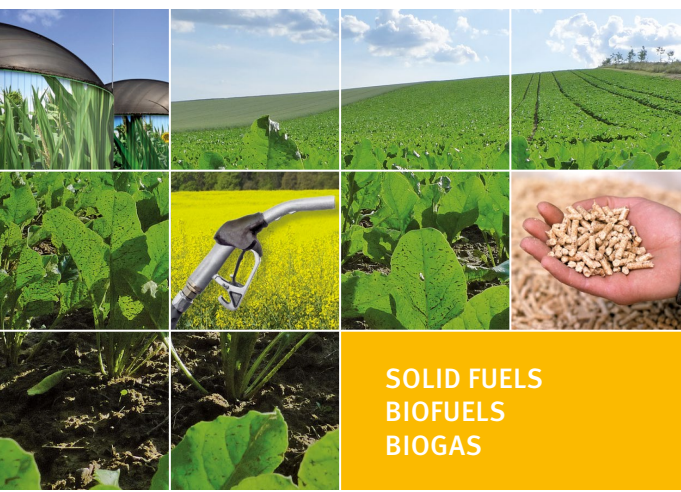
international.fnr.de

BIOENERGY IN GERMANY
FACTS AND FIGURES 2017



SOLID FUELS
BIOFUELS
BIOGAS

With support from

Federal Ministry
of Food
and Agriculture

by decision of the
German Bundestag

FNR
Fachagentur Nachwachsende Rohstoffe e.V.

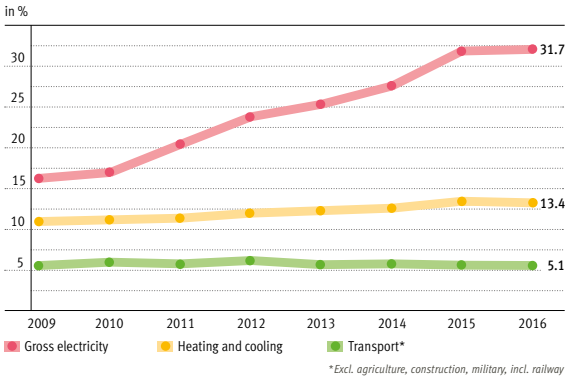
RENEWABLE ENERGIES (BIOENERGY)

Targets of the German Federal Government for renewable energies

Share of	2016	Targets 2020
Primary energy consumption	12.6 %	18 %
Electricity consumption	31.7 %	min. 35 %
Final energy consumption Heating and cooling	13.4 %	14 %
Final energy consumption Transport	Transport (incl. electricity) 5.1 %	6 % GHG savings in the transport sector by biofuels

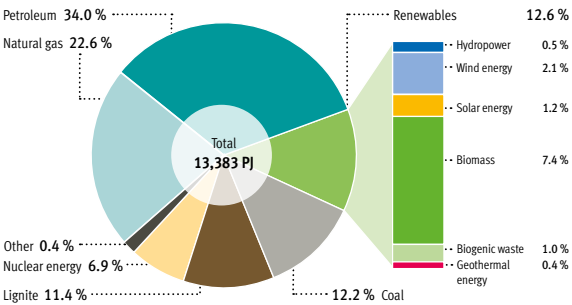
Source: FNR based on AGEE-Stat (February 2017)

Growth of renewable energies in relation to final energy consumption 2016



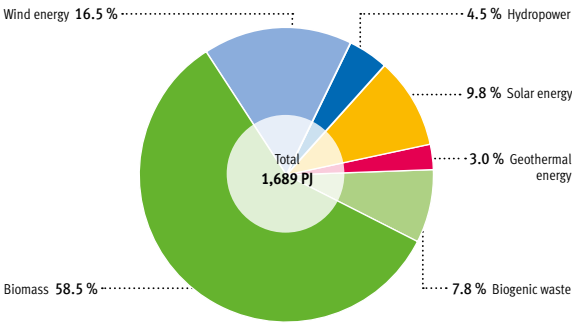
Source: BMWi, AGEE-Stat (February 2017)

Primary energy consumption 2016



Source: FNR based on ZSW/AGEB (January 2017)

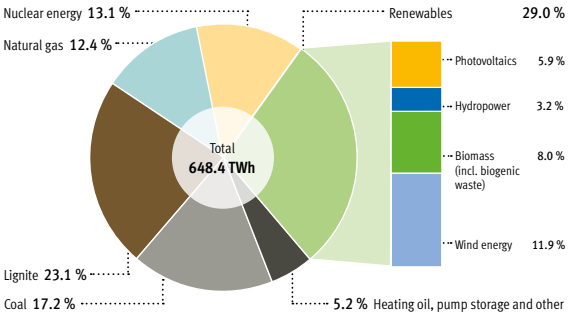
Primary energy consumption of renewables 2016



Source: FNR based on ZSW/AGEB (January 2017)

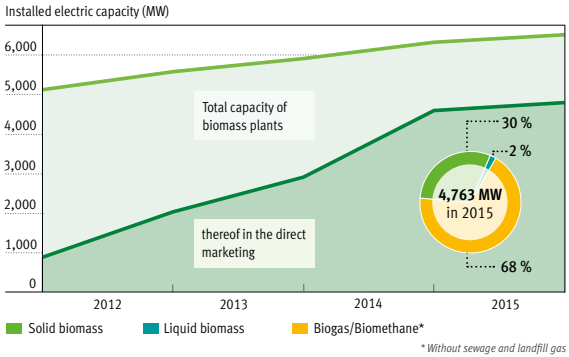
Gross electricity generation 2016

Gross electricity generation: 648.4 TWh – Renewables: 29.0 %
Gross electricity consumption: 594.7 TWh – Renewables: 31.7 %
(Difference: 53.7 TWh electricity export balance in 2016)



Source: FNR based on AGEB (February 2017)

Direct marketing of electricity from biomass

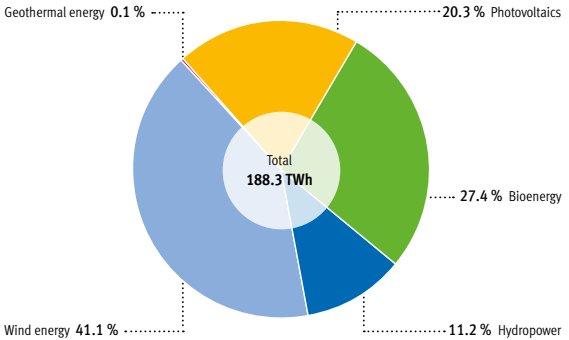


** Without sewage and landfill gas*

Source: Fraunhofer IWES, www.netztransparenz.de, AGEE-Stat (2016)

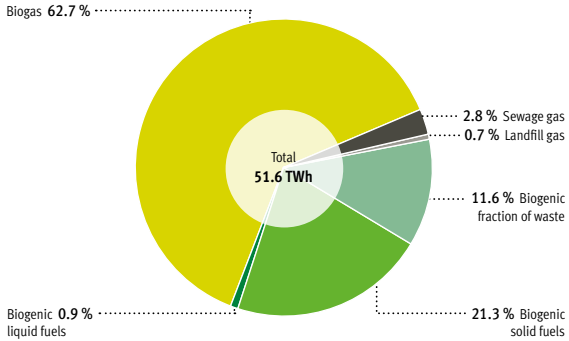
Electricity generation from renewable energies 2016

Share of bioenergy 27.4 %



Source: BMWi, AGEE-Stat (February 2017)

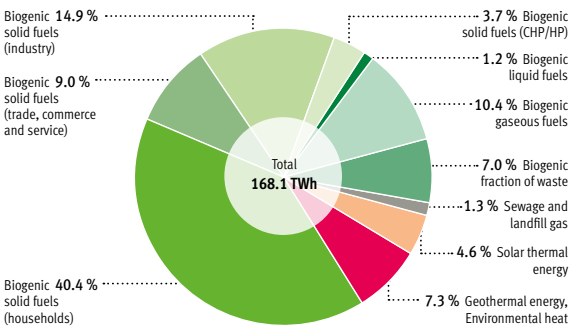
Electricity generation from biomass 2016



Source: BMWi, AGEE-Stat (February 2017)

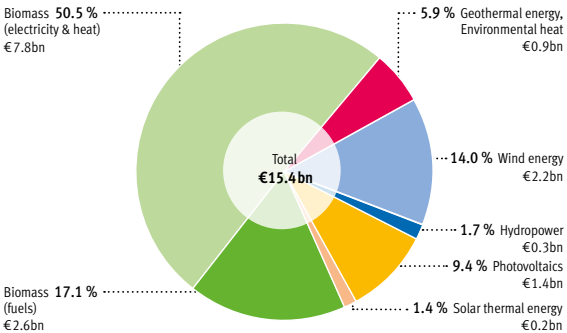
Heat from renewable energies

Share of bioenergy 88.1 % – corresponds to approx. 13.4 % of the total heat supply



Source: BMWi, AGEE-Stat (February 2017)

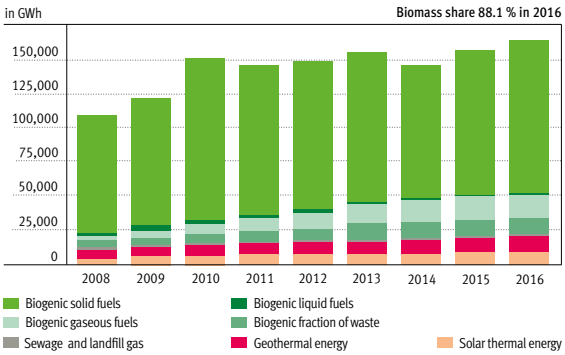
Total turnover from renewable energy sources 2016



Source: BMWi, AGEE-Stat (February 2017)

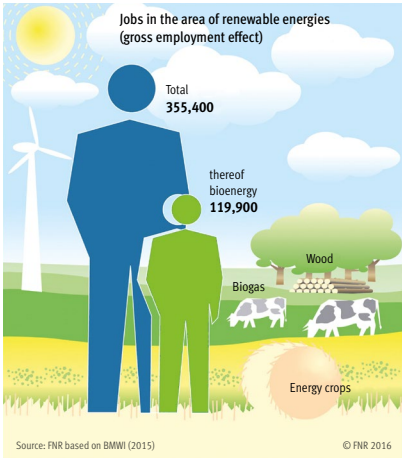
Heat from renewable energies: Development

168 TWh in 2016 – thereof 88.1 % or 148 TWh from biomass



Source: BMWi, AGEE-Stat (February 2017)

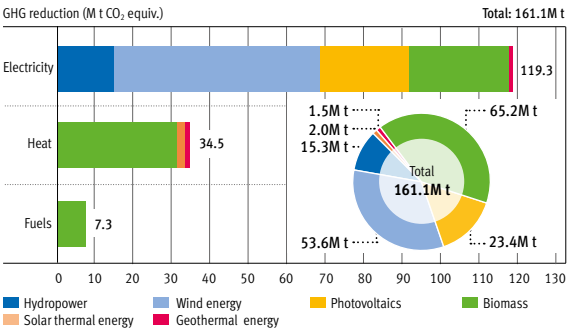
Economic factor bioenergy



Source: FNR based on BMWI (2015)

Avoidance of GHG emissions by the use of renewable energies 2016

Total avoidance of GHG emissions: 161.1M t – through biomass 65.2M t or approx. 40.5 %



GHG: Greenhouse gas

Source: AGEE-Stat (August 2017) and BLE (October 2017)

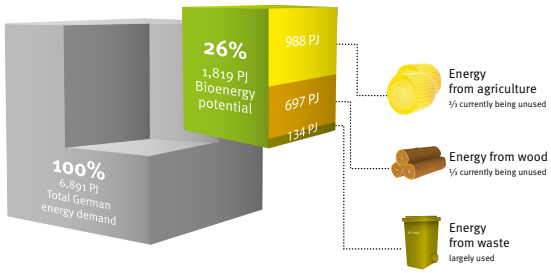
Greenhouse gases (GHG) in CO_2 equivalent include CO_2, CH_4 and N_2O.

GHG avoidance by bioenergy 2016

	GHG avoidance in 1,000 t CO_2 equiv.			
	Electricity	**Heat**	**Fuels**	**Total**
Solid biofuels	12,045	27,009	n/a	39,054
Liquid biofuels	230	346	7,241	7,817
Biogas	14,628	3,650	75	18,353
Total	**26,903**	**31,005**	**7,316**	**65,224**

Source: FNR based on AGEE-Stat (August 2017) and BLE (October 2017)

Domestic bioenergy: Potential 2050

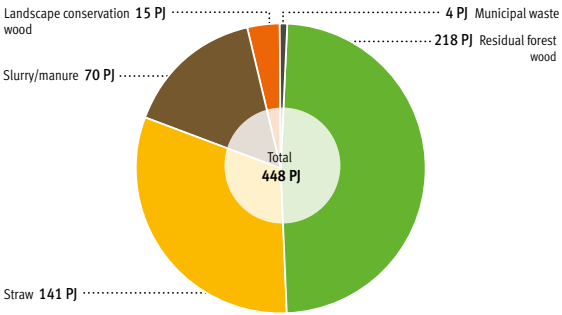


Rounded figures

Source: FNR

Domestic biomass will contribute substantially to the energy supply in Germany. It can cover up to 26 % of the need for heat, electricity and fuels in 2050. Energy from agriculture, from wood and from waste offers the potential to generate energy to a large extent sustainably.

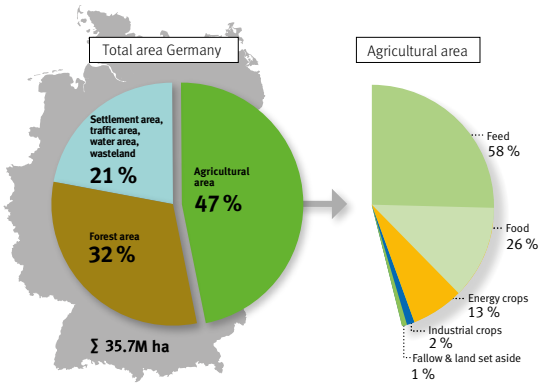
Unused potentials from biogenic residual and waste materials



Source: DBFZ (2015)

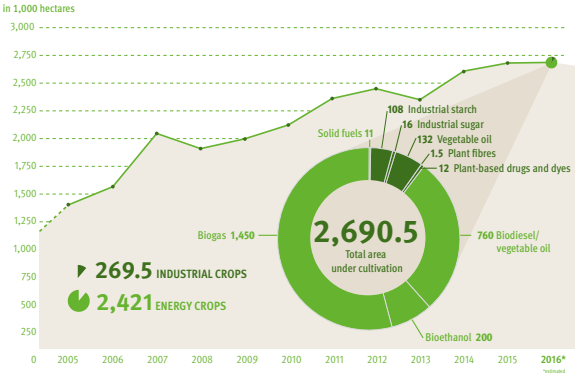
CULTIVATION OF RENEWABLE RESOURCES

Land use in Germany



Source: FNR based on Statistisches Bundesamt, BMEL (2015)

Cultivation of renewable resources in Germany



Source: FNR (2017)

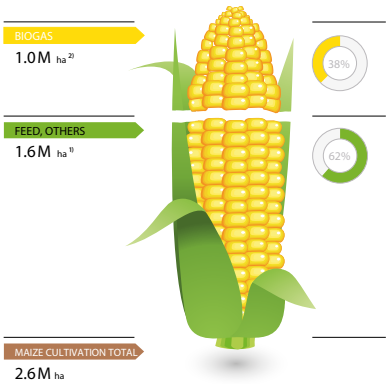
Cultivation of renewable resources in Germany 2015/2016 (in hectares)

Plants	Feedstock	2014	2015*	2016**
Industrial crops	Industrial starch	106,000	108,500	108,000
	Industrial sugar	12,500	15,000	16,000
	Technical rapeseed oil	115,500	129,000	122,500
	Technical sunflower oil	6,000	6,500	6,000
	Technical linseed oil	3,500	3,500	3,500
	Plant fibres	1,000	1,500	1,500
	Plant-based drugs and dyes	12,000	12,000	12,000
	Industrial crops total	**256,500**	**276,000**	**269,500**
Energy crops	Rapeseed oil for biodiesel/ vegetable oil	798,500	800,000	760,000
	Crops for bioethanol	188,000	200,000	184,000
	Crops for biogas	1,353,500	1,400,000	1,450,000
	Crops for solid fuels (e. g. farmed wood, miscanthus)	10,500	11,000	11,000
	Energy crops total	**2,350,500**	**2,411,000**	**2,421,000**
Total acreage of renewable resources		**2,607,000**	**2,687,000**	**2,690,500**

Source: FNR (2017)

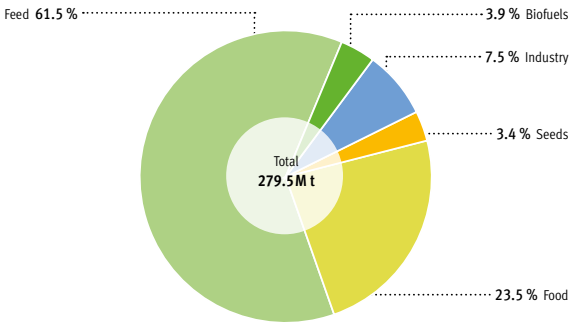
** Preliminary values; **Estimated values*

Cultivation of maize (crop year 2016)



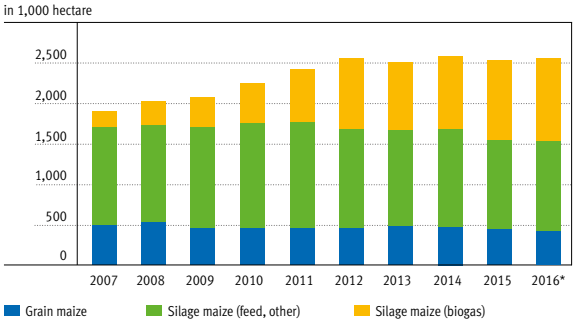
Source: 1) Statistisches Bundesamt (2017), 2) DMK/FNR e. V.

Use of cereals in the EU-28 (2014/15)



Source: European Commission (2015)

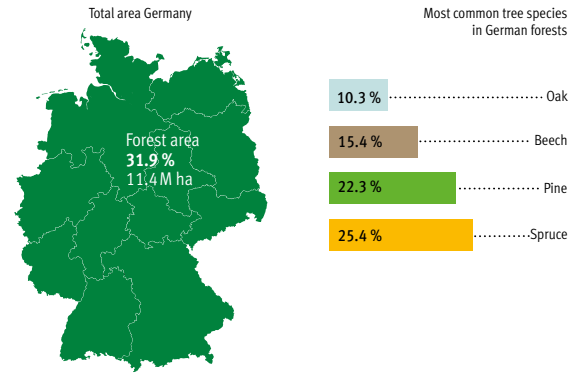
Development of the cultivation area of maize



** Outlook*

Source: FNR based on Stat. Bundesamt, DMK, BDBe, BLE, VDGS

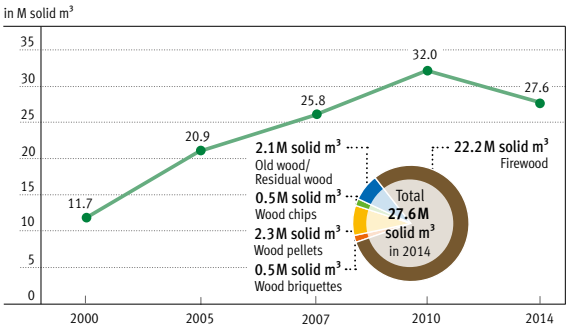
German forest in figures



Source: BMEL (2014)

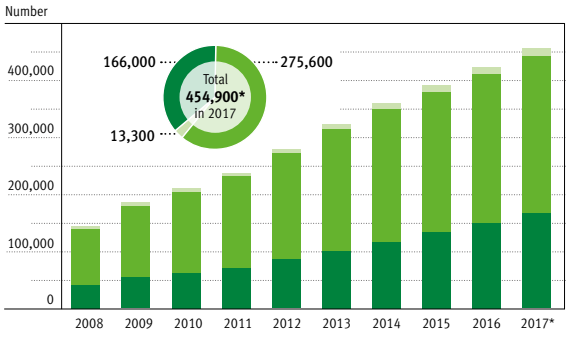
SOLID FUELS

Use of energy wood in private households



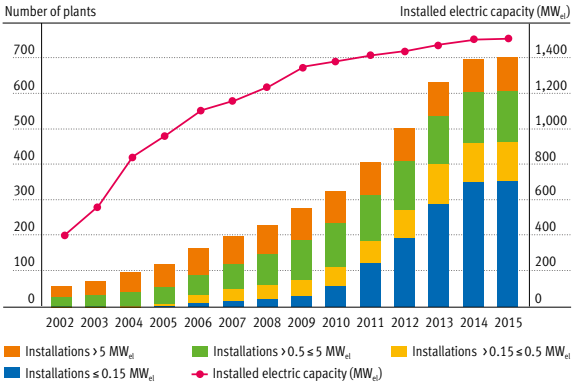
Source: P. Döring, S. Glasenapp, U. Mantau: "Energieholzverwendung in privaten Haushalten 2014" (2016) © FNR 2016

Installed pellet boilers in Germany



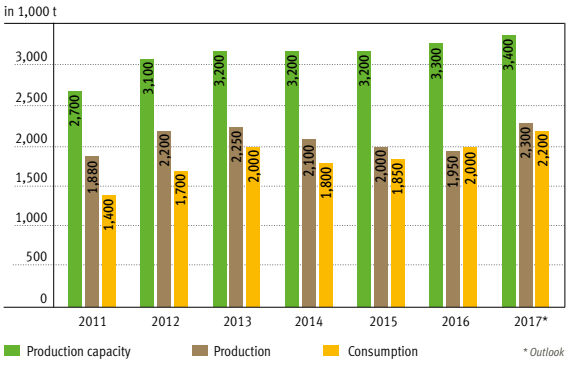
Source: Deutsches Pelletinstitut (February 2017) © FNR 2017

Number of biomass power plants and installed electric capacity



Source: DBFZ (2017) based on EEG monitoring © FNR 2017

Wood pellets – Production and consumption



Source: Deutsches Pelletinstitut (2017) © FNR 2017

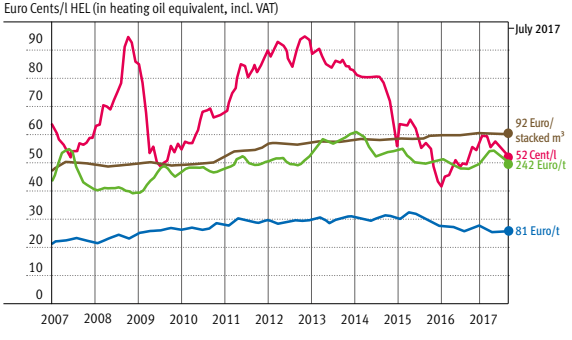
Equivalent prices of wood fuels with regard to the heating value

Heating oil in €/litre	Wood pellets (w ‹10 %) in €/t	Beech logs (w = 15 %) in €/stacked m³	Spruce chips (w = 30 %) in €/loose m³
0.4	200	76	30
0.5	250	95	37
0.6	300	114	45
0.7	350	133	52
0.8	400	152	60
0.9	450	172	76
1.0	500	191	75
1.1	550	210	82
1.2	600	229	89

Source: FNR (2016)

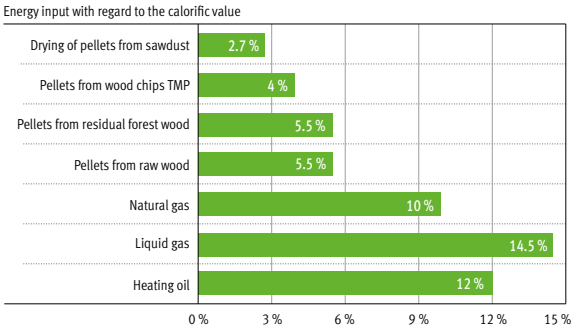
Fuel prices are compared with regard to the lower heating value.

Development of energy prices



Source: FNR based on TFZ (2017)

Energy input for preparation of fuels



TMP: Thermo-Mechanical-Pulping

Source: Deutsches Pelletinstitut, H. Schellinger, J. Bergmair (TU Graz)

Standardisation of solid biofuels

Fuel specifications and classes

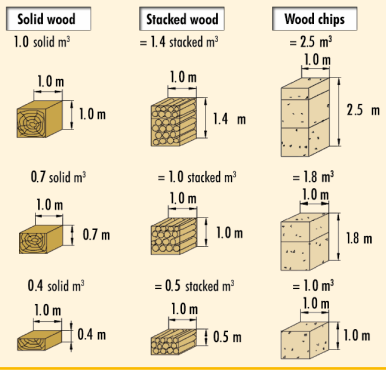
Fuel	Standard
General requirements	DIN EN ISO 17225-1:2014-09
Wood pellets	DIN EN ISO 17225-2:2014-09
Wood briquettes	DIN EN ISO 17225-3:2014-09
Wood chips	DIN EN ISO 17225-4:2014-09
Firewood	DIN EN ISO 17225-5:2014-09
Non-wooden pellets*	DIN EN ISO 17225-6:2014-09

Source: Beuth Verlag

** Stalk-type biomass; fruit biomass; defined and undefined biomass blends*

General conversion factors for wood quantities

	$t_{abs\ dry}$	Solid m^3	Stacked m^3	Loose m^3
1 $t_{abs\ dry}$	1.0	1.3–2.5	2.9	4.9
1 Solid m^3	0.4–0.7	1.0	1.4	2.5
1 Stacked m^3	0.3	0.7	1.0	1.8
1 Loose m^3	0.2	0.4	0.5	1.0



Note

The undimensioned edge length amounts to 1 m each.

Abbreviations

abs dry: Absolutely dry (0 % water content)

Solid m^3: Common measure in the forestry and timber industry for one cubic metre of solid wood without gaps.

Stacked m^3: Common measure in the forestry and timber industry for one cubic metre of stacked wood including air spaces.

Loose m^3: Common measure in the forestry and timber industry for one cubic metre of poured wood parts (e. g. wood chips, bulk material).

Source: Handbuch Bioenergie Kleinanlagen, FNR (2013) and own calculations

Calculation of water content and wood moisture

$$\text{Water content w [\%]} = \frac{\text{Weight of water [kg]}}{\text{Weight of moist wood [kg]}} \cdot 100$$

$$\text{Wood moisture u [\%]} = \frac{\text{Weight of water [kg]}}{\text{Weight of dry wood [kg]}} \cdot 100$$

Water content in %	10	15	20	25	30	40	50
Wood moisture in %	11	18	25	33	43	67	100

Calculation of the heating value of the moist total mass

$$H_i\,(w) = \frac{H_i\,(wf) \cdot (100 - w) - 2.44 \cdot w}{100}$$

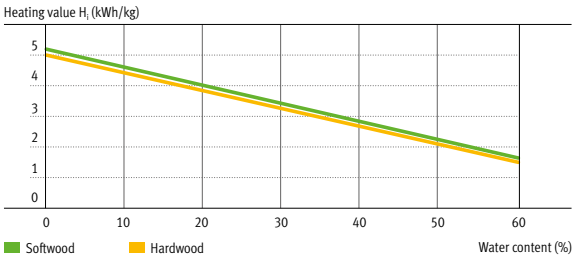
H_i (w): Heating value of wood (in MJ/kg) at a water content w

H_i (wf): Heating value of the wood dry matter in MJ/kg in anhydrous state

2.44: Evaporation heat of water in MJ/kg at 25 °C

w: Water content in %

Heating value of wood depending on the water content



Source: Bayerisches Landesanstalt für Forstwirtschaft (Merkblatt 12)

Typical mass and energy yields in agriculture and forestry

	Mass yield (w = 15 %) in t/(ha •a)	Average heating value H_i (w = 15 %) in MJ/kg	Gross annual fuel yield in GJ/(ha • a)	Heating oil equivalent in l/(ha •a)
Residual materials				
Residual forest wood	1.0	15.6	15.6	433
Grain straw	6.0	14.3	85.8	2,383
Rapeseed straw	4.5	14.2	63.9	1,775
Hay from landscape conservation	4.5	14.4	64.8	1,800
Energy crops				
Short rotation plantations	12.0	15.4	185.0	5,133
Whole grain plants	13.0	14.1	183.0	5,092
Forage grasses	8.0	13.6	109.0	3,022
Miscanthus	15.0	14.6	219.0	6,083

Source: Leitfaden Feste Biobrennstoffe, FNR (2014)

Biofuels in comparison with heating oil

Heating values and densities of selected fuels in comparison

Fuel	Density	Energy content in		Oil equivalent in	
		kWh/kg	kWh/l	l/l_{OE}	kg/kg_{OE}
Heating oil	0.85 kg/l	11.83	10.06	1.00	0.98
Rapeseed oil	0.92 kg/l	10.44	9.61	1.04	1.14
Coal (w = 5.1 %)	860 kg/m³	8.25	7.10	1.40	1.21
Ethanol	0.79 kg/l	7.41	5.85	1.70	1.35
Wood pellets (w = 10 %)	664 kg/m³	5.00	3.32	3.00	1.99
Straw pellets (w = 10 %)	603 kg/m³	4.90	2.95	3.37	2.03
Beech logs 33 cm (w = 15 %)	445 kg/ stacked m³	4.15	1.85	5.40	2.40
Spruce logs 33 cm (w = 15 %)	304 kg/ stacked m³	4.33	1.32	7.56	2.30
Pine chips (w = 15 %)	203 kg/m³	4.33	0.88	11.33	2.30
Spruce sawdust (w = 15 %)	160 kg/m³	4.33	0.69	14.37	2.30
Whole grain plants (w = 15 %)	150 kg/m³	3.92	0.59	16.96	2.54
Grain straw, big bales (w = 15 %)	140 kg/m³	3.96	0.55	17.98	2.52
Miscanthus, chopped (w = 15 %)	130 kg/m³	4.07	0.53	18.85	2.45

Source: FNR

w: Water content; l: Litre; OE: Oil equivalent

Combustion data for solid, liquid and gaseous biofuels

Fuel	Quantity/ Unit	Water content w in %	Mass (incl. water) in kg	Heating value (at w) in MJ/kg	Quantity of fuel in		
					MJ	kWh	Heating oil equivalent (l)
Logs (stacked)*							
Beech 33 cm, air-dry	1 stacked m^3	15	445	15.3	6,797	1,888	189
Beech 33 cm, surface dry	1 stacked m^3	30	495	12.1	6,018	1,672	167
Spruce 33 cm, air-dry	1 stacked m^3	15	304	15.6	4,753	1,320	132
Spruce 33 cm, surface dry	1 stacked m^3	30	349	12.4	4,339	1,205	121
Wood chips*							
Beech, dry	m^3	15	295	15.3	4,503	1,251	125
Beech, limitedly storable	m^3	30	328	12.1	3,987	1,107	111
Spruce, dry	m^3	15	194	15.6	3,032	842	84
Spruce, limitedly storable	m^3	30	223	12.4	2,768	769	77
Pellets							
Wood pellets, by volume	m^3	8	650	17.1	11,115	3,088	309
Wood pellets, by weight	1 t	8	1,000	17.1	17,101	4,750	475
Fuels by weight							
Beech, air-dry	1 t	15	1,000	15.3	15,274	4,243	424
Beech, surface dry	1 t	30	1,000	12.1	12,148	3,374	337
Spruce, air-dry	1 t	15	1,000	15.6	15,614	4,337	434
Spruce, surface dry	1 t	30	1,000	12.4	12,428	3,452	345
Stalk-type biomass (e. g. straw)	1 t	15	1,000	14.3	14,254	3,959	396
Biofuels							
Rapeseed oil	m^3	< 0.1	920	37.6	34,590	9,609	961
Biodiesel (Rapeseed oil methyl ester)	m^3	< 0.03	880	37.1	32,650	9,093	909
Biogas	m^3	2–7	1.2	15–22.5	18–27	5–7.5	0.6

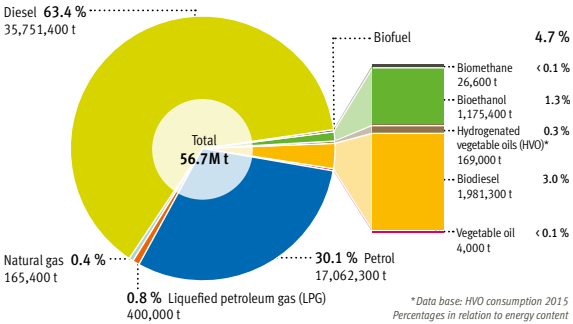
Source: Handbuch Bioenergie-Kleinanlagen, FNR (2013) and own calculations

** The occurring change of volume below 25 % water content was considered.*

BIOFUELS

Fuel consumption in the transport sector 2016

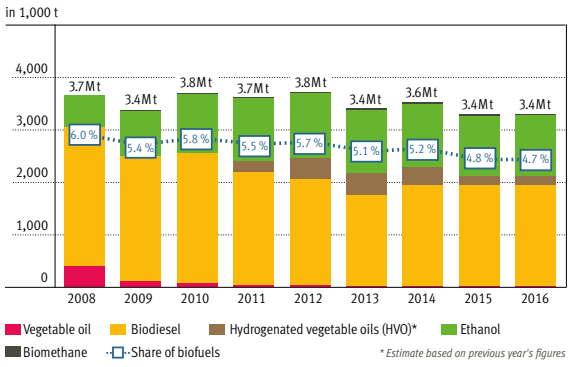
Biofuel share 4.7 % (by energy)



Source: FNR based on BAFA, Destatis, DVFG, BDEW, BLE (July 2017)

In Germany 56.7 million t fuels were used in the transport sector in 2016. Besides Diesel with 63.4 % and petrol with 30.1 % the share of biofuels amounted to 4.7 % or rather 3.4 million t.

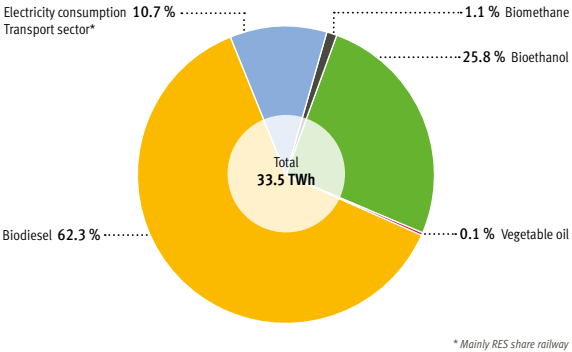
Development of biofuel consumption



Source: BAFA, BMF, AGEE-Stat, FNR (July 2017)

Renewable energies in the transport sector 2016

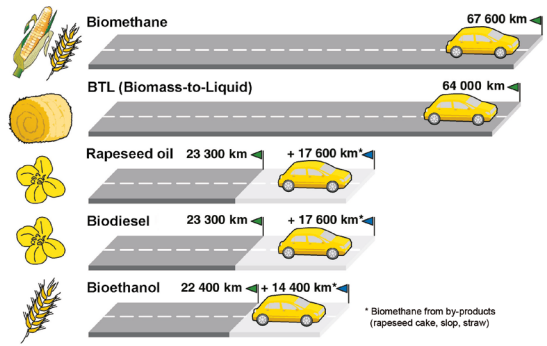
Share of renewable energies 5.1 % (energetically)



Source: FNR based on AGEE-Stat (February 2017)

Biofuels in comparison

Range of a passenger car with biofuels from 1 ha cropland



Passenger car fuel consumption: petrol 7.4 l/100 km; diesel 5.1 l/100 km

Source: FNR

Biodiesel (raw materials for production)

Raw materials	Biomass yield (FM) [t/ha]	Biodiesel yield [l/t BM]	Biodiesel yield [l/ha]	Required biomass per litre of fuel [kg/l]
Rapeseed oil	3.9	455	1,775	2.2
Palm oil	20.0	222	4,440	4.5
Soya oil	2.9	222	644	4.5
Jatropha oil	2.5	244	610	4.1

Source: Meo, FNR, harvest report of BMEL (2015)

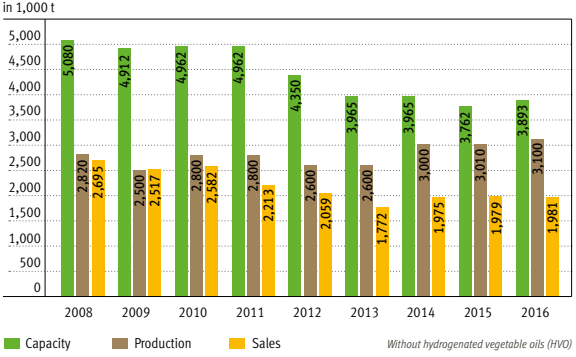
FM: Fresh matter; BM: Biomass

Sales of biodiesel

Sales (in 1,000 t)	2011	2012	2013	2014	2015	2016
Admixture	2,116	1,928	1,741	1,970	1,972	1,981
Pure biofuels	97	131	30	5	3	< 1
Total sales	2,213	2,059	1,772	1,975	1,975	1,981

Source: BAFA, BMF, FNR (July 2017)

Biodiesel production and sales



Without hydrogenated vegetable oils (HVO)

Source: FNR, BLE, BAFA, UFOP, AGQM, VDB (2017)

Bioethanol (raw materials for production)

Raw materials	Biomass yield (FM) [t/ha]	Bioethanol yield [l/t BM]	Bioethanol yield [l/ha]	Required biomass per litre of fuel [kg/l]
Grain maize	9.9	400	3,960	2.5
Wheat	7.7	380	2,926	2.6
Rye	5.4	420	2,268	2.4
Sugar beets	70.0	110	7,700	9.1
Sugar cane	73.0	88	6,424	11.4
Straw	7.0	342	2,394	2.9

Source: Meo, FNR, BDBe, harvest report of BMEL (2015)

FM: Fresh matter; BM: Biomass

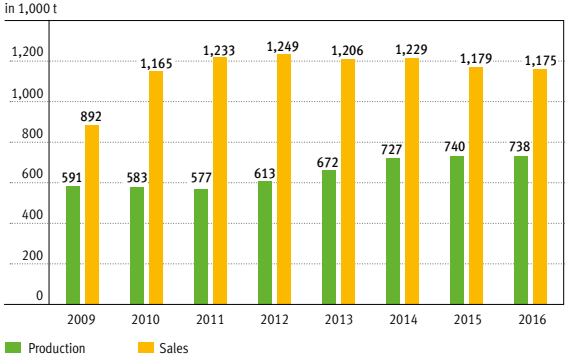
Sales of bioethanol

Sales (in 1,000 t)	2011	2012	2013	2014	2015	2016
E 85 (ethanol share)	19 (16)	21 (17)	14 (11)	10 (8)	7 (6)	n/a
Ethanol*	1,054	1,090	1,041	1,082	1,054	1,047
ETBE**	162	142	154	139	119	129
Total sales	1,233	1,249	1,206	1,229	1,179	1,175

Source: FNR based on BAFA (July 2017)

** Only share of ethanol considered; ** ETBE: Ethyl tert-butyl ether; Bioethanol share by volume of ETBE = 47 %*

Bioethanol production and sales



Source: BAFA, BDBe (July 2017)

Vegetable oils (fuel characteristics)

Vegetable oil	Density (15 °C) in kg/l	Heating value in MJ/kg	Kinetic viscosity (40 °C) in mm²/s	Pour point in °C	Flash point in °C	Iodine value
Requirements DIN 51605 (rapeseed oil fuel)	0.910–0.925	min. 36.0	max. 36.0	n/a	min. 101	max. 125
Requirements DIN 51623 (vegetable oil fuel)	0.900–0.930	min. 36.0	max. 35.0*	n/a	min. 101	max. 140
Rapeseed oil	0.92	37.6	34.0	–2 to –10	› 220	94 to 113
Sunflower oil	0.92	37.1	29.5	–16 to –18	› 220	118 to 144
Soya oil	0.92	37.1	30.8	–8 to –18	› 220	114 to 138
Olive oil	0.92	37.8	n/a	–5 to –9	› 220	76 to 90
Jatropha oil	0.92	36.8	30.5	2 to –3	› 220	102
Coconut oil	0.92	35.3	n/a	14 to 25	› 220	7 to 10
Palm oil	0.92	37.0	26.9	27 to 43	› 220	34 to 61
Camelina oil	0.92	37.0	30.2	–11 to –18	› 220	149 to 155
Palm kernel oil	0.93	35.5	n/a	20 to 24	› 220	14 to 22

Source: TFZ, ASG, FNR (2015)

** Kinematical viscosity at 50 °C*

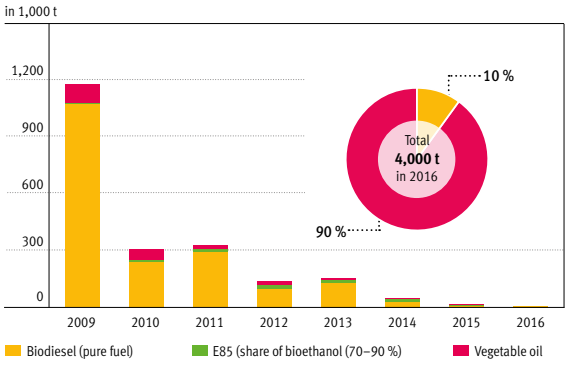
Comparison of centralised and decentralised vegatable oil production

Oil extraction from 1 t rapeseed*		decentralised	centralised
Proportion of oil extracted	[%]	80	99
Oil yield	[kg/t oilseed]	336	416
Rapeseed cake yield	[kg/t oilseed]	660	–
Extracion meal yield	[kg/t oilseed]	–	580
Oil yield	[l/t oilseed]	365	452
Oil yield	[l/ha]	1,420	1,760

Source: TFZ, FNR

** Seed oil content 42 %*

Sales of pure biofuels in Germany



Source: FNR based on BAFA (July 2017)

Biomethane

In Germany a network of more than 900 natural gas filling stations is available for currently more than 98,000 natural gas vehicles. Thereof 150 filling stations offer 100 % biomethane and more than 300 filling stations mixtures from biomethane and natural gas.

Sales of biomethane as fuel

	2011	2012	2013	2014	2015	2016
Sales in GWh	190	404	557	453	385	370

Source: AGEE-Stat (February 2017)

Sales of natural gas as fuel: 2,300 GWh in 2014

Biomass to liquid (Btl)

Btl belongs, just like Gtl (Gas to liquid) and Ctl (Coal to liquid), to the synthetic fuels, whose ingredients are precisely tailored to the needs of modern engines.

Raw materials for production of Btl fuels

Raw materials	Yield (FM) [t/ha]	Fuel yield [l/ha]	Required biomass per litre of fuel [kg/l]
Energy crops	15–20	4,030	3.7
Straw	7	1,320	5.3

Source: Meó, FNR (2009 – Biokraftstoffe – eine vergleichende Analyse)

FM: Fresh matter

Fuel comparison: Characteristics of biofuels

Fuel	Density [kg/l]	Heating value [MJ/kg]	Heating value [MJ/l]	Viscosity at 20 °C [mm²/s]	Cetane number	Octane number (RON)	Flash point [°C]	Fuel equivalence[h] [l]
Diesel	**0.83**	**43.1**	**35.87**	**5.0**	**50**	**–**	**80**	**1**
Rapeseed oil fuel	0.92	37.6	34.59	74.0	40	–	317	0.96
Biodiesel	0.88	37.1	32.65	7.5	56	–	120	0.91
Hydrogenated vegetable oils (HVO)[f]	0.78	44.1	34.30	› 3.5[g]	› 70	–	60	–
Biomass-to-Liquid (BtL)[a]	0.76	43.9	33.45	4.0	› 70	–	88	0.97
Petrol	**0.74**	**43.9**	**32.48**	**0.6**	**–**	**92**	**‹ 21**	**1**
Bioethanol	0.79	26.7	21.06	1.5	8	› 100	‹ 21	0.65
Ethyl tert-butyl ether (ETBE)	0.74	36.4	26.93	1.5	–	102	‹ 22	0.83
Biomethanol	0.79	19.7	15.56	–	3	› 110	–	0.48
Methyl tert-butyl ether (MTBE)	0.74	35.0	25.90	0.7	–	102	–28	0.80
Dimetyl ether (DME)	0.67[b]	28.4	19.03	–	60	–	–	0.59
Biomethane	0.72[e]	50.0	36.00[c]	–	–	130	–	1.5[d]
Biohydrogen	0.09[e]	120.0	10.80[c]	–	–	‹ 88	–	3.6[d]

Source: FNR

[a] *Basis Fischer-Tropsch-Fuels;* [b] *at 20 °C;* [c] *[MJ/m³];* [d] *[kg];* [e] *[kg/m³];* [f] *Source: VTT;* [g] *at 40 °C;*
[h] *Example: 1 l Biodiesel corresponds to 0.91 l Diesel • 1 kg Biohydrogen corresponds to 3.6 l petrol (when used by fuel cell 7 l)*

EU target 2020

The European directive on the promotion of the use of energy from renewable sources (Directive 2009/28/EC) defines binding targets for biofuels and regulates their sustainability.

- 10 % renewable energies in final energy consumption

The "Fuel Quality Directive" (98/70/EC) defines binding targets for GHG savings of fuels as well as sustainability criteria.

- 6 % GHG savings of marketed fuels

Germany – Target 2020

6 % GHG savings by biofuels marketed in 2020 – basis are reference values for petrol and diesel.

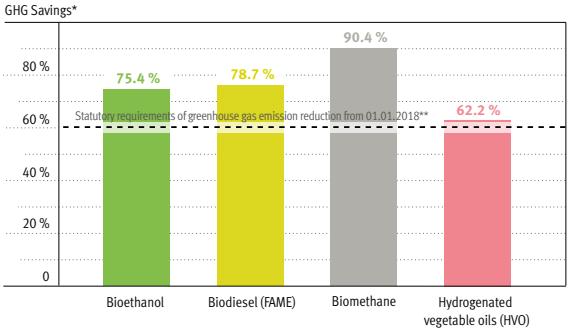
GHG: Greenhouse gas

New requirements for the EU member states

Options for implementation according Directive 2009/28/EC and 2015/1513[a]	Share to count towards the targets (in terms of energy content)
Biofuels from cultivated biomass (from grain, starch, sugar or oil plants)	Limitation to max. 7 %
"propspective biofuel options"	0.5 % (non-binding target)
Electromobility	– rail transport: 2.5-fold counting – road transport: 5-fold counting

[a] Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources and Directive (EU) 2015/1513 of 9 September 2015; [b] Directive 98/70/EC relating the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable resources

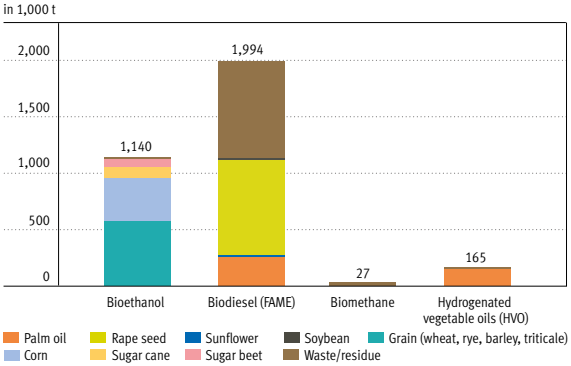
Greenhouse gas emission savings of biofuels



** Average greenhouse gas emission reduction compared to reference of fossil fuels (83.8 g CO_2 equiv./MJ).*
*** Applies to biofuel plants that started operation after Oct. 5th 2015 (50 % for previously implemented plants).*

Source: BLE (2017)

Biofuel production Germany 2016: raw materials



Source: BLE (2017)

Sustainability of biofuels

Requirements on the sustainability of biofuels and electricity from liquid biomass apply since January 2011. The criteria are defined in the German Biofuel Sustainability Regulation and the Sustainability Ordinance for Bioelectricity.

Biofuels must fulfil sustainability criteria along the whole manufacturing and distribution chain. For plants for manufacturing of biofuels apply GHG savings compared to fossil fuels of:

- 35 % until 2017 and 50 % from 2018 (plants which have been put into operation until 5 October 2015)
- 60 % (plants which have been put into operation after 5 October 2015)

Directive (EU) 2015/1513 of 9 September 2015 amending Directive 98/70/EC and Directive 2009/28/EC

Federal Immission Control Act (BImSchG)

(national implementation of the Fuel Quality Directive 98/70/EC)

Year	Diesel quota	Petrol quota	Total quota
from 2017	Decarbonisation 4.0 %		
from 2020	Decarbonisation 6.0 %		

Source: FNR based on BImSchG

Energy tax	
Diesel	47.04 Cent/l
Petrol	65.45 Cent/l
Biodiesel and vegetable oil fuel	45.03 Cent/l
Ethanol/E85	65.45 Cent/l

Gaseous fuels

→ Biomethane as fuel, Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG): reduced tax rate of 13.90 Euro per MWh until 2023

→ Liquified Petroleum Gas (LPG): reduced tax rate of 18.00 Cent/kg – progressive reduction of the tax benefit from 2019 until 2023

Fuel standardisation

The composition and quality labelling of fuels are regulated by the Federal Imission Protection Act (10. BImSchV).

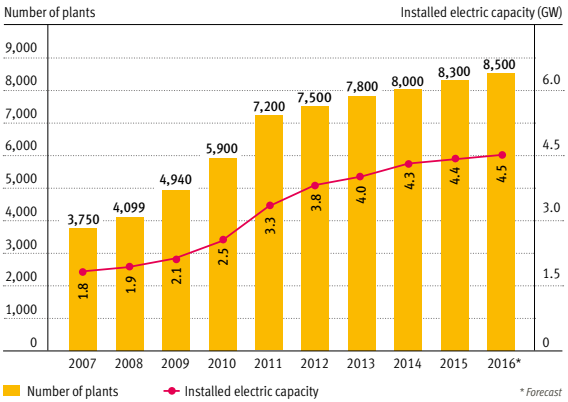
Fuel	Standard	Notes
Diesel (B 7)	DIN EN 590	Diesel with up to 7 vol% Biodiesel (Status: 04/2014)
Biodiesel (B 100)	DIN EN 14214	Fatty acid methyl esters (FAME) for diesel engines (Status: 06/2014)
Rapeseed oil fuel	DIN 51605	Rapeseed oil fuel for engines suitable for vegetable oils (Status: 01/2016)
Vegetable oil fuel	DIN 51623	Fuels for engines suitable for vegetable oils "Vegetable oil fuel" Requirements and test methods (Status: 12/2015)
Petrol (E 5)	DIN EN 228	Unleaded petrol with up to 5 vol% ethanol or rather 15 vol% ETBE (Status: 10/2014)
Petrol (E 10)	DIN EN 228	Petrol E 10 – with up to 10 vol% ethanol (Status: 10/2014)
Ethanol	DIN EN 15376	Ethanol as blend component in petrol (Status: 12/2014)
Ethanol (E 85)	DIN 51625	– min. 75 to max. 86 vol% ethanol – class A (summer) – min. 70 to 80 vol% ethanol – class B (winter)
Natural gas & Biomethane	DIN EN 16723-2	Biomethane must fulfill the standard for natural gas as fuel – a mixture of biomethane and natural gas is possible in any proportion (Status: 06/2014)

Source: FNR (July 2016)

vol%: Percentage by volume

BIOGAS

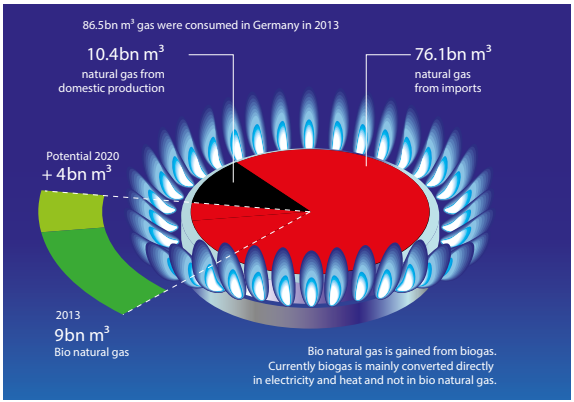
Biogas production plant sites in Germany



Without biomethan production sites

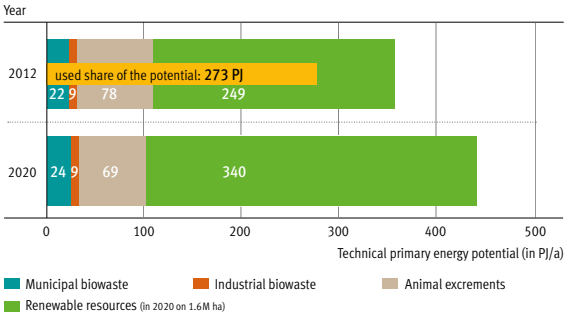
Source: DBFZ (2017)

Biogas – remarkable great potentials



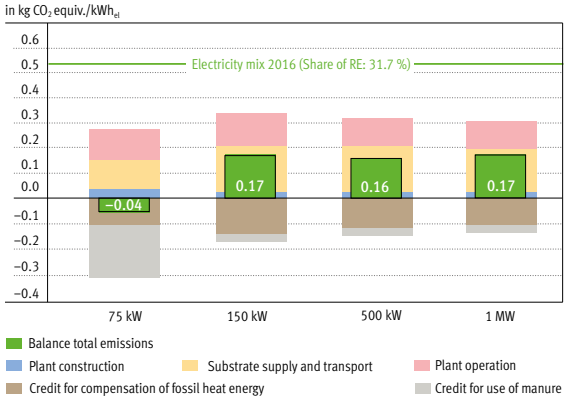
Source: AGEE, DBFZ, BMWi, AGEB, FNR (2014)

Technical primary energy potential for biogas



Source: FNR based on DBFZ (2014)

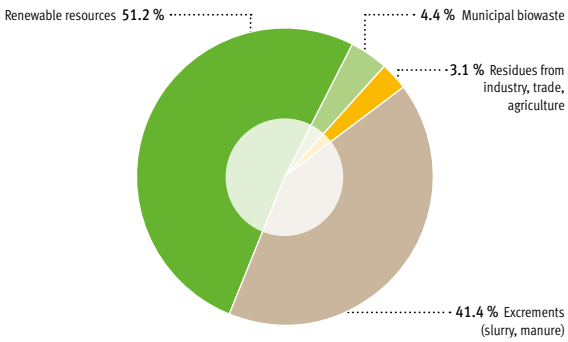
Greenhouse gas emissions of biogas plants in comparison to the German electricity mix



Source: KTBL (2011), UBA, AGEE-Stat (2017)

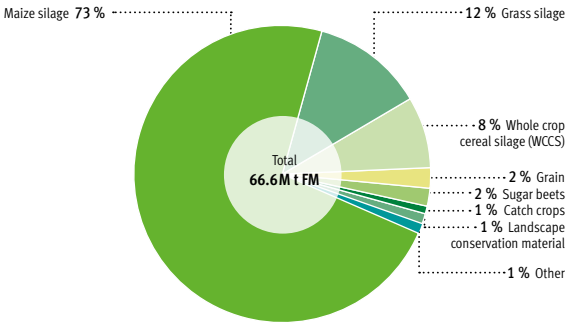
For further information visit "Grafiken Biogas" at https://mediathek.fnr.de

Substrate input in biogas plants 2015 (mass related)



Source: DBFZ Betreiberbefragung Biogas (2016)

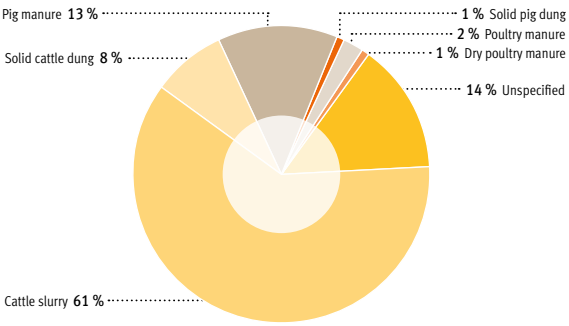
Renewable resource in biogas plants – mass related substrate input 2015



FM: Fresh matter

Source: DBFZ Betreiberbefragung Biogas (2016)

Farm manure in biogas plants – mass related substrate input 2014



Source: Stromerzeugung aus Biomasse, DBFZ (2015)

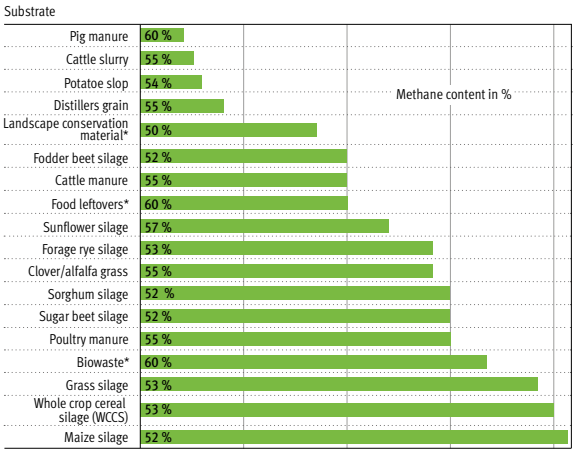
Theoretical electricity potential of different energy crops (in hectare)

Energy crop	Harvest yield [t FM]	Methane yield [Nm³]	Electricity yield [kWh]	Number of households supplied
Maize	50	4,945	18,731	5.2
Sugar beets	65	4,163	15,769	4.4
Whole crop cereal silage (WCCS)	40	3,846	14,568	4.0
Cup plant	55	3,509	13,291	3.7
Grassland	29	2,521	9,549	2.7

Source: FNR based on KTBL (2014)

Assumptions: average yields, 12 % storage losses, for sugar beets 15 % (lagoon); CHP efficiency rate 38 %; Electricity consumption 3,600 kWh/a • household

Biogas yields of selected substrates



** Varies widely*

Source: KTBL (2015)

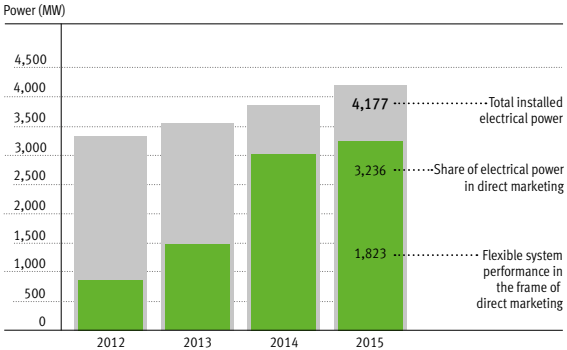
Energy supply from biogas

Year	Electricity generation [GWh]	Heat generation [GWh]
2008	11,001	3,495
2009	13,249	5,352
2010	15,656	8,033
2011	19,316	9,897
2012	25,477	11,951
2013	27,480	14,029
2014	29,324	15,339
2015	31,288	16,715
2016*	32,370	17,437

Source: AGEE-Stat (February 2017)

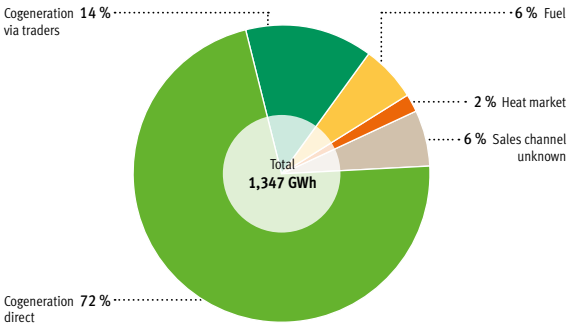
** Preliminary, without sewer gas, landfill gas and biogenic fraction of waste*

Direct marketing and flexible electricity generation



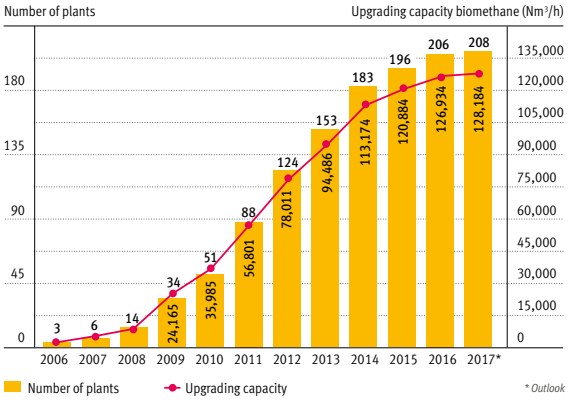
Source: Fraunhofer IWES based on BNetzA and netztransparenz.de (2016)

Marketing of biomethane 2014



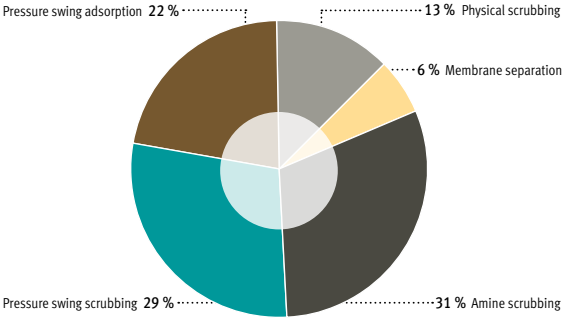
Source: "Stromerzeugung aus Biomasse", DBFZ (2015)

Plants for biomethane production



Source: FNR based on dena (September 2017)

Upgrading treatment processes in Germany



Source: FNR based on dena (2016)

Characteristic values of different biogas treatment processes

	Pressure swing adsorption (PSA)	Pressure water scrubbing (PWS)	Physical absorption*	Chemical absorption*	Membrane processes	Cryogenic processes
Electricity requirement (kWh/Nm³)	0.20–0.25	0.20–0.30	0.23–0.33	0.06–0.15	0.18–0.25	0.18–0.33
Heat requirement (kWh/Nm³)	0	0	~ 0.3	0.5–0.8	0	0
Temperature process heat (°C)	–	–	55–80	110–160	–	–
Process pressure (bar)	4–7	5–10	4–7	0.1–4	5–10	–
Methane loss (%)	1–5	0.5–2	1–4	0.1	2–8	–
After-treatment of exhaust gases required? (legislation: EEG & GasNZV)	yes	yes	yes	no	yes	yes
Fine desulphurisation of the raw gas required?	yes	no	no	yes	recommended	yes
Water demand	no	yes	no	yes	no	no
Demand for chemicals	no	no	yes	yes	no	no

Source: Fraunhofer-IWES based on DWA (2011)

** With organic solvents*

Rules of thumb

The following figures can be used as guide values for general calculations of agricultural biogas plants.

General conversion biogas and biomethane	
1 m^3 biogas	5.0–7.5 kWh energy content
1 m^3 biogas	50–75 % methane content
1 m^3 biogas	approx. 0.6 l heating oil equivalent
1 m^3 methane	9.97 kWh energy content
1 m^3 methane	heating value 36 MJ/m^3 or 50 MJ/kg
1 m^3 methane	1 l heating oil equivalent

Average composition of biogas	
Component	**Concentration**
Methane (CH_4)	50–75 vol%
Carbon dioxide (CO_2)	25–45 vol%
Water vapour (H_2O)	2–7 vol%
Hydrogen sulphide (H_2S)	20–20,000 ppm
Oxygen (O_2)	< 2 vol%
Nitrogen (N_2)	< 2 vol%
Ammonia (NH_3)	< 1 vol%
Hydrogen (H_2)	< 1 vol%
Trace gases	< 2 vol%

Biogas yield of	
Dairy cow (17 m^3 manure/ space per animal • a)	289 Nm^3 methane ≙ 1,095 kWh_{el}/space per animal • a*
Fattening pig (1.6 m^3 manure/ space per animal • a)	19 Nm^3 methane ≙ 73 kWh_{el}/space per animal • a*
Fattening cattle (2.8 t solid manure/ space per animal • a)	185 Nm^3 methane ≙ 562 kWh_{el}/space per animal • a*
Riding horse (11.1 t solid manure/ space per animal • a)	388 Nm^3 methane ≙ 1,472 kWh_{el}/space per animal • a*
Chicken (2.0 m^3 rotting manure/ 100 animal spaces • a)	164 Nm^3 methane ≙ 621 kWh_{el}/100 animal spaces • a*
1 ha silage maize (40–60 t FM**)	3,956–5,934 Nm^3 methane ≙ 14,985–22,477 kWh_{el}/ha*
1 ha sugar beets (55–75 t FM**)	3,523–4,803 Nm^3 methane ≙ 13,343–18,195 kWh_{el}/ha*
1 ha whole crop cereal silage (WCCS) (30–50 t FM**)	2,884–4,807 Nm^3 methane ≙ 10,926–18,210 kWh_{el}/ha*
1 ha cup plant (45–60 t FM**)	2,871–3,828 Nm^3 methane ≙ 10,874–14,499 kWh_{el}/ha*
1 ha sudangrass (35–55 t FM**)	2,392–3,759 Nm^3 methane ≙ 9,061–14,238 kWh_{el}/ha*
1 ha grassland (23–43 t FM**)	2,001–3,808 Nm^3 methane ≙ 7,579–14,424 kWh_{el}/ha*
1 ha grain rye (4.3–6.8 t FM**)	1,390–2,179 Nm^3 methane ≙ 5,264–8,255 kWh_{el}/ha*

Process parameters		
Temperature	*mesophilic*	32–34 °C
	thermophilic	50–57 °C
pH value	*hydrolysis/ acidogenesis*	4.5–7
	acetogenesis/ methanogenesis	6.8–8.2
Digester load		Ø 3.2 kg ODM/(m³ • d); (from 1.1–9.3)
Average hydraulic retention time	*single-stage*	22–88 days (Ø 58)
	multistage	37–210 days (Ø 101)
VOA/TIC value		< 0.6
Gas permeability of biogas tanks		1–5 ‰ biogas/day
Electricity demand BGP		Ø 7.6 %
Heat demand BGP		Ø 27 %
Workload BGP per year		1.15–8.5 MHr/(kW_{el} • a)
Breakdowns BGP per year		1.2 / 10 kW_{el}

Key figures gas utilisation	
CHP efficiency rate$_{el}$	28–47 %
CHP efficiency rate$_{th}$	34–55 %
CHP efficiency rate$_{total}$	approx. 85–90 %
CHP extent of use	60,000 operating hours
Micro gas turbine efficiency rate$_{el}$	26–33 %
Micro gas turbine efficiency rate$_{th}$	40–55 %
Fuel cell efficiency rate$_{el}$	40–60 %
ORC system efficiency rate$_{el}$	6–16 %

Economic figures	
Specific investment costs	
BGP 75 kW_{el}	approx. 9,000 €/kW_{el}
BGP 150 kW_{el}	approx. 6,500 €/kW_{el}
BGP 250 kW_{el}	approx. 6,000 €/kW_{el}
BGP 500 kW_{el}	approx. 4,600 €/kW_{el}
BGP 750 kW_{el}	approx. 4,000 €/kW_{el}
BGP 1,000 kW_{el}	approx. 3,500 €/kW_{el}
BGP with gas upgrading 400 Nm³/h	approx. 9,600 €/Nm³ • h
BGP with gas upgrading 700 Nm³/h	approx. 9,100 €/Nm³ • h
ORC system 13–375 kW_{el}	approx. 5,000–7,700 €/kW_{el}
Electricity generation costs	
BGP 75 kW_{el}	approx. 30 ct/kWh
BGP 500 kW_{el}	approx. 17 ct/kWh
BGP 1,000 kW_{el}	approx. 15 ct/kWh
Production costs biomethane	
400 Nm³/h	7–9 ct/kWh
700 Nm³/h	6–8 ct/kWh

Example: annual need for substrate of a biogas plant 75 kW_{el}
3,300 t cattle slurry (194 dairy cows; with Ø 8,000 milk yield/a)
790 t maize silage (18 ha; with Ø 50 t FM/ha yield**)

Example: annual need for substrate of a biogas plant 500 kW_{el}
2,200 t cattle slurry (129 dairy cows; with Ø 8,000 l milk yield/a)
6,500 t maize silage (148 ha; with Ø 50 t FM/ha yield**)
1,100 t Whole crop cereal silage (31 ha; with Ø 40 t FM/ha yield**)
1,100 t grass silage of permanent grassland
(42 ha; with Ø 30 t FM/ha yield**)

** CHP efficiency rate 38 %$_{el}$*
*** 12 % silage losses considered, for sugar beets 15 % (lagoon), for grain rye 1.4 %*

Source: Biomasse-Verordnung (2012); Faustzahlen Biogas (KTBL, 2013); Leitfaden Biogas (FNR, 2013); Leitfaden Biogasaufbereitung und -einspeisung (FNR, 2014); Stromerzeugung aus Biomasse (DBFZ, 2014) and own calculations

APPENDIX

Renewable Energy Sources Act (EEG) 2017

(effective from 01.01.2017)

With the amended EEG 2017 the promotion for electricity from biomass will be tendered annually. (tender deadline 1 September).

Path for further expansion of electricity from biomass
Gross capacity increase for new and existing plants

- 2017–2019 – annual 150 MW installed capacity
- 2020–2022 – annual 200 MW installed capacity

(waste wood plants are excluded from promotion)

Funding period

- for new plants 20 years
- for existing plants one-time additional 10 years

Conditions

- needs-based and flexible electricity generation
- limited use of grain and maize
  – 2017 and 2018 max. 50 percent by weight
  – 2019 and 2020 max. 47 percent by weight
  – 2021 and 2022 max. 44 percent by weight

Remuneration (startup of operations 2017)
Maximum values for tenders (market premium)

- for new plants 14.88 ct/kWh
- for existing plants 16.9 ct/kWh

(degression rate 1 % per year)

Feed-in remuneration (without tenders)

- for small plants up to 150 kW = 13.32 ct/kWh
- for small manure plants = 23.14 ct/kWh
- for plants for biowaste up to 500 kW = 14.88 ct/kWh
- for plants for biowaste › 500 kW to 1 MW = 13.05 ct/kWh

(degression rate 0.5 % half-yearly)

Without participation at direct marketing:
reduction of remuneration by 0.2 ct/kWh

Source: EEG 2017

Market reports and prices for fuels and biomass

Biodiesel	www.ufop.de
Oilseeds and vegetable oils	www.oilworld.biz
Wood chips and pellets	www.carmen-ev.de
Wood logs	www.tfz.bayern.de
Pellets	www.depi.de
Agricultural sector	www.ami-informiert.de
Federal Statistical Office	www.destatis.de
Heating oil/crude oil	www.tecson.de/oelweltmarkt.html

Conversion of units

	MJ	kWh	m³ natural gas
1 MJ	1	0.278	0.032
1 kWh	3.6	1	0.113
1 m³ natural gas	31.74	8.82	1

	m³	l	Barrel
1 m³	1	1,000	6.3
1 l	0.001	1	0.0063
1 barrel	0.159	159	1

Signs for units

Prefix	Sign	Factor	Numeral
Kilo	k	10^3	thousand
Mega	M	10^6	million
Giga	G	10^9	billion
Tera	T	10^{12}	trillion
Peta	P	10^{15}	quadrillion
Exa	E	10^{18}	quintillion

Further information

Bioenergy
https://bioenergie.fnr.de

Mediathek – Facts and Figures
https://mediathek.fnr.de/grafiken.html

Bioenergy in Germany – Facts and Figures
https://factsandfigures.fnr.de

Bioenergy villages
https://bioenergiedorf.fnr.de

Energy crops
https://energiepflanzen.fnr.de

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