

and



**Deutsches Biomasse  
ForschungsZentrum**  
gemeinnützige GmbH  
**German Biomass Re-  
search Centre**

## **IEA Bioenergy Task 40: Country Report Germany**

prepared by

**Uwe R. Fritsche, Klaus Hennenberg, Katja Hünecke**

Energy & Climate Division  
Öko-Institut, Darmstadt Office

**Daniela Thrän, Janet Witt, Christiane Hennig,  
Nadja Rensberg**

Bioenergy Systems Division  
German Biomass Research Centre

**Darmstadt/Leipzig, Junly 2009**

**Öko-Institut, Darmstadt Office**

Rheinstr. 95  
D-64295 Darmstadt  
ph: +49-61 51-81 91-0  
fax: +49-61 51-81 91-33  
[www.oeko.de](http://www.oeko.de)

**German Biomass Research Centre**

Torgauer Str. 116  
D- 04347 Leipzig  
ph +49-341-2434-0  
fax +49-341-2434-133  
[www.dbfz.de](http://www.dbfz.de)

## Content

<b>List of Tables</b>	<b>iv</b>
<b>List of Figures</b>	<b>v</b>
<b>1 Introduction and Overview</b>	<b>1</b>
1.1 The IEA Bioenergy Task 40	1
1.2 Germany: A Brief Profile	1
1.3 Overview of this Report	1
<b>2 The German Energy System</b>	<b>2</b>
2.1 Primary Energy in Germany	2
2.2 End-Energy Demand in Germany	3
2.3 Greenhouse-Gas Emissions in Germany	4
2.4 Development of Renewable Energies in Germany	5
2.5 Renewables in the Electricity Sector	6
2.6 Renewables in the Heat Sector	7
2.7 Renewables in the Transport Sector	8
<b>3 German Policy on Bioenergy</b>	<b>10</b>
3.1 Renewable Energy Sources Act (EEG)	10
3.2 Renewable Energy Heat Act	11
3.3 Market Incentive Programme for Renewable Energy	11
3.4 Biomethane Policy	12
3.5 Liquid Biofuel Legislation	13
3.6 General Targets for Renewable Energy	13
3.7 Specific Targets for Bioenergy (Electricity, Heat, Biofuels)	14
3.8 National Biomass Action Plan	14
<b>4 Biomass Resources in Germany</b>	<b>16</b>
<b>5 Current and Expected Future Energy Use of Biomass</b>	<b>19</b>
5.1 Total Use of Bioenergy in Germany	19
5.2 Solid Biofuels	21
5.2.1 <i>Solid Biofuels for Electricity Generation</i>	22
5.2.2 <i>Heat Generation from Solid Biofuels</i>	26
5.3 Gaseous Biofuels	29
5.3.1 <i>Electricity Generation from Gaseous Biofuels</i>	29
5.3.2 <i>Heat Generation from Gaseous Biofuels</i>	32
5.4 Liquid Biofuels	32
5.4.1 <i>Electricity and Heat Generation from Bioliquids</i>	32
5.4.2 <i>Bioliquids for Transport</i>	33

<b>6</b>	<b>Biomass Prices and Consumption</b>	<b>36</b>
6.1	Wood Pellets	36
6.2	Demolition Wood and Wood Wastes	38
6.3	Woodchips	39
6.4	Firewood	40
6.5	Wood Briquettes	41
6.6	Sawdust	42
6.7	Price Comparison of Various Solid Biofuels and Fossil Fuels	43
6.8	Vegetable Oil	44
<b>7</b>	<b>Bioenergy Trade: Status, Barriers and Opportunities</b>	<b>45</b>
7.1	Status of Bioenergy Trade in Germany	45
7.2	Barriers and Opportunities for Bioenergy Trade	46
<b>8</b>	<b>Conclusions for Bioenergy Developments in Germany</b>	<b>48</b>
	<b>Literature</b>	<b>49</b>
	<b>List of Abbreviations</b>	<b>52</b>

## List of Tables

Table 1	Development of the Renewable Energies' Share of Energy Supply in Germany 1998-2007.....	5
Table 2	Contributions of Renewable Energies to the Energy Supply in Germany in 2008.....	6
Table 3	Development of Renewable Energies' Share in Electricity Generation in Germany 1990-2007.....	7
Table 4	Development of Renewable Energies' Share in Heat Supply in Germany 1990-2007.....	8
Table 5	Development of Renewable Energies' Share in Transport Fuel Supply in Germany 1990-2007.....	9
Table 5	Development of Renewable Energies' Share in Transport Fuel Supply in Germany 1990-2007.....	12
Table 7	Development of Renewable Energies' and Bioenergy Shares in Germany 2007 and 2020.....	15
Table 8	Renewable Energy Use in Germany 2007 and Future Potentials.....	18
Table 9	Renewable Energy Use in Germany 2008.....	19
Table 10	Estimated Heat Generation from Solid Biofuels in 2020.....	28
Table 11	Consumption of Liquid Biofuels in the German Transport Sector.....	34
Table 12	Expected Production of Biofuels in Germany by 2020.....	35

## List of Figures

Figure 1	Development of Primary Energy Supply in Germany 1990- 2007 .....	2
Figure 2	Development of Domestic Primary Energy Supply in Germany 1990- 2007.....	3
Figure 3	Development of End-Energy Demand in Germany 1990- 2007.....	3
Figure 4	Development of End-Energy Supply in Germany 1990- 2007 .....	4
Figure 5	Sustainable Bioenergy Potentials in Germany by 2030 .....	16
Figure 6	Bioenergy Feedstocks in the Sustainable Bioenergy Potential for Germany by 2030 .....	17
Figure 7	Total Bioenergy Use and Bioenergy in the Transport Sector in Germany in 2008 .....	20
Figure 8	Electricity Generation from Bioenergy in Germany 2008 .....	20
Figure 9	Heat Supply from Bioenergy in Germany 2008.....	21
Figure 10	Number of Biomass Cogeneration Plants and Installed Capacity in Germany 1999-2008.....	22
Figure 11	Distribution of Wood Use in Plants with Different Sizes .....	24
Figure 12	Distribution of Solid Biomass Plants in Germany 2008.....	25
Figure 13	Number of Biomass Cogeneration Plants and Installed Capacity.....	26
Figure 14	Development of Pellet Systems in Germany 2000-2007 .....	27
Figure 15	Development of Woodchips Systems in Germany 2002-2007.....	28
Figure 16	Development of Biogas Plants and Installed Capacity.....	29
Figure 17	Distribution of Biogas Plants in Germany in 2008 .....	30
Figure 18	Expected Installed Capacity and Required Land for Biogas Production in Germany until 2020 .....	31
Figure 19	Development of Electricity from Bioliquids in Germany 2003-2008 .....	33
Figure 20	Development of the Consumption of FAME, Vegetable Oil and Bioethanol in Germany .....	34
Figure 21	Market Development for Pellets in Germany 2000-2008 .....	37
Figure 13	Scenarios for the Pellet Demand in Germany .....	38
Figure 23	Market Development of Used Wood in Germany 2000-2008 .....	39

Figure 24	Market Development of Woodchips in Germany 2002-2008 .....	40
Figure 25	Market Development for Firewood in Germany 2001-2008 .....	41
Figure 26	Market Development for Wood Briquettes in Germany 2003-2007 .....	42
Figure 27	Market Development of Sawdust in Germany 2000-2008 .....	43
Figure 28	Prices of Solid Biofuels Compared to Fossil Fuels 2000-2008 .....	44
Figure 29	Price Development for Vegetable Oil in Germany 2001-2008 .....	45
Figure 30	Biomethane Potential in Europe 2020 .....	46
Figure 31	Biomethane Costs and Fossil Fuel Prices in Europe 2020 .....	47

## 1 Introduction and Overview

### 1.1 The IEA Bioenergy Task 40

The International Energy Agency (IEA) established the Task 40 “Sustainable International Bioenergy Trade: securing supply and demand” in December 2003<sup>1</sup>. Currently, countries participating in Task 40 are Austria, Belgium, Brazil, Canada, Finland, Germany, Italy, Japan, the Netherlands, Norway, Sweden, the United Kingdom, and the USA.

### 1.2 Germany: A Brief Profile

Germany is located in the centre of Europe, sharing approx. 3,600 km of borders with 9 EU Member States, and covers an area of 357,093 km<sup>2</sup> (DETATIS 2008). In 2008, Germany had a population of 82 million living in 40 million households, and generated a GDP of 2.270 billion € (expressed in €<sub>2000</sub>).

A share of approximately 31% (11 mill. ha) of the German land area is covered by forests, and approx. 20% (7.5 mill. ha) is managed forests<sup>2</sup>. Agricultural area covers approx. 17 million hectares (48%), of which some 12 mill. ha are arable land, and about 5 mill. ha pasture and grassland. The agroforestry sector in Germany had a share of 0.9 % of the gross value added in 2007.

### 1.3 Overview of this Report

This report highlights the state and prospects of bioenergy utilization in Germany, covering all bioenergy sources and applications.

**Section 2** gives a brief **overview** of the German energy system.

In **Section 3**, the German **policies on bioenergy** are described.

**Section 4** briefly discusses bioenergy potentials in Germany, while **Section 5** presents the current and future **markets of biofuels** including production and key market segments.

**Section 6** gives a brief overview to bioenergy prices and consumption, and **Section 7** discusses the **crossborder trade** of biomass, including barriers and opportunities.

In **Section 8**, conclusions are drawn regarding the challenges and possibilities of emerging biofuels markets in Germany

Work for this report was carried out within ongoing research activities on bioenergy of Oeko-Institut and DBFZ, sponsored by the German Federal Ministry for Environment, and the Federal Ministry for Agriculture through their respective Agencies FNR and UBA.

---

<sup>1</sup> For details, see [www.bioenergytarde.org](http://www.bioenergytarde.org)

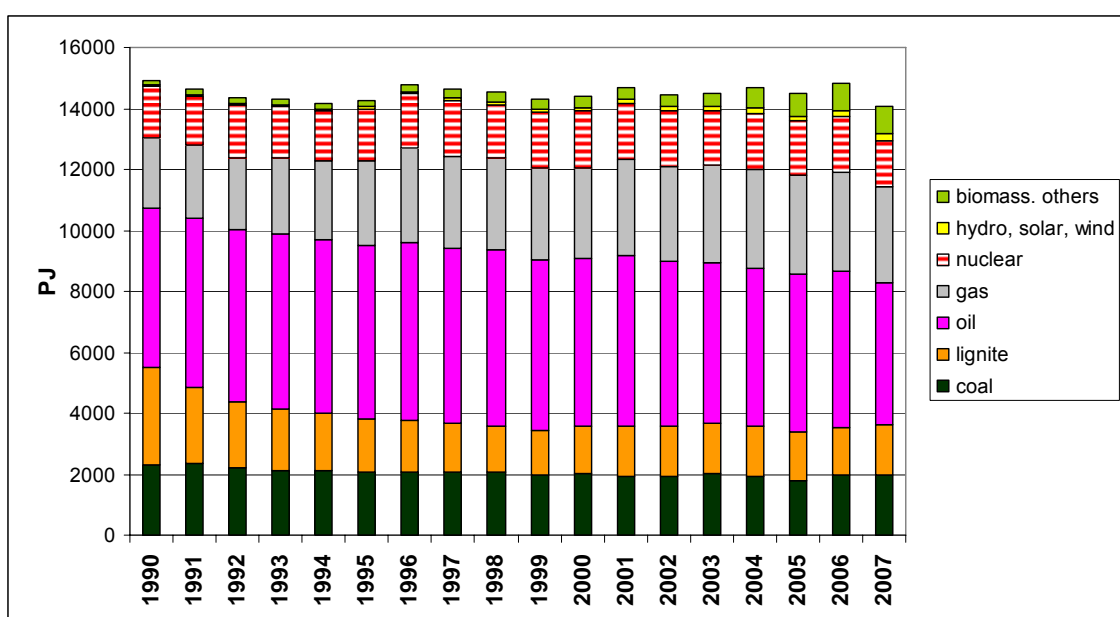
<sup>2</sup> The forest sector and subsequent timber and wood industries had an annual turnover of approx. 160 billion € in 2008, and employed approx. 1.2 million people.

## 2 The German Energy System

### 2.1 Primary Energy in Germany

The energy system in Germany is comparatively stable over the last decades, as shown in Figure 1. Since 1990, overall demand fluctuates around 14,000 PJ, with slightly rising contributions of natural gas and renewables (mainly biomass and wind), and slightly decreasing roles of coal and oil.

Figure 1 Development of Primary Energy Supply in Germany 1990-2007



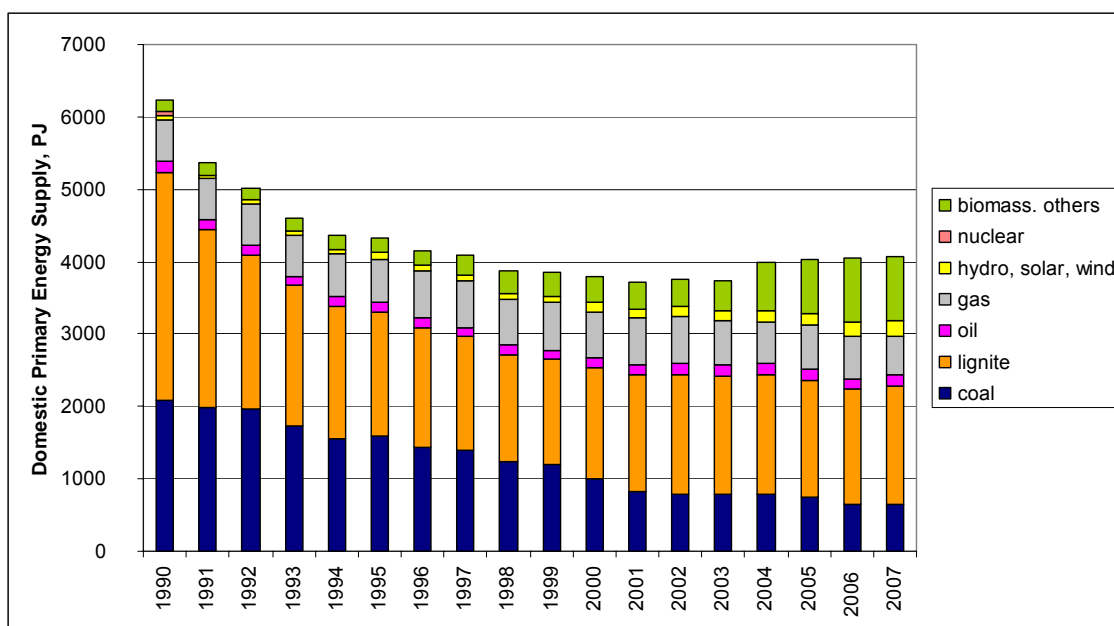
Source: Oeko-Institut calculation based on AGEb; DESTATIS

On the margin, though, it is changing rapidly – away from fossil and nuclear domination towards renewable supply, with demand- and supply-side efficiency being an additional important resource.

The stabilization of the primary energy demand is due to a massive increase in energy efficiency and comparatively stable population, as economic development in the last decades still had an average growth rate of approx. 1.5% per year.

Domestic supply of primary energy changed more visibly, as shown in Figure 2. Domestic provision of coal and lignite was reduced significantly in the last two decades, and renewables – again, mainly bioenergy and wind – showed a stable annual increase. The small domestic natural gas and oil extraction is steadily declining.

Figure 2 Development of Domestic Primary Energy Supply in Germany 1990- 2007

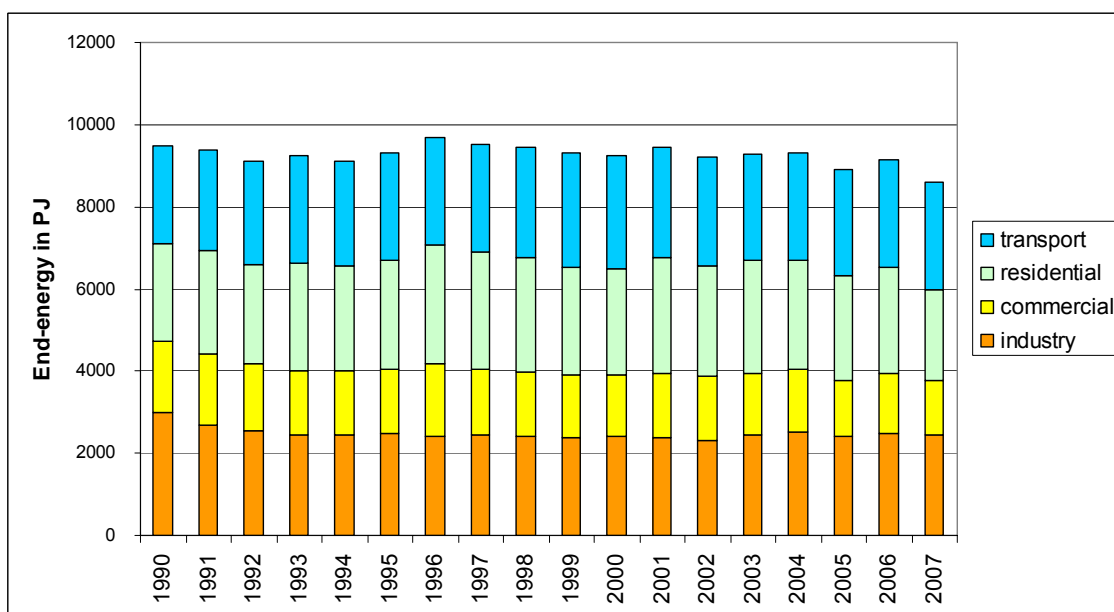


Source: Oeko-Institut calculation based on AGEb; DESTATIS

## 2.2 End-Energy Demand in Germany

The end-energy demand, i.e. the demand for final energy from sectors, also remained comparatively stable, as shown in the following figure.

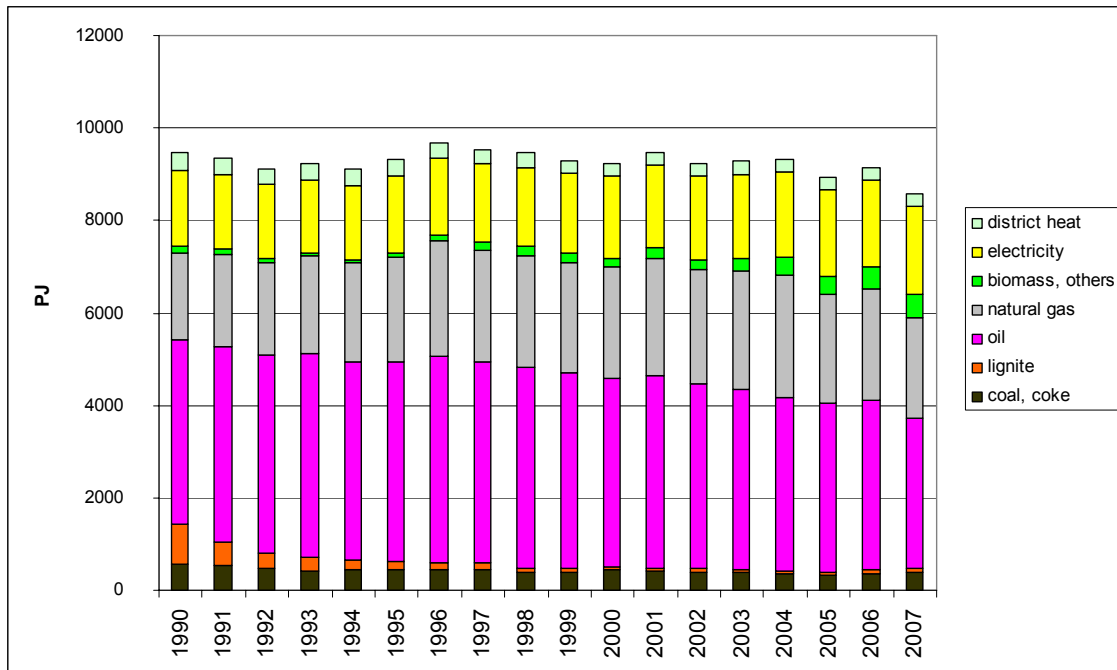
Figure 3 Development of End-Energy Demand in Germany 1990- 2007



Source: Oeko-Institut calculation based on AGEb; DESTATIS

The supply structure of end-energy changed, though: the sharp decline in solid fossil fuels since the 1990ies was due to the restructuring of the East German industry and residential heat supply, and the growth in biomass since 1995 is a result of national policies (see Section 3).

Figure 4 Development of End-Energy Supply in Germany 1990- 2007



Source: Oeko-Institut calculation based on AGEB; DESTATIS

### 2.3 Greenhouse-Gas Emissions in Germany

The energy policy in Germany can be characterized as a mix of security of supply and economic as well as environmental concerns, with the latter gaining importance since 1995, especially regarding the reduction of greenhouse-gas (GHG) emissions.

With Germany being a Party to the UN Framework Convention on Climate Change (UNFCCC), and the respective Kyoto Protocol (KP) as well as being part of the EU commitments under the KP and participating in the EU Emission Trading Scheme (ETS), reduction requirements for GHG are a key concern, and both domestic and international targets to reduce GHG emissions require further changes in Germany's energy mix.

Under the KP and the respective EU burden sharing agreement, Germany is obliged to reduce its national GHG emissions by 21% by 2012, compared to the 1990 levels. Under the EU Climate Package, Germany must reduce its GHG emissions further until 2020, and has a national target of 30% reduction by that time, compared to the 1990 levels.

## 2.4 Development of Renewable Energies in Germany

In response to the requirements of reducing GHG emissions, diversifying energy supply, and creating innovative and competitive export industries, Germany has since the 1990ies a very strong policy towards increasing the domestic supply from renewable energies.

The results of this policy can be seen in the rapid development of renewables in the German energy system.

*Table 1 Development of the Renewable Energies' Share of Energy Supply in Germany 1998-2007*

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
<b>Final energy consumption (FEC)</b>	<b>[%]</b>									
Electricity generation (in relation to total gross electricity consumption)	4.8	5.5	6.3	6.7	7.8	8.1	9.5	10.4	11.7	14.2
Heat supply (in relation to total heat supply) <sup>1)</sup>	3.5	3.5	3.9	3.8	3.9	4.6	4.9	5.4	5.8	6.6
Fuel consumption <sup>2)</sup> (in relation to total fuel consumption)	0.2	0.2	0.4	0.6	0.9	1.4	1.8	3.8	6.3	7.6
<b>Renewables as a share of total FEC</b>	<b>3.1</b>	<b>3.3</b>	<b>3.8</b>	<b>3.8</b>	<b>4.3</b>	<b>4.9</b>	<b>5.5</b>	<b>6.6</b>	<b>7.5</b>	<b>8.6</b>
<b>Primary energy consumption (PEC)</b>										
Electricity generation (in relation to total PEC)	0.8	0.9	1.1	1.1	1.4	1.5	1.6	2.1	2.5	3.2
Heat supply (in relation to total PEC)	1.3	1.3	1.4	1.4	1.5	1.8	1.9	2.0	2.1	2.3
Fuel consumption (in relation to total PEC)	0.03	0.03	0.06	0.1	0.1	0.2	0.3	0.6	1.0	1.2
<b>Renewables as a share of total PEC<sup>3)</sup></b>	<b>2.1</b>	<b>2.2</b>	<b>2.6</b>	<b>2.7</b>	<b>3.0</b>	<b>3.5</b>	<b>3.9</b>	<b>4.7</b>	<b>5.6</b>	<b>6.7</b>

- 1) Total heat supply for 2006 and 2007 estimated on the basis of 2005 figures, cf. also page 12
- 2) Until 2002, the reference variable was fuel consumption in road traffic, from 2003, the reference variable here is the total consumption of engine fuels, excluding fuel in air traffic
- 3) According to the physical energy content method, cf. appendix, para. 4

Source: BMU (2008)

Since 1998, the share of renewables in electricity generation tripled, and was doubled in heat supply. In the transport sector, the share increased by a factor of nearly 80.

The following table indicates the status of renewable energy supply in the German energy system.

Table 2 Contributions of Renewable Energies to the Energy Supply in Germany in 2008

	renewable energy source	end energy		primary energy	
		TWh	[%]	PJ	[%]
electricity	hydropower	20,9	3,4	75,2	0,5
	wind	40,4	6,5	145,4	1,0
	solar PV	4,0	0,6	14,4	0,1
	bioenergy, solid	10,4	1,7	93,4	0,7
	bioenergy, liquid	1,5	0,2	13,3	0,1
	bioenergy, gaseous	9,2	1,5	81,9	0,6
	organic wastes	5,0	0,8	44,3	0,3
	geothermal	0,1	0,0	0	0,0
	<b>total electricity</b>	<b>91,4</b>	<b>14,8</b>	<b>467,9</b>	<b>3,3</b>
heat	bioenergy, solid (residential)	63,6	4,5	228,8	1,6
	bioenergy, solid (industrial)	16,8	1,2	60,5	0,4
	bioenergy, solid (DH)	6,3	0,4	22,5	0,2
	bioenergy, liquid	5,1	0,4	18,4	0,1
	bioenergy, gaseous	5,3	0,4	19,1	0,1
	organic wastes	5,0	0,4	18,1	0,1
	solar thermal	4,1	0,3	14,9	0,1
	geothermal	2,5	0,2	9,1	0,1
	<b>total heat</b>	<b>108,7</b>	<b>7,7</b>	<b>391,4</b>	<b>2,8</b>
fuels	biodiesel	28,7	4,6	103,4	0,7
	SVO	4,4	0,7	15,7	0,1
	bioethanol	4,6	0,7	16,7	0,1
	<b>total transport fuels</b>	<b>37,7</b>	<b>6,1</b>	<b>135,8</b>	<b>1,0</b>
<b>TOTAL</b>		<b>237,8</b>	<b>9,7</b>	<b>995,1</b>	<b>7,1</b>

Source: BMU (2009a)

## 2.5 Renewables in the Electricity Sector

In absolute figures, the most prominent development occurred in the electricity sector where renewables increased their share from about 3.4 % in 1990 to 14.2 % in 2007, driven mainly by wind and biomass (see following table).

**Table 3** *Development of Renewable Energies' Share in Electricity Generation in Germany 1990-2007*

	Hydro-power <sup>b)</sup>	Wind energy	Biomass <sup>3)</sup>	Biogenic share of waste <sup>3)</sup>	Photo-voltaics	Geothermal energy	Total electricity generation	Share of gross electricity consumption
	[GWh]	[GWh]	[GWh]	[GWh]	[GWh]	[GWh]	[GWh]	[%]
1990	17,000	40	222	1,200	1	0	18,463	3.4
1991	15,900	140	250	1,200	2	0	17,492	3.2
1992	18,600	230	295	1,250	3	0	20,378	3.8
1993	19,000	670	370	1,200	6	0	21,246	4.0
1994	20,200	940	570	1,300	8	0	23,018	4.3
1995	21,600	1,800	670	1,350	11	0	25,431	4.7
1996	18,800	2,200	853	1,350	16	0	23,219	4.2
1997	19,000	3,000	1,079	1,400	26	0	24,505	4.5
1998	19,000	4,489	1,642	1,750	32	0	26,913	4.8
1999	21,300	5,528	1,791	1,850	42	0	30,511	5.5
2000	24,936	7,550	2,279	1,850	64	0	36,679	6.3
2001	23,383	10,509	3,206	1,859	116	0	39,073	6.7
2002	23,824	15,786	4,017	1,945	188	0	45,760	7.8
2003	20,350	18,859	6,970	2,162	313	0	48,654	8.1
2004	21,000	25,509	8,347	2,116	557	0.2	57,529	9.5
2005	21,524	27,229	10,495	3,039	1,282	0.2	63,569	10.4
2006	20,000	30,710	15,500	3,639	2,220	0.4	72,069	11.7
2007	20,700	39,500	19,500	4,250	3,500	0.4	87,450	14.2

The energy supply from hydropower, wind energy and solar energy is subject to natural fluctuations which can affect the total annual energy yield on both a short-term and seasonal basis. On the generation of electricity from photovoltaic energy, see appendix, para. 5.

- 1) In the case of pumped-storage power plants, electricity generated from natural inflow only
- 2) Until 1998, only feed-in to the general supply grid
- 3) Share of biogenic waste estimated at 50 %

Sources: BMU based on AGEE-Stat and ZSW [3]; EnBW [12]; BWE [16]; StBA [5]; BMELV [75]; IE [8], [13], [20], [70]; VDN [9]; BDEW [71]; AGEb [2], [18]; FNR [7]; SFV [28]; BSW [10]; ZFS [19]; Erdwärme-Kraft [79]; DEWI [62], [67], [76], [77], [78]; geox GmbH [66]

Source: BMU (2008)

## 2.6 Renewables in the Heat Sector

In the heat sector, the development of renewables was not as quick as in the electricity sector, but again bioenergy showed a rapid and massive increase as well, followed by solar- and geo-thermal energy, as can be seen in the following table.

**Table 4**      *Development of Renewable Energies' Share in Heat Supply in Germany 1990-2007*

- 1) In contrast to previous years, from 2003 onwards figures are according to §§ 3, 5 (cogeneration and heating plants) and § 8 (industry) of the 2003 Energy Statistics Act and direct use of sewage gas  
 2) Biogenic waste share in waste incineration plants estimated at 50 %

	Biomass <sup>0</sup>	Biogenic share of waste <sup>2)</sup>	Solar thermal energy	Geothermal energy	Total heat generation	Share of heat consumption
	[GWh]	[GWh]	[GWh]	[GWh]	[GWh]	[%]
1990	N/A	N/A	130	N/A	N/A	N/A
1991	N/A	N/A	166	N/A	N/A	N/A
1992	N/A	N/A	218	N/A	N/A	N/A
1993	N/A	N/A	279	N/A	N/A	N/A
1994	N/A	N/A	351	N/A	N/A	N/A
1995	N/A	N/A	440	1,425	N/A	N/A
1996	N/A	N/A	550	1,383	N/A	N/A
1997	45,646	2,900	695	1,335	50,576	N/A
1998	48,625	2,988	857	1,384	53,854	3.5
1999	47,811	3,140	1,037	1,429	53,417	3.5
2000	51,036	3,278	1,279	1,433	57,026	3.9
2001	52,043	3,283	1,612	1,447	58,385	3.8
2002	51,302	3,324	1,919	1,483	58,028	3.9
2003	62,555	3,806	2,183	1,532	70,076	4.6
2004	66,251	3,694	2,487	1,558	73,990	4.9
2005	72,190	4,692	2,828	1,601	81,311	5.4
2006	73,892	4,911	3,274	1,934	84,011	5.8
2007	79,289	4,910	3,700	2,299	90,198	6.6

Sources: BMU based on AGEE-Stat and other sources, on page 16 and VDEW [17], [47], [74]

Source: BMU (2008)

## 2.7 Renewables in the Transport Sector

The most aggressive development of renewables in Germany occurred in the transport sector in which the 1990 contribution was zero, but rapid growth occurred after that, driven by dedicated biofuels policy (see Section 3.5).

It should be noted that due to the recent changes in the German liquid biofuels policies for the transport sector, the growth was significantly reduced in 2007, and this continues in 2008 and 2009, respectively.

**Table 5**      *Development of Renewable Energies' Share in Transport Fuel Supply in Germany 1990-2007*

	Biodiesel	Vegetable oil	Bioethanol	Total biofuels	Share of fuel consumption
	[GWh]	[GWh]	[GWh]	[GWh]	[%]
1990	0	0	0	0	0.0
1991	2	0	0	2	0.0
1992	52	0	0	52	0.01
1993	103	0	0	103	0.02
1994	258	0	0	258	0.04
1995	310	0	0	310	0.05
1996	517	0	0	517	0.1
1997	827	0	0	827	0.1
1998	1,033	0	0	1,033	0.2
1999	1,343	0	0	1,343	0.2
2000	2,583	0	0	2,583	0.4
2001	3,617	0	0	3,617	0.6
2002	5,683	0	0	5,683	0.9
2003	8,267	52	0	8,319	1.4
2004	10,850	52	484	11,386	1.8
2005	18,600	2,047	1,936	22,583	3.8
2006 <sup>1)</sup>	29,444	7,417	3,556	40,417	6.3
2007 <sup>2)</sup>	34,389	8,750	3,417	46,556	7.6

1) The volume of biodiesel for 2006 also includes vegetable oil, because biodiesel and vegetable oil were collected jointly until August 2006

2) For 2007, this volume corresponds to:  
Biodiesel: approx. 3,320,000 tonnes;  
Vegetable oil: approx. 840,000 tonnes;  
Bioethanol: 460,000 tonnes

Sources: BMU based on AGE-Stat and other sources, see page 12 and BMVBS [57], BMELV/BMU [40]

Source: BMU (2008)

### 3 German Policy on Bioenergy

Where, how and how much biomass contributes to energy supplies depends to a great extent on the legal context. There are not just considerations of regional development, planning and pollution to take into account but also laws regulating waste and fertiliser use. In Germany, laws such as the Renewable Energy Sources Act (EEG<sup>3</sup>) or the Mineral Oil Duty Act forced the expansion of bioenergy through fixed payments for bioelectricity and tax relief for biofuels.

In addition to legislation, the German Federal Government is supporting the expansion of bioenergy through various research, development and market introduction programmes.

As a result, the framework conditions for using biomass as renewable source of energy have improved significantly in the last 20 years and led to a significant expansion of bioenergy in the German energy system.

#### 3.1 Renewable Energy Sources Act (EEG)

The most important legal instrument to promote electricity production from renewable sources in Germany is the Renewable Energy Sources Act (EEG) which was first enacted in April 2000, and was revised in July 2004, and June 2008. The latest amendment came into force on 1 January 2009

The EEG offers fixed payments (feed-in tariffs) for every kilowatt-hour of renewable electricity supplied to the national grid. There are different tariffs according to type of renewable energy source, conversion technique and plant size. There are also additional tariff elements (bonus payments) for using wood and other renewable resources that have been specifically cultivated for energy production (the “biomass bonus”), for CHP plants (“cogeneration bonus”) and for the use of innovative technologies (“innovation bonus”). The 2004 revision of the EEG’s tariff scheme which especially considered bioenergy led to a massive increase in the amounts of electricity produced from biomass.

The further improvements of the tariff scheme of the 2009 version of the EEG is expected to contribute to a further expansion of electricity (and cogenerated heat) from biogas, and from solid biomass CHP plants.

The 2009 EEG authorized the Federal Ministry for Environment (BMU) in cooperation with the Federal Agricultural Ministry (BMELV) to define sustainability requirements for the production of biomass used and the emission reductions achieved when producing electricity from biomass. This power was used in early 2009 to introduce the Bioelectricity Sustainability Ordinance which applies for liquid biofuels used to generate electricity, and which makes the feed-in tariff biomass bonus of the EEG subject to proof that sustainability requirements have been complied with (BMU 2009b).

---

<sup>3</sup> Erneuerbares-Energien-Gesetz

### 3.2 Renewable Energy Heat Act

Germany's Renewable Energy Heat Act (Erneuerbare-Energien-Wärmegesetz, or EEWärmeG) came into effect on January 1, 2009. Its provisions place owners of newly constructed buildings under obligation to use renewable energy to meet a portion of their heat requirements. Along with solar and ambient heat, bioenergy and geothermal heat may also be used.

Under the Act, bioenergy may only be used if it is generated using highly efficient technology (e.g. liquid biomass for conversion to fuel and gaseous biomass in CHP plants). For renewably generated heat, the provisions of the Act also allow building owners the option to use CHP and energy saving measures and to obtain heat from district heating plants if the network is fed from a CHP plant or partially supplied with renewable energy.

### 3.3 Market Incentive Programme for Renewable Energy

In Germany, using biomass to produce energy is – in general - more expensive than using fossil energy sources such as oil or gas where investment costs are concerned.

Not only are the plants technically more complex but they are still produced in relatively small quantities. As bioenergy could only assert itself slowly on the market despite its positive environmental effects, the Federal Government and the Federal States decided to accelerate its market introduction by various promotional schemes.

Since 2000, the Federal Government has been supporting the purchase of biomass plants such as central heating units using logs or wood pellets, biomass power stations and biogas plants through its Market Incentive Programme (Marktanreizprogramm, MAP). This promotional scheme has given an impressive stimulus. From the beginning of the scheme until mid 2006, the BAFA<sup>4</sup> subsidised 70,846 small biomass plants (< 100 kW) altogether at a total cost of 126.5 million € and thereby released a total investment of 1 billion euros. A loan scheme by the "Kreditanstalt für Wiederaufbau" (Credit Institute for Reconstruction) has assisted with 1,239 biogas plants, 1,185 biomass heating stations and 60 biomass CHP plants since it first started, representing a total investment volume of 725.5 million euros.

In 2008, the German government made up to €350 million available for MAP to promote renewables-generated heat. This amount will be increased to as much as €500 million for the period of 2009 to 2012. MAP research activities will focus on investment in buildings to increase the share of renewable energy in overall heat supply.

---

<sup>4</sup> Federal Office of Economics and Export Control (BAFA), [www.bafa.de](http://www.bafa.de)

In addition, numerous biogas and biomass plants have been built in the agricultural sectors thanks to the Agricultural Investment Support Programme (AFP) of the joint scheme on “Improving the Structure of Agriculture and Coastal Protection” (GAK). The Federal government provides 60 percent of the funding for GAK measures. Applying for and coordinating promotional measures is a Länder responsibility. GAK also provides for bioenergy advisory services which are currently under review with regard to expanding their scope.

*Table 6 Development of Renewable Energies’ Share in Transport Fuel Supply in Germany 1990-2007*

BAFA	KfW
Grants	Interest-reduced loans and partial debt relief
Biomass plants up to 100 kW	Biomass plants from 100 kW (incl. CHP)
Solar thermal plants	Solar thermal plants from 40 m <sup>2</sup>
Efficient heat pumps	District heating networks
Plus bonus and innovation grants	Geothermal plants
	Heat accumulators
	Crude biogas pipelines and plants for the processing and feed-in of biogas into the natural gas network

Source: BMU (2008)

### 3.4 Biomethane Policy

The opportunities to feed upgraded biogas (biomethane) into the natural gas distribution grid to supply heat or being used in CHP plants and in the transport sector were improved through Germany’s Gas Grid Access Ordinance (GasNZV), Gas Grid Payment Ordinance (GasNeV) and Incentives Ordinance (AregV) which were amended in 2007 and 2008 and entered into force on April 12, 2008. The most significant changes involve the setting of a 6 percent target by 2020 and a 10 percent target by 2030 for Germany’s gas demand to be met with biomethane.

The new regulation also helps to remove barriers against biomethane grid-feed via special provisions, e.g., uniform quality standards, longer balance periods, greater scope for flexibility and special terms.

### 3.5 Liquid Biofuel Legislation

Liquid biofuels for transport are regulated by European and national framework conditions. The EU passed Guideline 2003/30/EG in order to increase their share of the market. This commits Member States to increase the share of biofuels to 5.75 % by 2010. With the Renewable Energy Sources Directive of December 2008, a EU-wide mandatory target for renewable transport fuels was established which requires each Member State to achieve a 10% contribution of renewable transport fuels by 2020.

Under EU Guideline 2003/96/EG, member states can grant partial or full tax relief on biofuels. Biofuels were free of tax until July 2006 under the oil tax law in Germany, but now fall under the Energy Tax Law. This sets tax rates that rise year-on-year between August 2006 and 2012 until they reach the level of diesel and petrol. The agricultural and forestry sectors do not have to pay any taxes on biofuels.

There are also strict regulations about mixing biofuels in with other fuels. Fuel standards allow five percent of biodiesel to be added to diesel (DIN EN 590) and of ethanol to petrol (DIN EN 228) respectively.

Germany's Biofuel Quota Act obliges the petroleum industry to mix in set quotas of biofuels since 2007.

From 2004 onwards, all biofuels for transport and heating became eligible for tax concessions. Following adoption of the Biofuels Quotas Act (Biostoffquotengesetz) by the German Bundestag (Lower House of Parliament) in October 2006, the tax concessions have been confined to pure biofuels **beyond** the quota, while admixtures to fossil fuels are supported via the biofuels quota, and tax exemptions are gradually phased-out.

In recent years, Germany saw a significant upward trend in biofuels, and by the end of 2007, biofuels already accounted for 7.6 % of total fuel consumption in Germany. Under the "Updated strategy on bioenergy" presented by BMU in April 2008, the expansion of biofuels will occur at a slower pace than previously planned, and expansion targets were adjusted accordingly. Under the new strategy, the total energy quota for 2009 under the Biofuels Quotas Act will be reduced from 6.25 % to around 5 %. The net climate protection contribution for 2020 previously envisaged in the Government draft on the Biofuels Quotas Act is to be reduced from 10 % to 7 %. The resultant national biofuel target of 17 % in energy terms (gross target) was reduced to 12 % (BMU/BMELV 2009).

### 3.6 General Targets for Renewable Energy

On 6 June, 2008 the German parliament enacted the new Renewable Energy Sources Act (EEG) and the Renewable Heat Sources Act (EE -WärmeG), defining the national targets: the contribution of renewables to electricity supply is to be increased to at least 30 % by the year 2020 and the contribution of renewables to heat supply is to be increased to 14 %.

### 3.7 Specific Targets for Bioenergy (Electricity, Heat, Biofuels)

The German government has made a clear commitment to promoting renewable energy sources and renewable raw materials. Its goals are largely a result of the EU Climate and Energy Package agreed in December 2008, and also of the outcome of a special Cabinet meeting held in Meseberg in late 2007. The goals include:

- Increasing the share of renewable energy in electricity production to at least 30 percent by 2020.
- Using biofuels to achieve greater reductions in greenhouse gas emissions in the transport sector; from 2015, rather than being set relative to energy content, biofuel quotas will be based on net greenhouse gas reductions.
- Increasing the share of biofuels in overall fuel consumption to 7 percent of net greenhouse gas reductions by 2020 (equivalent to approximately 12 percent energy content).
- Increasing the share of renewables-generated heat from the current 6.6 percent to 14 percent by 2020.

Against this backdrop, the question arises as to how efficient, long-term socially and environmentally compatible promotion of biomass can be achieved while taking account of its availability and viability.

### 3.8 National Biomass Action Plan

The aim of the National Biomass Action Plan agreed between the Federal Ministries for Environment and Agriculture is to provide a holistic concept to significantly increase the bioenergy share in Germany's energy supply while adhering to sustainability criteria.

Bioenergy is an ideal choice in efforts to mitigate the effects of climate change, secure supply and promote economic development. It also serves in boosting domestic value creation – especially in rural areas.

According to the Action Plan, the development of bioenergy will be different in the demand sectors, and will show differences in the assumed increases until 2020 (see following table).

The Action Plan is – as its name implies – a plan, not a law nor legally binding in any other fashion. Still, the two key Federal ministries agreed on this “road-map”, and orient their policy development to this joint plan.

**Table 7**      *Development of Renewable Energies' and Bioenergy Shares in Germany 2007 and 2020*

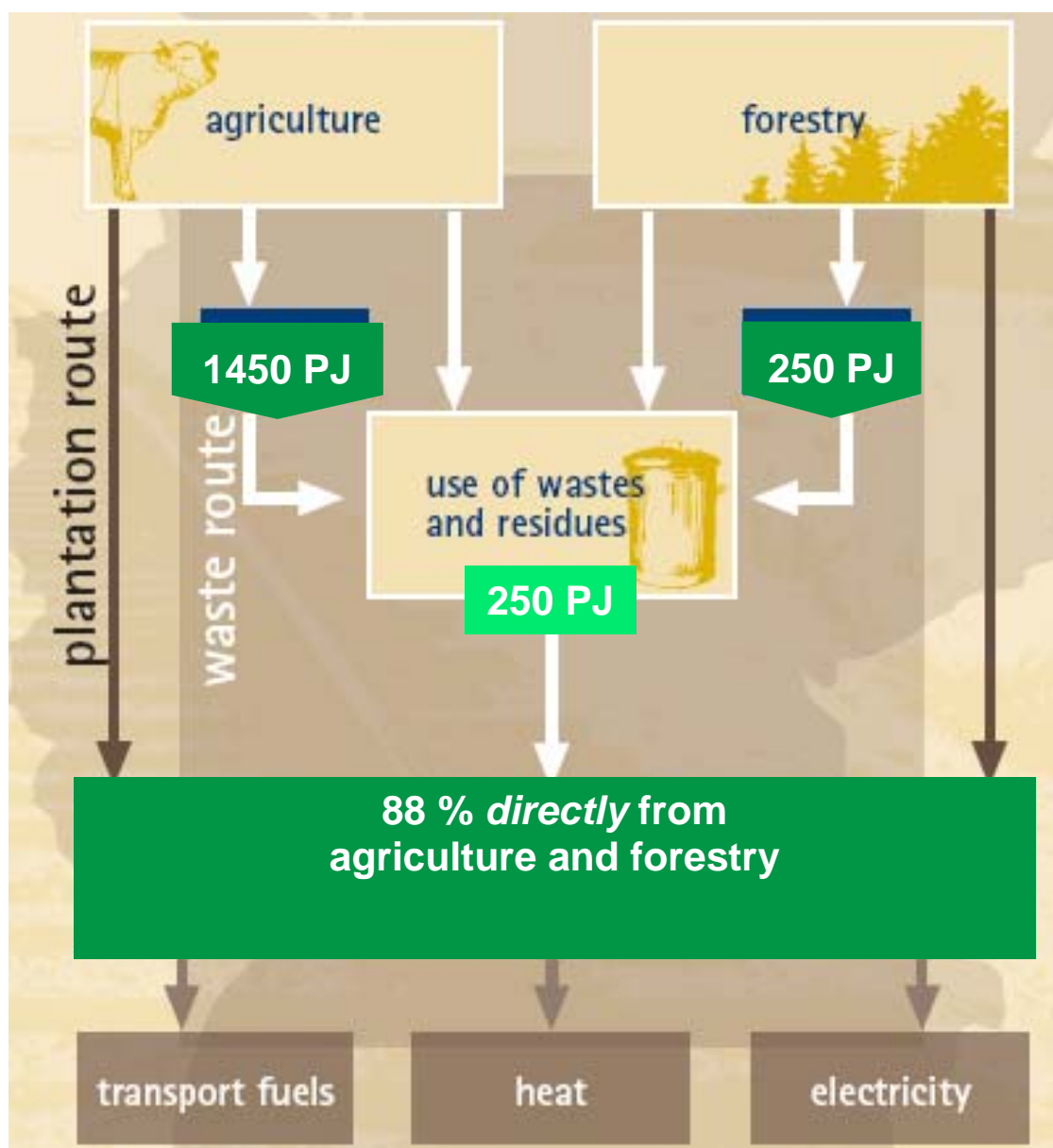
	2007		2020	
	all renewables	of which bio-energy	all renewables	of which bio-energy
Share of RE in primary energy consumption	6.7 %	4.9 %	16 %	11 %
Share of RE in end-energy	8.6 %	6.2 %	18 %	10.9 %
Share of RE in primary gross electricity consumption	14.2 %	3.9 %	minimum 30 %	8 %
Share of RE in heat supply	6.6 %	6.1 %	14 %	9.7 %

Source: BMU/BMELV (2009)

## 4 Biomass Resources in Germany

The overall availability of biomass for energy in Germany has been subject to various studies in the last decade, with specific studies on the sustainable potential being carried out in the early 2000s (OEKO 2004; IE/BFH/OEKO 2006). The key results are shown in the following figure.

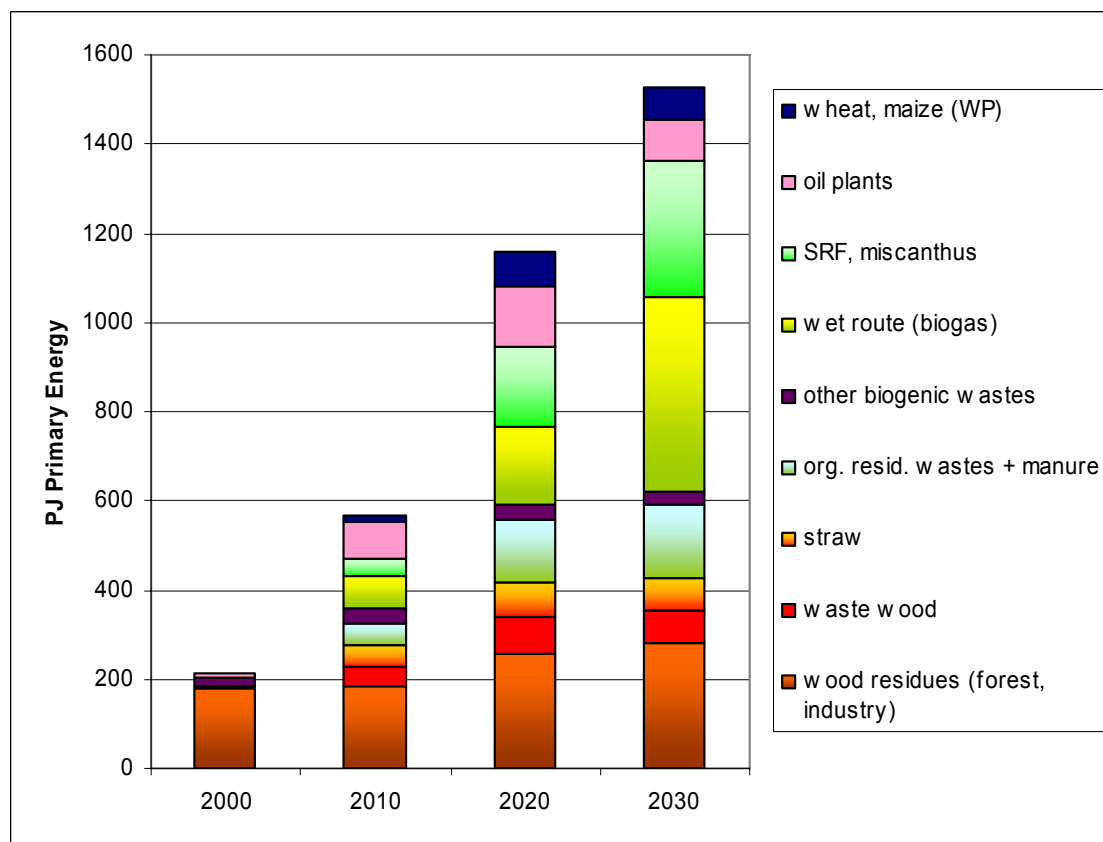
Figure 5 Sustainable Bioenergy Potentials in Germany by 2030



Source: OEKO (2004)

The domestic sustainable potential is changing in its composition of specific biomass feedstocks, as perennial feedstocks will gain drastically (see following figure).

Figure 6 Bioenergy Feedstocks in the Sustainable Bioenergy Potential for Germany by 2030



Source: OEKO (2004)

It should be noted that the shown domestic potential with regard to energy crops assumes that only the land area will be used which is “freed” from previous agricultural production due to yield increase, lacking economic competitiveness, and overall demand reduction which includes reduced exports of excess agricultural production.

The potential further **excludes** future available grassland due to the unfavourable greenhouse-gas balance of converting such land for bioenergy production.

The translation of the bioenergy potential into useful energy and respective installed capacities was determined in several other studies, as shown in the following table.

Table 8 Renewable Energy Use in Germany 2007 and Future Potentials

	Utilisation	Potential		Comments
	2007	Yield	Capacity	
Electricity generation	[TWh]	[TWh/a]	[MW]	
Hydropower <sup>1)</sup>	20.7	25	5,200	Run-of-river plants and natural inflow to reservoirs
Wind energy				
onshore	39.5	68	35,000	
offshore	-	135	35,000	
Biomass <sup>2)</sup>	23.8	50	10,000	Generation partly in combined heat/power generation
Photovoltaics	3.5	105	115,000 <sup>3)</sup>	Only suitable roof, facade and human settlement areas
Geothermal energy	0.0004	150	25,000	Bandwidth 66 - 290 TWh depending on heat utilisation requirements (combined heat/power)
<b>Total</b>	<b>87.5</b>	<b>533</b>		
Share in relation to gross electricity consumption, 2007	14.2 %	87 %		
Heat generation	[TWh]	[TWh/a]		
Biomass	84.2	150		Including useful heat from combined heat/power generation
Geothermal energy	2.3	330		Only energy supply from hydrothermal sources
Solar thermal energy	3.7	300		Only suitable roof and human settlement areas
<b>Total</b>	<b>90.2</b>	<b>780</b>		
Share in relation to final energy consumption for heat, 2007 <sup>4)</sup>	6.6 %	51 %		
Fuels	[TWh]	[TWh/a]		
Biomass	46.6	155		
<b>Total</b>	<b>46.6</b>	<b>155</b>		
Share in relation to fuel consumption, 2007	7.6 %	25 %		
<b>Share in relation to total final energy consumption, 2006</b>	<b>8.6 %</b>	<b>57 %</b>		<b>The percentile share of renewables rises above 57 % if final energy consumption is reduced versus 2006 levels (improvement in energy efficiency)</b>

Imports of energy carriers based on renewable energy sources are not included in the figures.

- 1) Excluding marine energy
- 2) Including biogenic portion of waste
- 3) Capacity figure relates to the modular capacity (MW<sub>e</sub>); the corresponding AC capacity is 106,000 MW
- 4) Room heat, hot water and other process heat

Sources: BMU [27]; Arbeitsgemeinschaft; WI, DLR, IFEU [38]; ZSW [3]

Source: BMU (2008)

As there are varying assumptions regarding the availability of suitable locations, the technical characteristics of the utilising technologies, plus various other factors, the results of potential estimates may differ considerably. The guideline values given here make particular allowance for the requirements of nature and landscape conservation, and hence represent the lower limit of the technically feasible potential.

The energetic use of biomass indicates a high level of flexibility. Depending on requirements, therefore, the percentages allocated to the areas of electricity, heat and fuel supply may vary. This is particularly applicable to the cultivation of energy crops (based here on a cultivation area of 4.5 million hectares).

As can be seen, bioenergy offers a high potential in Germany, but in the longer-term, other renewables – especially wind, geothermal and solar – will have significantly higher contributions with the exception of the transport sector where biofuels are thought to dominate until 2030.

## 5 Current and Expected Future Energy Use of Biomass

In this section, the current and future use of biomass for energy is discussed, including key biomass users.

### 5.1 Total Use of Bioenergy in Germany

Biomass traditionally contributes to cover the demand of energy in Germany. Due to the political and economic energy framework the utilization of energy from biomass shall be increased on all energy markets (electricity, heat, fuels).

The total energy use of biomass in Germany was about 858 PJ in 2008. The utilization of bioenergy increased steadily over the past years. Bioenergy is mainly used for generation of electricity and heating. The share of bioenergy in the total final electricity consumption accounted for 4.2 % and 7.3 % of the heat consumption. Biofuels had a share of 6.1 % of the fuel consumption in 2008.

Table 9 Renewable Energy Use in Germany 2008

Energy source	Electricity generation <sup>5</sup> [TWh]	Heat generation <sup>6</sup> [PJ]	Transport sector <sup>7</sup> [PJ]	Primary energy <sup>8</sup> [PJ]
Hydro power	20.8	-	-	74.9
Wind power	40.4	-	-	145.4
Solar energy	4.3	16.0	-	31.5
Biomass	25.9 <sup>9</sup>	404.0	132.0	789.0
Ambient heat, Geothermal energy	0.021	26.5	-	26.5
<b>total</b>	<b>91.4</b>	<b>446.4</b>	<b>132.0</b>	<b>1067.3</b>

Source: Lenz/Kaltschmitt/Schwenker (2009)

<sup>5</sup> Including combined heat and power (CHP) generation

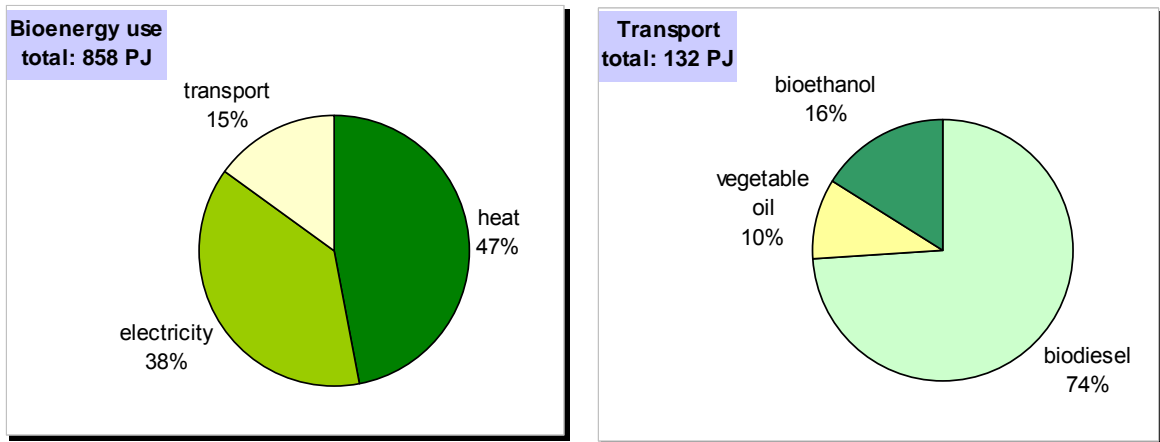
<sup>6</sup> energy contained in the fuel (LHV) including cogenerated heat

<sup>7</sup> bioliquids

<sup>8</sup> Conversion of electric energy from hydro, wind, solar and geothermal electricity via efficiency method; biomass according to fuel provided

<sup>9</sup> Including electricity generation from landfill and sewage gas and organic wastes

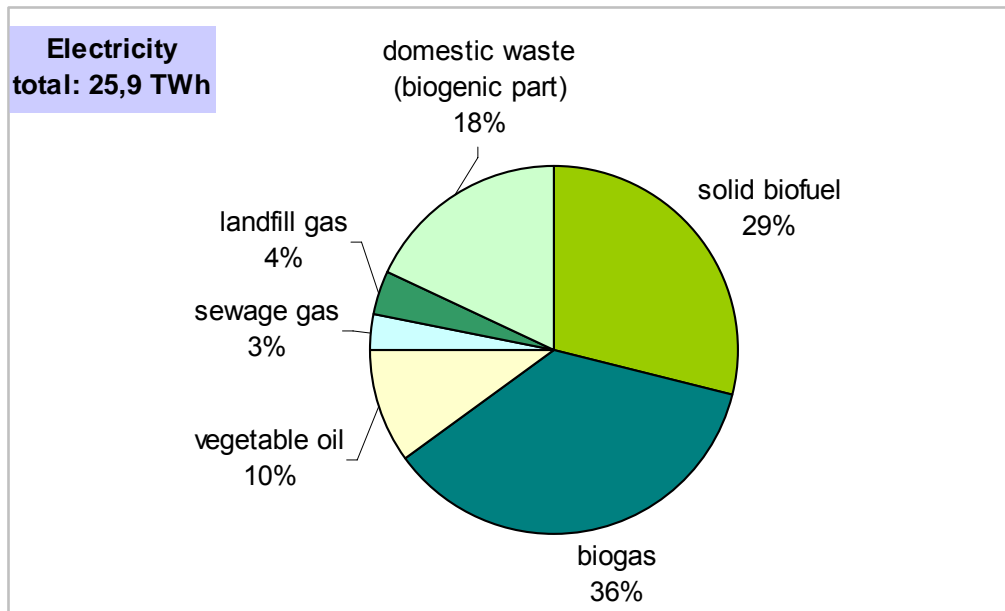
Figure 7 Total Bioenergy Use and Bioenergy in the Transport Sector in Germany in 2008



Source: Lenz/Kaltschmitt/Schwenker (2009)

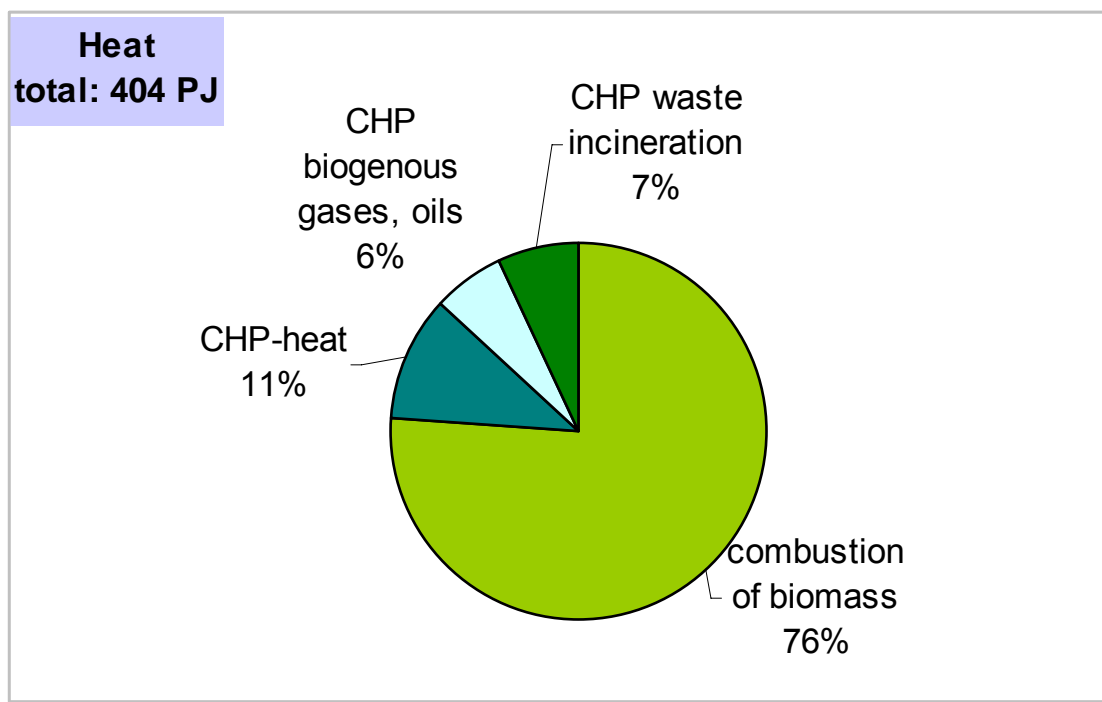
For the generation of electricity from bioenergy, solid biomass and gaseous biomass have a significant share, whereas liquid biofuels play an important role in the transport sector. Heat generation comes predominantly from solid biofuels.

Figure 8 Electricity Generation from Bioenergy in Germany 2008



Source: Lenz/Kaltschmitt/Schwenker (2009)

Figure 9 Heat Supply from Bioenergy in Germany 2008



Source: Lenz/Kaltschmitt/Schwenker (2009)

## 5.2 Solid Biofuels

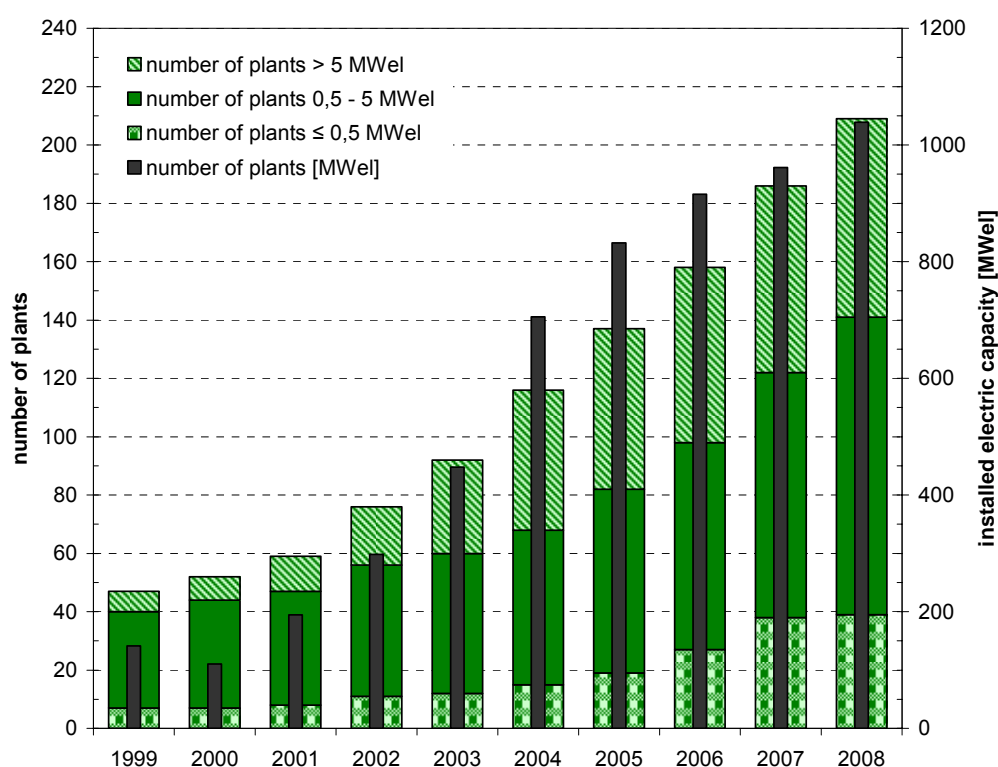
Solid biofuels are mainly used in commercial plants for the generation of electricity and combined heat and power, respectively. Heat generation based on solid biomass is solely done in small-scale plants. Both the small- and large-scale market has experienced an enormous growth in 2008, whereas the dynamics of the previous year dropped particularly in plants for electricity generation.

There are different operators of cogeneration plants based on solid biofuels. Small- to medium-scale plants are operated by companies of the timber industry, e.g. sawmills, pellet producers or manufacturing companies of windows and doors. Furthermore, it could be noted that cogenerating plants based on biomass are mostly run by utilities or municipal energy suppliers operate. More and more local and national utilities use biomass for the generation of heat and electricity. Moreover, other companies besides the timber industry use solid biomass for heat and electricity generation, e.g. companies for waste recovery or production of animal feed as well as production companies for central-heating boilers.

### 5.2.1 Solid Biofuels for Electricity Generation

The number plants installed and the related capacity has increased within the Renewable Energies Act. Until the end of 2008, about 220 generating plants including cogeneration plants with a range of an installed capacity of 120 kW<sub>el</sub> to 100 MW<sub>el</sub> were in use. 209 plants receive feed-in-tariffs according to the Renewable Energies Act. The installed capacity of biomass plants that generate electricity from solid biomass is about 1,040 MW<sub>el</sub> (see following figure).

Figure 10 Number of Biomass Cogeneration Plants and Installed Capacity in Germany 1999-2008



Source: DBFZ (2009a)

A small number of biomass plants (approx. 1.5 MW) is not entitled to receive EEG feed-in tariffs, as they generate electricity for own needs (e.g. demonstration plants). Furthermore, there are 6 cogenerating plants from the pulp&paper industry with a total installed capacity of about 190 MW<sub>el</sub> which are outside of the EEG due to their plant size (> 20MW<sub>el</sub>) (figure 3).

At the end of 2008, about 220 plants for the generation of electricity from solid biomass were in use, with a total installed capacity of nearly 1,200 MW<sub>el</sub>. The potential annual gross electricity generation of these plants is about 8.1 TWh/a

(including plants from the pulp&paper industry). Due to the commissioning of new plants in the course of the year, the real production was about 7.6 TWh at the end of 2008.

More and more plants combine power generation with an effective heat utilization. For this reason, ORC plants gained importance – 55 ORC plants are already in use, and 12 new plants are still under construction. Furthermore, there are some smaller commercial wood gasification plants.

The fuel used in CHP plants is estimated<sup>10</sup> as 5.3 – 7.6 million tons of dry mass. The majority of facilities (50%) use exclusively natural wood (forest wood and wood from landscape conservation) as a fuel. About 25% of the plants use demolition wood and wood wastes, especially byproducts from sawmills. Generally, demolition wood utilized belongs to categories AI and AII. The wood wastes are often used in the timber industry for own generation, in most cases heat is used to dry sawnwood or for belt dryers used in pellet production. Only about 20% of the plants within the capacity range of less than 0.5 MW<sub>el</sub> and 0.5 – 5 MW<sub>el</sub> use exclusively demolition wood (DBFZ 2009a).

Plants with an installed capacity above 5 MW<sub>el</sub> show another composition of fuel used. About 18% of the plants use exclusively natural wood (forest wood and wood from landscape conservation).

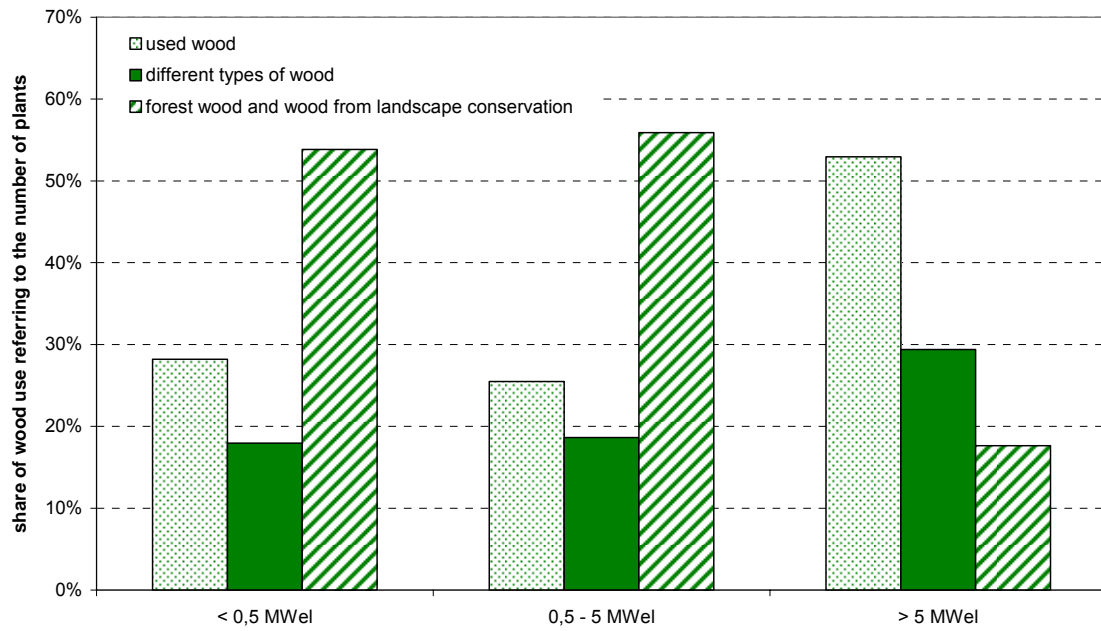
In contrast, about 53% of the plants use exclusively demolition wood. The remaining number of facilities (29%) use both demolition wood, forest residues and wood from landscape conservation.

At present, nearly all available demolition wood is subject to contracts between plant operators and suppliers. Therefore, no further expansion of demolition wood application in CHP plants (up to 20 MW<sub>el</sub>) is expected (DBFZ 2009a).

---

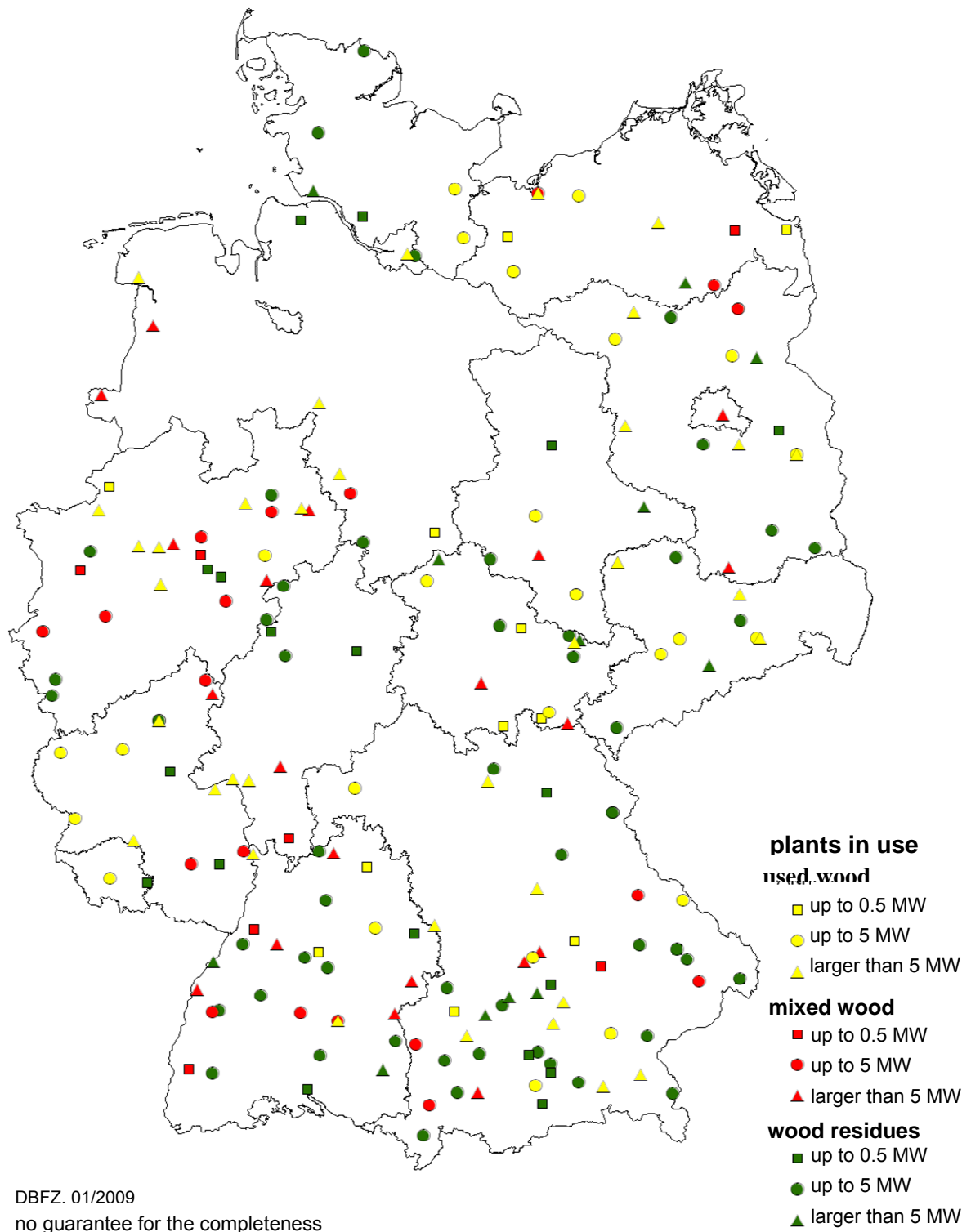
<sup>10</sup> Following electric gross efficiency considering heat extraction are assumed for the calculation: plants with an installed capacity  $\leq 0,5$  MW<sub>el</sub>: 8-13%, plants with an installed capacity 5 – 10 MW<sub>el</sub>: 10-15%, plants with an installed capacity  $>5$  MW<sub>el</sub>: 20-28%. The estimation takes also the different dates of commissioning into account.

Figure 11 Distribution of Wood Use in Plants with Different Sizes



Source: DBFZ (2009a)

Figure 12 Distribution of Solid Biomass Plants in Germany 2008



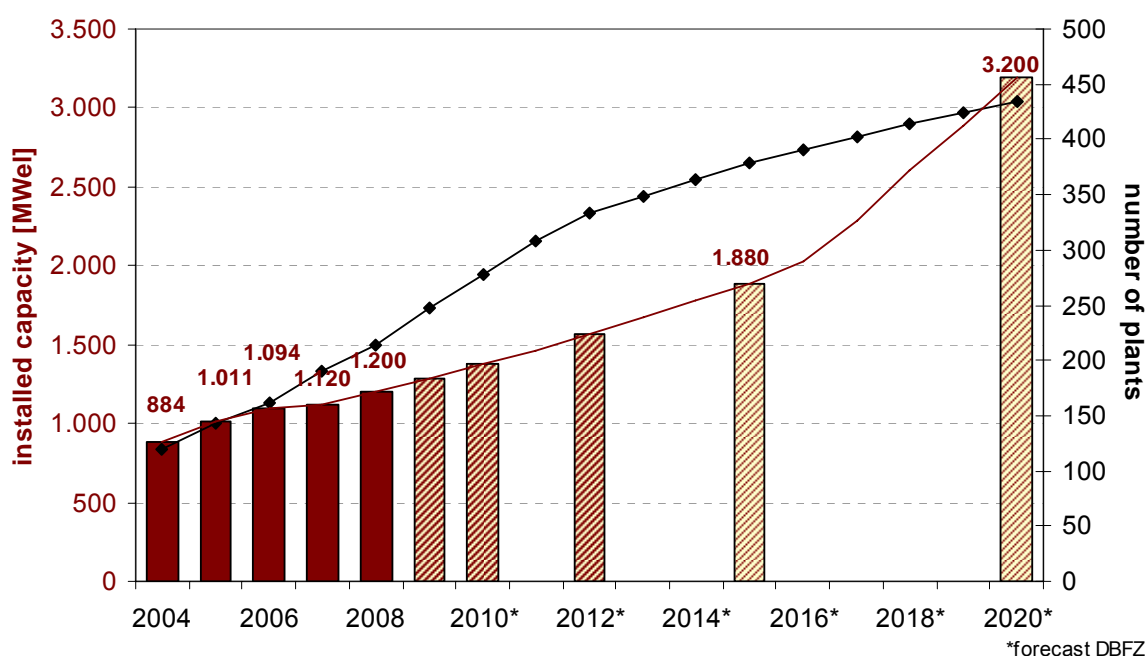
Source: DBFZ (2009a)

Currently, at least 26 new biomass CHP plants are under construction and are going to start their operations between 2009 and 2011. Furthermore, about 26 plants are in the planning and permission process.

Hence, it is assumed that the further development of plant efficiencies and an increasing use of wood gasification technologies will increase installed electric capacity up to 3,200 MW<sub>el</sub> by 2020, raising the number of plants up to approx. 450. In parallel, heat extraction will increase to about 15 TWh<sub>th</sub> in 2020.

The following figure shows the assumed development of the biomass cogeneration plants until 2020.

Figure 13 Number of Biomass Cogeneration Plants and Installed Capacity



Source: DBFZ (2009b); data include inclusive biomass CHP plants in the pulp & paper industry

## 5.2.2 Heat Generation from Solid Biofuels

In the past years the level of substitution of fossil fuels by the use of bioenergy has increased continuously. This is particularly apparent in the increasing number of biomass plants and the number of new biomass combustion plants in use. At present, about 305 PJ heat is generated from solid biomass fuels. The heat market is dominated by fuel wood (e.g. pellets, woodchips, firewood).

The heat generation stems primarily from small-scale combustion. At present, there is different information on the number of installed solid biomass furnaces.

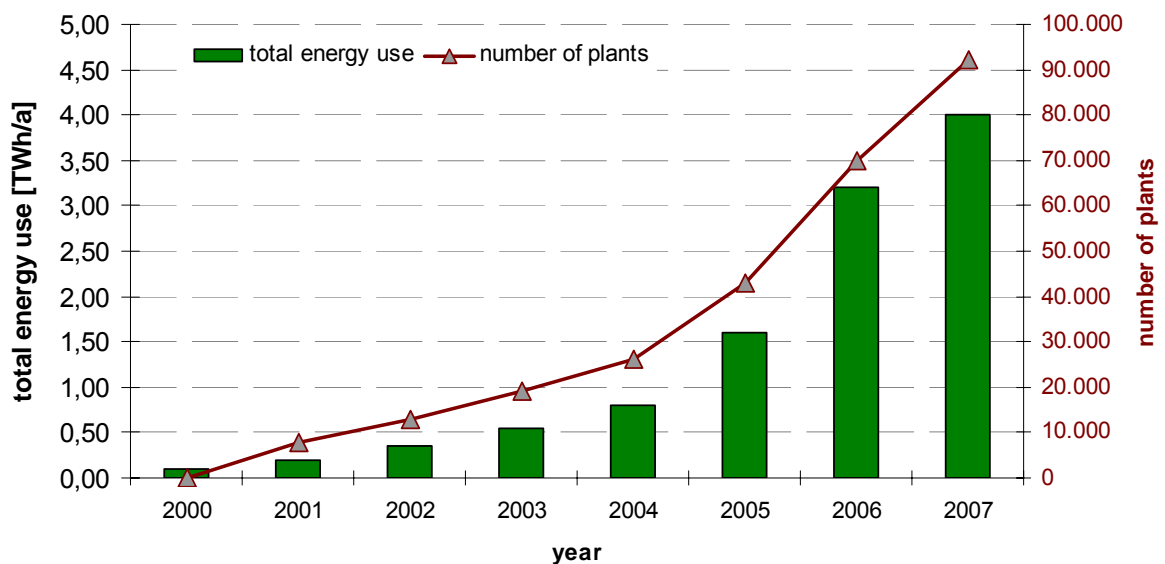
The estimated number of firewood combustion applications is 10.8 million units in Germany.

The use of pellet systems rose drastically in the last years. About 92.000 pellet stoves were in Germany in use in 2007. Due to the increased use, pellets consumption gained approx. 4 TWh/a in this sector.

The following figure shows the development of wood chip combustion plants from 2002 to 2007.

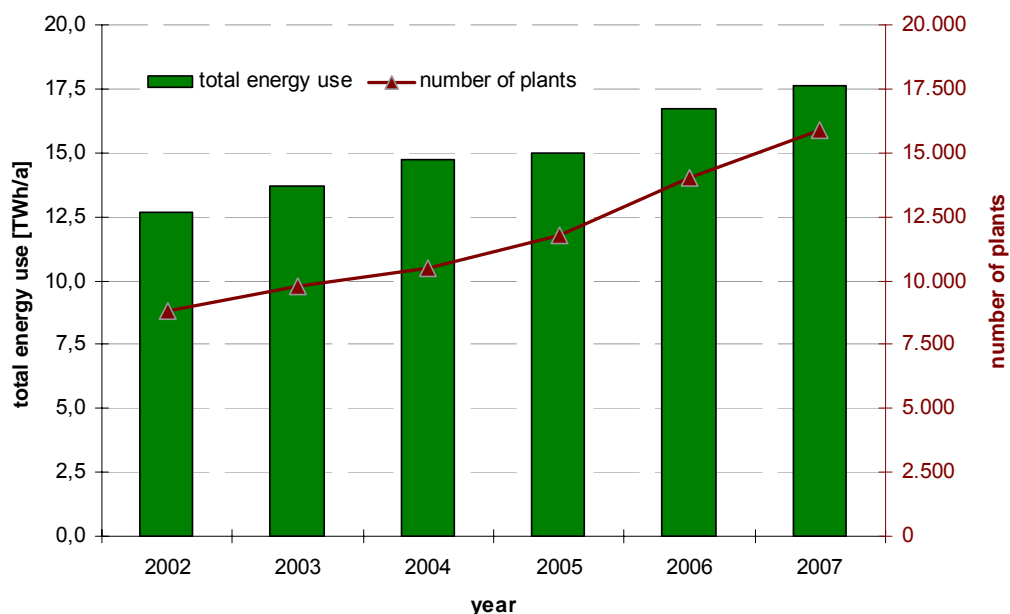
The number of wood chip boilers for heat generation purposes is amounted to 15,700 units in 2007. Thereby, the production of heat reached a level of 17.7 TWh/a.

Figure 14 Development of Pellet Systems in Germany 2000-2007



Source: DBFZ (2009b)

Figure 15 Development of Woodchips Systems in Germany 2002-2007



Source: DBFZ (2009b)

The projection for the future use of solid biofuels extrapolates the current development, and includes advanced technologies. With that, the number of firewood combustion applications is assumed to increase up to 17.1 million units with a heat generation of 77 TWh/a until 2020. The future heat generation from pellets is also based on an extrapolation which results in about 295.000 pellet stoves units which means about 12.3 TWh/a heat generated by pellet stoves in 2020. The number of woodchip heating systems would reach 32.900 units by 2020, with heat from woodchips increasing by 29.7 TWh/a.

The following table gives an overview of the estimated future heat generation from solid biomass fuels.

Table 10 Estimated Heat Generation from Solid Biofuels in 2020

	unit	Split logs	Wood chips	Pellets	Heat from CHP
number of plants		17,090,000	32,900	295,000	
Heat	TWh <sub>th</sub> /a	76.6	29.7	12.3	15.5

Source: DBFZ (2009b)

### 5.3 Gaseous Biofuels

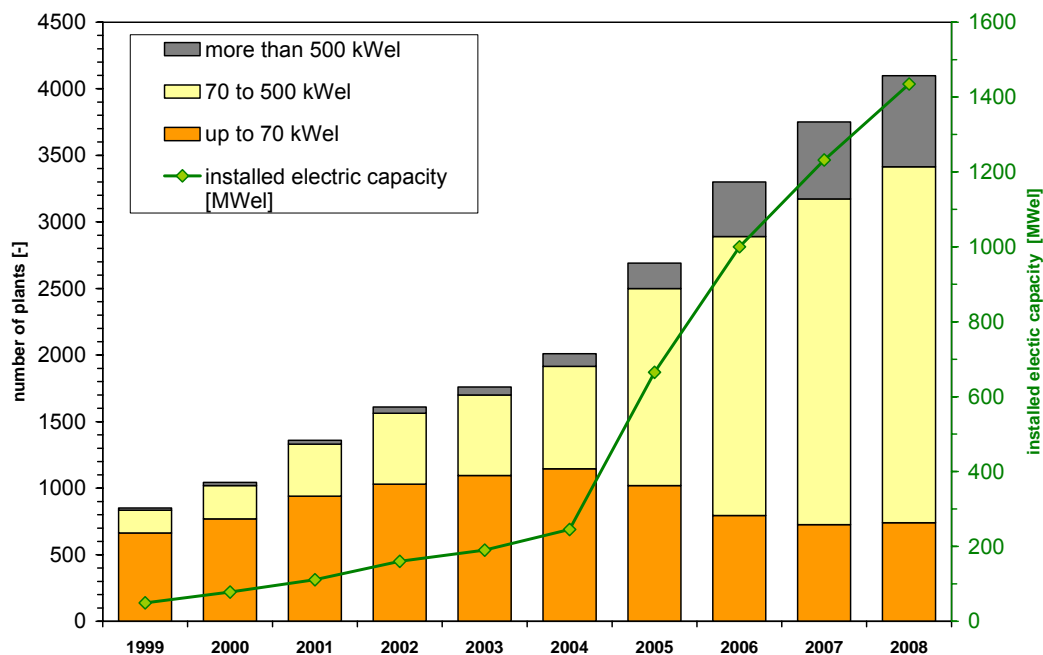
Gaseous biofuels (in particular biogas) are used to generate electricity as well as for CHP. Biogas is mostly produced in rather small-scale plants on farms or larger landfill and sewage gas plants.

Gaseous biofuels are used in different sectors. Thereby to a large part in agricultural holdings which operate biogas plants. In general agricultural biogas plants are small to medium size with an installed capacity of 350 kW<sub>el</sub> on average. Furthermore biogas plants that utilise organic waste and industrial waste, respectively, often operate with a higher installed capacity than the mentioned average agricultural plants. Most of the biogas plants are designed for the generation electricity which is fed into the electricity network.

#### 5.3.1 Electricity Generation from Gaseous Biofuels

At the end of 2008, about 4.000 biogas plants with an installed capacity of approximately 1.400 MW were in use in Germany. Compared to the proceeding years, the number of new installations of biogas plants slowed down in 2008, with only 200 to 250 new biogas plants. This was mainly due to the expected improved feed-in tariffs for biogas according to the amendment of the Renewable Energies Act coming into effect in 2009. The following figure shows the development of installed biogas plants, with an average installed biogas plant capacity between 70 and 500 kW<sub>el</sub>.

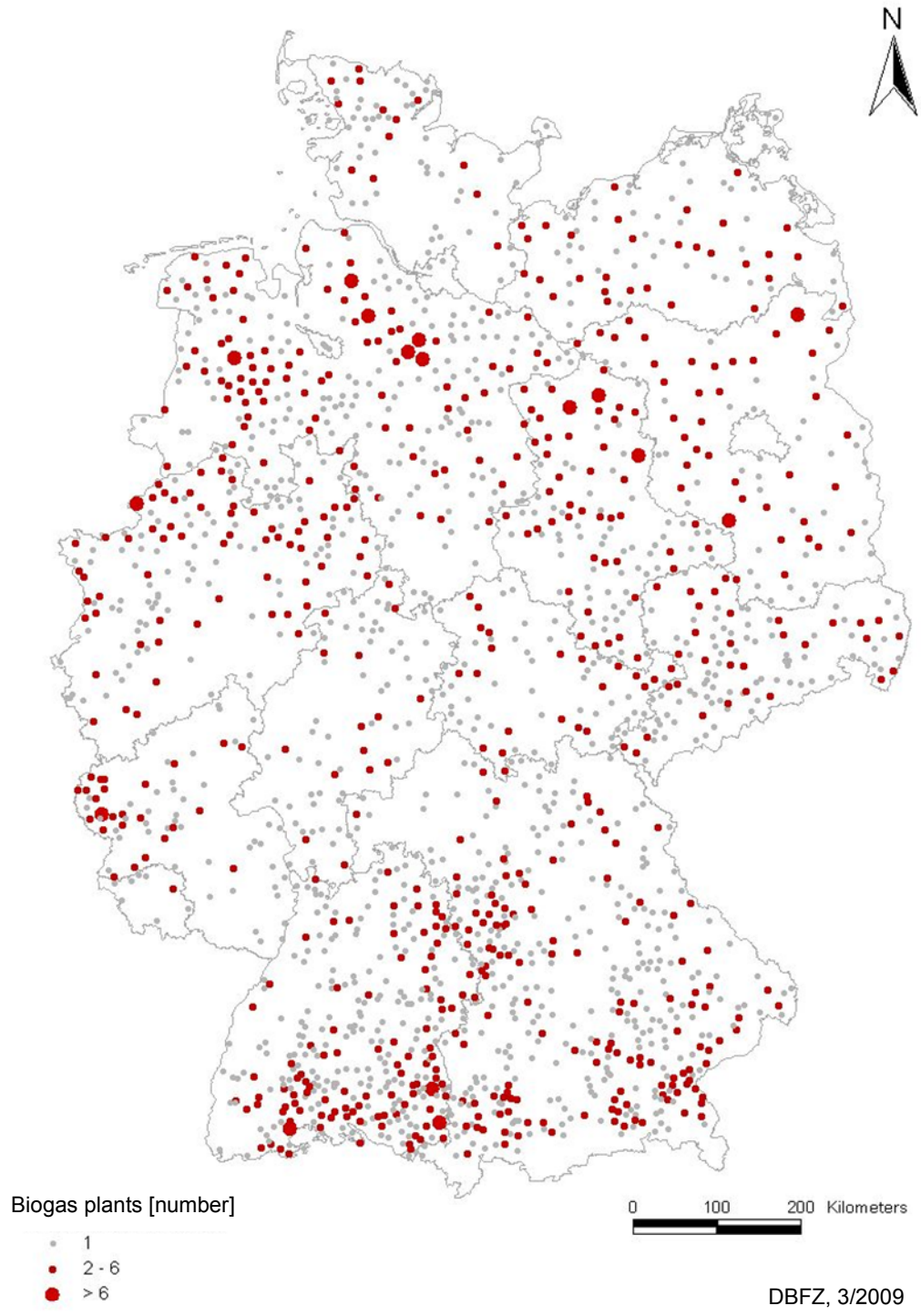
Figure 16 Development of Biogas Plants and Installed Capacity



Source: DBFZ (2009a)

Electricity generation from biogas was 9.2 TWh in 2008.

Figure 17 Distribution of Biogas Plants in Germany in 2008

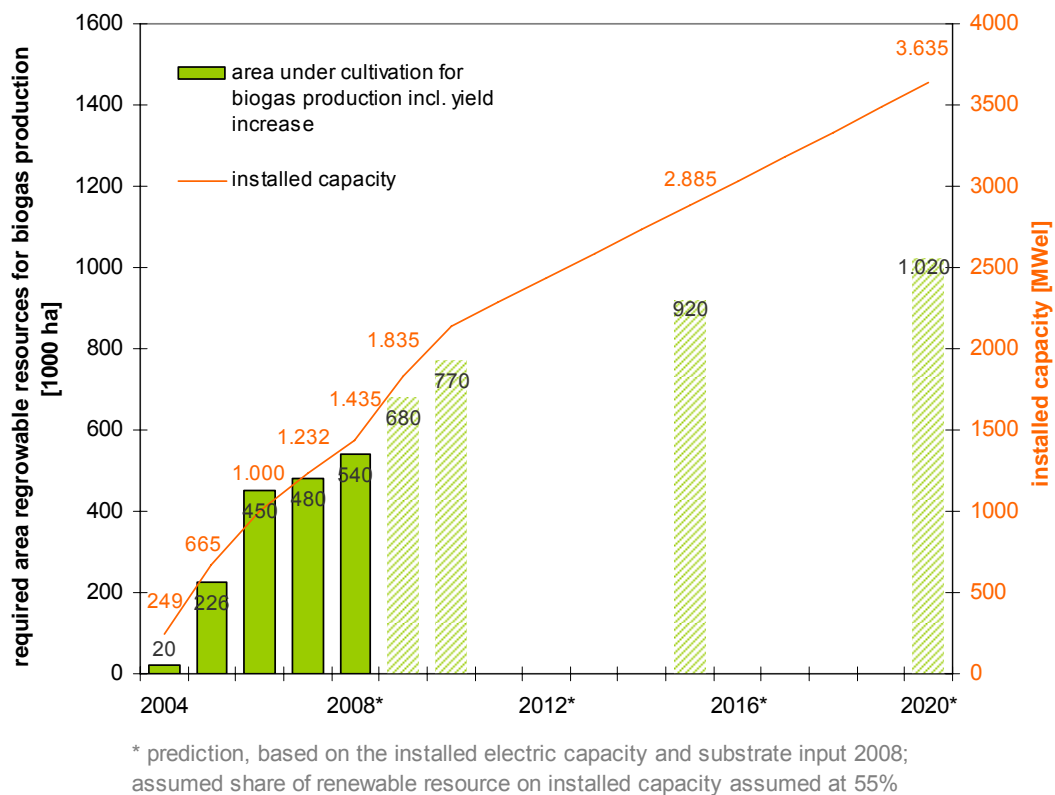


Source: DBFZ (2009a)

Furthermore, at the end of 2008, 15 plants feeding biogas into the gas distribution system were in use. The installed capacity of these plants is in total about 80 MW<sub>th</sub>. The realised feed-in from biomethane into the gas distribution system is estimated to an amount of approx. 420 GWh. Moreover, landfill gas plants provided about 1TWh/a. At present approximately 700 sewage gas plants with an installed electric capacity of about 160 MW are in use. The electricity generation from sewage gas plants was approx. 1 TWh in 2008.

Assuming that the number of new biogas plants will rapidly increase as a result of the amendment of the Renewable Energies Act 2009, a moderate growth of the number of biogas plants for the future energy use of biogas can be projected. Under these assumptions the installed capacity of biogas plants will increase up to 3,635 MWe<sub>l</sub> until 2020. It is expected that two-thirds of installed electric capacity will be used for the on-site power generation and one third will be fed into the gas distribution network. About 10 % of the fed-in biogas will be used in the transport sector. According to this expected development, the current substrate input and the required area under cultivation including yield increase is about 1 million hectares (see following figure).

Figure 18 Expected Installed Capacity and Required Land for Biogas Production in Germany until 2020



Source: DBFZ (2009b)

### 5.3.2 Heat Generation from Gaseous Biofuels

Referring to the total produced energy amount the used heat amount is about 20 %. According to the assumed real electricity generation from biogas plants, the underlying average efficiency of cogeneration units and the average degree of heat utilization the used heat amount from biogas plants is estimated between 3.8 and 4.4 TWh<sub>th</sub> in 2008.

According to the actual heat utilization and the estimated future installed capacity for biogas production (3,635 MW<sub>el</sub>), the possible future heat utilization from biogas will be roughly between 9 and 13 TWh<sub>th</sub>.

## 5.4 Liquid Biofuels

In 2008 the production capacity of vegetable oil methyl ester stayed the same compared to 2007. The production capacity is about 4.8 million t/a. Due to the increase of vegetable oil prices, decreasing prices for fossil fuels and the increasing taxes biodiesel production in Germany the production capacity was not fully utilized but at an average of 60%. That means that most of the 44 plants had to temporarily stop their production. However, the production capacity of bioethanol rose up to 0.85 million t/a in 2008.

Liquid biofuels are predominantly used in the transport sector. Besides, liquid biofuels as vegetable oil and biodiesel are also used in cogeneration plants for the generation of electricity and heat.

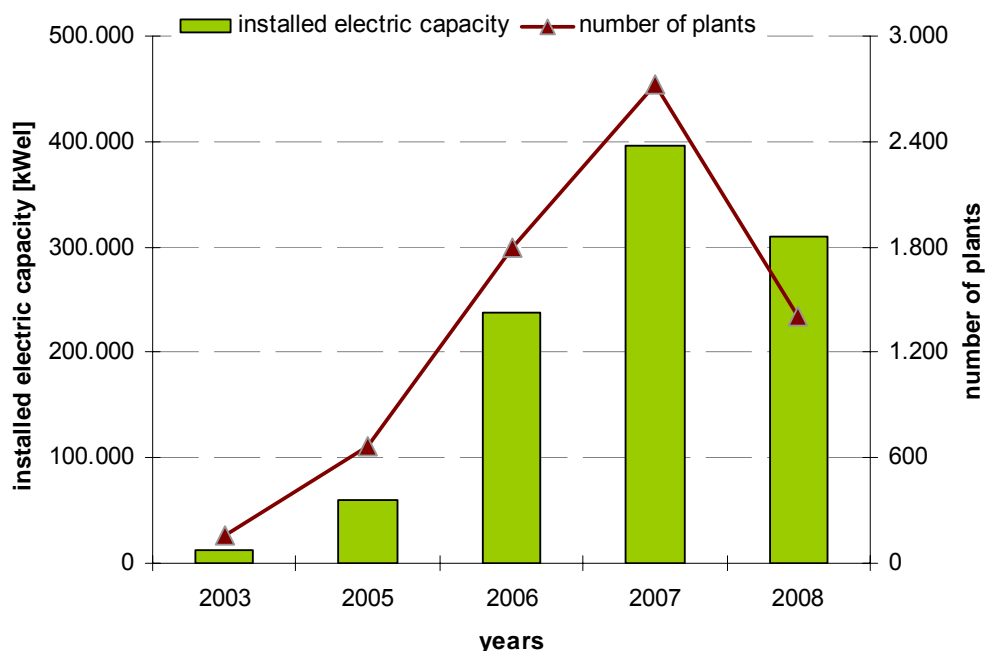
Liquid biofuels for the generation of heat and electricity are operated in different fields. Plants with smaller installed capacity (<10kW<sub>el</sub>) are predominantly used in residential buildings and operated by private persons. In this case liquid biofuels are used for the generation of heat and hot water. Plants with medium installed capacity are partly in use as basic or additional income in order to generate heat for residential buildings, greenhouses or companies. Municipal energy suppliers and utilities often own plants operated based on liquid biomass with a higher installed capacity. Furthermore liquid biofuel plants are in use as a local installation.

### 5.4.1 Electricity and Heat Generation from Bioliquids

About 11% of the liquid biofuel plants are electricity-operated. In 2008, predominantly pure vegetable oil (especially imported palm oil) and domestic rapeseed oil were used for electricity generation. Most of the cogeneration plants (more than 70%) that use liquid biofuels are heat-operated. Due to the high prices for vegetable oil a lot of plants can not operate profitable any longer. Thus the amount of fed-in electricity to the distribution network is declining.

In 2008, about 1,400 liquid biofuel plants were in use. The installed electric capacity was about 310 MW<sub>el</sub>. The inducted amount of electricity fed into the public grid was about 1.9 TWh<sub>el</sub> (figure 13)

Figure 19 Development of Electricity from Bioliquids in Germany 2003-2008



Source: DBFZ (2009b)

Several cogenerating plants using vegetable oil were shut down due to technical difficulties and economic reasons in the last year. Thus, a rather stagnating development is estimated. Furthermore, the amendment of the Renewable Energies Act causes further restrictions to the use and compensation of vegetable oil for electricity generation. Hence, a constant heat extraction of about 2 TWh/a is estimated.

#### 5.4.2 Bioliquids for Transport

In 2008, the use of biofuels in the transport sector was about 3.7 million t with a high share of biodiesel (fatty acid methyl ester, FAME). Biodiesel gains about 74% of the total use of liquid biofuels and is used as admixture to fossil fuels (60%) and as non-blended biofuel (B100) up to 40%.

The total consumption of liquid biofuels in the transport sector was about 132 PJ in 2008. Compared to the preceding year, a decline of about 15% occurred as a result of the decreasing sale of non-blended biofuels (B100) and decreasing use of pure vegetable oil. The consumption of FAME was about 2.7 million t (102 PJ) in 2008. In addition, approx. 16 PJ of bioethanol was used, especially as ethyl tert-butyl ether (ETBE). The use of vegetable oil in the transport sector

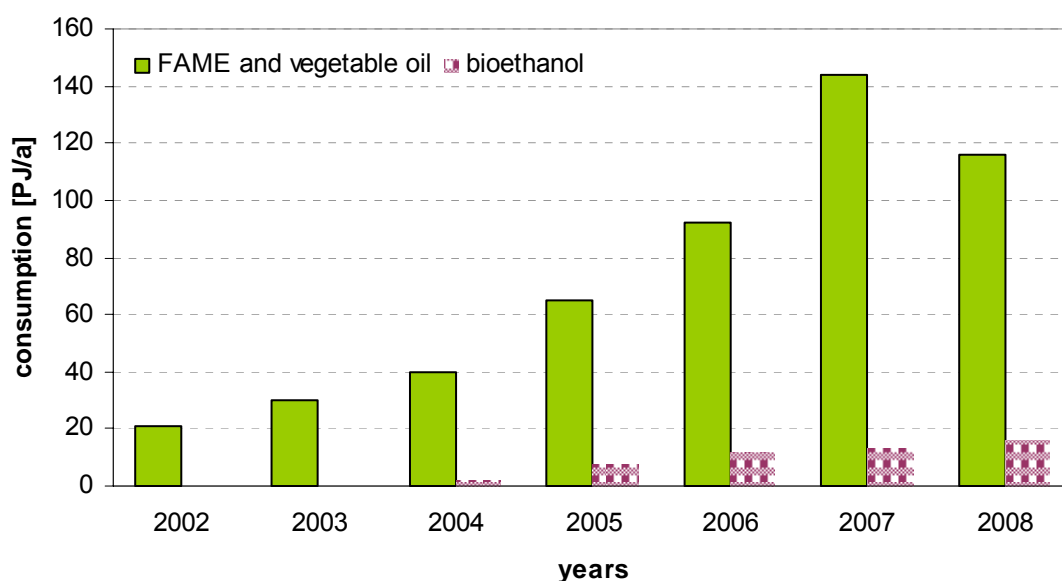
amounted to 0.36 million t (14 PJ) in 2008. Compared to 2007, the use of plant oil is regressive.

*Table 11 Consumption of Liquid Biofuels in the German Transport Sector*

	million t	PJ
Fatty acid methyl ester (FAME)	2.7	102
Bioethanol, ethyl tert-butyl ether (ETBE)	0.64	16
vegetable oil	0.36	14
<b>total consumption</b>	<b>3.7</b>	<b>132</b>

Source: Lenz/Kaltschmitt/Schwenker (2009)

*Figure 20 Development of the Consumption of FAME, Vegetable Oil and Bioethanol in Germany*



Source: DBFZ (2009b)

The production of biodiesel will decline until 2020, whereas the production capacity of bioethanol will increase. Furthermore, 2<sup>nd</sup> generation biofuels are expected to contribute up to about 100 PJ/a, with lignocellulosic bioethanol contributing about 55 PJ/a. Therefore, it is important to establish 2<sup>nd</sup> generation technologies (BTL, Bio-SNG and lingo-ethanol) in the market until 2020.

Table 12 Expected Production of Biofuels in Germany by 2020

	FAME	Bioethanol		BTL	Biomethane		total
		1 <sup>st</sup> generation	lingo-cellulosic		from gasification	from biogas	
production [million t/a]	2.1	0.9	0.9	0.6			5.4
[MW <sub>th</sub> ]					(1,000)	(1,000)	(2,000)

Source: DBFZ (2009b)

## 6 Biomass Prices and Consumption

Statistics on the price and quantity development of the different biofuels are published regularly in Germany. The most statistics date back to the year 2000. However, the data for the majority of the biofuels is not gathered centrally at the Federal Statistical Office as it is practice for conventional energy sources but rather by research institutions and market observers. Prospectively, it is desirable that information on bioenergy prices will be covered by the Federal Statistical Office as well in order to guarantee highest possible coverage of price data. It has been noted, that research institutes can not produce an over-all picture of the price development due to various reasons as regional price surveys and lack of funds.

Below the price development for the main biofuels in Germany between 2000 and 2008 are shown. All prices include VAT and other fees.

### 6.1 Wood Pellets

In Germany, pellets from wood wastes are primarily used at the small-scale level due to the legal framework promoting the use of pellets in the residential sector. Only about 5 % of all installed pellet boilers have a rated heat output above 100 kW. In the last years, the pellet market for small- and medium-scale applications experienced a rapid growth.

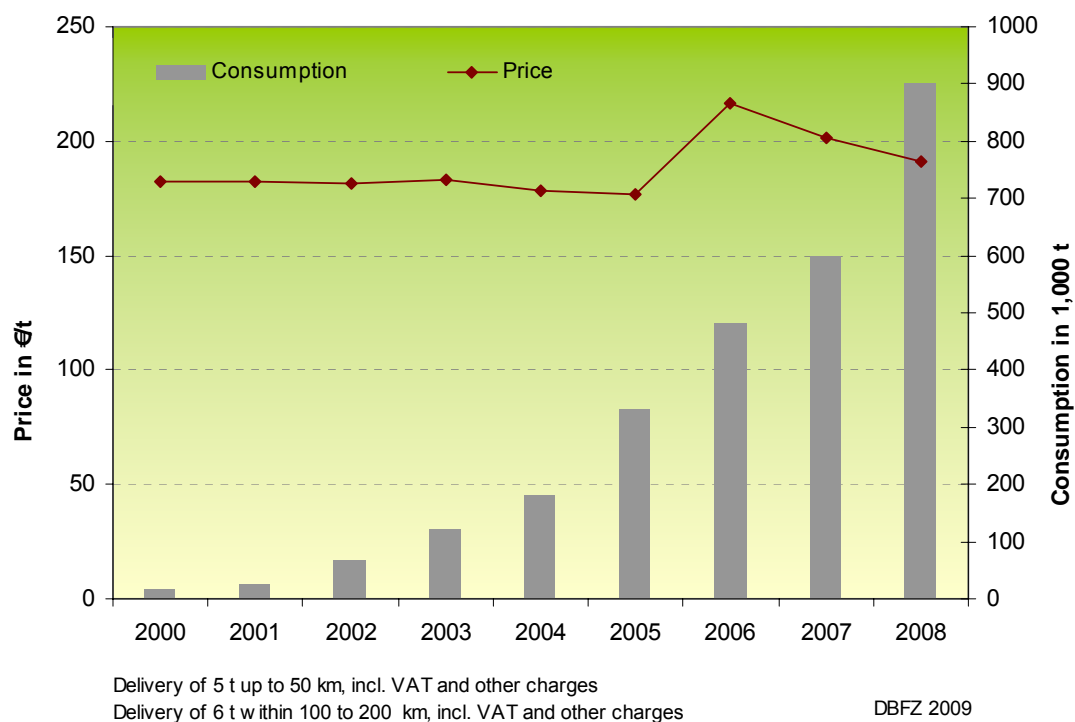
Market data on pellets - price development, quantities consumed and produced - is mainly gathered by two organisations: the Central Network for Marketing and Development of Agricultural Resources in Germany (C.A.R.M.E.N. e.V.) and the German energy pellet association (DEPV).

C.A.R.M.E.N. e.V. provides monthly prices based on information from pellet retailers. For price calculations, C.A.R.M.E.N. e.V. refers to a purchase quantity of 5 t delivered within a radius of 50 km. DEPV refers to a purchase quantity of 6 t delivered within a radius of 100 to 200 km. Figures have been available for the years 2002 to 2008. Previous price data starting from 2000 could not be obtained since no data has been recorded by that time. Experts mention a price of 180 to 185 €/t for the years 2000 and 2001. Moreover, DEPV observes the pellet market concerning the consumption rate, production and production capacity.

Both the price development and consumed quantity of pellets for domestic use is shown in the following figure. The values are average prices derived from the prices provided by C.A.R.M.E.N. e.V. and DEPV.

The average price of pellets for large-scale use was in the range of 110 to 135 €/t during the last years (IE 2008). Only in 2006/2007, a price increase up to 160 €/t could be observed.

Figure 21 Market Development for Pellets in Germany 2000-2008



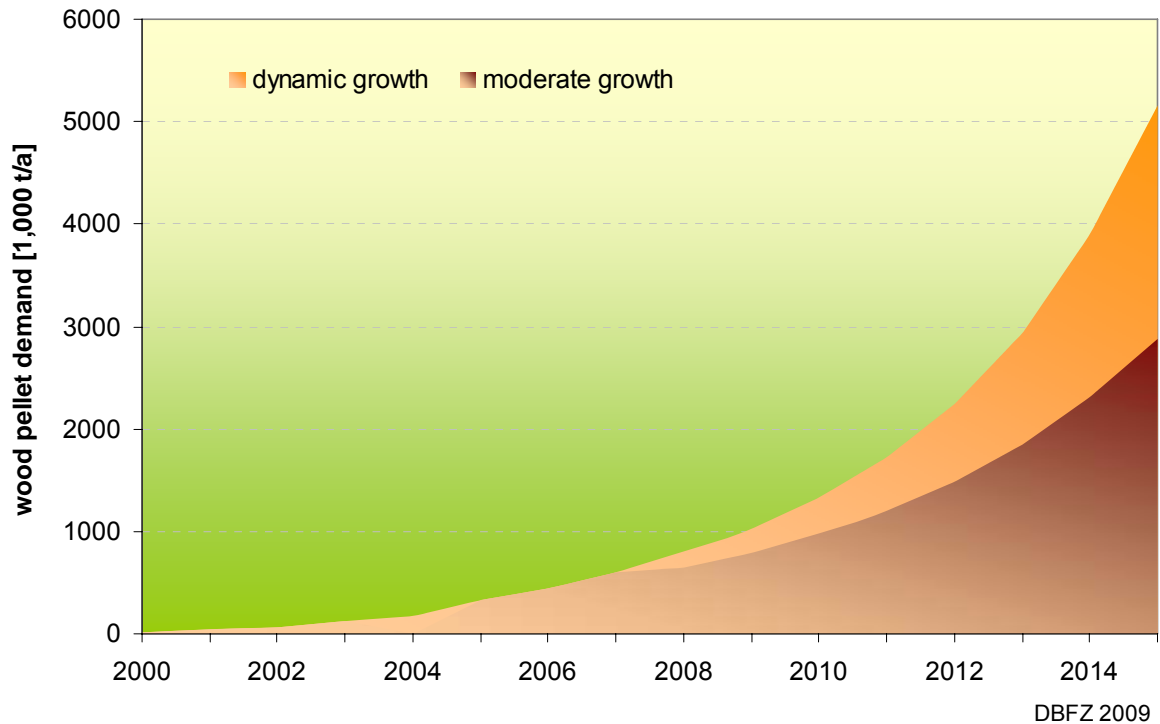
Source: CARMEN, DEPV

Under consideration of the different policy instruments promoting the use of wood pellets for energy generation and the current market structure, the future development of the wood pellet demand has been assessed in two scenarios:

A **moderate** market growth related to past growth, and a **dynamic growth** scenario assuming a boom of the bioenergy markets due to the legislative framework and the increase of fossil fuel prices.

The scenarios for the domestic consumption are shown in the following figure.

Figure 22 Scenarios for the Pellet Demand in Germany



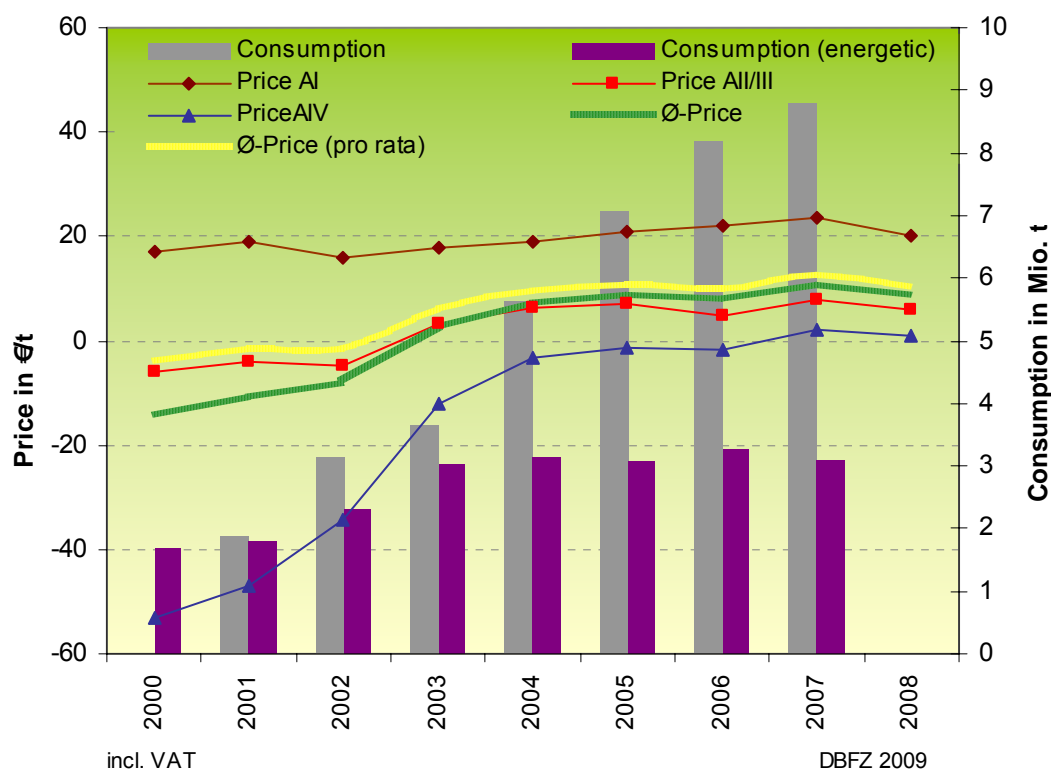
## 6.2 Demolition Wood and Wood Wastes

Information on the price development of used wood is provided by the scientific journal European economic service (EUWID). The magazine publishes quarterly the prices for the four different categories of used wood: I – untreated wood, II & III – wood treated with paint and glue, IV - wood treated with preservatives. Since 2000 the prices for each category have risen, in particular for category IV. This is due to the increased energetic use of used wood promoted by the Renewable Energies Act.

The price development for used wood is shown in the following figure.

Concerning the amounts of used wood applied for energetic purposes there is no institution in place providing this data. The Federal Statistical Office publishes numbers on the waste produced in Germany among which woody waste is listed plus the import and export amounts of used wood. Based on this information the generally consumed quantity of used wood can be determined. The amount of used wood only applied for energy purposes is based upon own estimates. The development of both numbers over the last years is shown in figure 17.

Figure 23 Market Development of Used Wood in Germany 2000-2008



Source: DBFZ (2009a); EUWID; DESTATIS

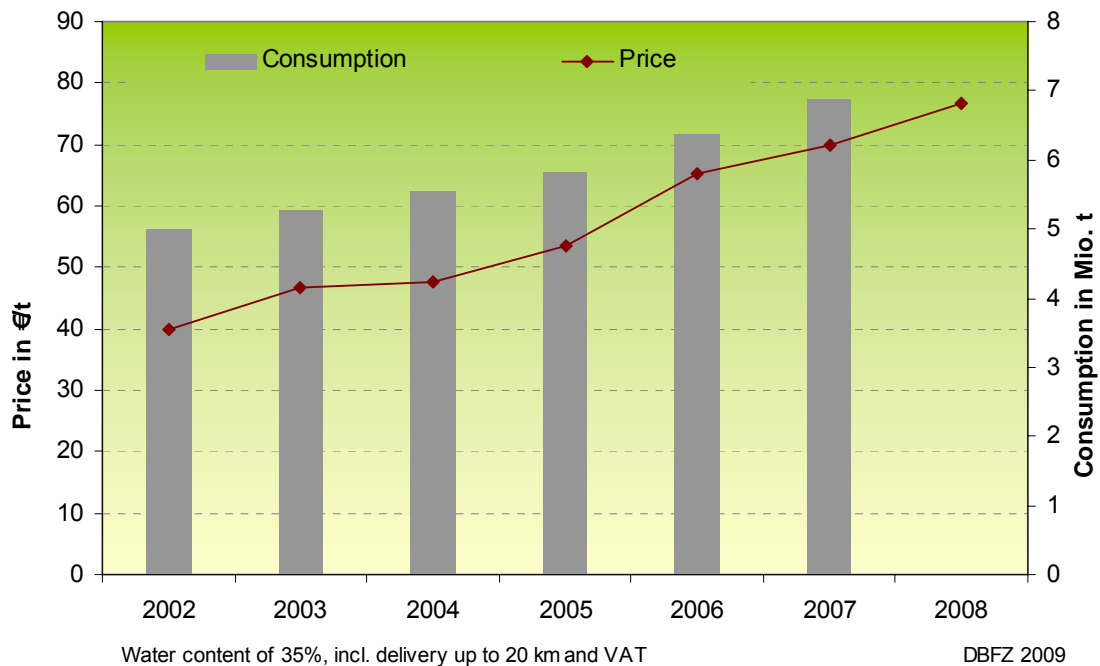
### 6.3 Woodchips

As for wood pellets, C.A.R.M.E.N. e.V. surveys the price development of woodchips on the German market. Quarterly, the institution publishes the prices for a purchase quantity of 80 bulk cubic meters of wood chips delivered within a radius of 50 km and a water content of 35 %. Since the prices have been recorded in 2002 a price increase of 90 % could be observed. Besides, it is noticed that the wood chip prices differ a lot depending on the quality like the type of wood and the region in Germany - a densely wooded area as in the South of Germany or a rather agrarian structure with less wood sources as in Northern Germany (DBFZ 2009b).

In the following figure, the prices for woodchips between 2002 and 2008 are illustrated.

Concerning the amount of woodchips used for energy, there is only few statistical data available. Hence, the quantity of woodchip consumed was determined based on the estimated number of woodchip furnaces installed. In the past, a continuous increase of woodchip heating systems could be observed as shown below.

Figure 24 Market Development of Woodchips in Germany 2002-2008



Source: DBFZ (2009b); CARMEN

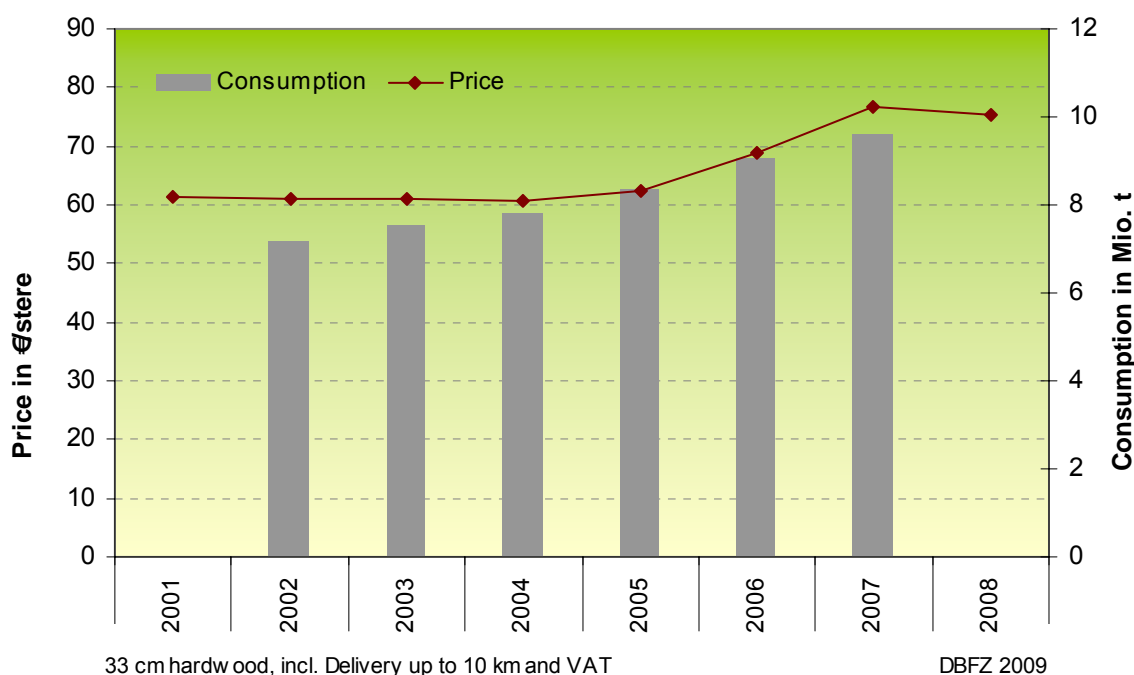
## 6.4 Firewood

The Technology and Support Centre (TFZ) publishes biannually the price development of firewood. Thereby, the prices refer to the supply of 6 stacked cubic meters of prepared hardwood made from oak, beech or ash; delivered within a radius of 10 km. The price for firewood has been rather stable since recording. An upward movement began in 2005 due to an intensified usage of firewood as fuel. Thus, the price has increased by roughly 20 % from 2001 till 2008.

As in the case of wood chip heating systems there is no official statistics on firewood usage in Germany in place. Thus, the quantity has been estimated via the amount of firewood furnaces installed and the related fuel input (DBFZ 2009b).

An overview on all numbers is presented in the following figure.

Figure 25 Market Development for Firewood in Germany 2001-2008



Source: DBFZ (2009b); TFZ

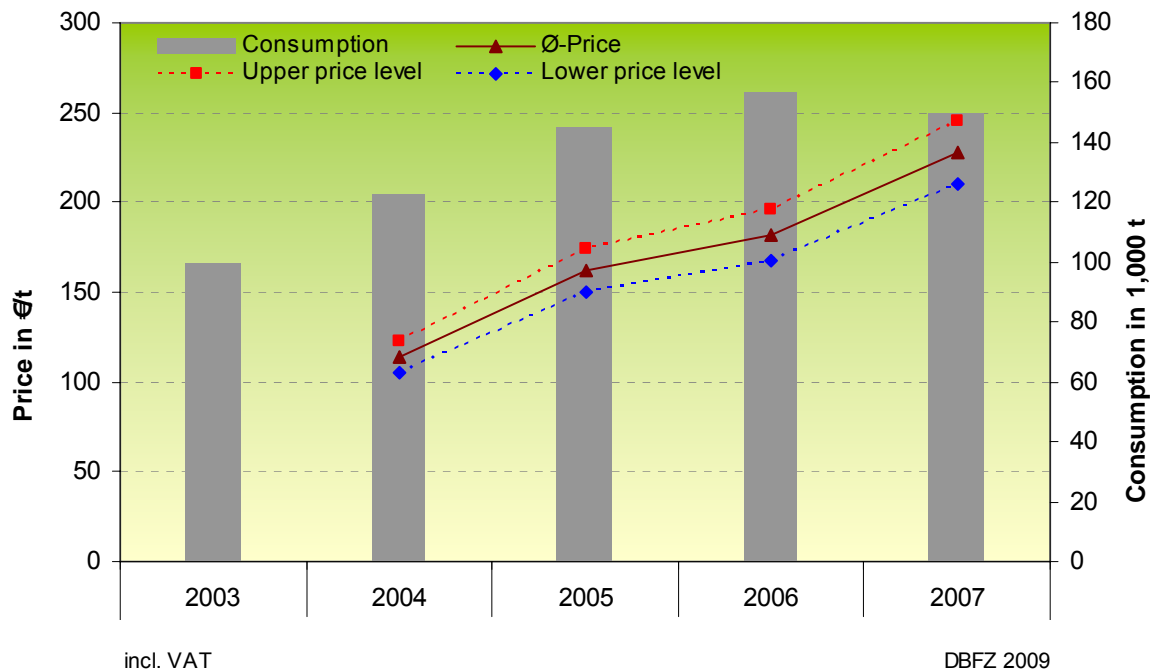
## 6.5 Wood Briquettes

The wood briquettes market offers the least official information among the considered solid biofuels. This is mainly due to the small size and immaturity of the wood briquette market. Market data could only be obtained by gathering figures directly from individual producers. In the period 2004 to 2007 the price for wood briquettes has experienced a rapid growth. Within four years the price has doubled owing to a greater demand for this biofuel.

Since 2003 the wood briquette market grew by 50 % in the market size. In 2007 150,000 t briquettes have been used for energy supply which is still a fairly small number compared to the other solid fuels. However, this market holds a high future growth potential.

An overview of the current wood briquette market and its development since 2003 is presented in following figure.

Figure 26 Market Development for Wood Briquettes in Germany 2003-2007



Source: IE (2008b)

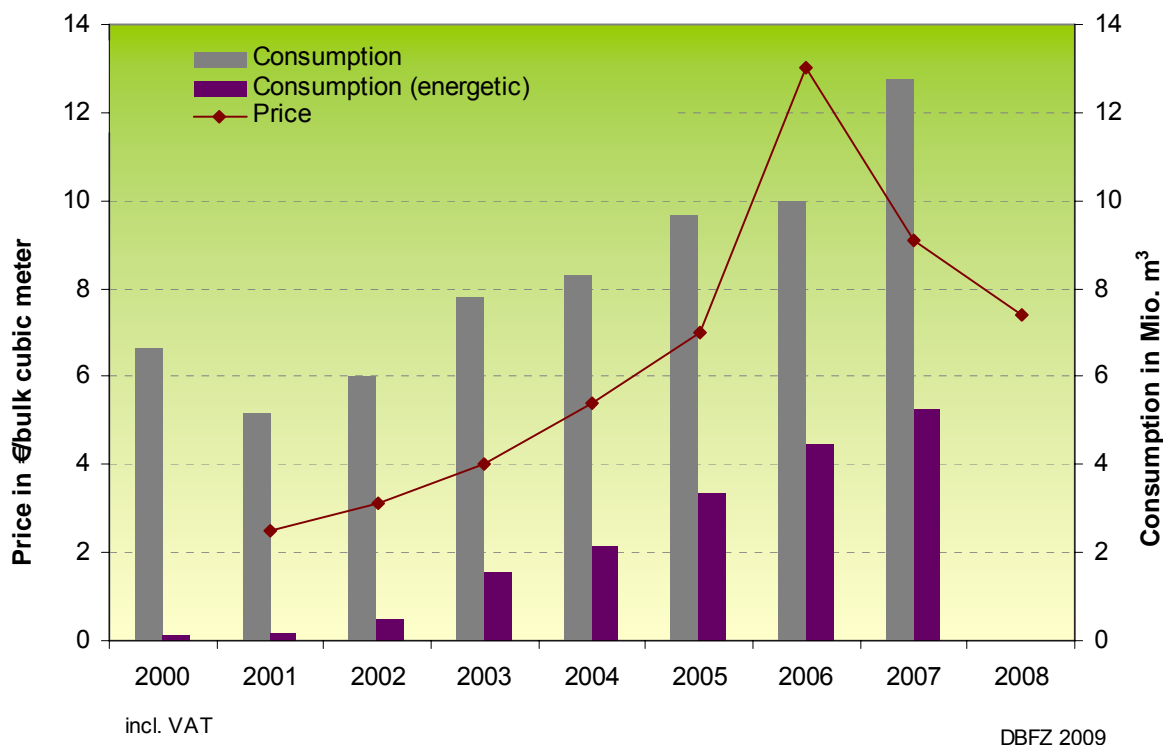
## 6.6 Sawdust

EUWID publishes every two to three months a market review on saw mill residues. By means of these reports and own surveys the price development could be traced back until 2001. Over the past years the price for sawdust has risen constantly with a peak in 2006. Currently, the price level corresponds to the 2005 level. The reason for the price rise was a sudden increase in the demand for wood pellets. Sawdust as a primary input material for wood pellets was directly affected by this development.

Figures on the consumed amount of sawdust for energetic purposes are not available. The Federal Statistical Office collects data on the production, export and import of sawdust in Germany. Based on these numbers the actual size of the market can be determined. Since 2000 it can be noticed that the production of sawdust has more than doubled. The import and export numbers have been more or less steady during the considered period, so that the amount of sawdust used in Germany doubled from 2000 to 2007. Considering the quantities of sawdust used for energetic purposes, derived from own estimates, a strong increase can be noted.

Thus, in 2000 roughly 2 % of the total quantity of sawdust was used in the energy sector but by 2007 the number reached already about 40 % with an upwards trend.

Figure 27 Market Development of Sawdust in Germany 2000-2008



Source: IE (2008b); DESTATIS (2007); EUWID (2007)

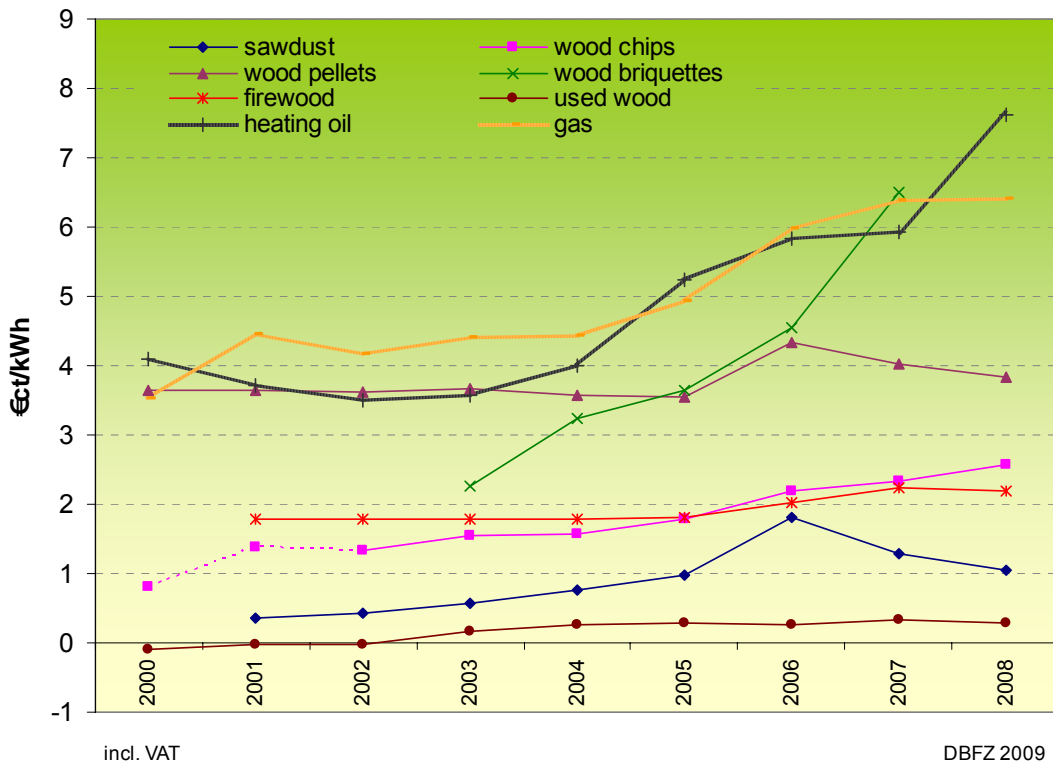
## 6.7 Price Comparison of Various Solid Biofuels and Fossil Fuels

Figure 28 shows the price development of the different solid biomass fuels in comparison to heating oil and gas as conventional energy sources in €/t/kWh.

Considering the different solid biomass fuels regarding the price for providing 1 kWh of energy, it can be noted that wood pellets and wood briquettes show the highest price for generating 1 kWh. This is mainly reasoned in a higher complexity of the production process of these fuels.

Comparing the prices of solid biomass fuels with fossil fuels it can be observed that between 2000 and 2004 the average prices for heating oil and wood pellets have been closely together. But in 2005 the price for heating oil took off while all other solid biomass prices, except for wood briquettes, show a rather slight increase over time.

Figure 28 Prices of Solid Biofuels Compared to Fossil Fuels 2000-2008



Source: DETATIS (2009)

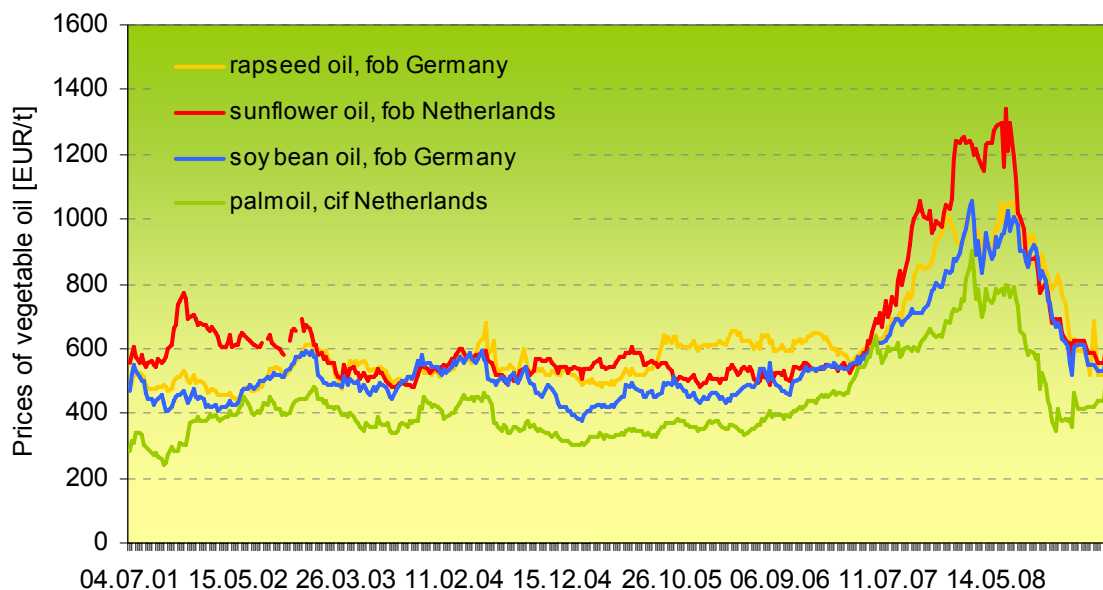
## 6.8 Vegetable Oil

Until 2007, the prices for vegetable oil remained nearly at the same level over the past years as shown in figure 23 below. However, in 2007/2008 a sharp increase due to a higher demand on the world market could be noted.

While the average price for rapeseed oil was 540 €/t (fob Germany) and for palm oil 340 €/t (cif Netherlands) in 2005, the prices have almost doubled until mid 2008 and ranged at an average of 916 €/t for rapeseed oil (fob Germany) and 647 €/t for palm oil (cif Netherlands).

This was followed by a decline in the second half of 2008.

Figure 29 Price Development for Vegetable Oil in Germany 2001-2008



Source: ZMP (2009)

## 7 Bioenergy Trade: Status, Barriers and Opportunities

### 7.1 Status of Bioenergy Trade in Germany

The main biomass fuels where flows of trade have established during the last years are wood pellets, woodchips, vegetable oil, biodiesel and ethanol.

For pellets, Germany has higher **exports** than imports. The main trading partners are the Austria, Baltic States, Scandinavia, the Benelux countries and various Eastern European countries. About 50 % of the German production is exported, mainly to the Belgium, Luxembourg, the Netherlands, and Scandinavia, and 30 % of the domestic consumption is imported from Austria and the Baltic States (data for 2007). According to FAO statistics, the majority of woodchips produced in Germany in 2007 (almost 70 %) is exported. The import figures are by far lower and account for 30 % of the total domestic consumption.

Regarding vegetable oil, Germany is also both an ex- and importer. However, the import figures are much higher than the export figures. In 2007, export figures of plant oil only amounted to 4 % of the domestic production, while imports amounted to 25 % of the total domestic consumption. In the case of rapeseed oil, almost all domestic production is used within Germany, additional oil is imported (mainly palm oil).

On the German biodiesel market, the level of imports corresponds to the level of exports. Biodiesel produced in Germany is exported mainly to the Netherlands,

Poland and France, and imports come from the Netherlands, the U.S. and Belgium (data for 2008).

## 7.2 Barriers and Opportunities for Bioenergy Trade

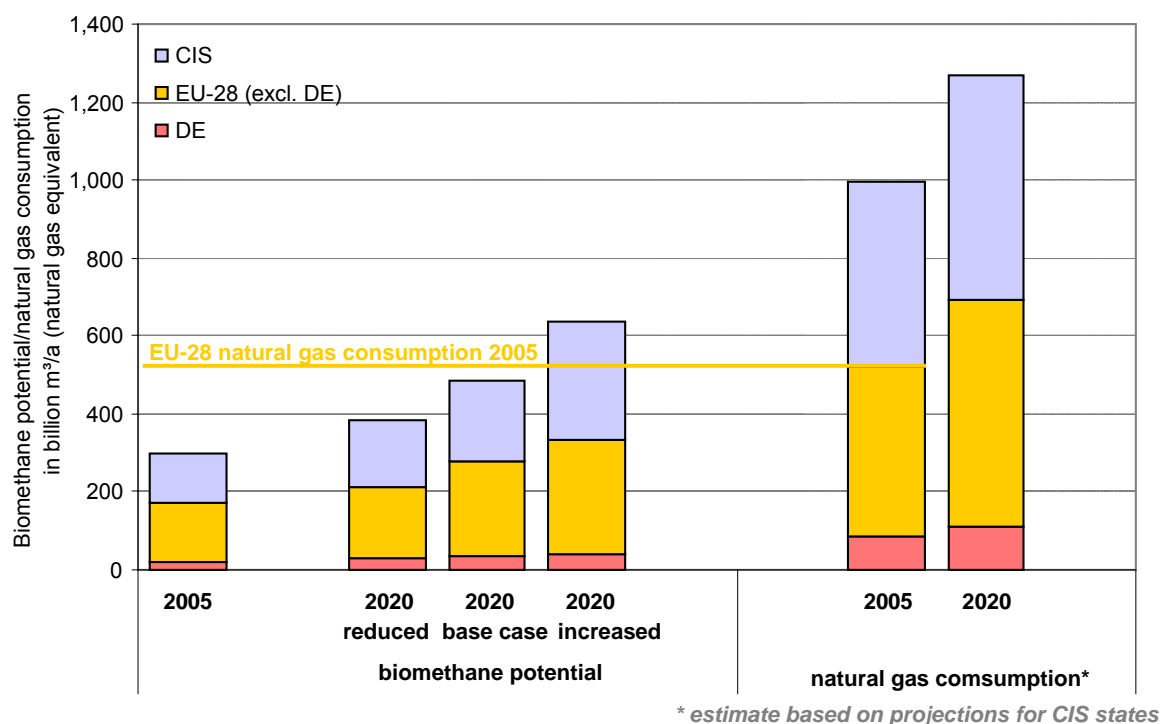
With regard to trading bioenergy, Germany shares the overall barriers for international liquid biofuel trade with all EU Member States, and has similar barriers to trading biomethane due to restrictions in grid access and high-pressure transit tariffs.

For solid bioenergy, no non-economic barriers exist, so that trade with e.g. woodchips and especially pellets increased in the last years due to rising oil and gas prices, and special investment aid programmes.

The greatest opportunities for trade in Germany clearly are biomethane (IE/OEKO 2007) and – in the longer-term – also lignocellulosic liquid biofuels from Central and Eastern European countries where land costs for feedstock production are comparatively lower than in the EU (IE/BFH/OEKO 2005).

The potentials for biomethane in Europe are quite significant, as shown in the following figure.

Figure 30 Biomethane Potential in Europe 2020

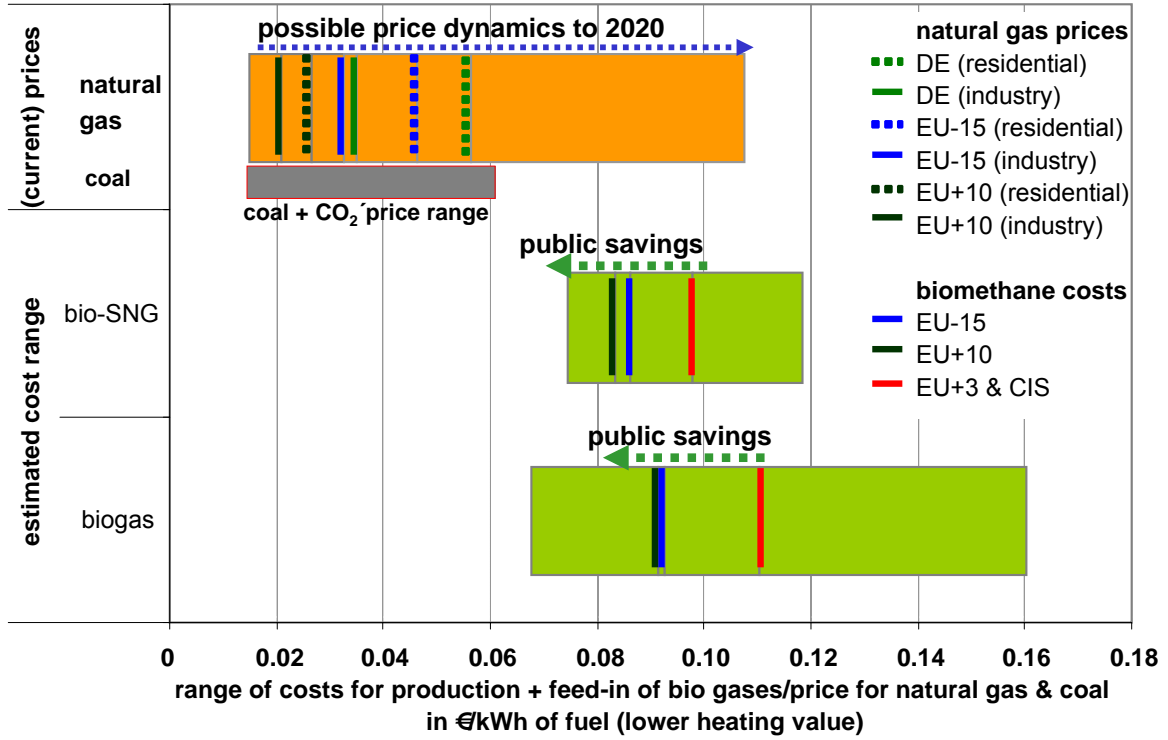


Source: IE/OEKO (2007)

The longer-term cost levels estimated for large-scale biomethane production, upgrading and pipeline feed-in seem competitive with the longer-term price

trends of fossil fuels, especially if costs of CO<sub>2</sub> certificates are included, as shown in the following figure.

Figure 31 Biomethane Costs and Fossil Fuel Prices in Europe 2020



Source: IE/OEKO (2007)

## 8 Conclusions for Bioenergy Developments in Germany

The domestic resource base for bioenergy in Germany, the technological improvements achieved already and foreseeable in the near future as well as the significant potentials for sustainable imports – especially from Eastern Europe – make bioenergy a key cornerstone of Germany's near- to medium-term renewable energy policy.

The governmental support for bioelectricity, bioheat and biomethane continues on the Federal and State level, while current liquid biofuels for transport receive less support, and will face more competition from imported biofuels in the coming years.

The development and demonstration of advanced, so-called 2<sup>nd</sup> generation liquid biofuels - especially synthetic biodiesel from BTL plants – are massively supported, though, and are expected to slowly enter German markets by 2020, allowing lignocellulosic feedstocks both from energy cropping and from residue and wastes to be converted into liquid biofuels.

The core concern of future bioenergy expansion in Germany is – similar to its European neighbors – the sustainability of land use, and risks of potential indirect effects.

Unless regulation on the EU level and abroad effectively addresses these concerns, it remains questionable, though, whether bioenergy will find the public and political support needed to fulfil its medium- to long-term prospect.

## Literature

- BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) 2008: Renewable Energy Sources -national and international development, Status June 2008; Berlin
- BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) 2009a: Entwicklung der erneuerbaren Energien in Deutschland im Jahr 2008 Grafiken und Tabellen, Stand: April 2009; Berlin
- BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) 2009b: Ordinance on requirements pertaining to sustainable production of bio-liquids for electricity production (Biomass-electricity-sustainability ordinance – Biomassestrom-Nachhaltigkeitsverordnung (BioSt-NachV)); Berlin
- BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit)/BMELV (Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz) 2009: National Biomass Action Plan for Germany - Biomass and Sustainable Energy Supply; Berlin
- BMWi (Bundesministerium für Wirtschaft und Technologie) 2009: Energiedaten - Nationale und Internationale Entwicklung; Excel-Datei, Berlin  
<http://www.bmwi.de/BMWi/Redaktion/Binaer/energie-daten-gesamt.property=blob,bereich=bmwi,sprache=de,rwb=true.xls>
- C.A.R.M.E.N. e. V. (Hrsg.) : Preisentwicklung bei Holzpellets  
<http://www.carmen-ev.de/dt/energie/pellets/pelletpreise.html>
- C.A.R.M.E.N. e. V. (Hrsg.): Preisentwicklung bei Hackschnitzeln  
<http://www.carmen-ev.de/dt/energie/bezugsquellen/hackschnipreise.html>
- DBFZ (Deutsches BiomasseForschungsZentrum) 2009a: Monitoring zur Wirkung des Erneuerbare Energien-Gesetzes (EEG) auf die Wirkung auf die Entwicklung der Stromerzeugung aus Biomasse; Leipzig
- DBFZ (Deutsches BiomasseForschungsZentrum) 2009b: Identifizierung strategischer Hemmnisse und Entwicklung von Lösungsansätzen zur Reduzierung der Nutzungskonkurrenzen beim weiteren Ausbau der energetischen Biomassenutzung; Leipzig
- DEPV e. V. (Hrsg.): Pellets Preisentwicklung  
<http://www.depv.de/marktdaten/pelletspreise>
- DESTATIS (Statistisches Bundesamt) 2006: Abfallentsorgung - Fachserie 19/Reihe 1; Wiesbaden
- DESTATIS (Statistisches Bundesamt) 2007: Produzierendes Gewerbe 1995-2007; Fachserie 4/Reihe 3.1; Wiesbaden
- DESTATIS (Statistisches Bundesamt) 2008: Statistical Yearbook 2008 for the Federal Republic of Germany; Wiesbaden
- DESTATIS (Statistisches Bundesamt) 2009: Daten zur Energiepreisentwicklung – lange Reihen von Januar 2000 bis Februar 2009 <https://www-ec.destatis.de/csp/shop/sfg/bpm.html.cms.cBroker.cls?cmspath=struktur,sfgsuc>

- [hergeb-nis.csp&action=newsearch&op\\_EVASNr=startswith&search\\_EVASNr=619](#)
- EEA (European Environment Agency) 2006: How much bioenergy can Europe produce without harming the environment? Report 7/2006; Copenhagen
- EEA (European Environment Agency) 2007: Estimating the environmentally compatible bio-energy potential from agriculture; EEA Technical Report 12/2007, Copenhagen  
[http://reports.eea.europa.eu/technical\\_report\\_2007\\_12/en/Estimating\\_the\\_environmentally\\_compatible\\_bio-energy\\_potential\\_from\\_agriculture.pdf](http://reports.eea.europa.eu/technical_report_2007_12/en/Estimating_the_environmentally_compatible_bio-energy_potential_from_agriculture.pdf)
- EEA (European Environment Agency) 2008: Maximising the environmental benefits of Europe's bioenergy potential; EEA Report No 10/2008; Copenhagen  
[http://reports.eea.europa.eu/technical\\_report\\_2008\\_10/en/Bioenergy\\_Potential.pdf](http://reports.eea.europa.eu/technical_report_2008_10/en/Bioenergy_Potential.pdf)
- EUWID 2007: Holz und Holzwerkstoffe. Nr. 44, Oktober
- EUWID: Erneuerbare Energien. Marktbericht für Altholz. Ausgaben 2003-2008
- Fritsche, Uwe R./Wiegmann, Kirsten 2008: Greenhouse-Gas Balances and Cumulated Primary Energy Requirements if Bioenergy Conversions Paths with Special Emphasize on Possible Land Use Changes; study for WBGU; Berlin (in German) [http://www.wbgu.de/wbgu\\_jg2008\\_ex04.pdf](http://www.wbgu.de/wbgu_jg2008_ex04.pdf)
- GBEP (Global Bioenergy Partnership) 2009: Summary of the GBEP Workshop on Indirect Land Use Change: Status of and Perspectives on Science-Based Policies; held on May 15, 2009 in New York  
[http://www.globalbioenergy.org/fileadmin/user\\_upload/gbep/docs/2009\\_events/Workshop\\_ILUC\\_NY\\_15May\\_2009/GBEP\\_iLUC\\_workshop\\_-\\_Summary.pdf](http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/2009_events/Workshop_ILUC_NY_15May_2009/GBEP_iLUC_workshop_-_Summary.pdf)  
<http://org.eea.europa.eu/news/Ann1149688459/index.html>
- IE (Institut für Energetik und Umwelt gGmbH) 2008a: Marktexpertise Biomassebereitstellung und –nutzung; Leipzig
- IE (Institut für Energetik und Umwelt gGmbH) 2008b: Marktexpertise Biomassebereitstellung und –nutzung; im Auftrag eines Finanzunternehmens; Leipzig
- IE (Institut für Energetik und Umwelt gGmbH)/BFH (Bundesforschungsanstalt für Holz)/OEKO (Oeko-Institut) 2005: Sustainable Strategies for Biomass Use in the European Context: Analysis in the charged debate on national guidelines and the competition between solid, liquid and gaseous bio-fuels; final report sponsored by German BMU; Leipzig/Hamburg/Hohenheim/Darmstadt  
<http://www.ie-leipzig.de/Biomassennutzung/E-Biomasse.htm>
- IE (Institut für Energetik und Umwelt gGmbH)/OEKO (Oeko-Institut) 2007: Möglichkeiten einer europäischen Biogas-Einspeisungsstrategie; Leipzig/Darmstadt  
[http://www.oeko.de/service/bio/dateien/ie2007biogas\\_osteuropa\\_teilberic](http://www.oeko.de/service/bio/dateien/ie2007biogas_osteuropa_teilberic)

[ht\\_1.pdf](#)

[http://www.oeko.de/service/bio/dateien/oeko2007biogas\\_osteuropa\\_teilb2.pdf](http://www.oeko.de/service/bio/dateien/oeko2007biogas_osteuropa_teilb2.pdf)

- Lenz, V./Kaltschmitt, M./Schwenker, A. 2009: Erneuerbare Energien in Deutschland – Stand 2008; in: BWK
- OEKO (Oeko-Institut - Institut für angewandte Ökologie e.V.) 2004: Material flow analysis for the sustainable energy use of biomass; Fritsche, Uwe R. et al., Öko-Institut (project coordination) in cooperation with FhL-UMSICHT, IE, IFEU, IZES, TU Braunschweig, TU Munich; final report (in German); sponsored by BMU; Darmstadt (see [www.oeko.de/service/bio](http://www.oeko.de/service/bio))
- OEKO (Oeko-Institut - Institute for applied ecology) 2009: Review of Bioenergy Life-Cycles: Results of Sensitivity Analysis; prepared for UNEP-DTIE; Darmstadt (<http://www.unep.fr/energy/bioenergy/documents/>)
- TFZ (Technologie und Förderzentrum) - Hrsg.: Aktuelle Scheitholzpreise <http://www.tfz.bayern.de/festbrennstoffe/17385/>
- ZMP (Zentrale Markt- und Preisberichtsstelle GmbH) 2009:: Pflanzenölpreise 2001-2009

## List of Abbreviations

a	year
BTL	biomass-to-liquid
CHP	combined heat & power
CO <sub>2</sub>	carbon dioxide
EEA	European Environment Agency ( <a href="http://www.eea.europa.eu">www.eea.europa.eu</a> )
EJ	ExaJoule = 1000 PetaJoule (PJ) = 1 million TeraJoule (TJ) = 1 billion GigaJoule (GJ)
FAME	fatty acid methy ether
GHG	greenhouse-gases
GJ	GigaJoule (10 <sup>9</sup> Joule)
IEA	International Energy Agency ( <a href="http://www.iea.org">www.iea.org</a> )
JRC	Joint Research Centre of the EU Commission
OEKO	Oeko-Institut - Institute for Applied Ecology ( <a href="http://www.oeko.de">www.oeko.de</a> )
RME	rapeseed oil methylester
SRC	short-rotation coppice
SRF	short-rotation forestry
t	tonne (metric)
TJ	TeraJoule (10 <sup>12</sup> Joule)