised draft regulation was published by the Ministry of Energy on 17/02/2017 – RES generators starting in a dedicated auction basket for units with more than 1 MW installed capacity using biogenic waste such as biogas units that use landfill gas or gas from sewage plants or, alternatively, incineration plants shall produce approx. 300 GWh electricity per year. In order to start in an auction, such projects should achieve a ready-to-build status, however, according to the EU state aid rules no investment decision should be made prior to auction, e.g. no balance-of-plant constructor should be awarded or no investment grant agreement should be signed prior to auction.

Due to the EU targets, Poland is obliged to achieve a share of recycling of waste amounting to 50%, whereas currently only 26% of waste is recycled. So, according to the plans of the Ministry of Environment in the coming years, the waste streams have to be fully reorganized by selective waste collecting at households. In such a market environment it is almost impossible to plan a 15-year RES electricity production and to secure the required waste stream for the contracted amount of energy.

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