Application of bioenergy for regional heat and power supply in Germany

frame conditions, technical, economic and ecological aspects

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Lecture during the TU-Gdansk-Workshop „Regional Energy Planning for Poland including RES“

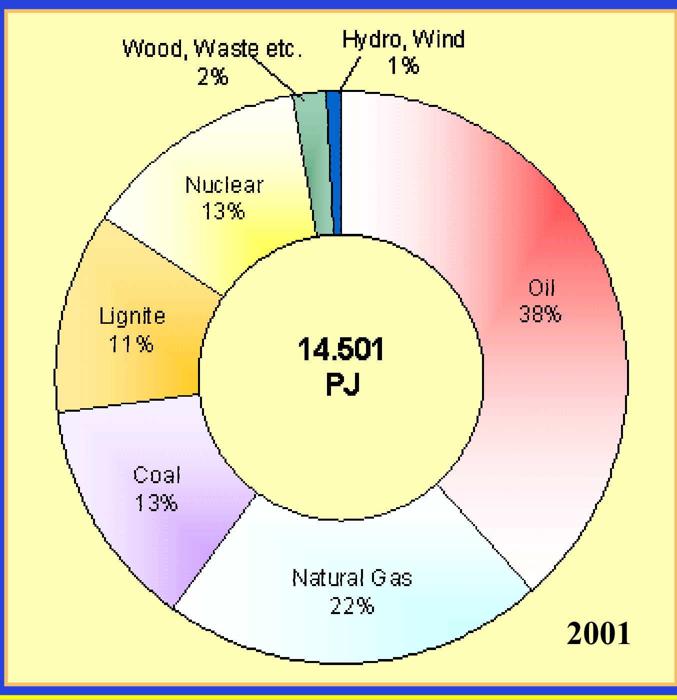
on Monday, 27.10.2003

Structure of the presentation

- **Introduction: Primary energy use and the share of bioenergy in Germany today, bioenergy potentials**
- **Technology: Biomass CHP technologies and their constraints and characteristics**
- **Examples: Bioenergy CHP in German practice**
- **Economy: Specific costs of biomass energy installations**
- **Ecology: Comparison of bioenergy to other RES**
- **Summary, conclusions: Present application and prospects for bioenergy in Germany**

Introduction

Primary energy consumption in Germany



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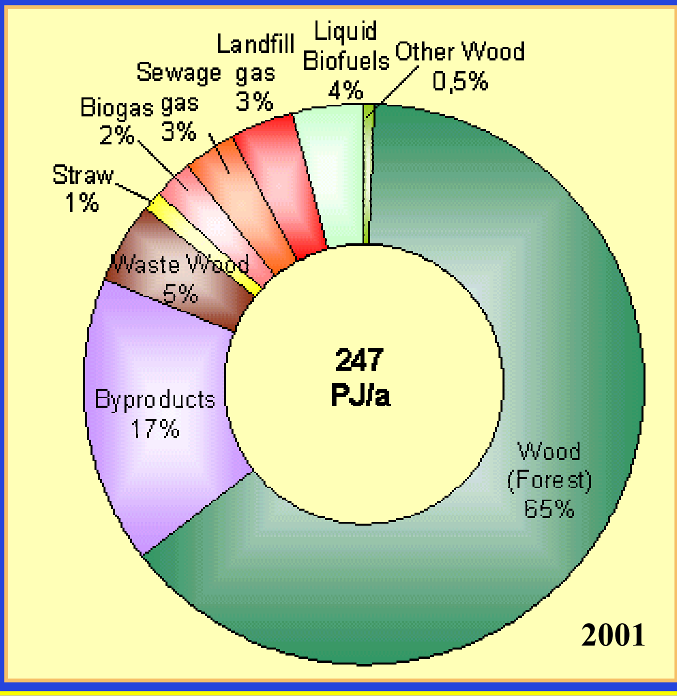
Bioenergy: It´s contribution to primary energy supply



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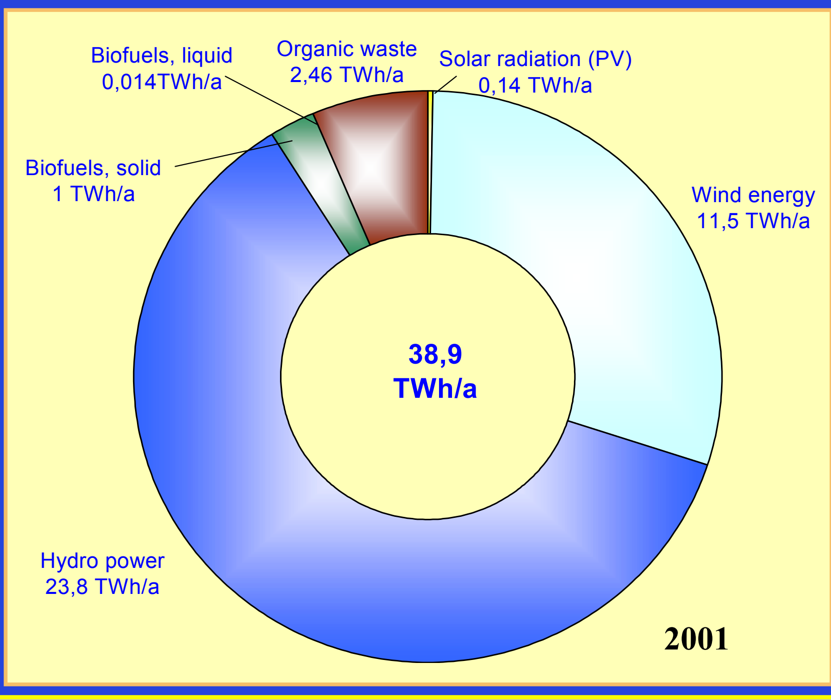
Bioenergy: It´s contribution to electricity supply



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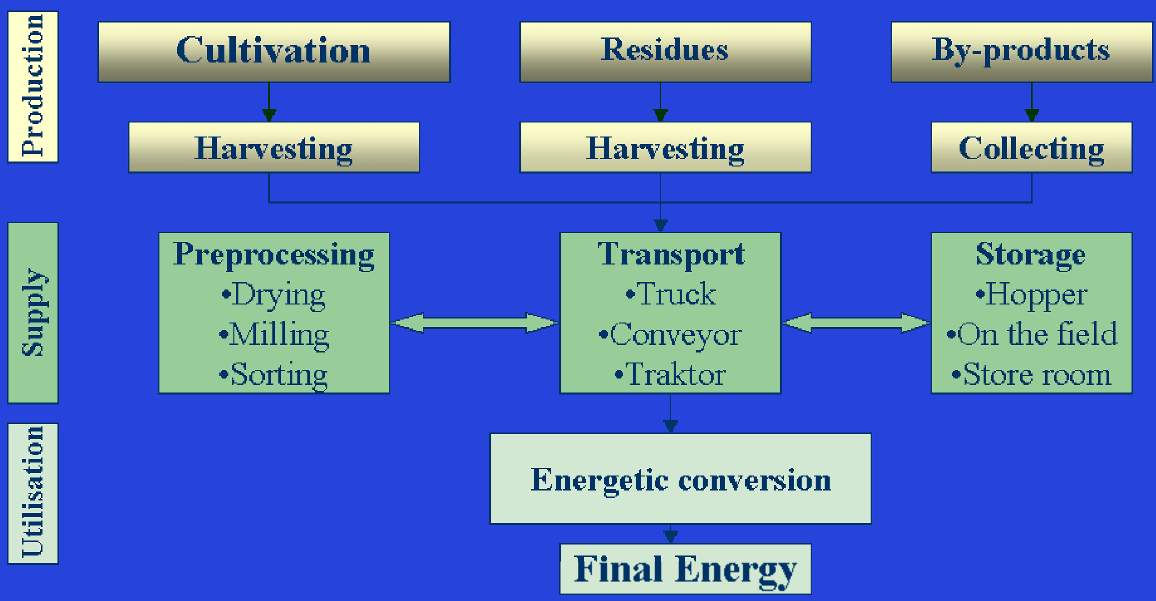
Biomass: Various origins and corresponding supply chains



Bioenergy source	Mass available, Mio. t/a	Technical potential in PJ/a
WOOD		
Wood residues (forestry)	7,1	110
Timber processing	3,5	55
Log Wood	6,1	95
Wood residues (Parks, road greenery etc.)	0,4	5
Thinnings (actually unused)	6,5	100
Waste Wood	4,8	75
Total Wood	*28,4*	*440*
STRAW and Agricultural by-products		
Straw	9,4	130
Fruits, Husks and other residues	4,6	65
Manure and other biogas substrates	4,7	81
Total Straw and agricultural by-products	*18,7*	*276*
ENERGY PLANTS (10% agrable land = 1,2 Mio.ha)	9,6	171
Total technical bioenergy potential per year	-	**887**

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Bioenergy:
Applicable CHP-technologies in comparison

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Characterisation of selected biomass CHP technologies

	Technology	Power range, (MW_{el})	Electr. efficiency (%)
Solid Biofuels	Steam turbine	0,5 - > 20	12 - 30
	Steam engine	0,2 - 1,5	10 - 20
	Stirling engine	0,01 - 0,15	8 - 22
	ORC – Process	0,1 - 3	10 - 15
Liquid / Gaseous Biofuels	Gas turbine	> 10	ca. 25
	Microgas turbine	0,05 - 1	ca. 20
	Gas engine	0,05 - 5	ca. 25
	Fuel cell	0,05 - 5	ca. 30

Advantages and disadvantages of steam turbines

Advantages	Disadvantages
➢ Mature, proven technology	➢ Small steam turbines < 1 MW_{el} offer only limited efficiencies
➢ Broad power range available	➢ Low efficiency at partial load
➢ For large installations: high efficiencies can be obtained by high steam temperatures and pressures	➢ High specific investment costs for small turbines
➢ Separation between combustion and power generation enables the use of ash containing fuels	➢ For biomass application: limited super heater temperature because of risk of high temperature corrosion
	➢ High quality steam is necessary

Advantages and disadvantages of steam engines

Advantages	Disadvantages
➢ Suitable for lower power ranges	➢ Maximum power output per steam engine is limited to about 1.2 MW el
➢ Saturated steam can be used	➢ High maintenance costs
➢ Very good performance at partial load	➢ Electrical efficiency is limited due to low steam pressures (< 25 bar)
➢ Steam extraction at various pressures possible due to modularity	➢ Heavy vibration and noise production
➢ Oil free construction avoids steam contamination and oil separation from steam cycle	

Advantages and disadvantages of ORC-technology

Advantages	Disadvantages
➢ Robust technology	➢ Relatively high specific investment costs
➢ Very good controllability and high degree of automation	➢ Long term experiences using biomass still missing
➢ Low maintenance required	➢ Organic thermal oil is inflammable and toxic
➢ Very good performance at partial load	➢ Due to low pressures (10 –20 bar) only limited electrical efficiency
➢ Low temperature waste heat can be used for power generation	

Advantages and disadvantages of Stirling engines

Advantages	Disadvantages
➢ Engine operates independently of type of heat source	➢ If solid biomass is used, relatively low electrical efficiencies are achieved because of low flue gas temperatures (< 1000 °C, ash melting point)
➢ Low quality demand with respect to fuel	➢ Until today: no reliable solution for sealing problems, mainly if Helium is used as working medium
➢ Low maintenance demand because of few moving parts and “external combustion”	➢ High specific investment costs
➢ If gaseous fuels, like biogas, are used, formation of emissions like CO and CH can be avoided due to external combustion of the gas	➢ Heat exchanger is exposed to extreme wear because of high temperature strain
	➢ Risk of high temperature corrosion in ash containing flue gases

Bioenergy:
Transfer into practice

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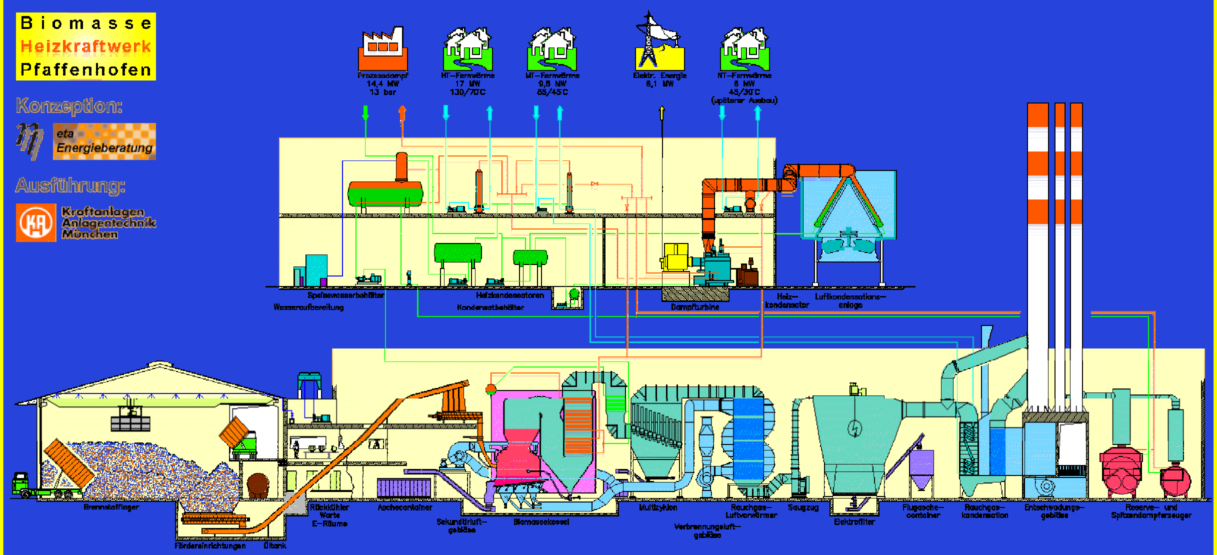
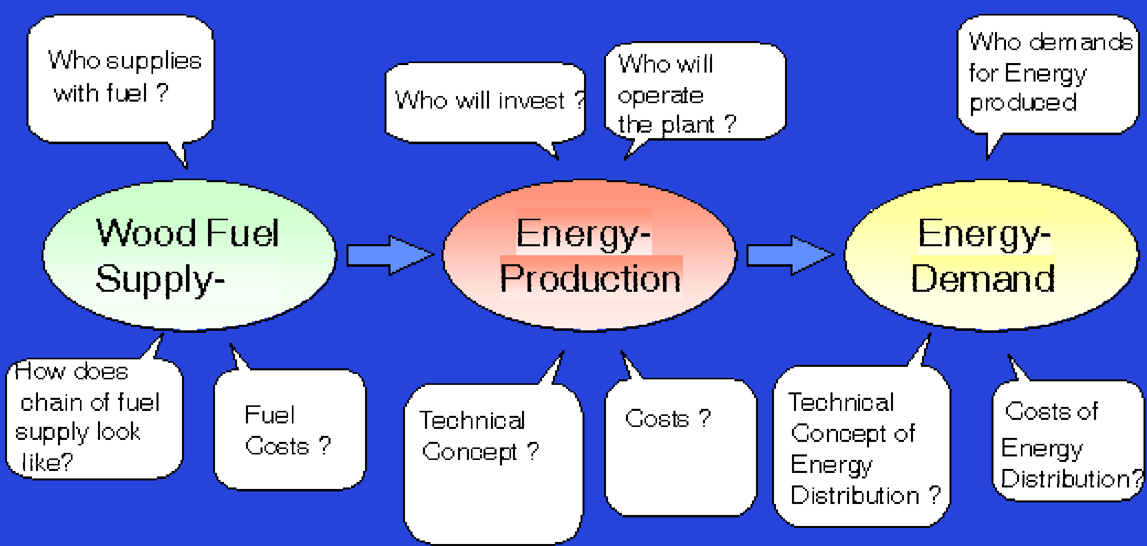
Example: The biomass CHP plant Pfaffenhofen

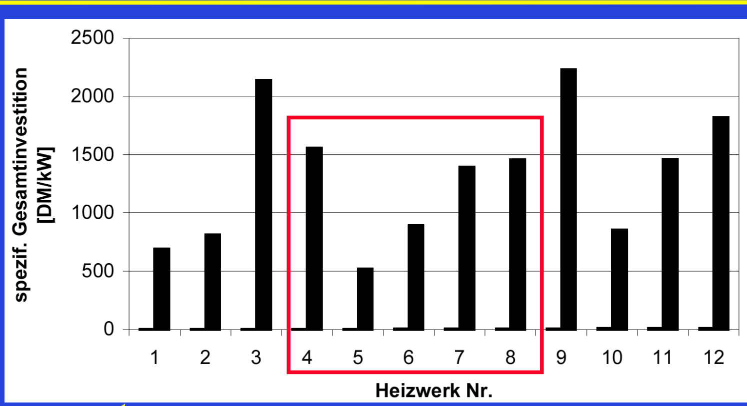
Example: The biomass CHP-plant Pfaffenhofen



Bioenergy: Crucial aspects for project realisation

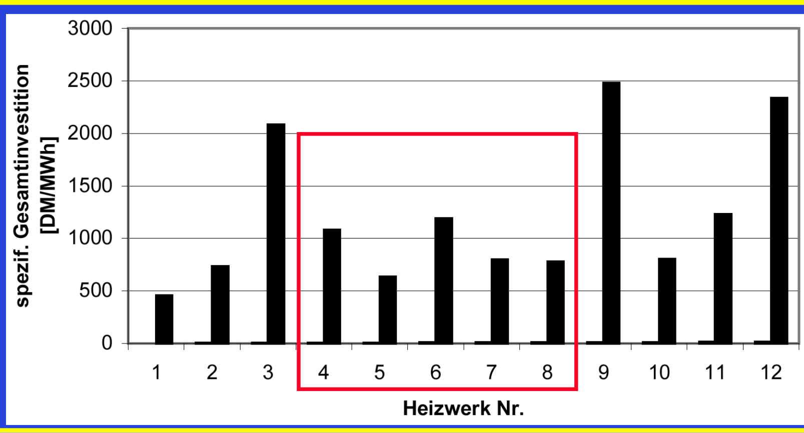


Specific investment costs for biomass heating facilities in Germany



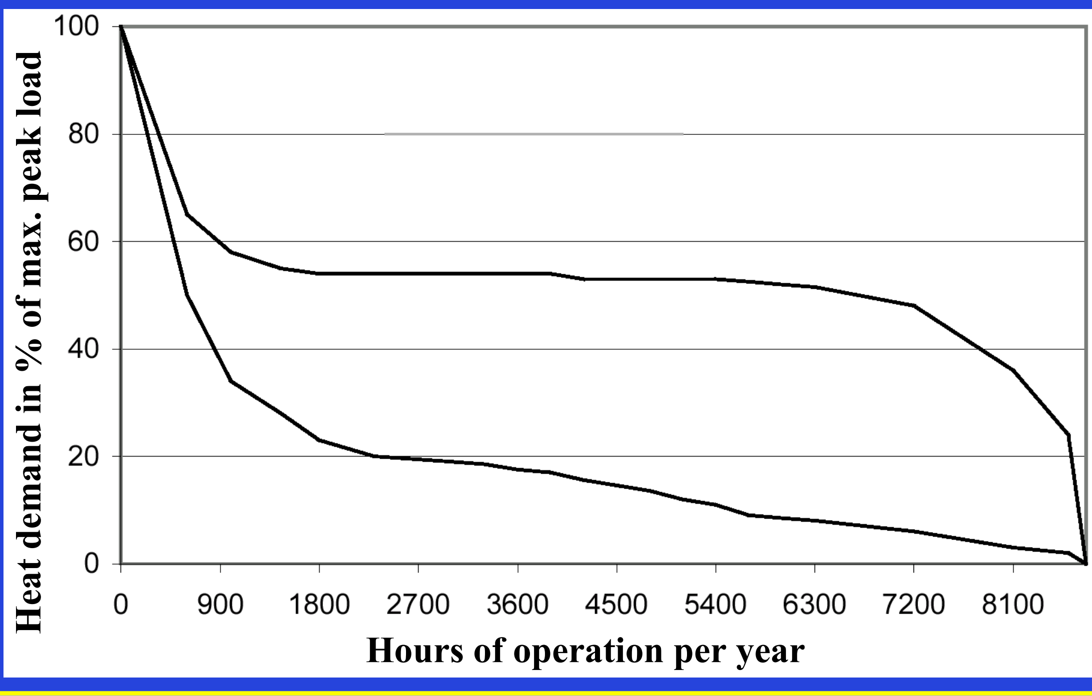
Per kW

Per MWh



DBU/C.A.R.M.E.N., 2002

Heat demand profile of two different district heating facilities



DBU/C.A.R.M.E.N., 2002

Biomass projects – suitability excellent

- Public bathes and swimming pools, schools, hospitals, hostals and homes
- Wood processing industries, especially wood drying
- Food processing industries like dairies, breweries, slaughter houses
- Existing district heating systems for dense populated areas, multi-storeyed

Biomass projects – suitability good

- New districts, only private houses, dense building
- Smaller public buildings
- Smaller industrial estates
- Individual industrial sites

Biomass projects – suitability fair

- New districts, only scarcely settled
- Smaller individual buildings like warehouses

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Bioenergy: Economic aspects

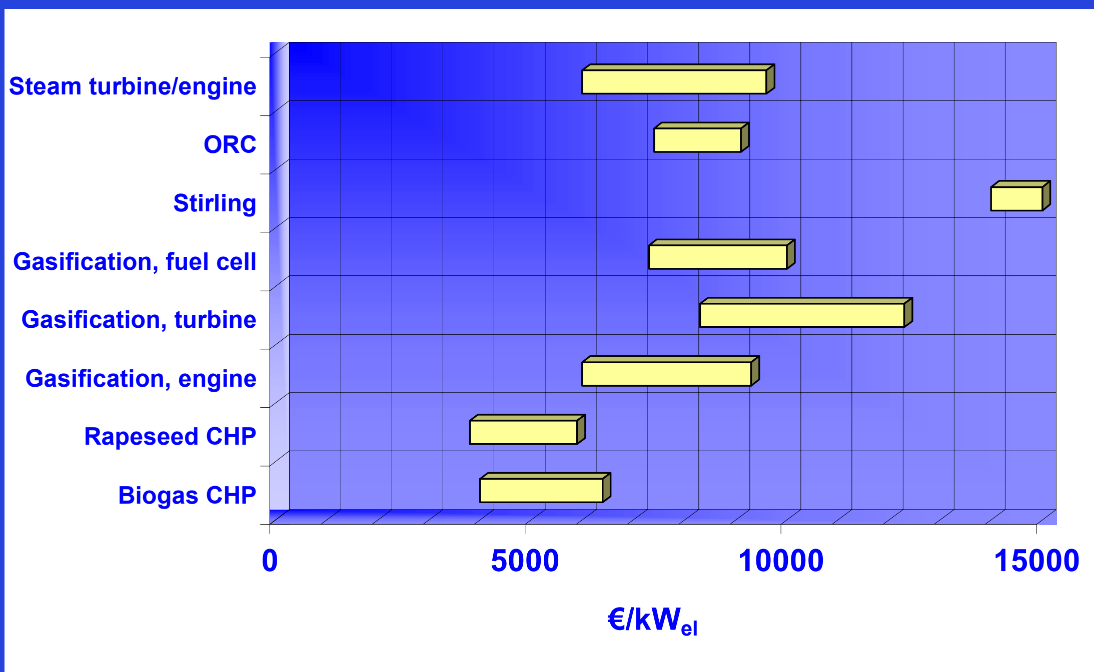
- EEG –
The German „Renewable Energy Source Act“

- Fixed reimbursement rates from electricity from biomass on a relatively high level:

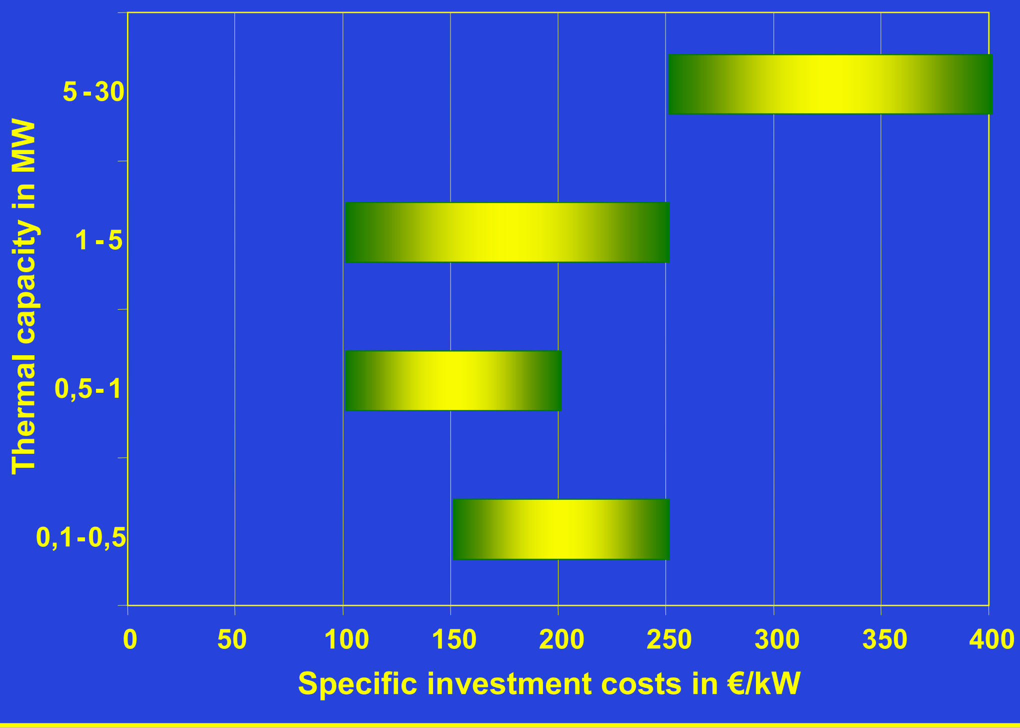
Installed electrical capacity (MW)	Reimbursement (€ct/kWh) Initial operation *before* 1.1.2002	Reimbursement (€ct/kWh) Initial operation *in* 2003
< 0,5	10,23	10,0
0,5 - 5	9,21	9,0
5 - 20	8,7	8,5

- Degressive rates, taking technological improvement into account
- Minimum rate, guaranteed for a period of 20 years

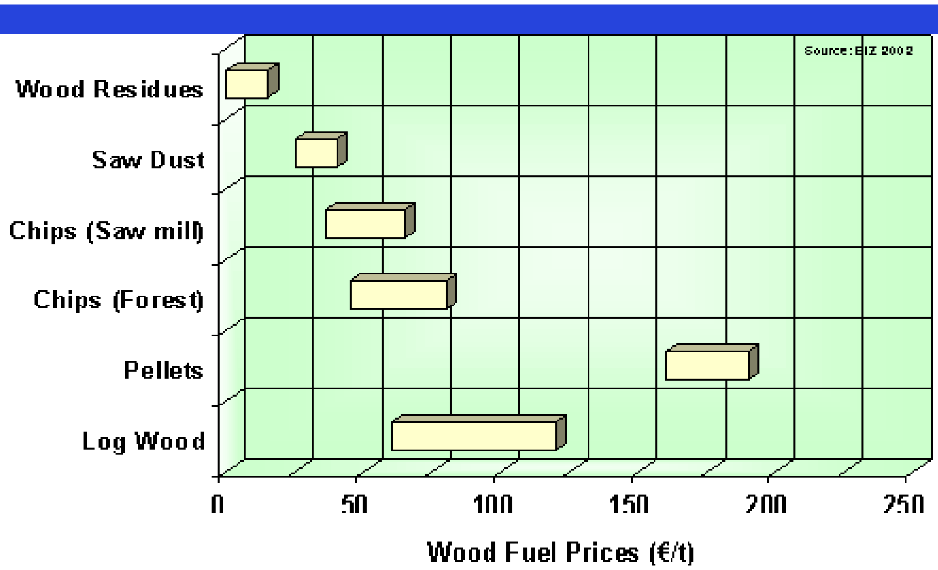
Specific investment costs for different biomass CHP technologies



Specific investment costs for wood boilers



Wood fuel prices (2002)



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Bioenergy: An ecological comparison of space heating solutions

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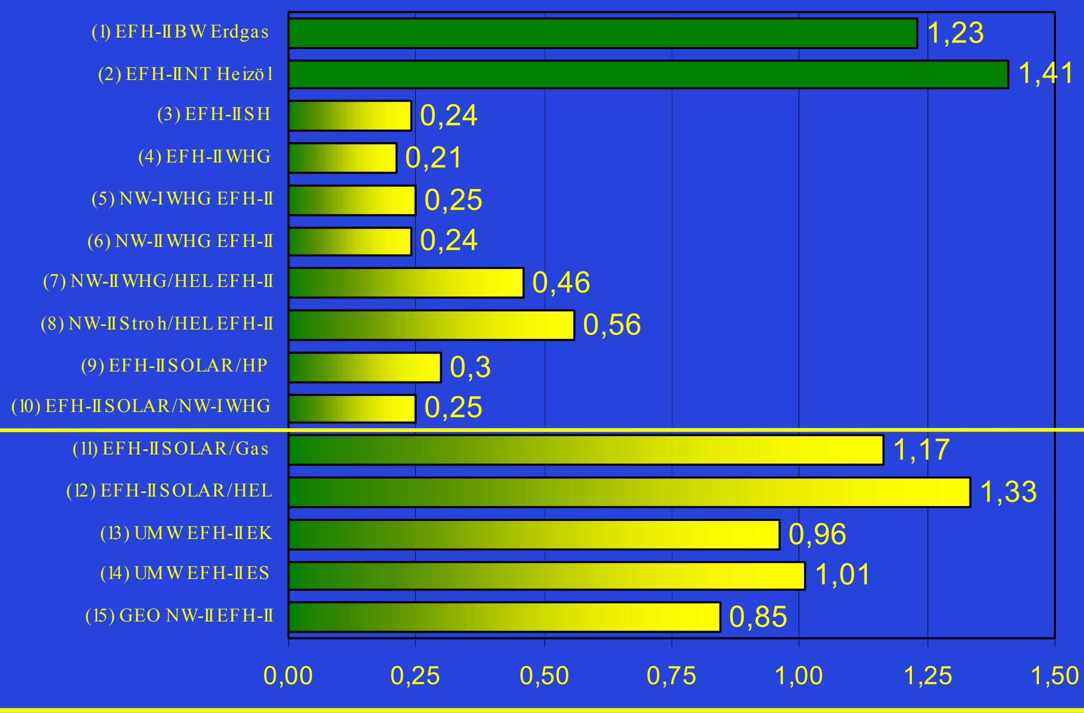
Heat supply from renewable energy

- Primary energy use (TJ_{Prim}/TJ_{Nutz}) -



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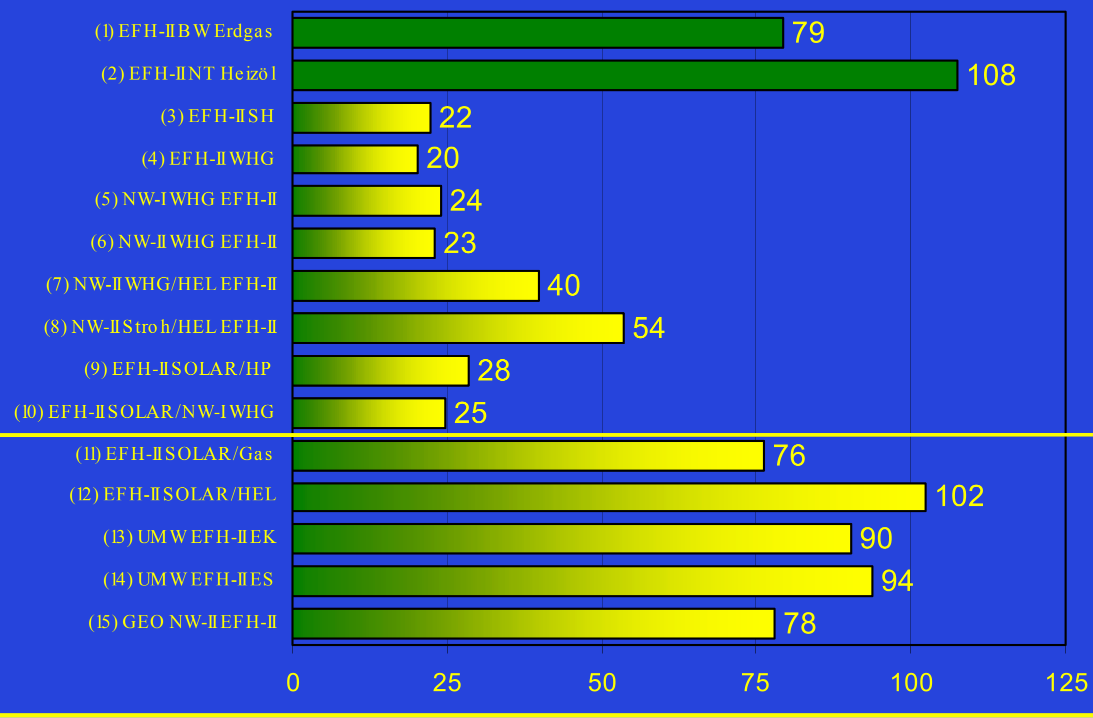
Heat supply from renewable energy

- Greenhouse gas emissions (t CO_2-Äquivalent/TJ_{Nutz}) -



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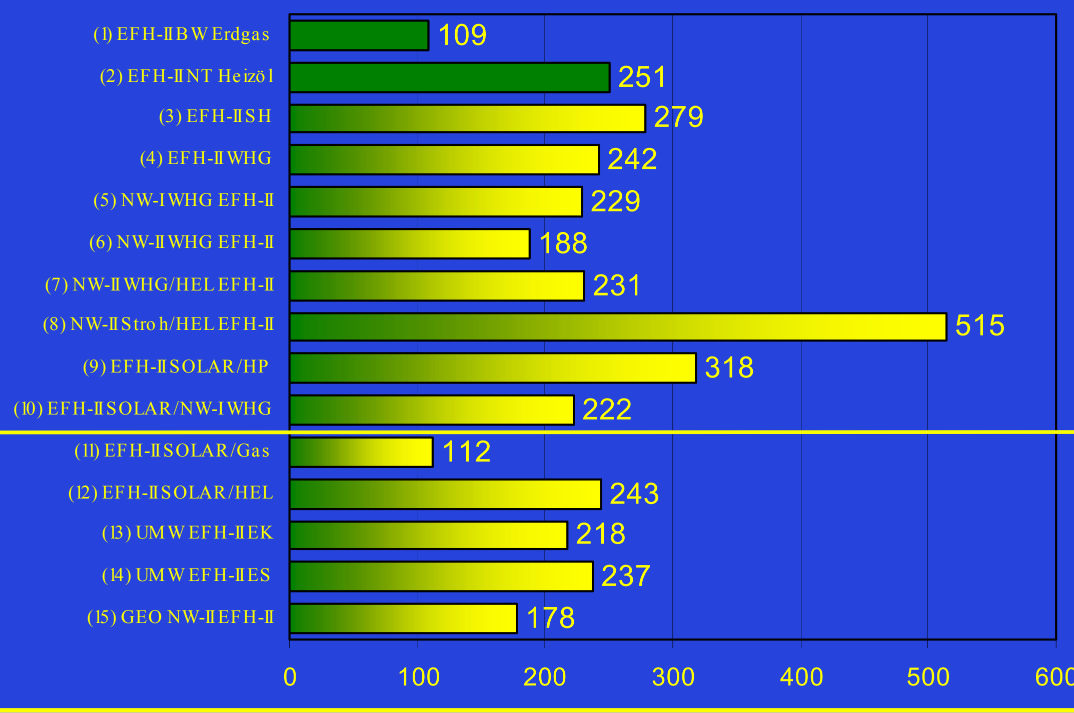
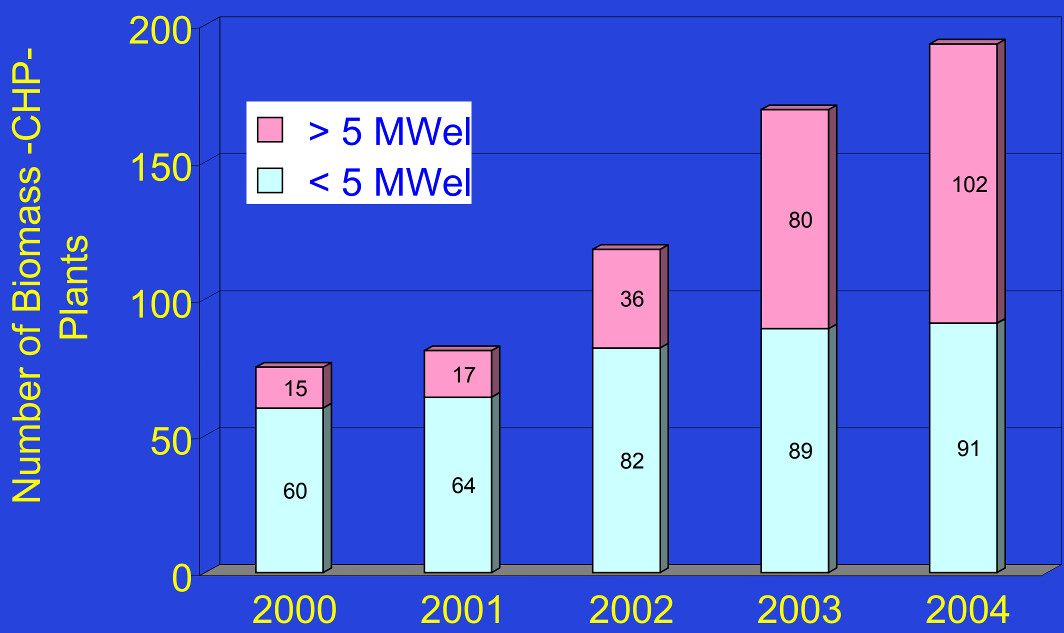
Heat supply from renewable energy

- Acidifying emissions (kg SO_2-Äquivalent/TJ_{Nutz}) -



Bioenergy:
Application and development

Biomass CHP-plants in Germany



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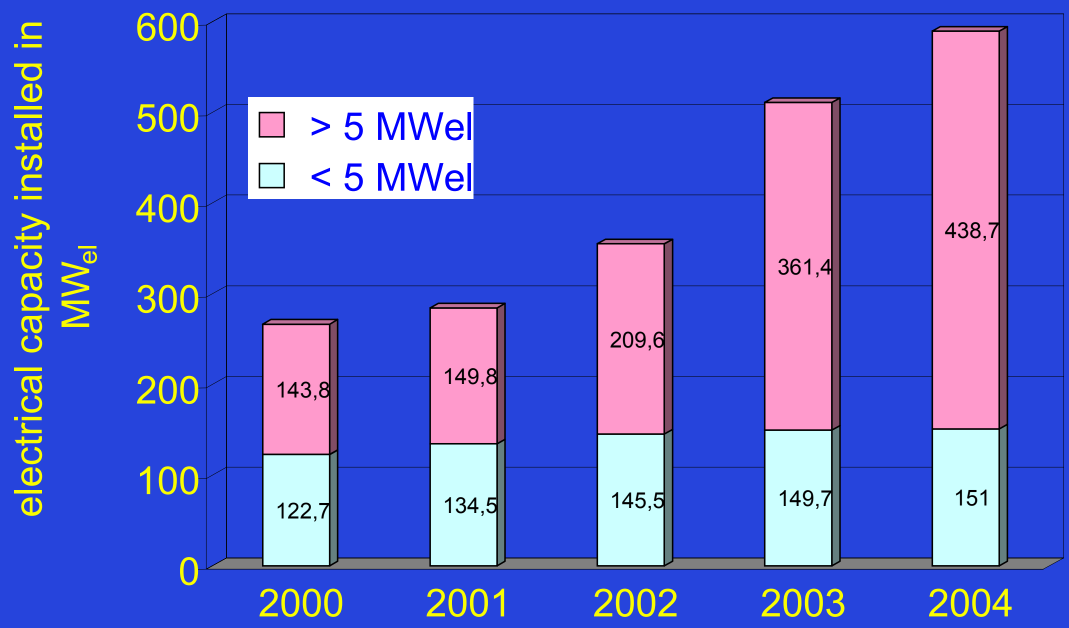
Biomass CHP-plants in Germany



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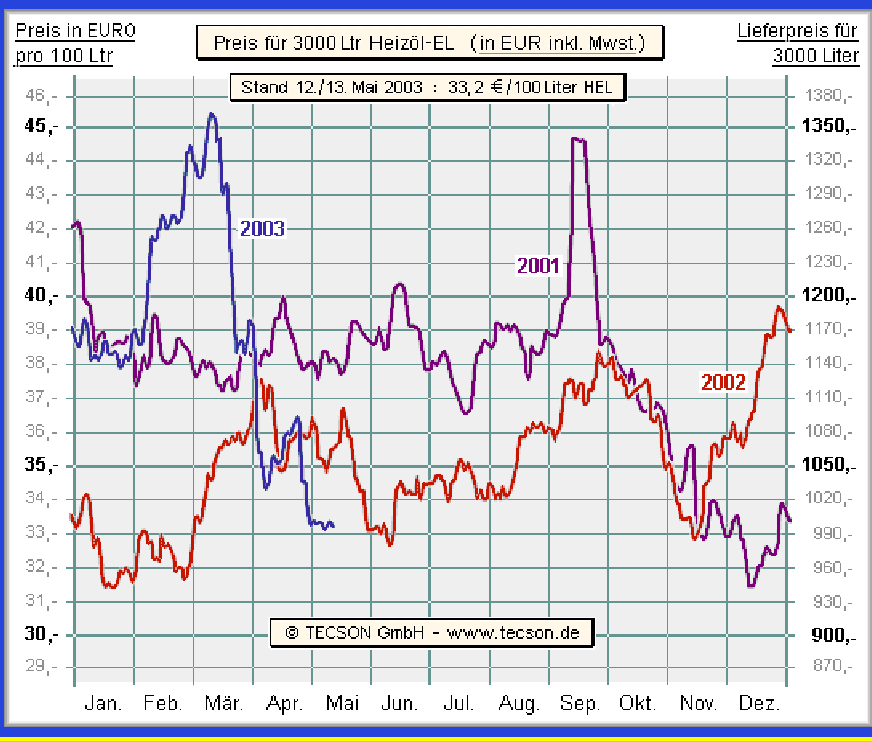
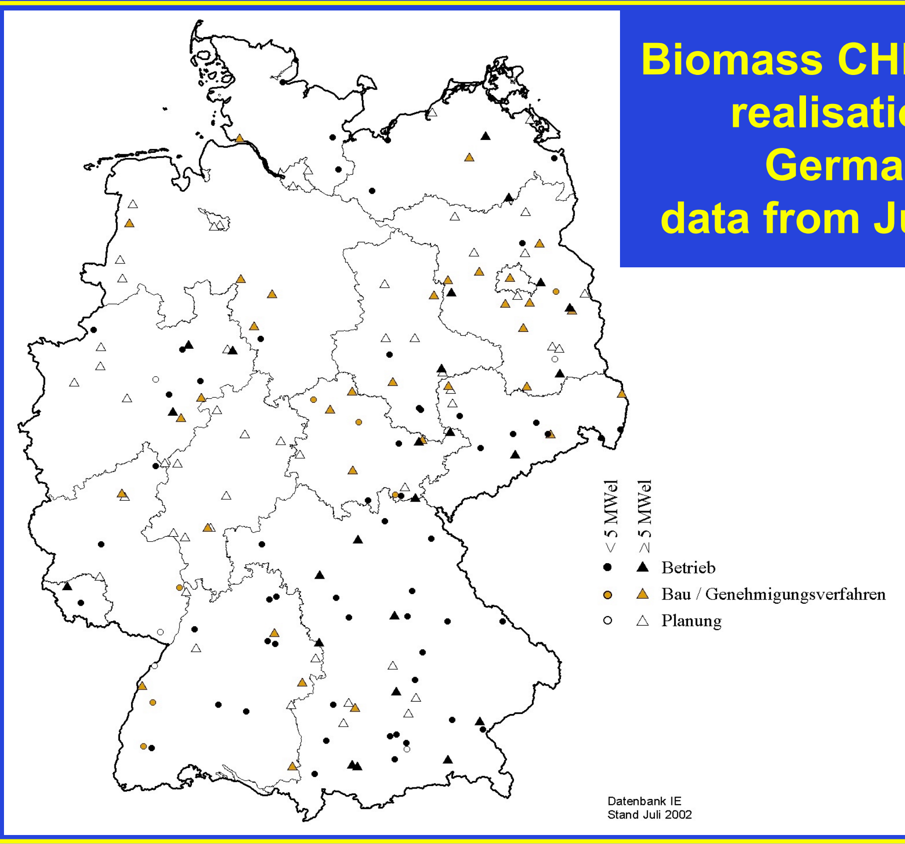
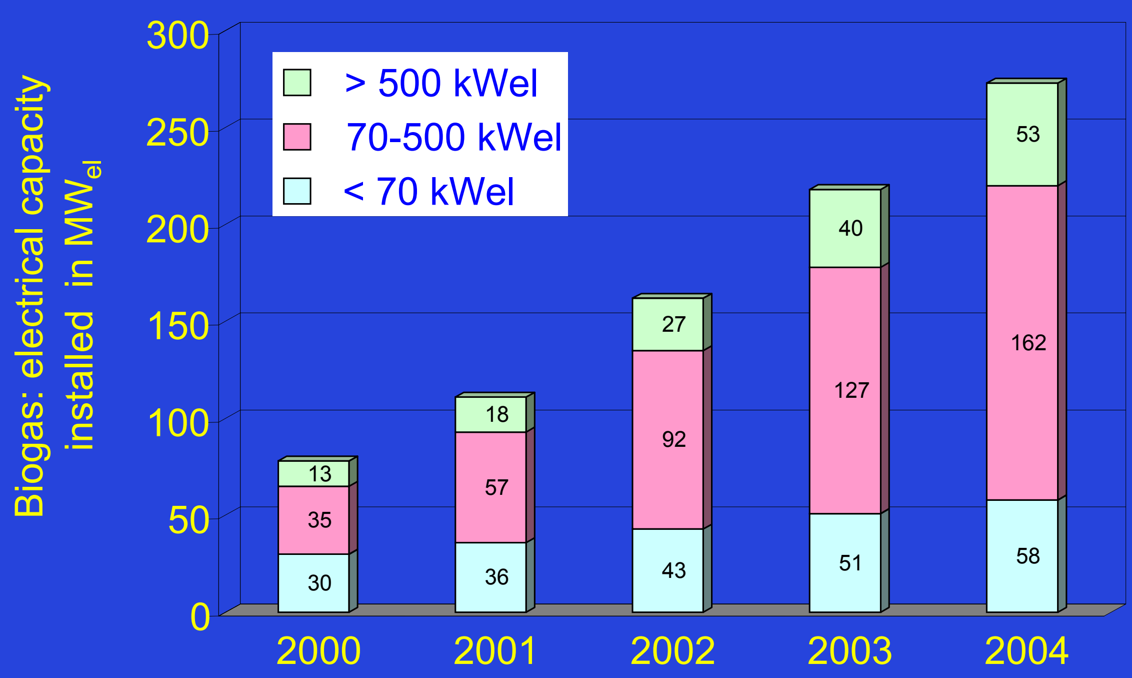
Fuel oil prices in Germany 2001-2003

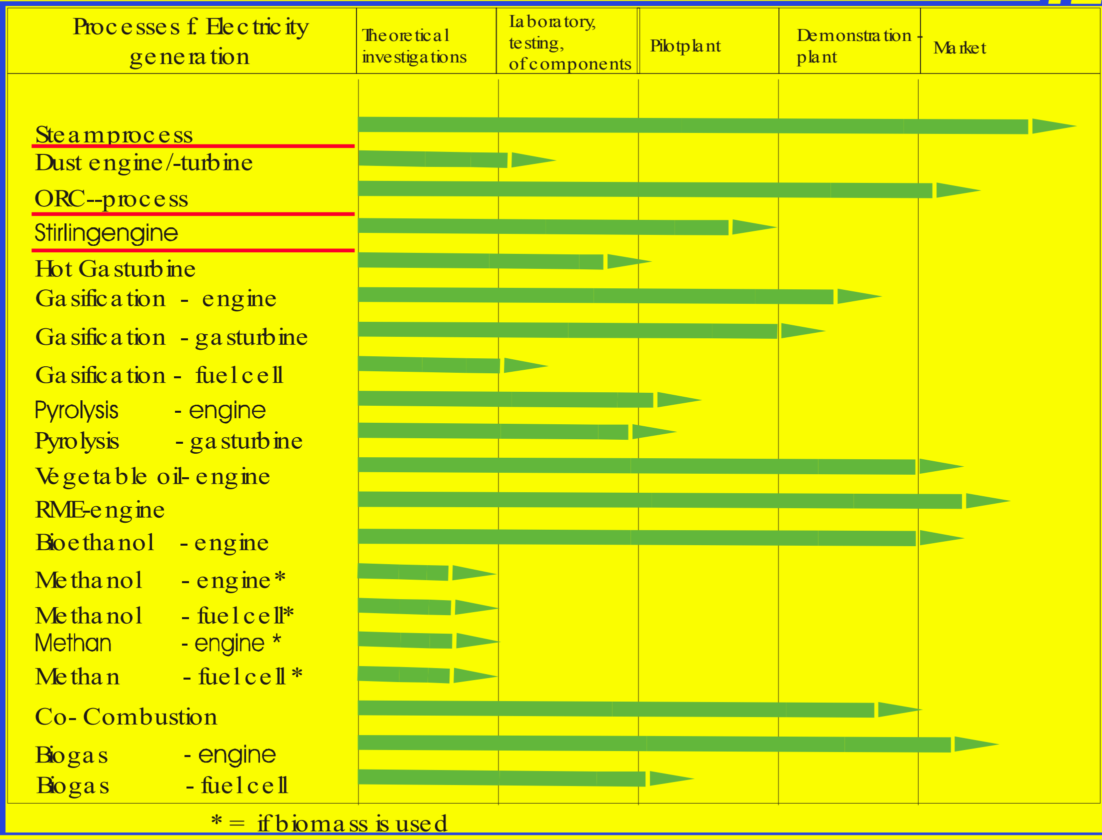


Biomass CHP-project realisation in Germany, data from July 2002

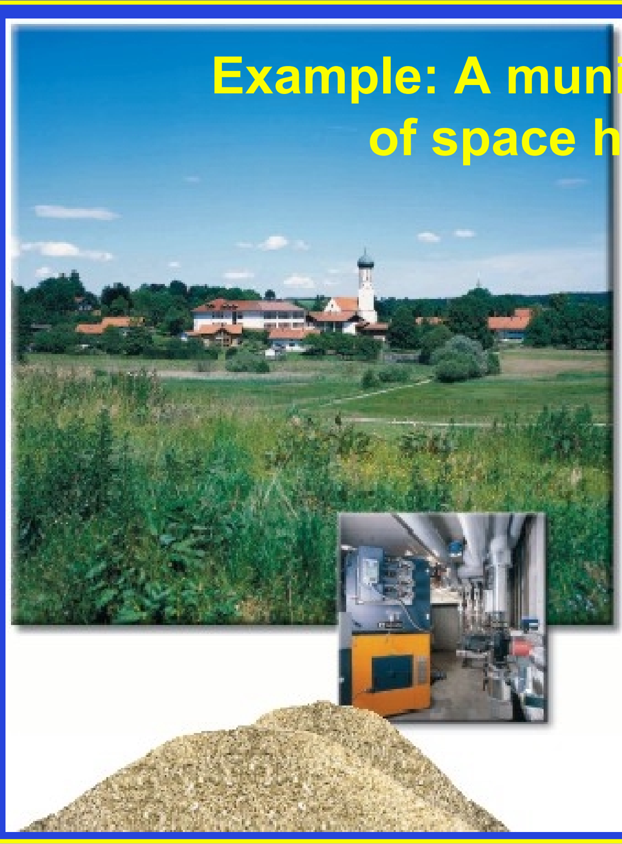


Biogas CHP-plants in Germany





Example: A municipal project of space heating



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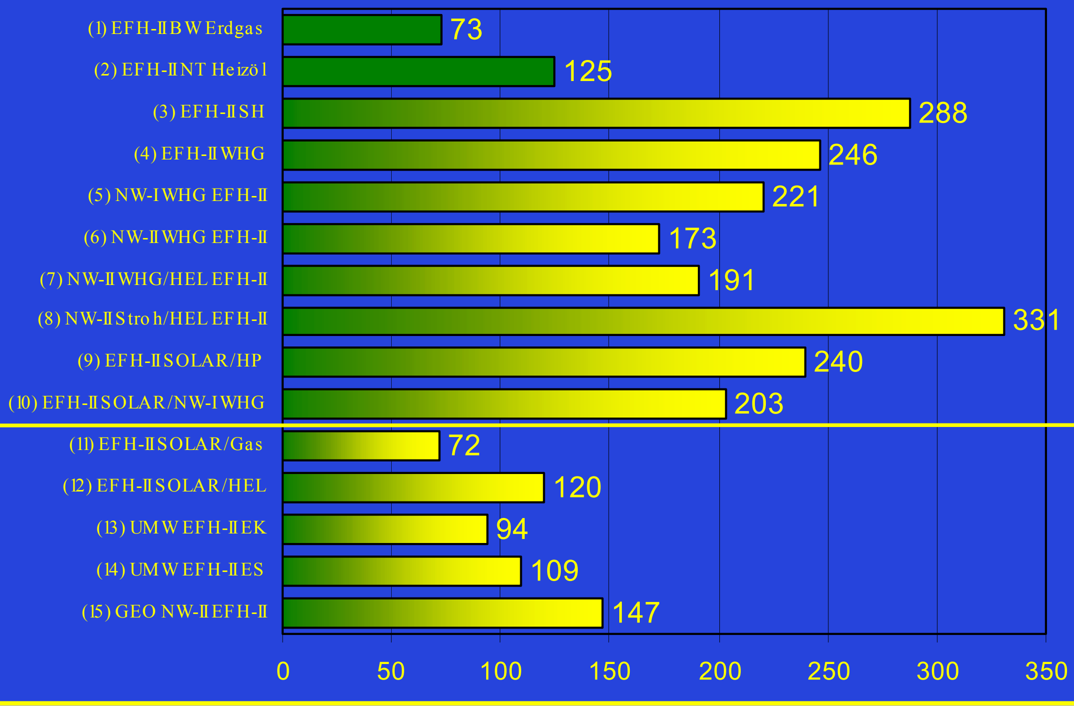
Heat supply from renewable energy

- Nitrogen oxide emissions (kg NO_X/TJ_{Nutz}) -



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Heat supply from renewable energy

- Sulfur dioxide emissions (kg SO_2/TJ_{Nutz}) -