Overview of CHP plants in Europe and Life Cycle Assessment (LCA) of GHG emissions for Biomass and Fossil Fuel CHP Systems

CIBE Conference „Cogénération biomasse dans l'industrie et sur les réseaux de chaleur opportunités - retours d'expérience - perspectives“

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Overview

Conclusions

Success stories in Austria

Main Results of the project BIOCOGEN

LCA Methodology and Results

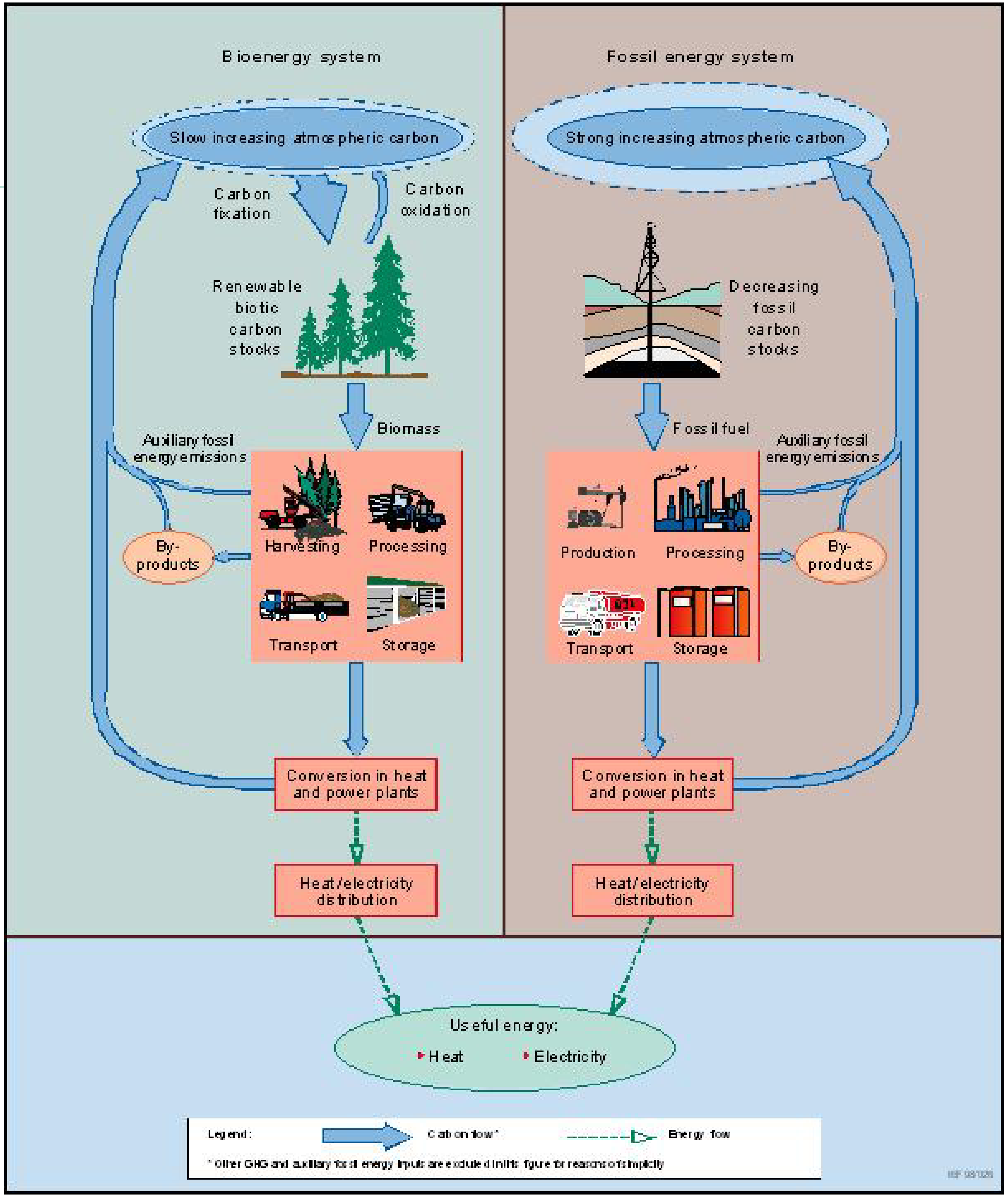
Methodology

According to

- ISO 14040 „*Life Cycle Assessment*“

- „*Standard Methodology*“ developed by IEA Task 38 „Greenhouse Gas Balance of Bioenergy Systems“

- Conclusions of COST Action E9 „Life Cycle Assessment of Forestry and Forest Products“



Selected Bioenergy Systems with CHP

Biomass-Production → **Biomass-Processing** → **Biomass-Fuels** → **Biomass-Combustion**

Biomass-Production

Forestry
- thinning
- clear cut

Agriculture
- energy wood
- miscanthus
- oil plants
- maize
- sugar-beet
- grain
- straw
- manure

Trade & Industry

Biomass-Processing

Mechanical
- chipping
- cleaving
- pelleting
- briquetting
- pressing

Thermic and/or chemic
- drying
- gasification
- pyrolysis
- estering

Biological
- methane fermentation
- alcohol fermentation

Biomass-Fuels

Solid Fuels
- wood logs
- wood chips
- wood pellets
- bark
- straw pellets
- straw balls
- paper

Liquid Fuels
- methylester
- oil from plants
- oil from pyrolysis
- alcohole
- lyne

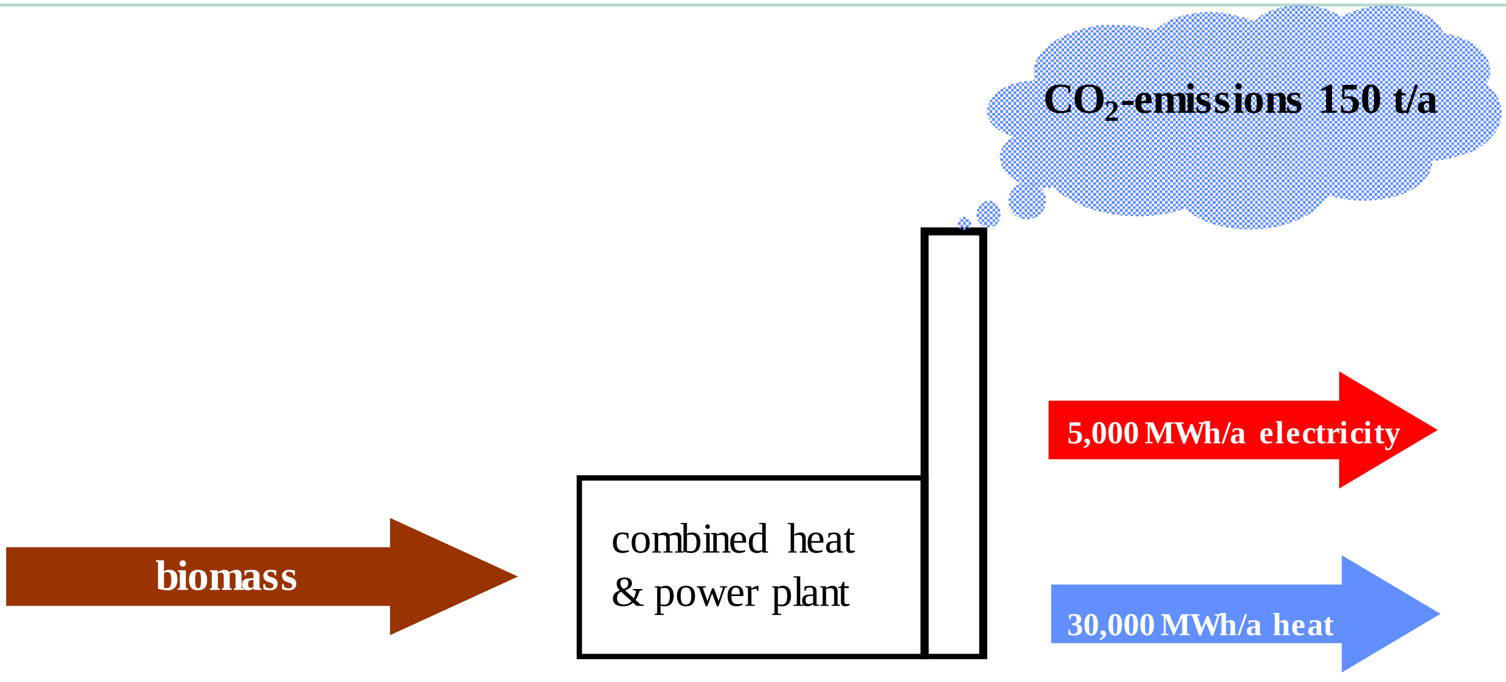
Gaseous Fuels

Biomass-Combustion

Electricity & Heat

- CHP plant with
  + steam turbine
  + gas turbine
  + gas & steam turbine
  + stirling engine
  + combustion engine
  + hot air engine
  + fuel cell

The CHP allocation problem



Avoid allocation:

combined heat and electricity production

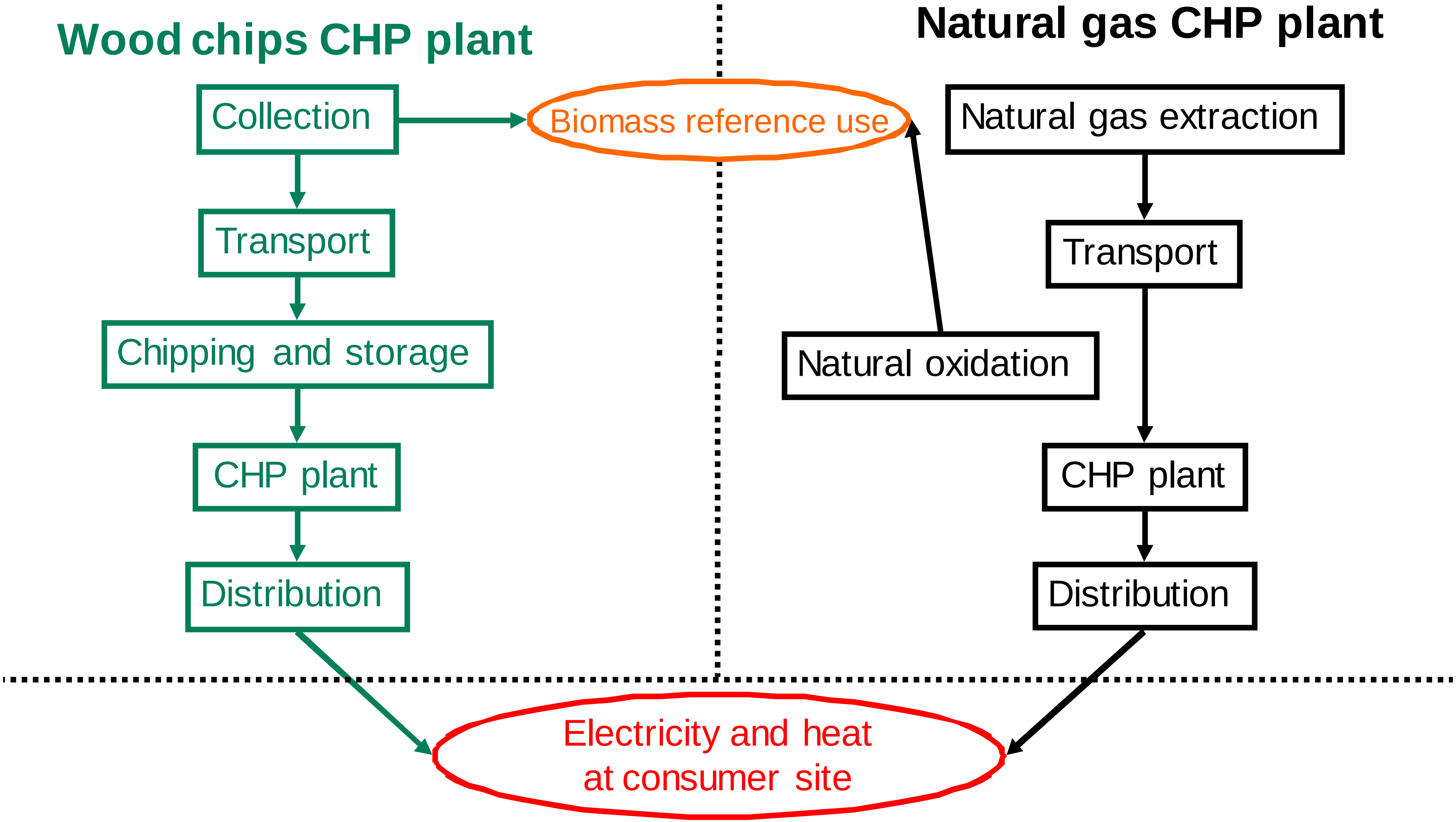
➲ functional unit 1 kWh of

$0{,}33\ \mathrm{kWh}_{electrcicty}$

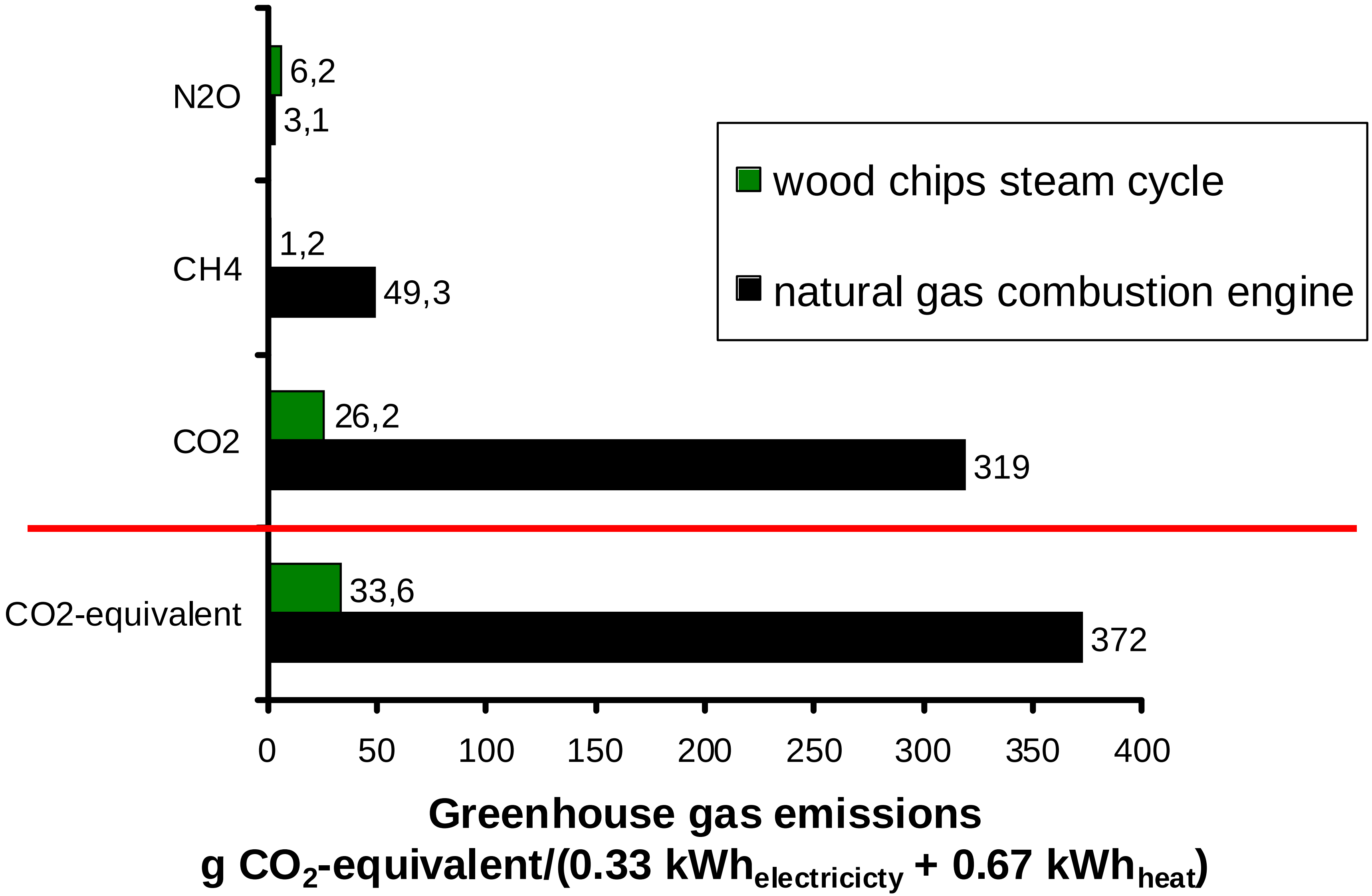
+

$0{,}67\ \mathrm{kWh}_{heat}$

Examples Process Chain



Examples Results (steam turbine)



Comparison
Biomass and Fossil Fuels

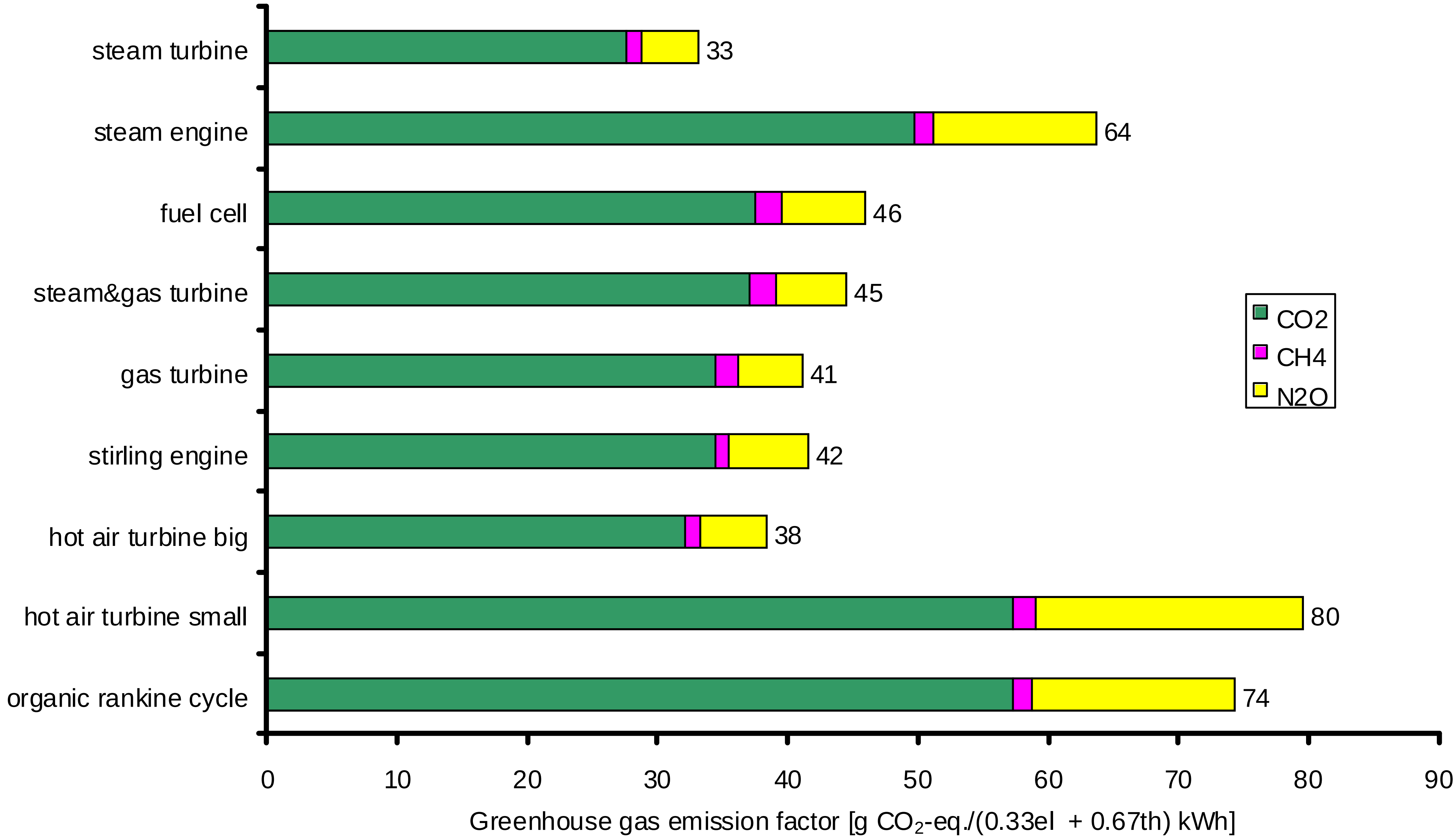
Fossil energy system

Year 2000

Bioenergy system

Bioenergy system	[g CO_2-eq/kWh]	hard coal steam cycle	lignite/steam cycle	light oil/combined cycle	light oil/combustion engine	heavy oil/steam cycle	heavy oil/combustion engine	natural gas/gas turbine	natural gas/combined cycle	natural gas/combustion engine
		513	508	433	391	433	467	319	329	372
wood chips/waste wood/steam cycle	40,3	-92%	-92%	-91%	-90%	-91%	-91%	-87%	-88%	-89%
wood chips/forestry/steam cycle/motor	73,1	-86%	-86%	-83%	-81%	-83%	-84%	-77%	-78%	-80%
wood chips/forestry/steam cycle small	47,3	-91%	-91%	-89%	-88%	-89%	-90%	-85%	-86%	-87%
wood chips/forestry/steam cycle big	33,6	-93%	-93%	-92%	-91%	-92%	-93%	-89%	-90%	-91%
wood chips/short rotation/poplar/steam cycle	69,4	-86%	-86%	-84%	-82%	-84%	-85%	-78%	-79%	-81%
wood chips/short rotation/willow/steam cycle	64,5	-87%	-87%	-85%	-84%	-85%	-86%	-80%	-80%	-83%
wheat (incl. straw)/steam cycle	128	-75%	-75%	-70%	-67%	-70%	-73%	-60%	-61%	-66%
miscanthus/steam cycle	79,3	-85%	-84%	-82%	-80%	-82%	-83%	-75%	-76%	-79%
bark/steam cycle	9,41	-98%	-98%	-98%	-98%	-98%	-98%	-97%	-97%	-97%
sewage sludge/steam cycle	90,8	-82%	-82%	-79%	-77%	-79%	-81%	-72%	-72%	-76%
shavings/steam cycle	27,9	-95%	-95%	-94%	-93%	-94%	-94%	-91%	-92%	-92%
straw/steam cycle	33,1	-94%	-93%	-92%	-92%	-92%	-93%	-90%	-90%	-91%
methylester/waste oil/combustion engine	-232	-145%	-146%	-154%	-159%	-154%	-150%	-173%	-170%	-162%
methylester/rape/combustion engine	20,7	-96%	-96%	-95%	-95%	-95%	-96%	-94%	-94%	-94%
oil/sunflower/combustion engine	270	-47%	-47%	-38%	-31%	-38%	-42%	-15%	-18%	-27%
oil/sunflower/combustion engine	140	-73%	-72%	-68%	-64%	-68%	-70%	-56%	-57%	-62%
biogas/organic waste/combustion engine	-50	-110%	-110%	-112%	-113%	-112%	-111%	-116%	-115%	-113%
biogas/manure/combustion engine	-603	-218%	-219%	-239%	-254%	-239%	-229%	-289%	-283%	-262%
biogas/co-digestion waste oil/combustion engine	-78,9	-115%	-116%	-118%	-120%	-118%	-117%	-125%	-124%	-121%

Influence of Technology - Same Fuel



BIOCOGEN: Overview of solid biomass CHP plants in Europe (2004)

- Turkey
- Netherlands
- UK
- Austria
- Denmark
- Finland
- France
- Germany
- Greece
- Portugal
- Italy
- Bulgaria
- Slovenia
- Switzerland
- Sweden

Biomass Cogeneration Network (BIOCOGEN)

PROJECT N° : NNE5-2001-00083

Solid biom

Name: Biomass Power Station Güssing

Database No. 10

Basic Info	
Country:	Austria
Location:	Güssing
Character of plant:	Pilote plant
Owner:	Güssing GmbH
Contact Person:	Ing. Reinhard Koch
Telephone:	+43/ 3322/ 44623
Fax:	+43/ 3322/ 4462333
email:	fwgue@bnet.at
webpage:	n.a.
Year of construction:	2001

Technology		**Fuel**	
Type of power generation:	Gas engine	Total fuel input:	n.a. t/a
Electric power:	2 MW_{el}	Tot. lower heating value:	2,9 kWh/kg
Thermal power:	4,5 MW_{th}	Moisture content:	n.a. % wet
Co-firing:	N		
Fuel conversion:	Gasification		
Annual production electricity:	n.a. GWh/a	Type of fuel 1:	Waste wood
Annual production heat:	n.a. GWh/a	Share of fuel 1:	n.a. %
Electric efficiency:	25 %	Input of fuel 1:	n.a. t/a
Thermal efficiency:	56,3 %		
Total efficiency:	81,3 %	Type of fuel 2:	Woodchips (forest residues)
Ratio electricity/ heat:	0,44	Share of fuel 2:	n.a. %
Fuel power:	8 MW_{fuel}	Input of fuel 2:	n.a. t/a
Boiler (if steam technology)			
Steam mass flow:	- t/h	Type of fuel 3:	-
Steam temperature:	- °C	Share of fuel 3:	- %
Steam pressure:	- bar	Input of fuel3:	- t/a

Costs		**Emissions**	
Investment costs:	10,684 Mio €	CO:	n.a. mg/Nm^3
Spec.investment costs (elec):	5,342 Mio€/MW_{el}	NO_x:	n.a. mg/Nm^3
Fuel costs:	n.a. €/t	Particles:	n.a. mg/Nm^3
Subsidies:	n.a. Mio €	C_xH_y:	n.a. mg/Nm^3
Number of employes:	n.a.	SO_2:	n.a. mg/Nm^3

Source:

Power production from biomass with gas engines, VDI Report 1588

n.a.... not available

Country: **Austria**

Total number of plants:	25
with co-firing:	5
fossil fuels for co-firing:	

Locations (+database No.):

Admont (1), Althofen (2), Attnang-Puchheim (3), Bruck an der Mur (4), Ebensee (5), Enns (6), [illegible]mlitz (7), [illegible] (8), [illegible] (9), [illegible]ssing (10), [illegible] (11), [illegible] (12), [illegible] (13), Lienz (14), Pischelsdorf (15), Reuthe (16), Sachsenburg (17), Seyring (18), St. Andrä (19), St. Gertraud (20), St. Veit (21), Steyrermühl (22), Stubenberg (23), Tamsweg (24), Zeltweg (25).

Webpage includes a database of 157 CHP plants with solid biomass in Europe

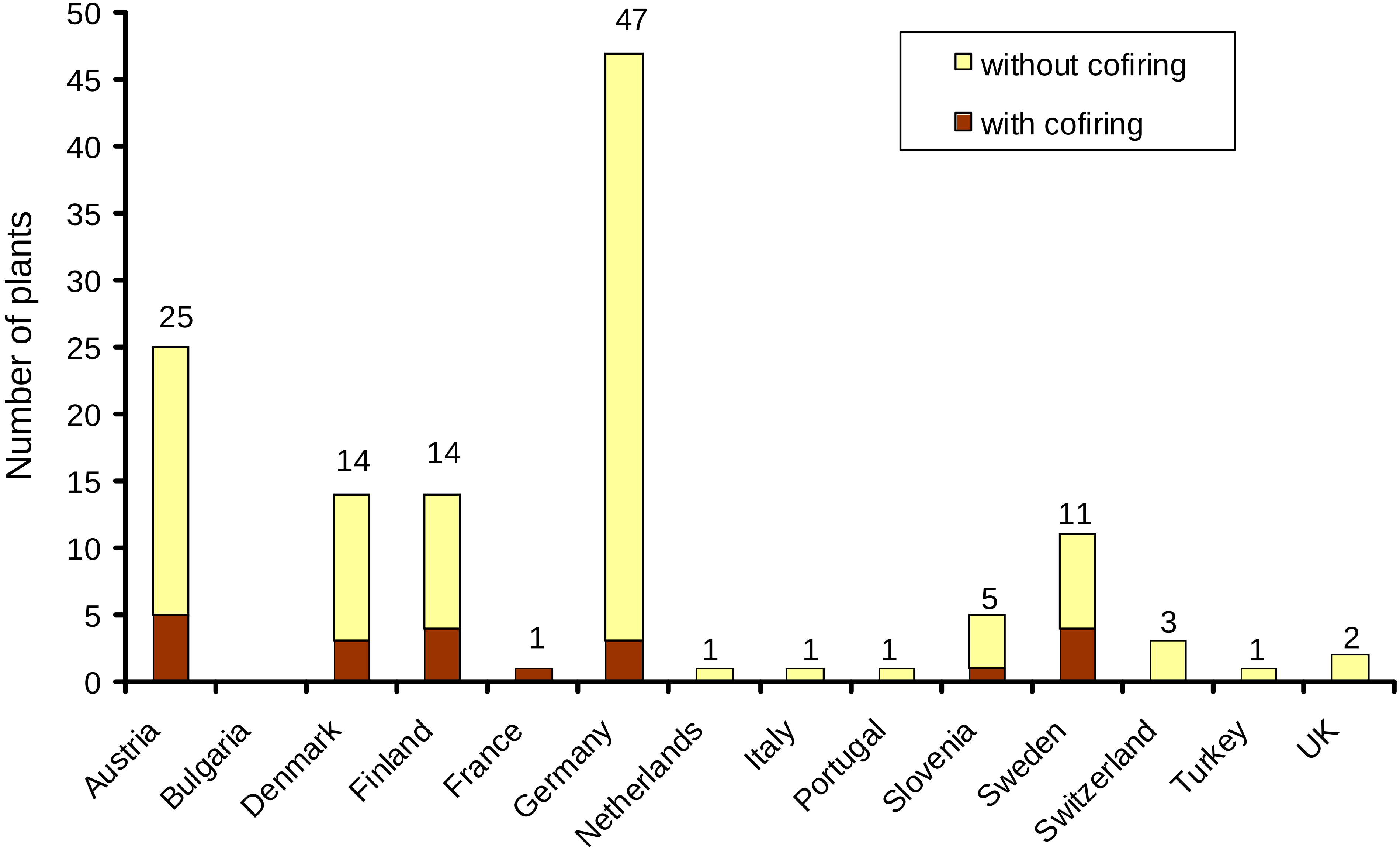
Year of construction	No.	
before 1995	6	24 %
1995 - 2000	2	8 %
after 2000	3	12 %
unknown	14	56 %

Type of power generation	No.		**Fuels**	No.*	
Steam turbine:	11	44 %	Woodchips (forest residues):	13	35 %
Steam engine:	2	8 %	Woodchips (saw industry):	8	22 %
Organic rankine cycle:	5	20 %	Paper sludge:	5	14 %
Stirling engine:	1	4 %	Waste wood:	2	5 %
Hot air engine:	0	0 %	Bark:	5	14 %
Gas engine:	5	20 %	Peat:	0	0 %
Gas turbine:	0	0 %	Straw:	0	0 %
Other (or n.a.):	1	4 %	Other (or n.a.):	4	11 %

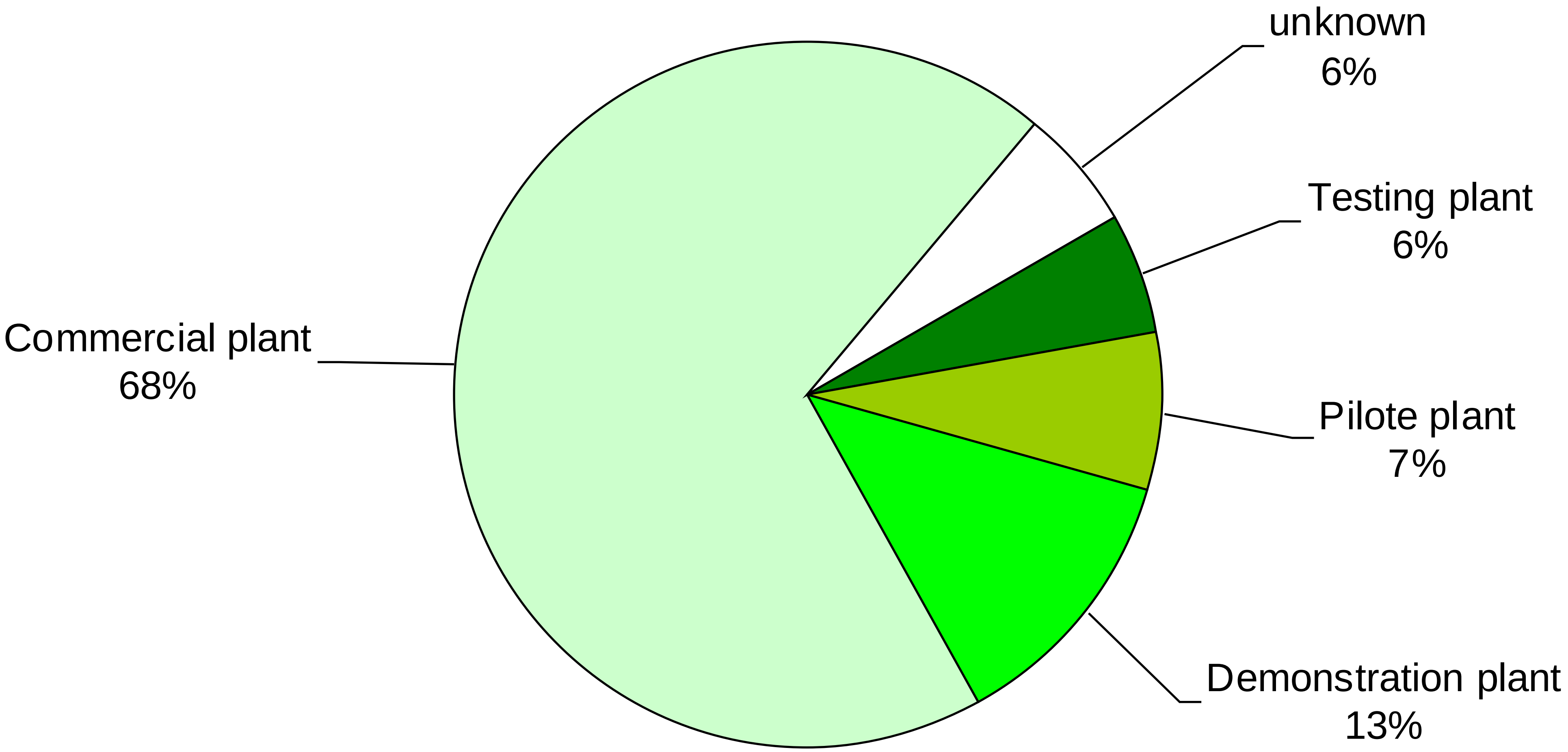
Character of plants	No.		**Electric power**	No.	
Testing plants:	3	12 %	<1MW:	10	40 %
Pilote plants:	4	16 %	1MW - <5MW:	8	32 %
Demonstration plants:	3	12 %	5MW - 20MW:	1	4 %
Commercial plants:	15	60 %	>20MW:	2	8 %
unknown:	0	0 %	unknown:	4	16 %

/biocogen/

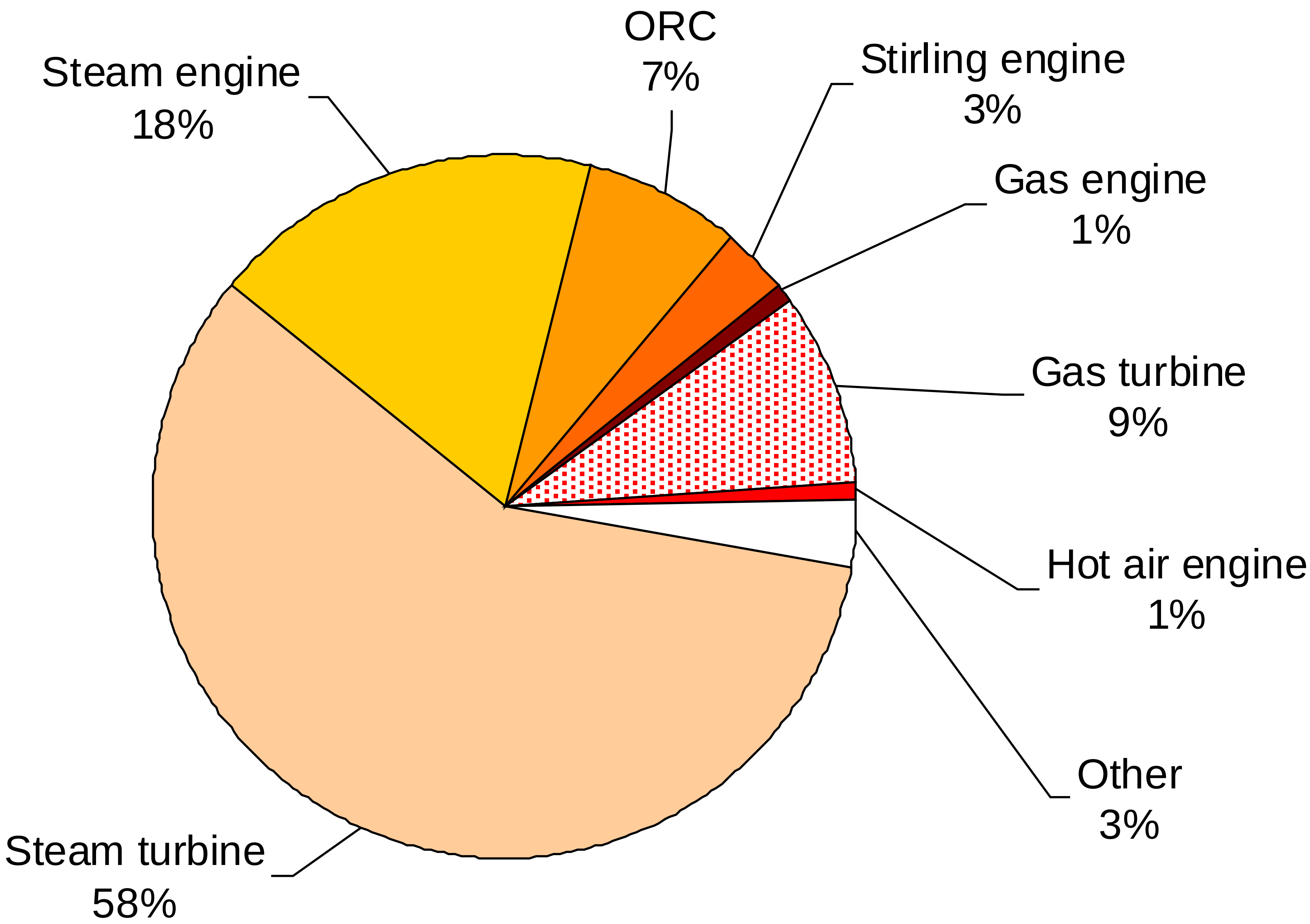
CHP plants in European Countries



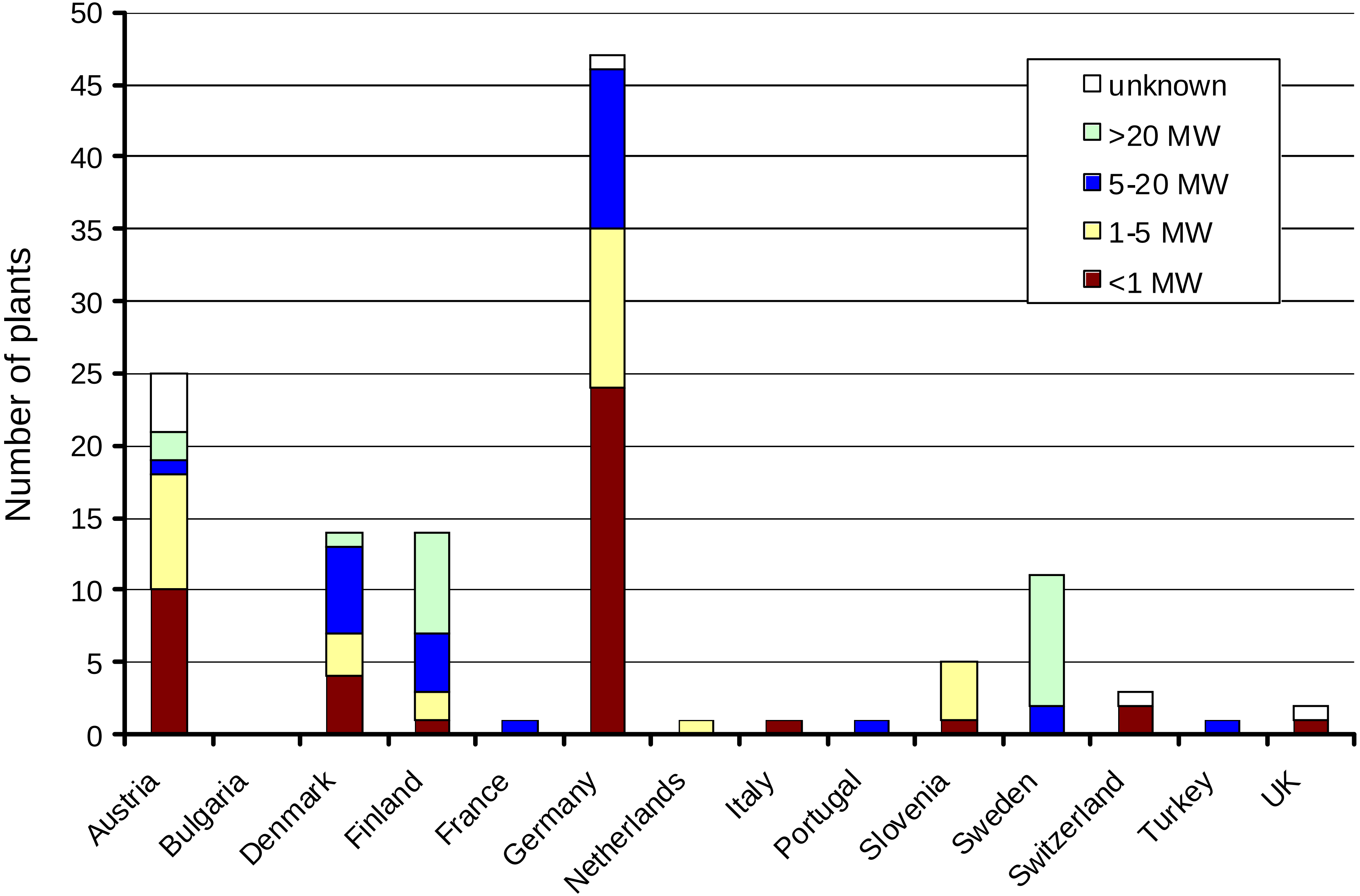
Distribution of Characters



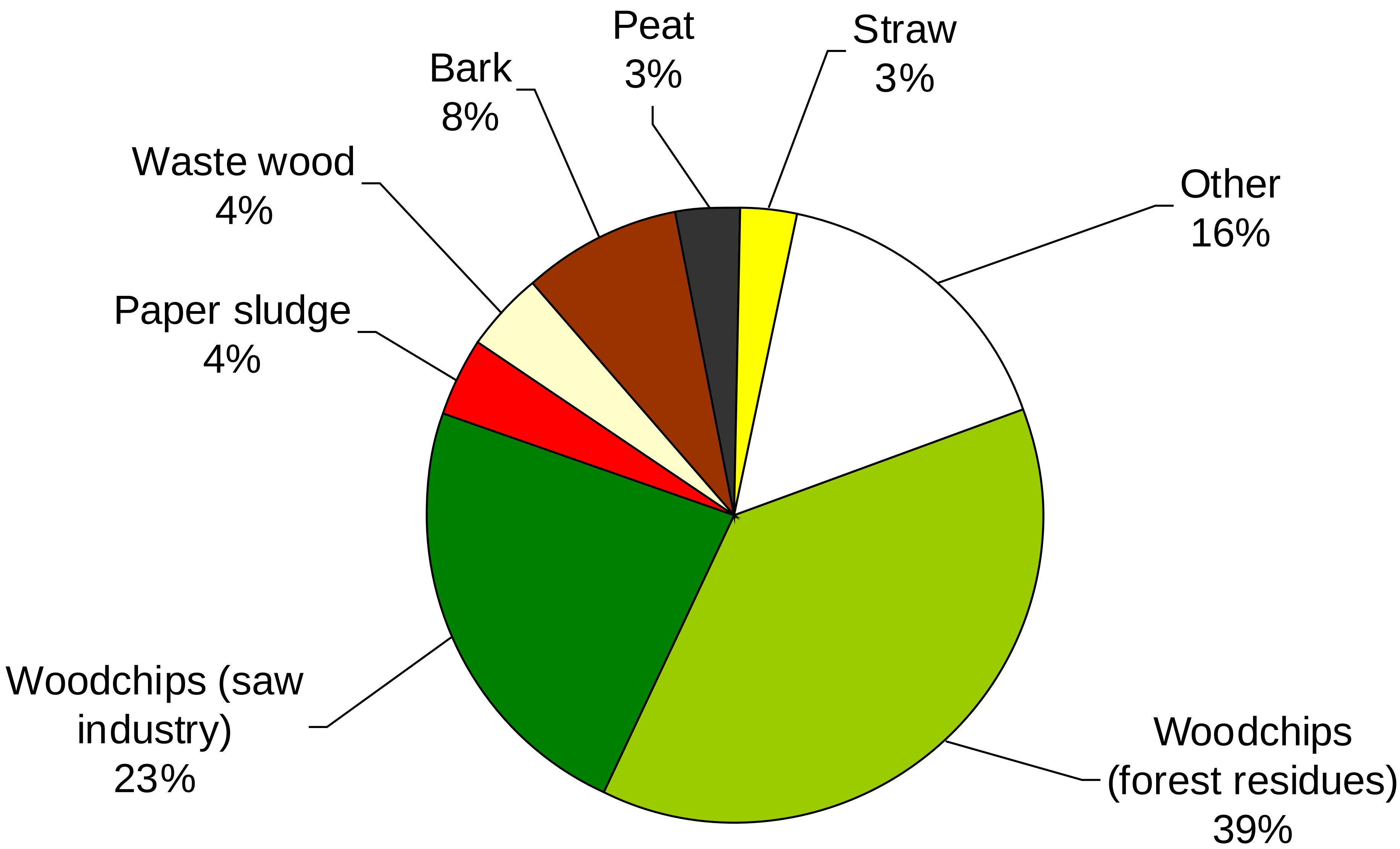
Distribution of Installed Technologies



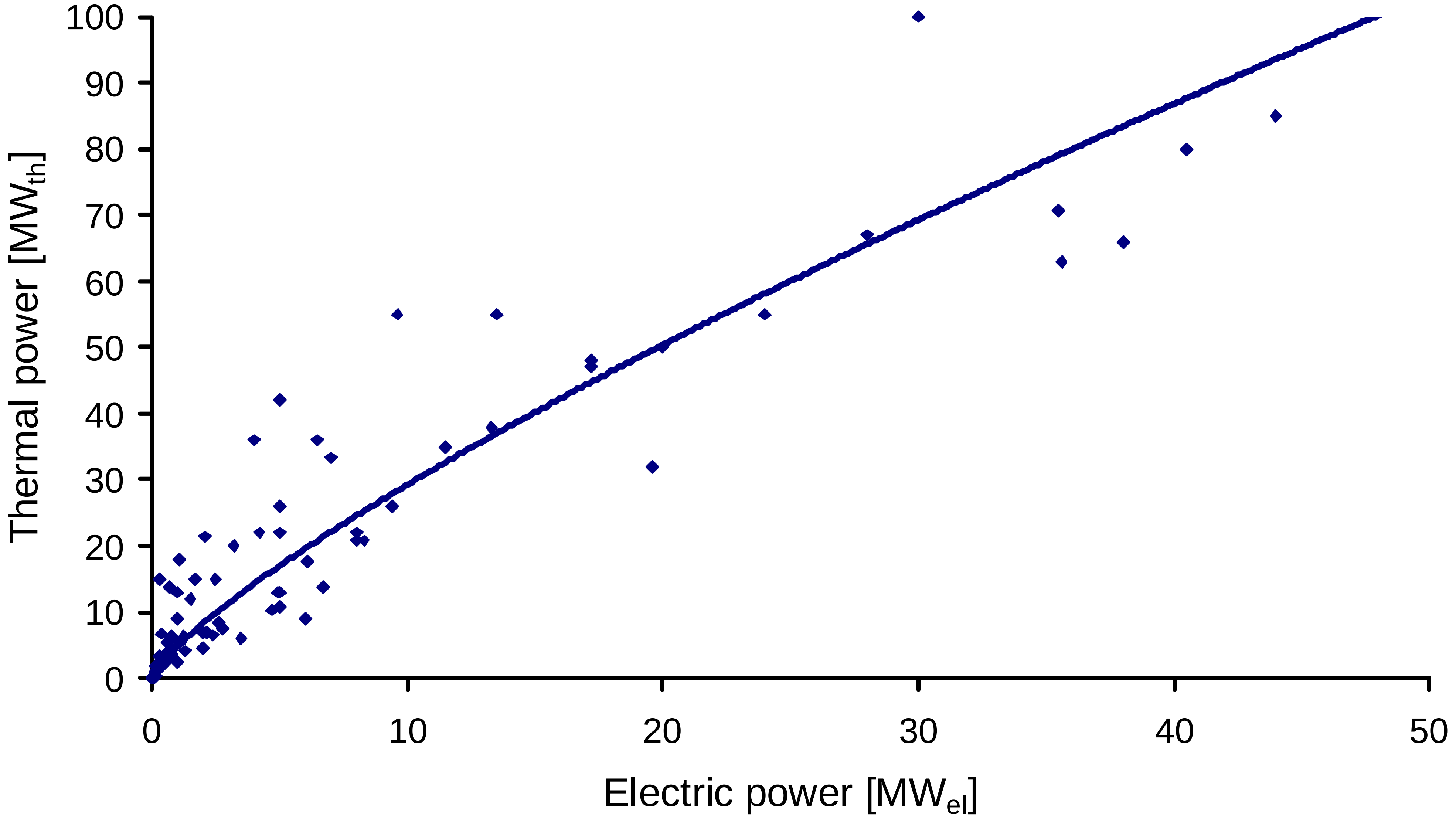
Electric Capacities of CHP Plants



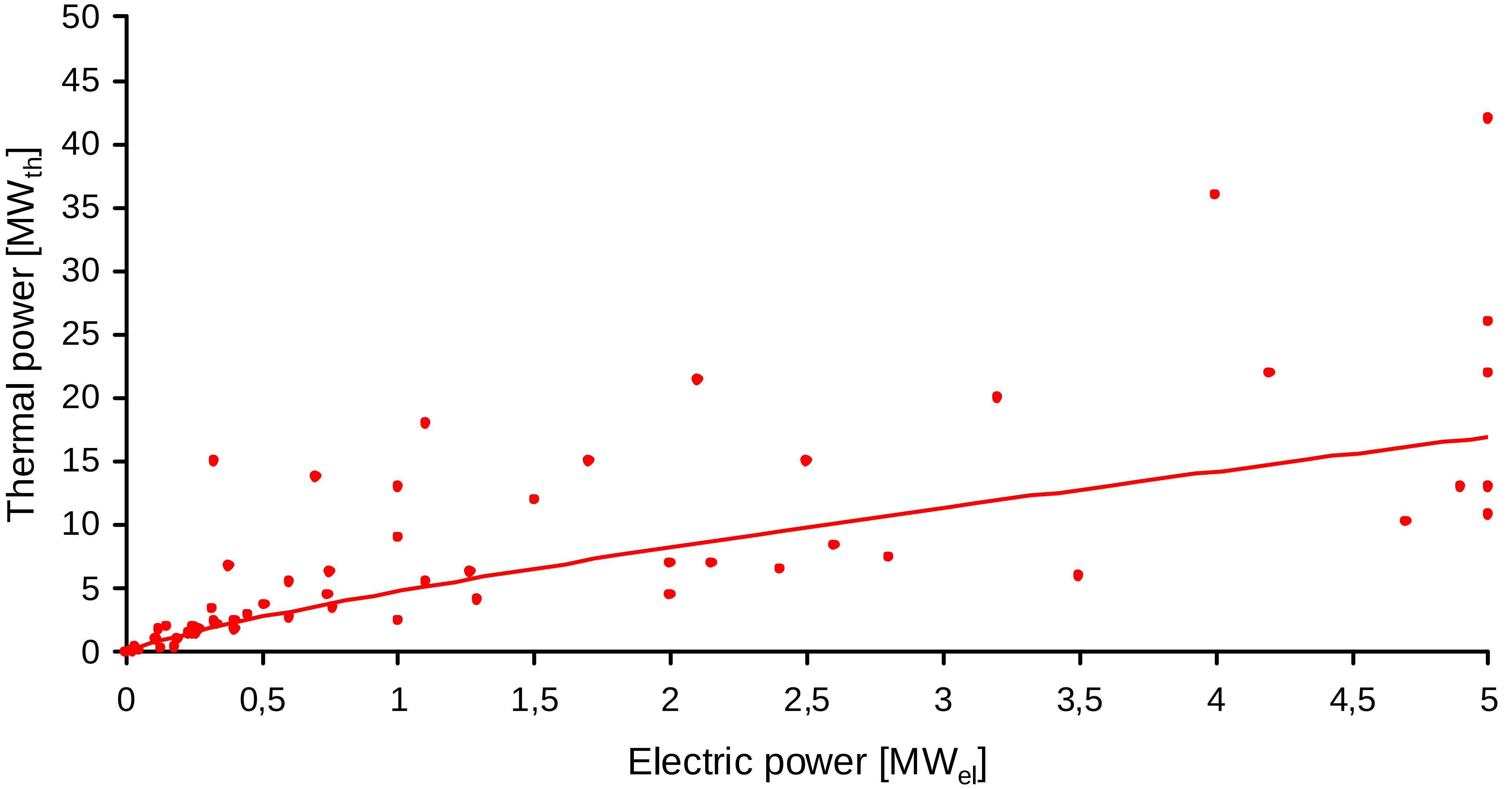
Distribution of Biofuels



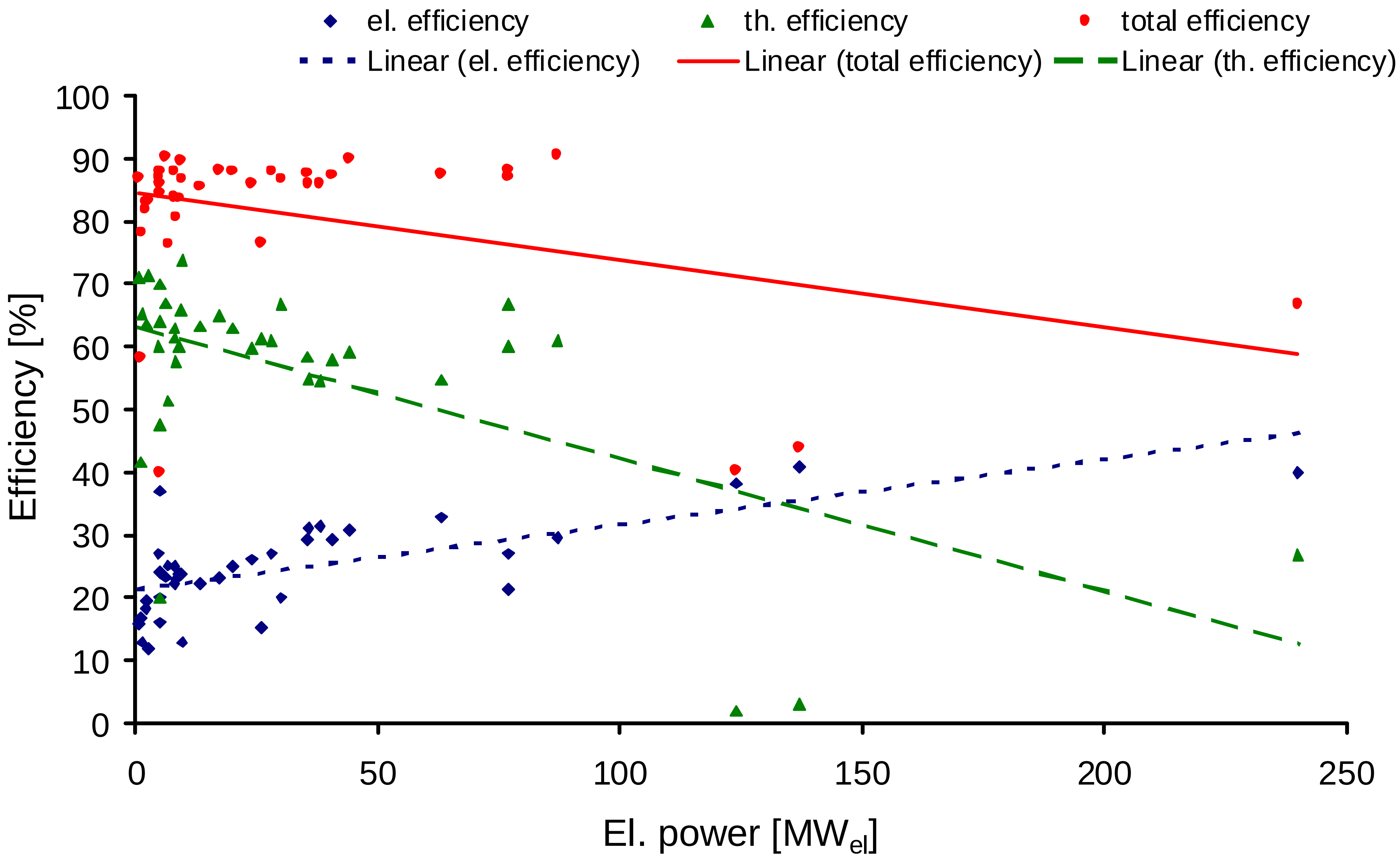
Ratio of Heat and electricity



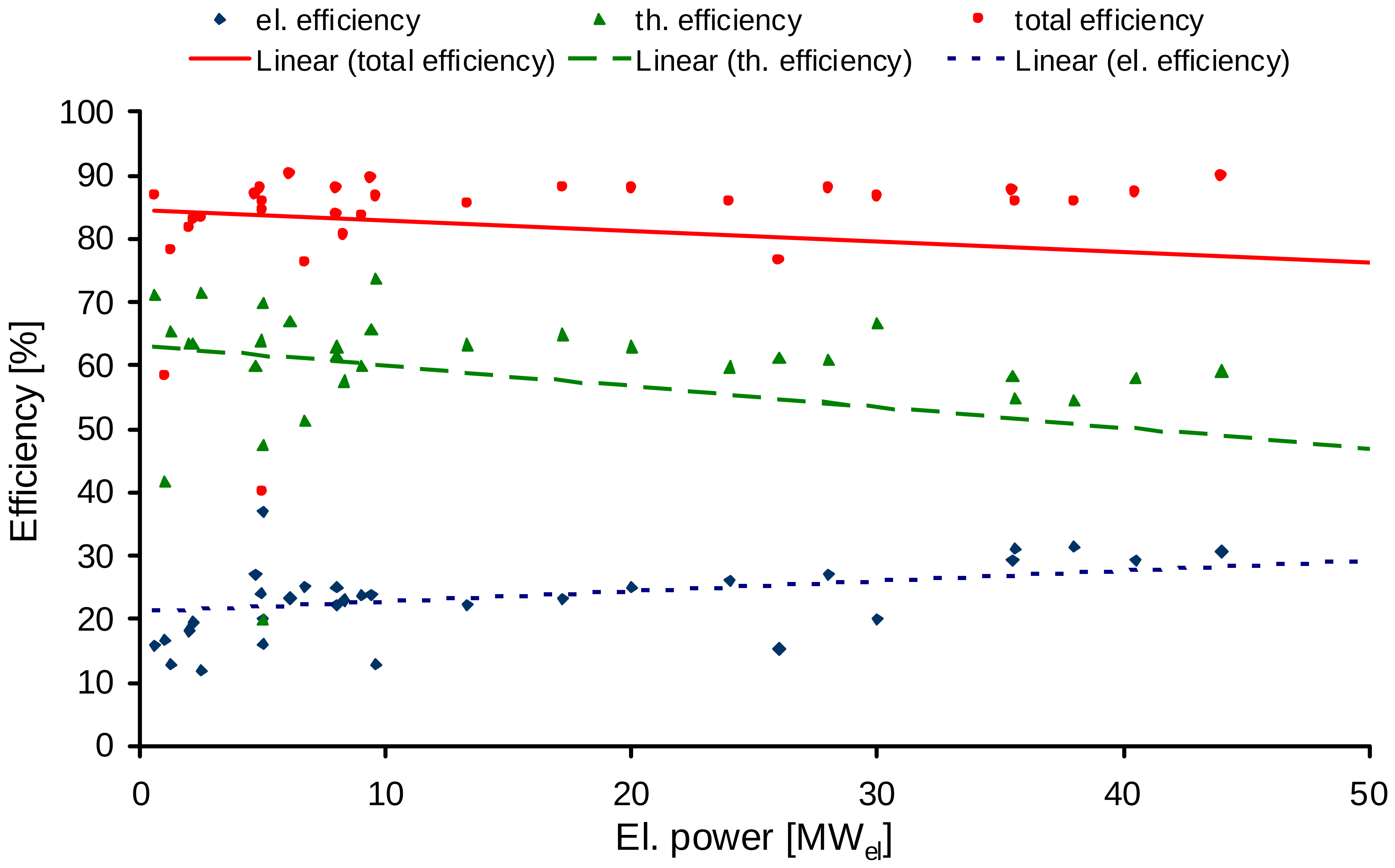
Ratio of Heat and electricity (selected < 5MWel)



Electric Power and Electric Efficiency of Steam Turbines



Electric Power and Electric Efficiency of Steam Turbines (selected < 50MWel)



Success stories in Austria

CHP Plant Güssing (Gas Engine)

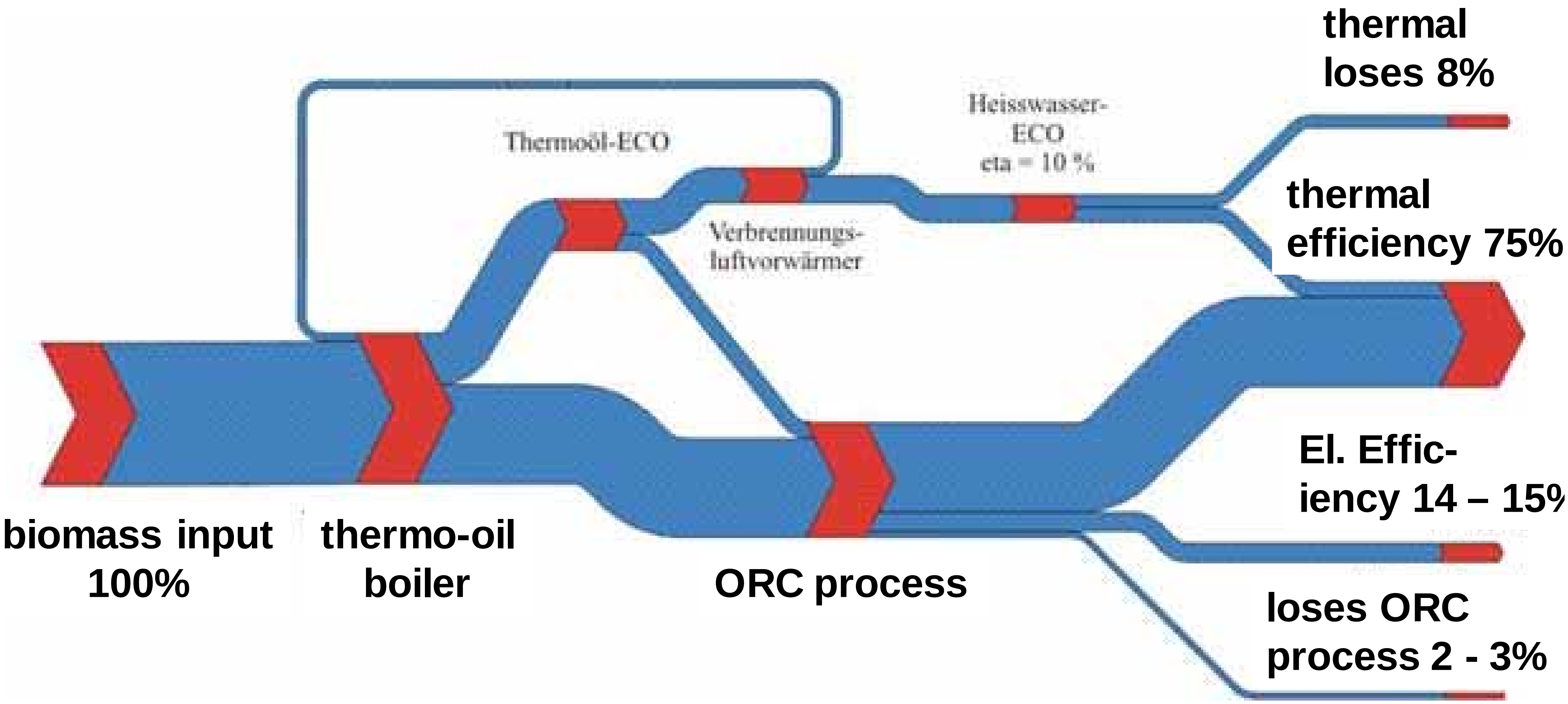
- Fluidized bed gasification + gas engine
- solid biomass (chips)
- 4.5 MW_{th} / 2 $MW_{el.}$

CHP Plant Lienz

- Organic Rankine Cycle (ORC)
- solid biomass (chips) combustion + second thermo-oil cycle
- 7.0 MW $_{heat}$ / 1.0 MW $_{el.}$
- Electricity efficiency 18%

Source: http://bios-bioenergy.at

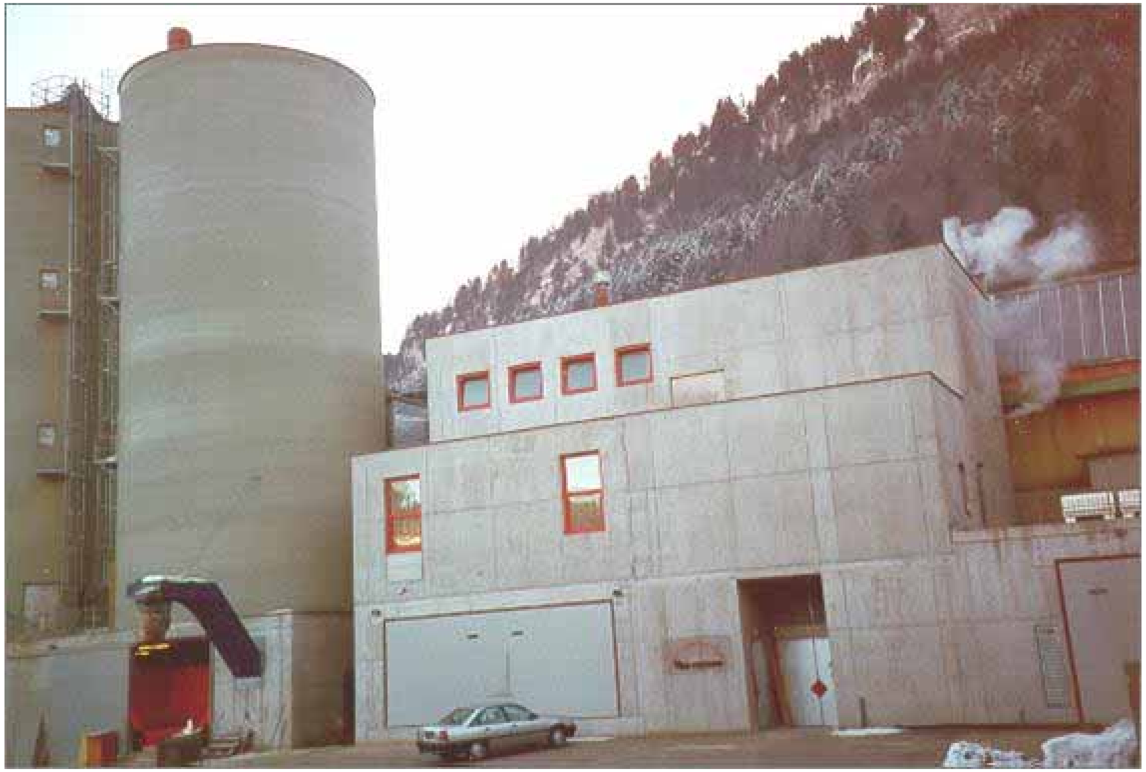
Energy flow of CHP Plant Lienz



Source: http://bios-bioenergy.at

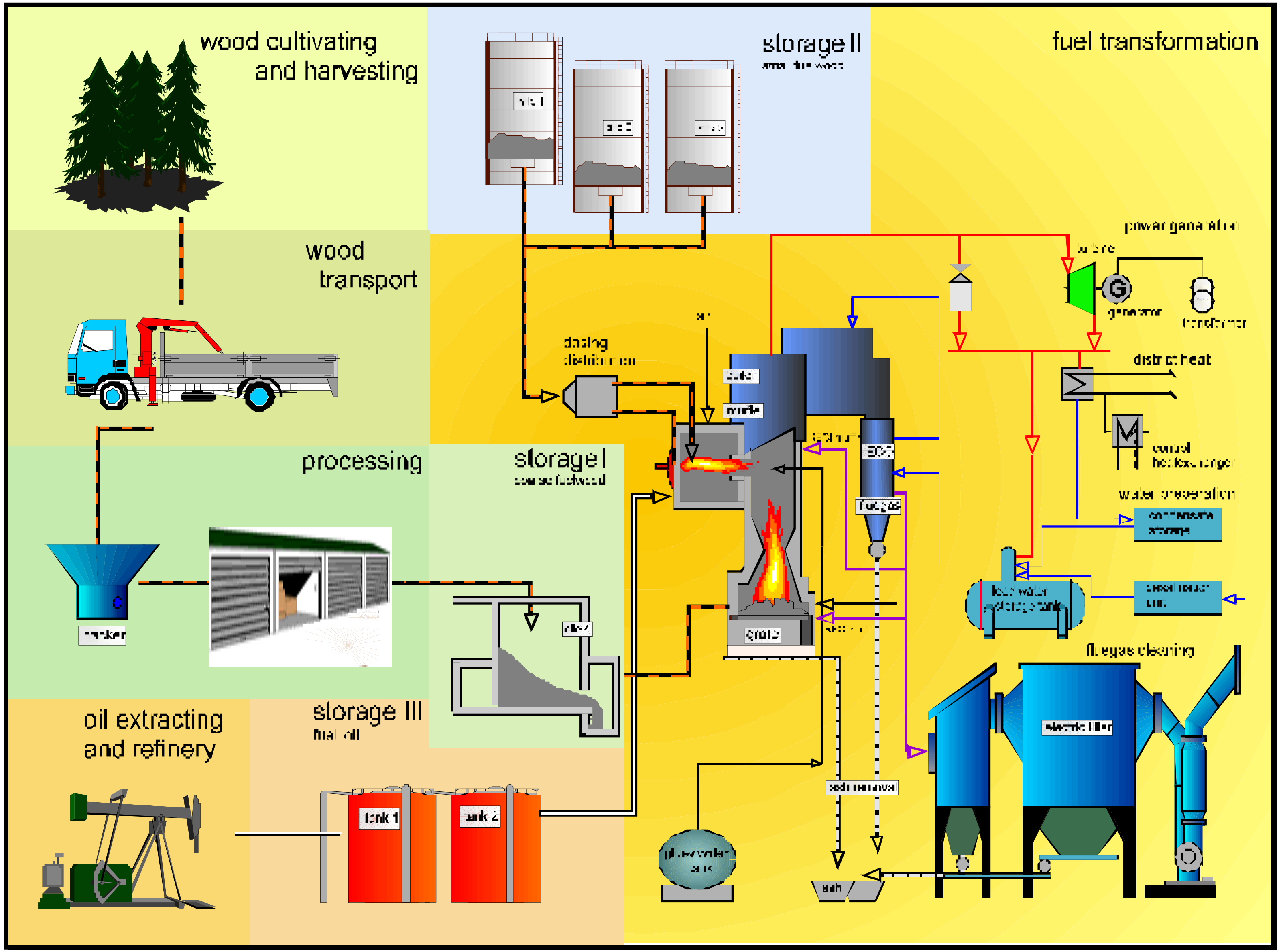
CHP Plant Reuthe (Steam Turbine)

VKW / Kaufmann Reuthe / Vorarlberg



- Conventional steam technology
- solid biomass (chips) 10 000 t/yr
- 6.3MW $_{heat}$ / 1.3MW $_{el.}$
- 4.5 mio €

Biomass Fuel Cycle Reuthe



Sourrce: VKW

Conclusions (1) LCA

- Application of international developed LCA methodology
- GHG from CHP plants emissions depend significantly on fuel and technology
- Biofuels less GHG emissions than fossil fuels
- Biomass CHP interesting potential for GHG reduction

Conclusions (2) Existing Plants

- Most solid biomass CHP plants are located in countries of considerable forest industry ( ),most without cofiring
- Steam turbine and engine are most common technologies, significant share of ORC technology ( ) Stirling engines
- High amount of Commercial plants
- Most plants were already installed before 1995 (except of)
- Smaller capacities <1 MW_{el} ( )
  larger capacities >20 MW_{el} ( )
- Most common biofuel is woodchips, others are bark( ) black liquor ( ), straw ( ) and peat ( )
- Increasing capacities leads to decreasing efficiencies