Hochschule für Forstwirtschaft Rottenburg
Hochschule für Angewandte Wissenschaften

Technologies for biomass conversion

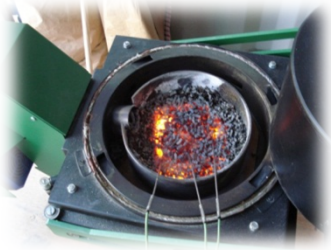
Thermochemical behavior of different biomass feedstocks

BIOENERGY PRODUCTION IN RURAL AREAS:
Creation of a biomass market in mediterranean areas and regions with declining water resources
8th and 9th of September, 2011, Murcia

Martin Brunotte
Gabriel Reichert

Renewable Energies and Energy Planning

University of Applied Sciences
Rottenburg, Germany



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University of Applied Sciences Rottenburg (HFR):
Studying in the name of sustainability

- Forestry, B.Sc.
- Bioenergy, B.Sc.
- Water Resource Management, B.Sc.
- Applied Wood Technology, B.Sc.
- Sustainability Economics and Energy Technology, (SENCE), M.Sc.

- 700 students
- 20 professors
- 20 research scientists
- More than 20 research projects ongoing

AUSGEZEICHNET! Stifterverband für die Deutsche Wissenschaft Sieger Bundeswettbewerb Exzellenzstrategien

Nachhaltigkeit lernen Weltdekade der Vereinten Nationen 2005–2014 Bildung für nachhaltige Entwicklung UNESCO Offizielles Projekt der Weltdekade 2010 / 2011

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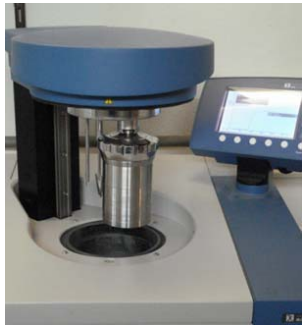
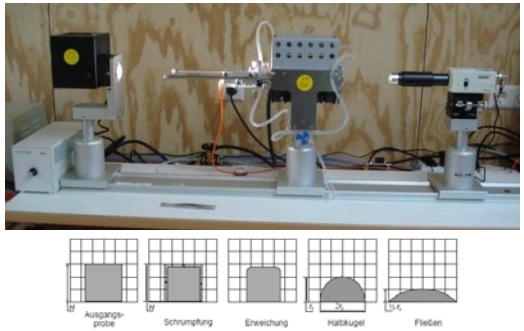
Laboratory facilities at the HFR

- Characterization of Biomass
  - Mechanical properties
  - Chemical properties
- Processing of biomass
  - Drying
  - Pelletizing
- Testing of combustion technologies
  - Emissions
  - Analyzing of ashes





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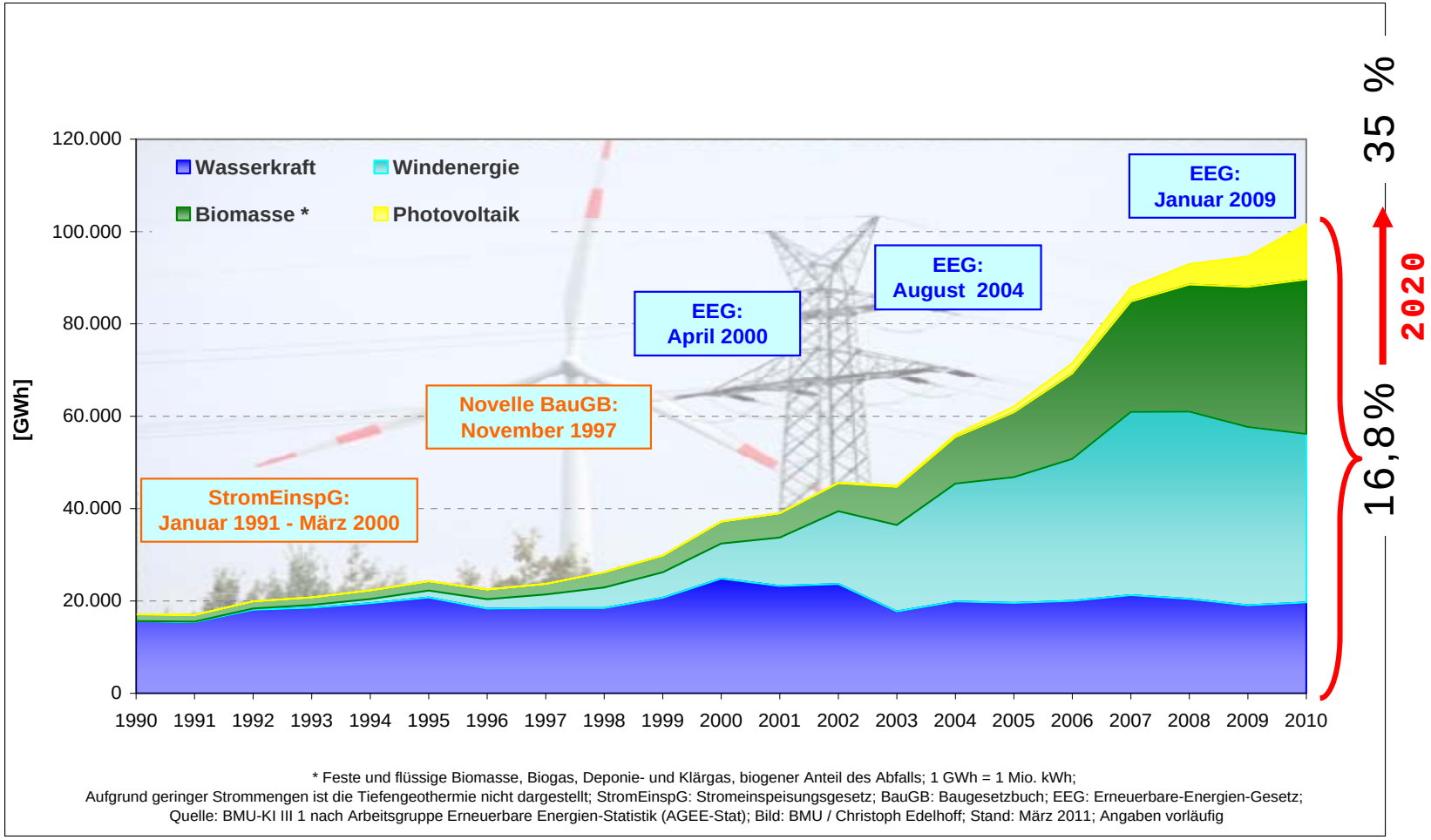
Electricity from renewable energies in Germany



* Feste und flüssige Biomasse, Biogas, Deponie- und Klärgas, biogener Anteil des Abfalls; 1 GWh = 1 Mio. kWh;
Aufgrund geringer Strommengen ist die Tiefengeothermie nicht dargestellt; StromEinspG: Stromeinspeisungsgesetz; BauGB: Baugesetzbuch; EEG: Erneuerbare-Energien-Gesetz;
Quelle: BMU-KI III 1 nach Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat); Bild: BMU / Christoph Edelhoff; Stand: März 2011; Angaben vorläufig

Source: BMU – KI III 1

Yield of electric energy per area in Murcia:

How many households can be supplied with electricity from 65 ha?

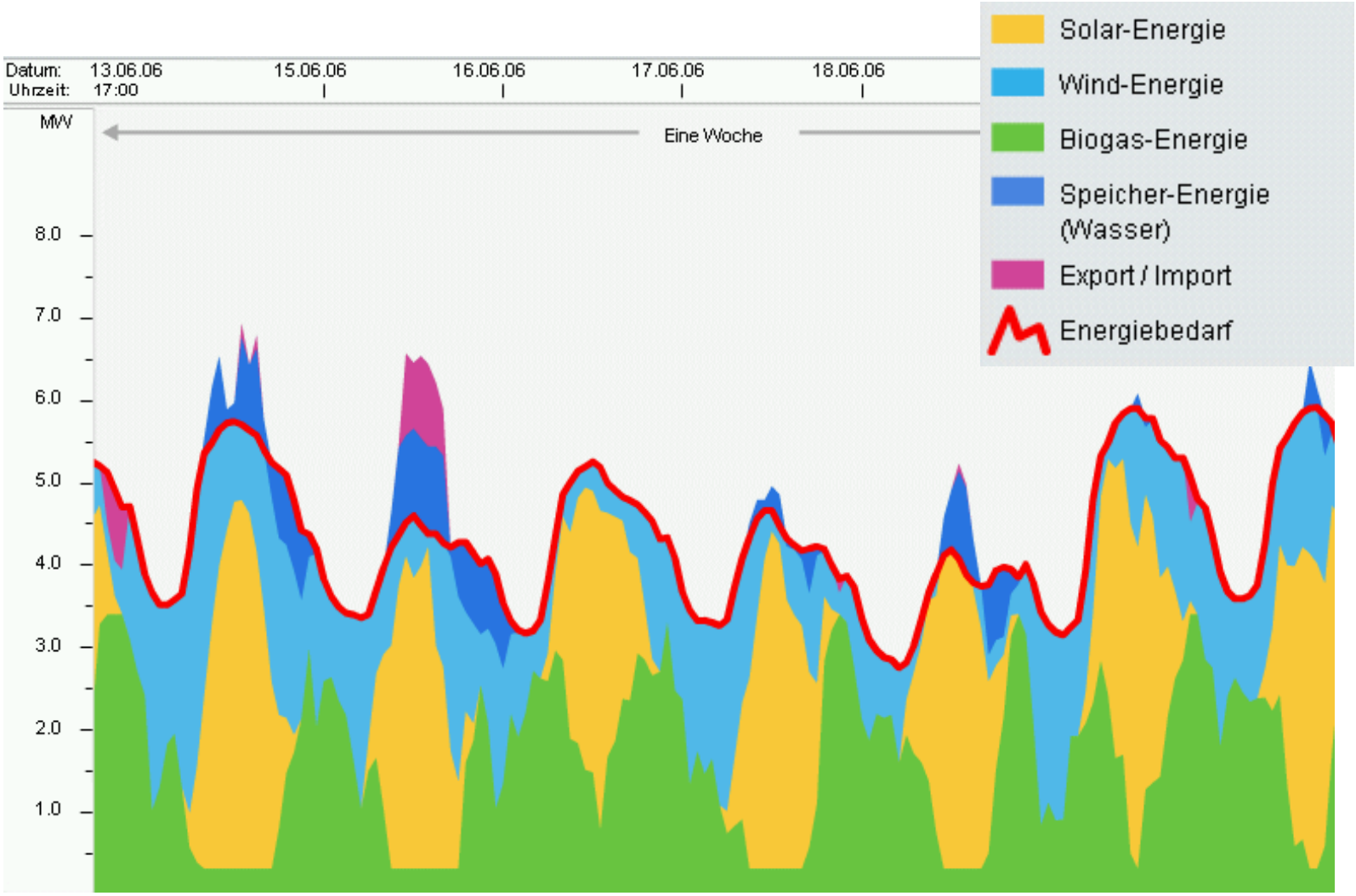
30 MW-Solar thermal power plant
in Puerto Errado near Calasparra

65 ha => **12 000** households

Short rotation coppice plant (10 t/ha)
and biomass power plant

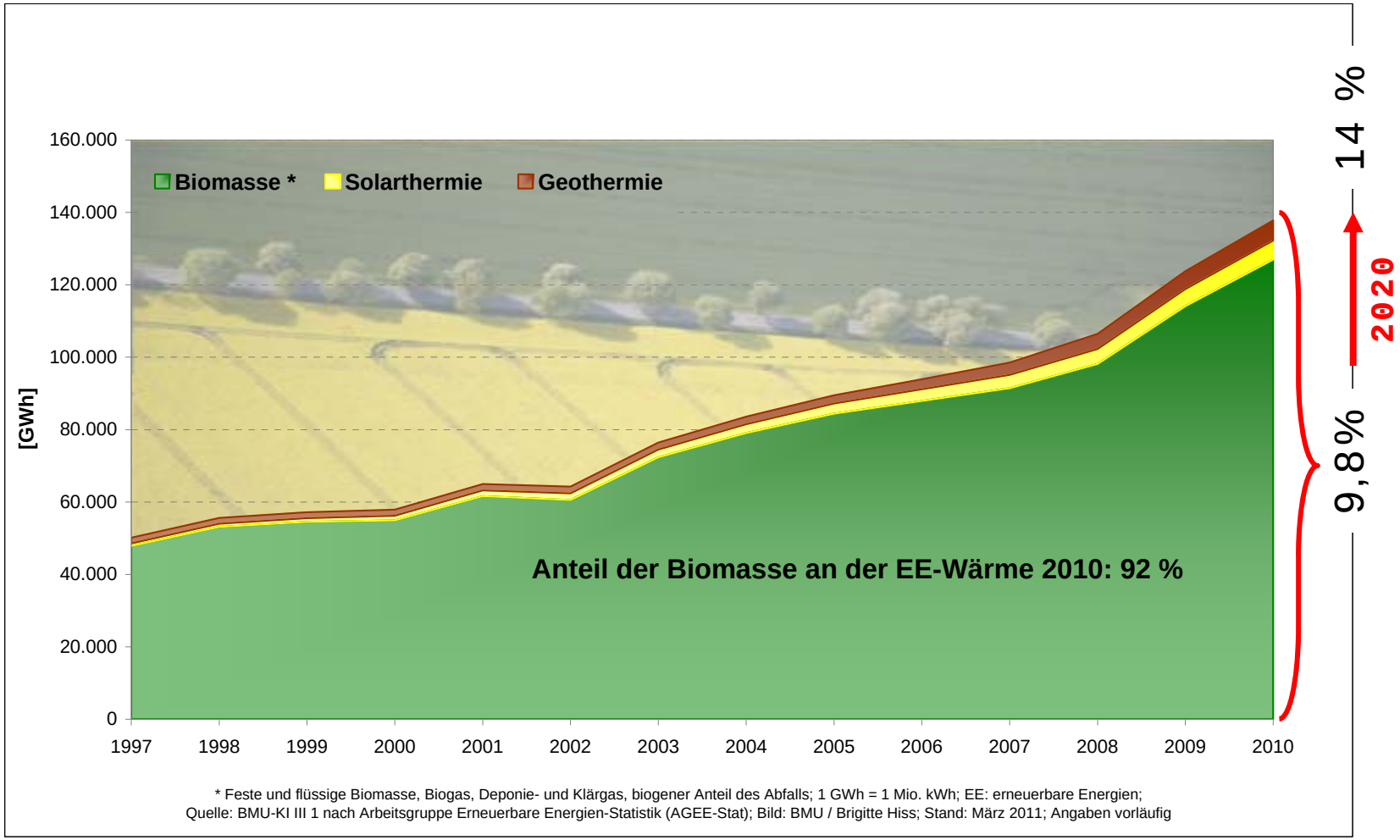
65 ha => **250** households

The role of biomass in a 100% renewable energy scenario



Quelle: www.kombikraftwerk.de

Heat from renewable energy in Germany

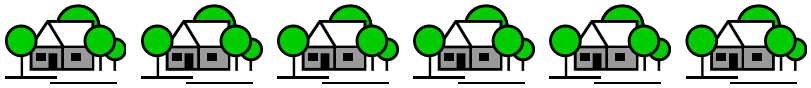


Source: BMU – KI III 1

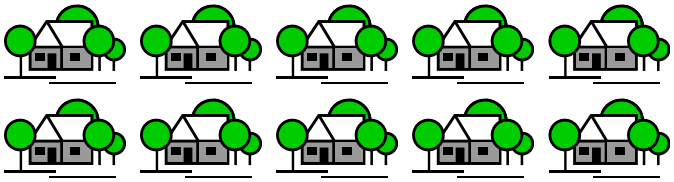
Efficiency in the use of biomass:
How many houses can be heated with 20 m³ of firewood?

- old house with 30 year old single furnaces

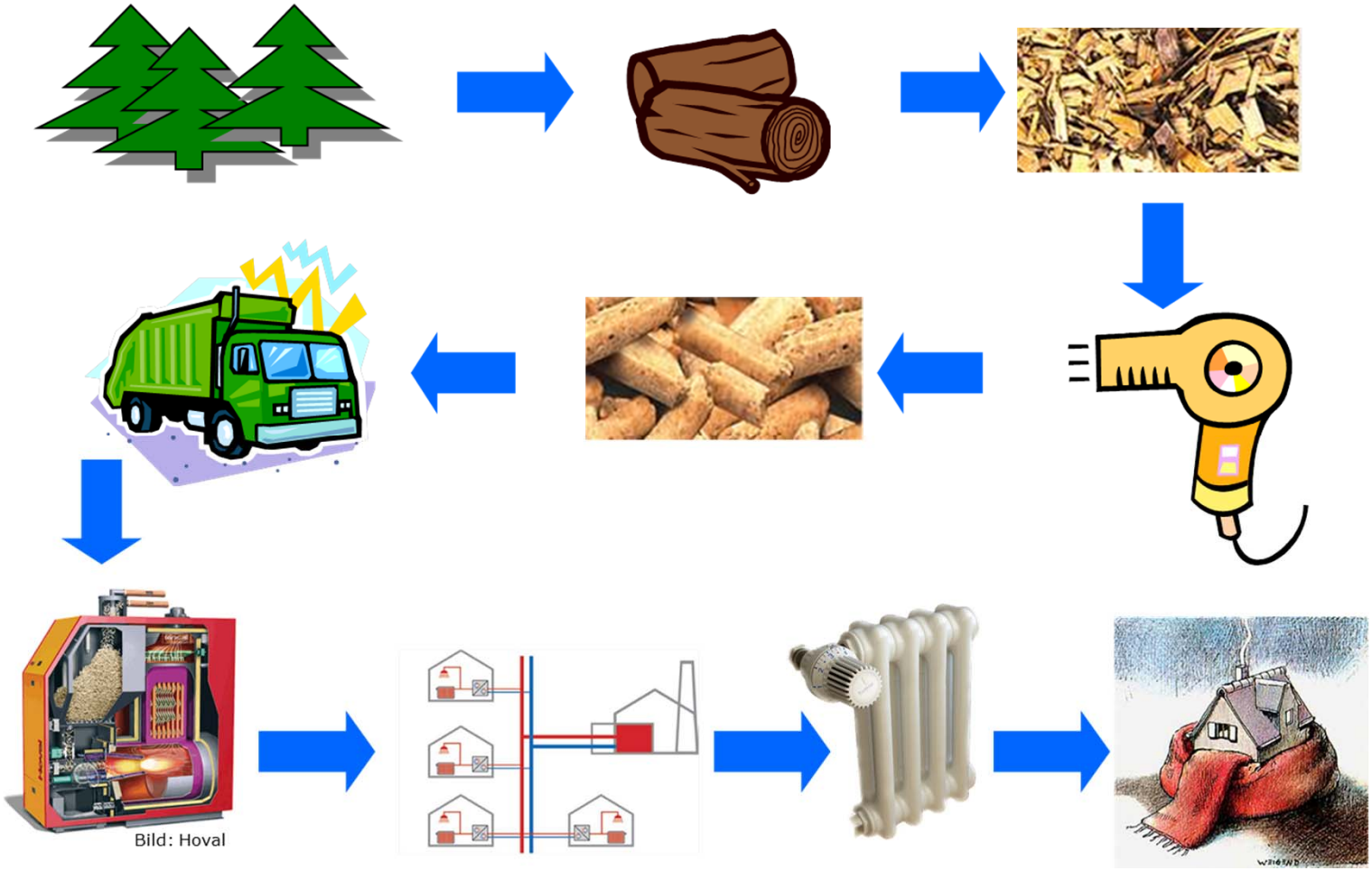
- insulated house with modern wood-fired boiler



- additional solar heating system



Bioenergy value chain : From the forest to a warm house



Bioenergiedorf Mauenheim: Village with over 100% energy supply from renewables

- Biogas (430 kW) , PV (>200 kW_p), wood chips (1 MW)
- Produces 9 times more electricity than it needs
- Supplies 90% of heating needs

http://bioenergiedorf-mauenheim.de

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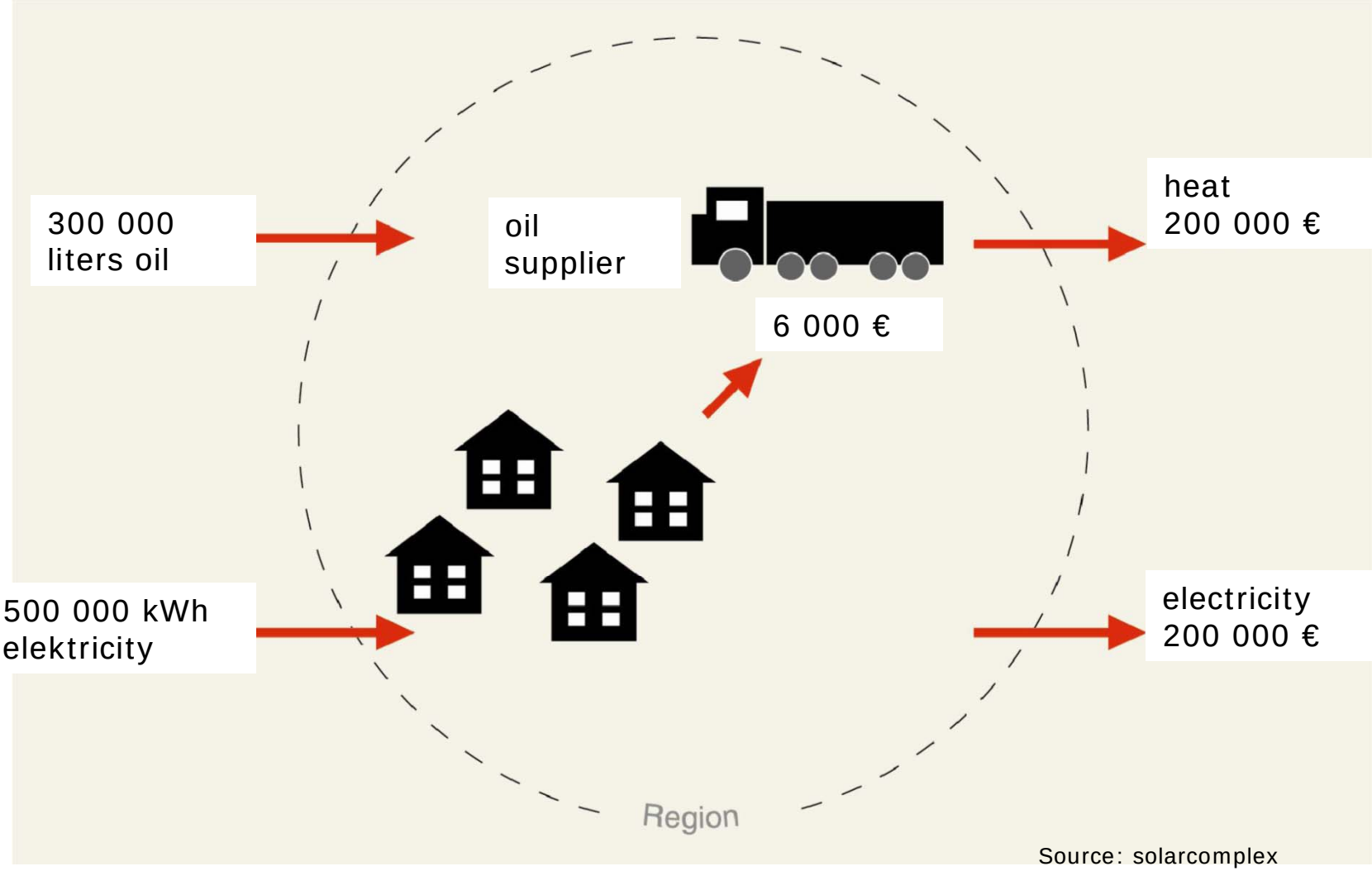
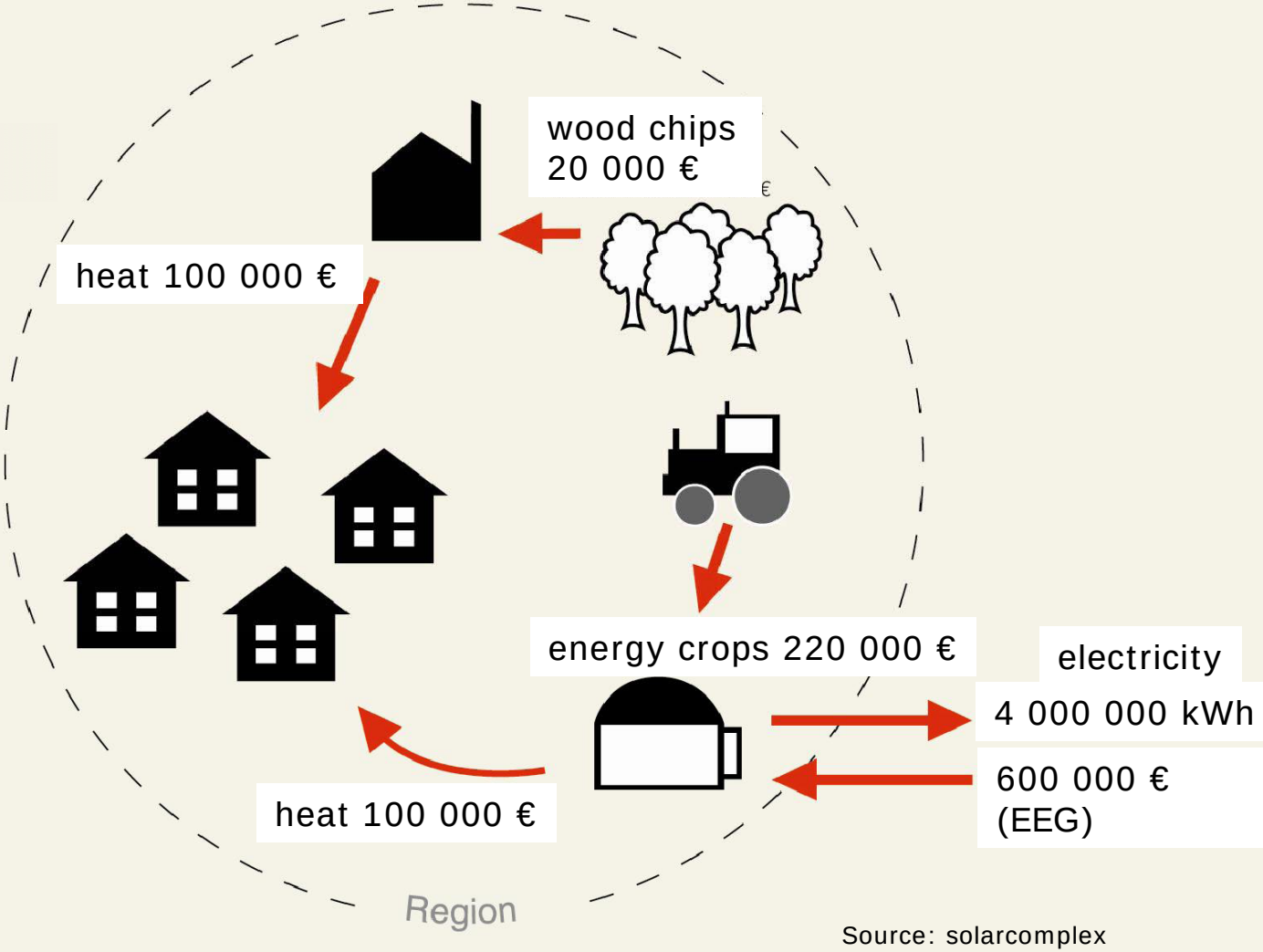
Mauenheim <u>before</u> becoming a "Bioenergy Village"



Source: solarcomplex

Mauenheim after becoming a "Bioenergy Village"



Source: solarcomplex

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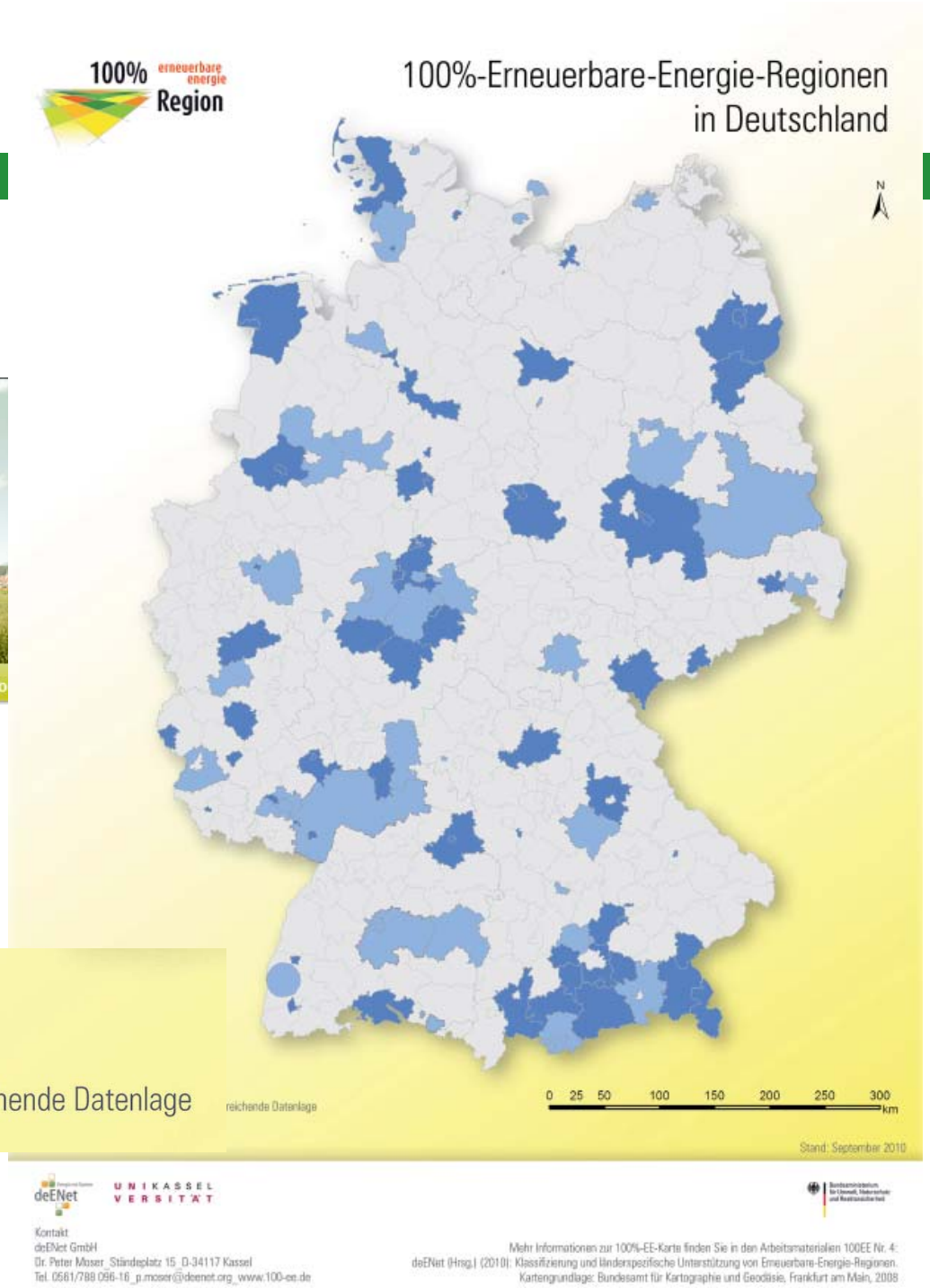
100% Renewable Energy Regions



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Nachhaltigkeit lernen
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Overview on different feedstocks for thermal conversion

Overview on different feedstocks for thermal conversion

- Wood
  - forest wood
  - bark
  - saw dust
  - waste wood
  - landscaping residues
  - short rotation coppice (SRC)
- Energy crops
  - miscanthus
  - igniscum
  - Switchgrass (Panicum virgatum)
- Forest- and agricultural residues
  - straw (wheat, rapeseed,…)
  - whole crops
  - energy grasses
  - husks
  - corn cobs
  - press cakes
  - nutshell
  - Stones from fruits
- Other biomass
  - residues of biogas plants

Customizing biofuels for combustion

- Wood chips

Source: www.komptech.de

- Briquets

Source: www.hartmut-mueller-gmbh.de

- Split logs

Source: www.binderberger-holzspalter.de

- Pellets

Source: www.akahl.de

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Small- scale biomass combustion systems (< 100 kW)

Application:

- residential heating

Fuels used:

- pellets
- log wood
- wood chips

Technologies:

- wood pellet boilers
- wood log boilers
- wood chip boilers
- wood stoves
- fire-place inserts

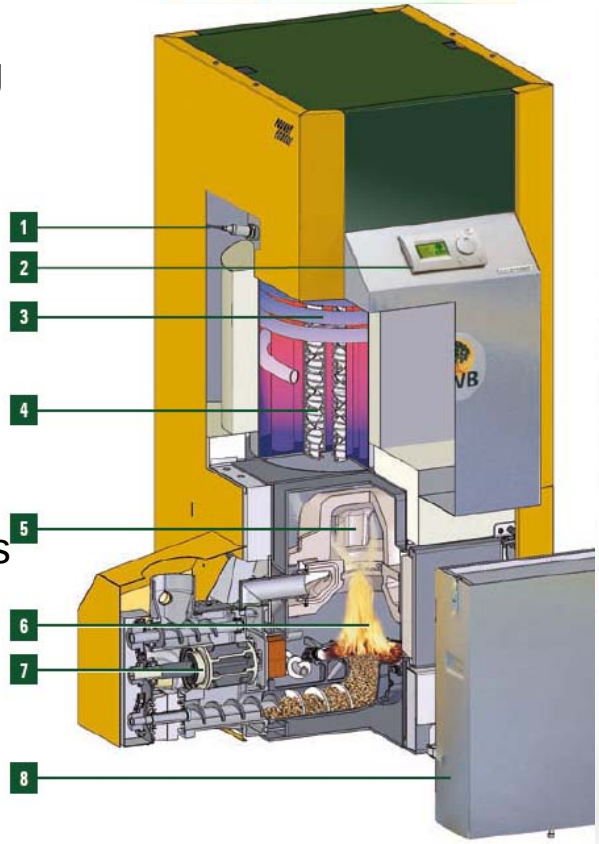


Figure: www.kwb.at

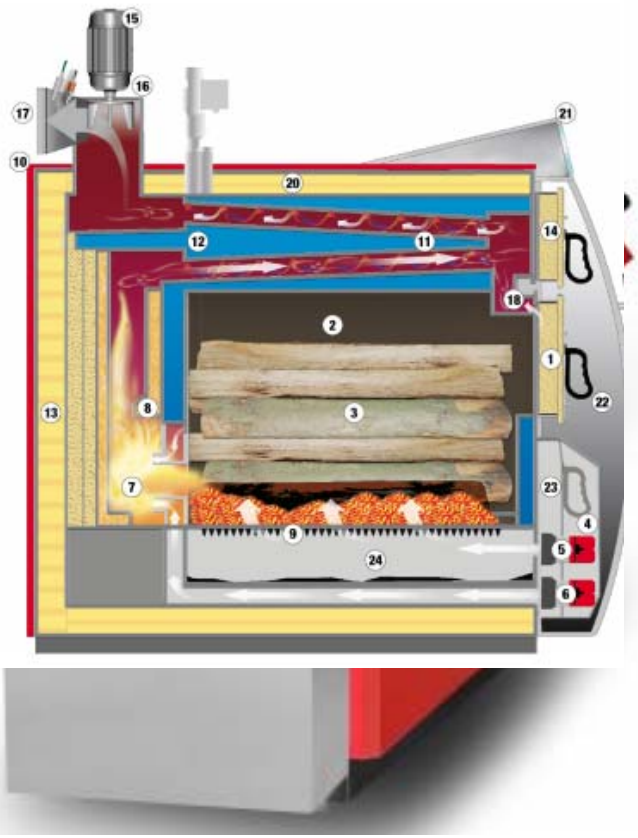


Figure: www.hargassner.at

Source: Obernberger 2010

Medium- scale combustion systems (up to 20 MW)

Application:

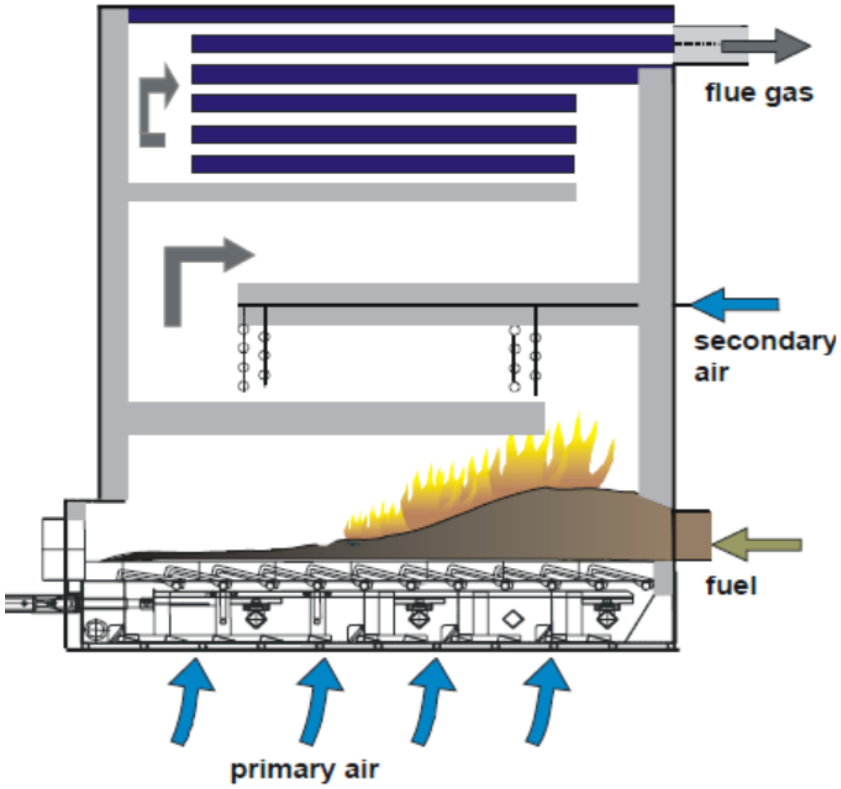
- district heating
- process heating and cooling
- CHP

Fuels used:

- wood chips
- bark
- forest residues
- waste wood
- straw

Technologies:

- underfeed stokers
- grate- fired systems
- dust burners



Source: Obernberger 2010, MAWERA Holzfeuerungsanlagen GmbH

Biomass-CHP with ORC-cycle

- 200 -2000 kW el.
- el. efficiency 10-20%
- total efficiency up to 90%
- temperature: < 300 °C
- Steam preassure: 10 -20 bar

400 kW_{el} - ORC-container modul

CHP biomass plant Schilling /Schwendi

Large- scale combustion systems (more than 20 MW)

Application:

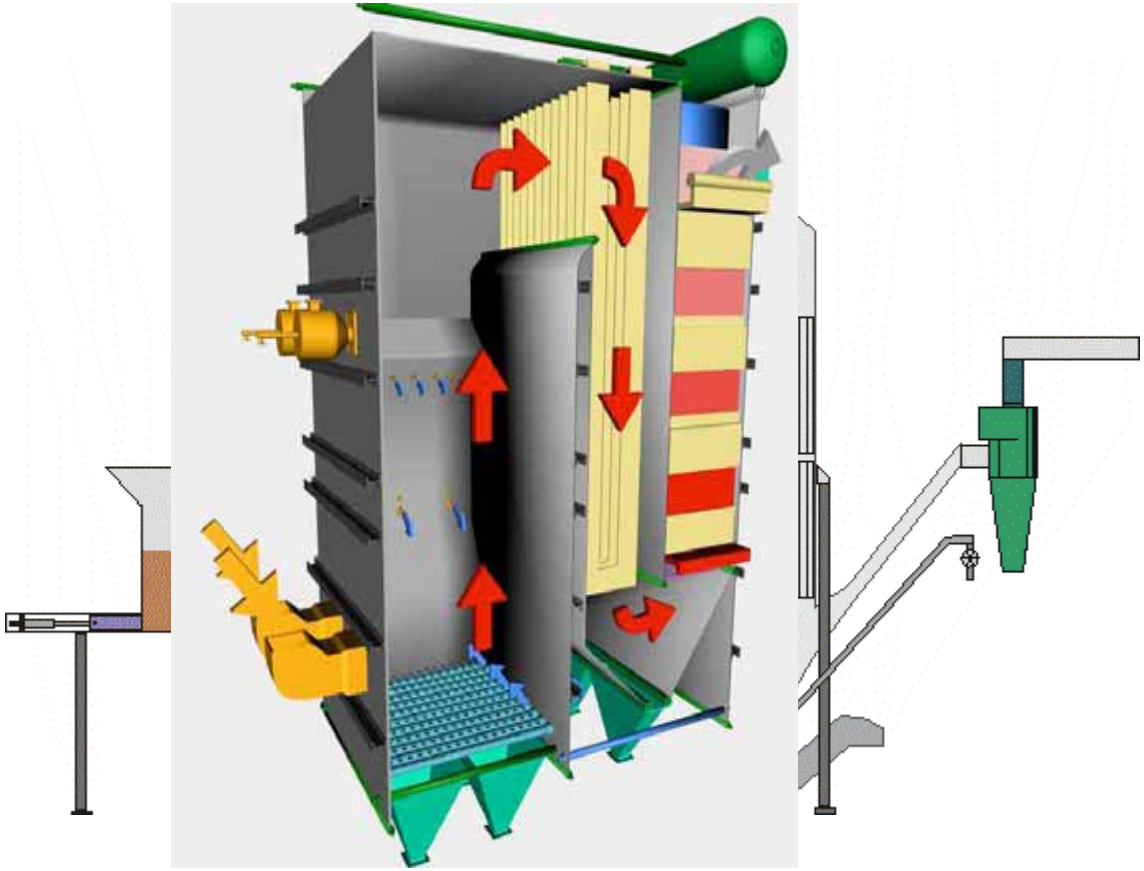
- CHP
- electricity only

Fuels used:

- bark
- forest residues
- waste wood
- straw, cereals
- fruit stones, kernels, husks, shells

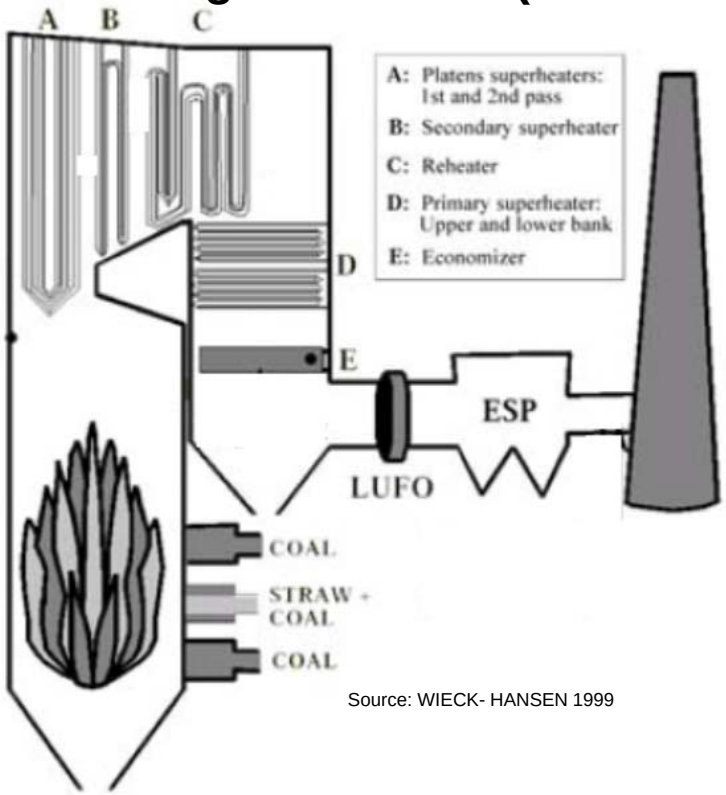
Technologies:

- grate- fired systems
- fluidized beds



Source: Obernberger 2010, AE & E Austria GmbH & Co. KG.

Large- scale combustion systems with co-firing of biomass (>100 MW)



Source: WIECK- HANSEN 1999

Application:

- electricity only
- CHP (very limited)

Fuels used:

- forest residues
- sawdust, wood chips
- pellets
- straw
- fruit stones, kernels, husks, shells

Technologies:

- Co- firing of finely milled biomass mingled with coal
- Biomass co- firing in fluidized bed combustion systems
- Co- firing in separate combustion units and junction of steam
- Biomass gasification and utilization of the product gas as fuel in a coal combustion system

Source: Obernberger 2010

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Relevant characteristics of solid biofuels

Chemical properties

- Carbon (C),
- Hydrogen (H),
- Oxygen (O)
- Chlorine (Cl)
- Nitrogen (N)
- Sulfur (S)
- Flour (F)
- Potassium (K)
- Sodium (Na)
- Magnesium (Mg)
- Calcium (Ca)
- Phosphor (P)
- Heavy metals (e.g. Zn, Cd, Pb, Cr)

Physical properties

- Moisture content
- Net calorific value/ gross calorific value
- Volatiles
- Ash content
- Ash melting behavior
- Bulk density
- Particle Density
- Physical dimension, form, size distribution
- Abrasion resistance (for wood pressings)

Comparison of different solid biofuels and effects on combustion behavior

feedstock	sawdust	miscanthus	rape straw	weath straw	hay straw
Gross calorific value [MJ/kg$_{db}$]	19,8	17,3	16,2	16,6	16,6
Ash content [%m$_{db}$]			[illegible]		
Deformation temperature [°C]			[illegible]		
N [%m$_{db}$]			0,84		
S [%m$_{db}$]			0,27		
Cl [%m$_{db}$]			0,47		
K [%m$_{db}$]			0,8		

high ash contents 10× - 20×

Low deformation temperature (300°C – 600°C below wood)

high concentrations of S, Cl, N, alkalimetals

wide range of fuel characteristics

increasing risk of slagging and fouling

increasing of gaseous and PM emissions (NO_x, SO_2, PM…)

corrosion risk

combustion design and controll

Ash related problems

- fine particulate emissions

Photo: REICHERT/ HFR

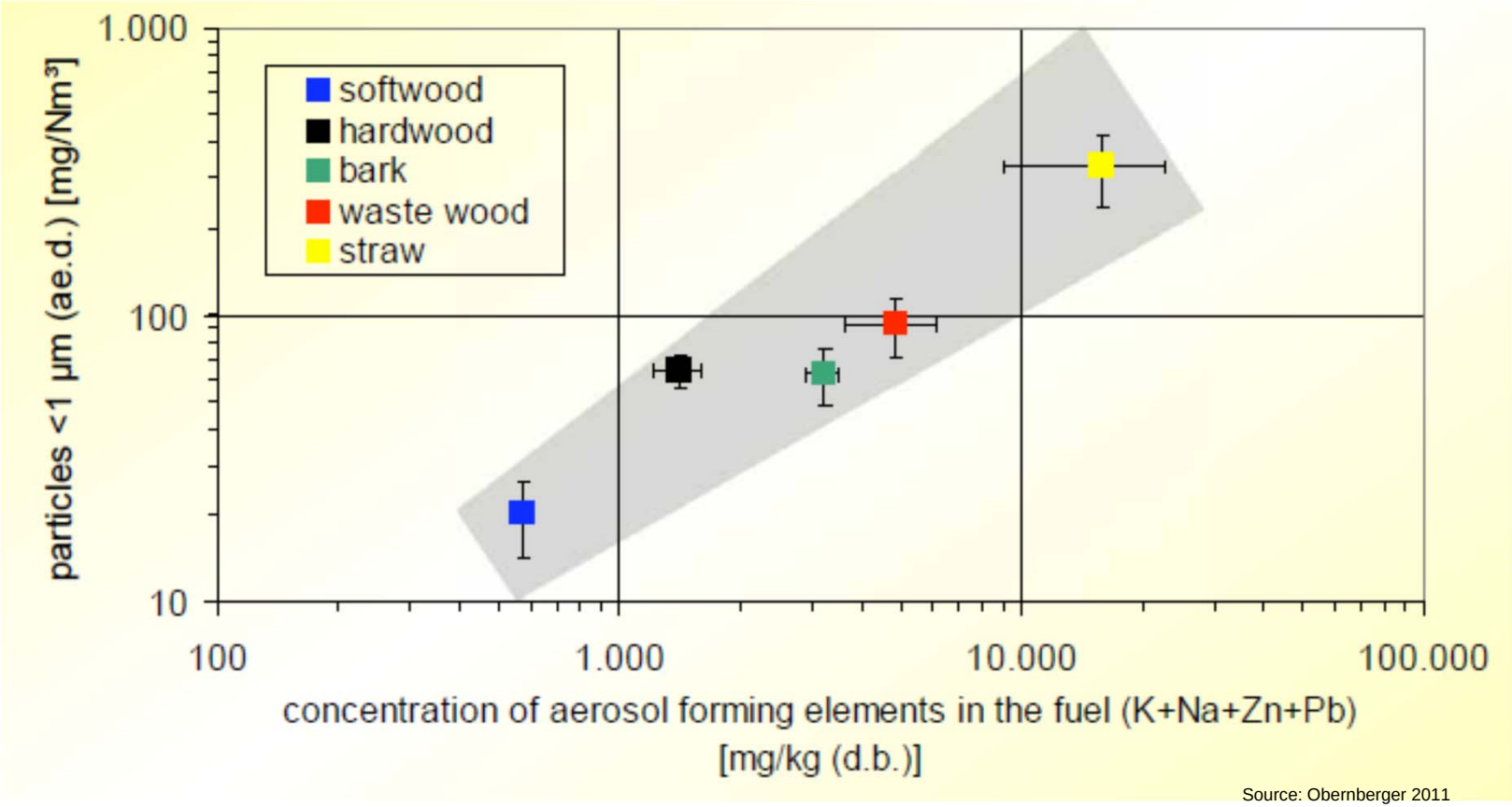
- ash melting / slagging and fouling

Photo: REICHERT/ HFR

- corrosion

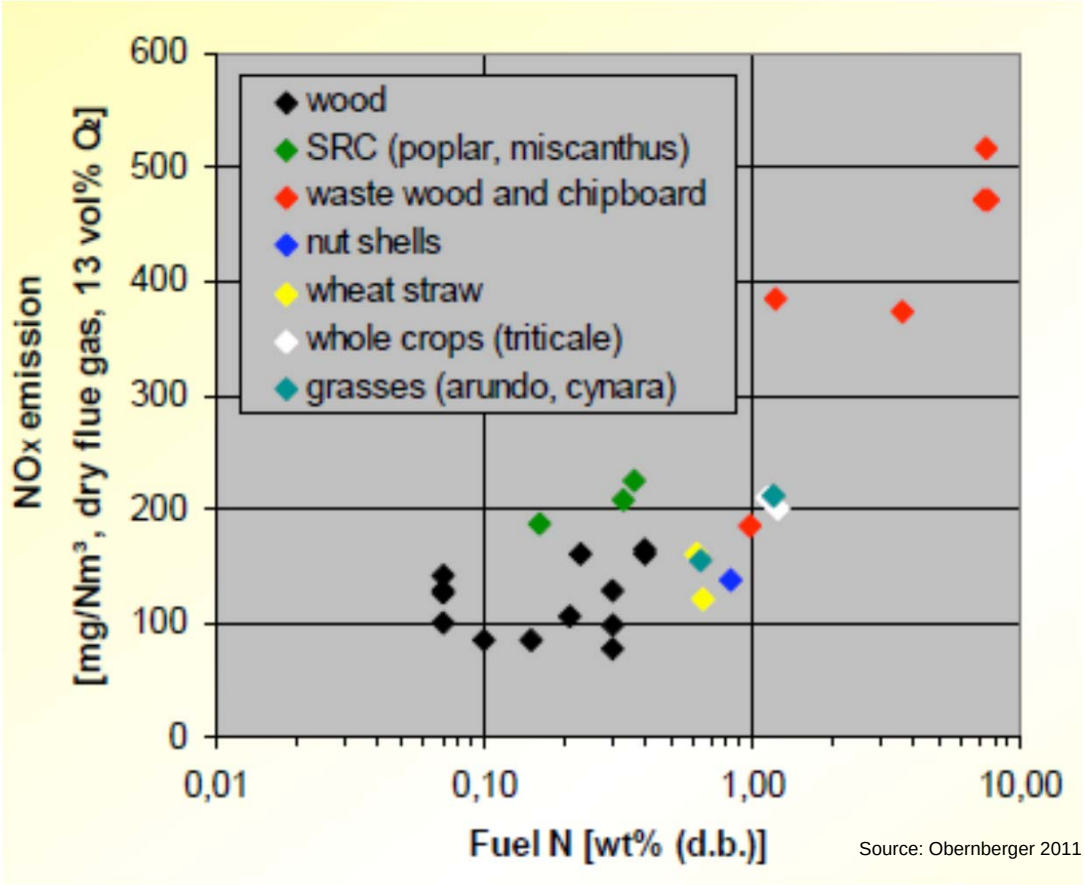
Source: Obernberger 2011

Influence of biofuel on aerosol concentration



Source: Obernberger 2011

NO_x emissions



Source: Obernberger 2011

high concentrations of gaseous NO_x- emissions are mainly caused by high nitrogen content in feedstock

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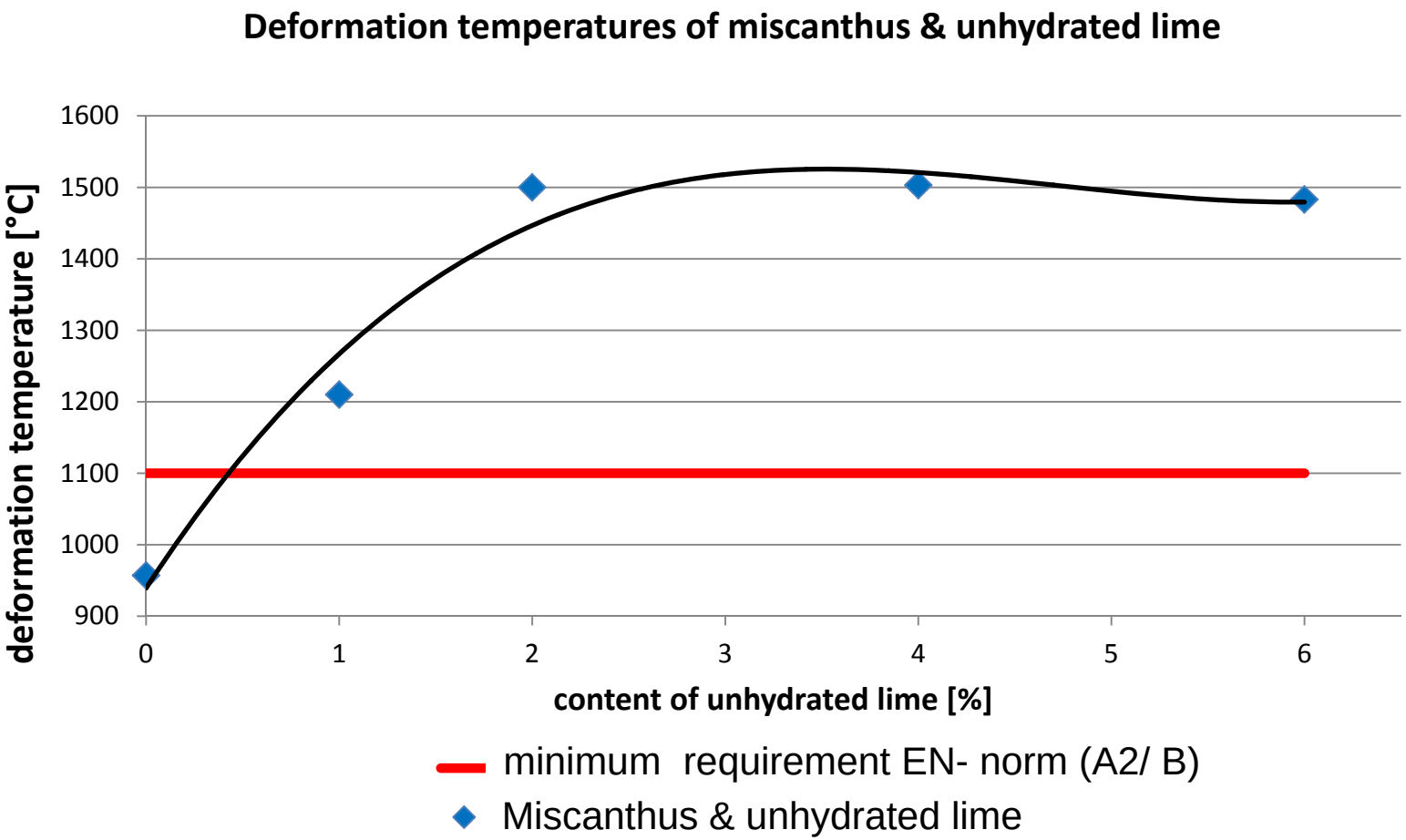
Reducing of slagging by fuel- addition of limistone



Combustion of spelt husks in an underfeed stoker

Photos: REICHERT/ HFR

Combustion of spelt husks in an underfeed stoker

wood pellets DINplus 100%
failure- free operation possible

→ little ash in the combustion chamber

wood pellets DINplus 85%
& spelt husks 15%
failure- free operation possible

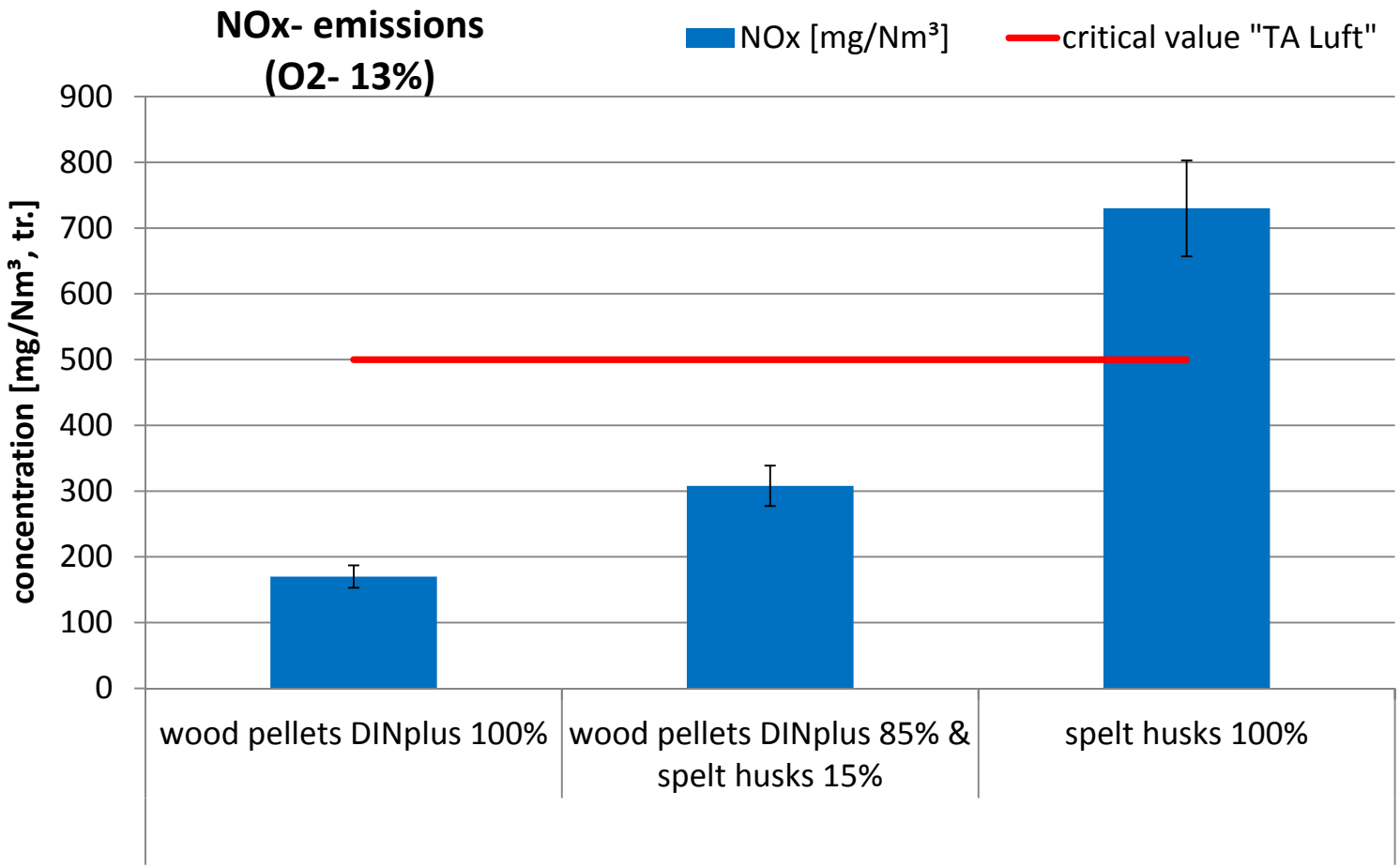
→ more ashes in the combustion chamber/ higher NO_x and PM emissions

spelt husks 100%
failure- free operation **not** possible

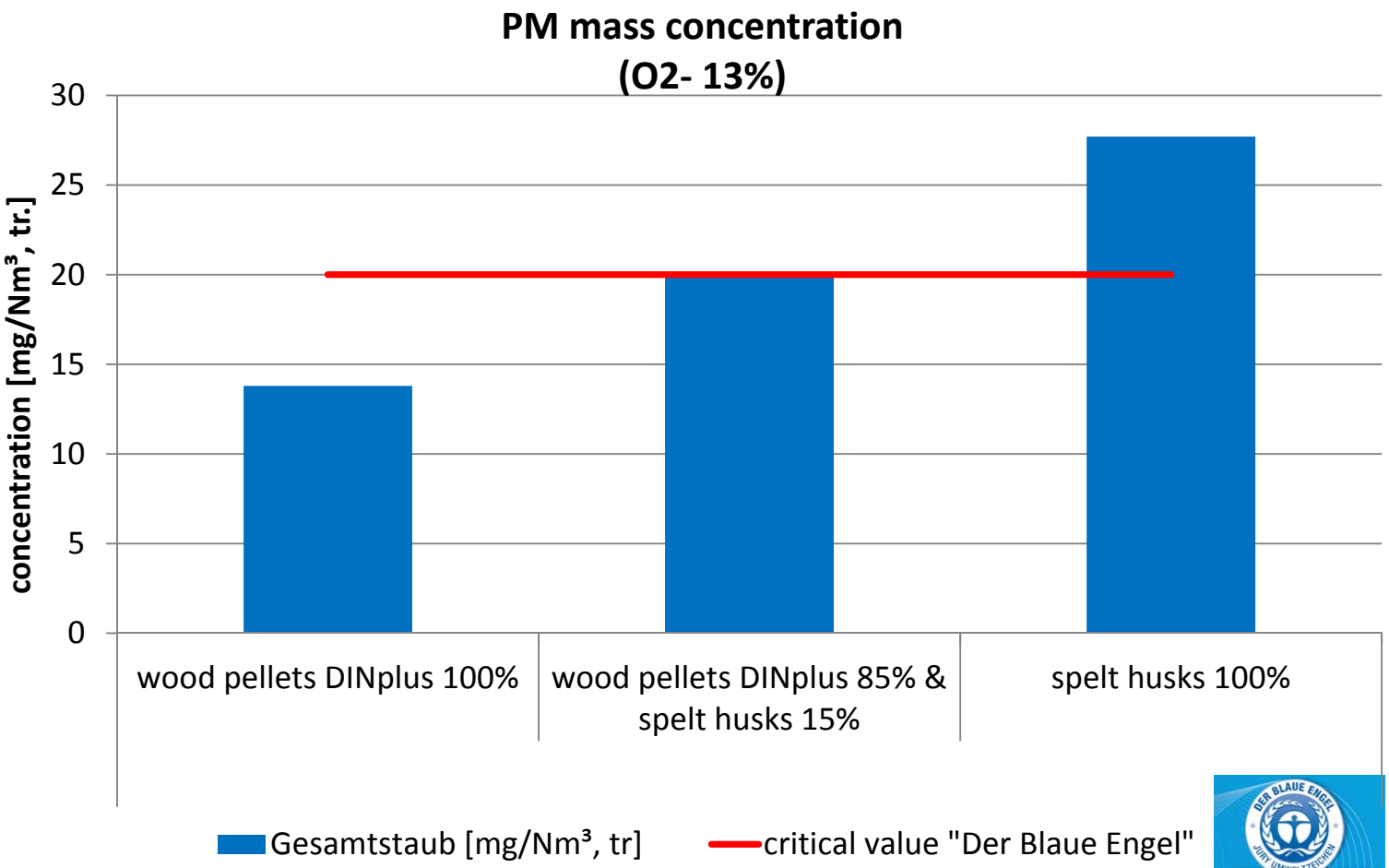
→high concentration of ash in the combustion chamber/ high NO_x and PM emissions
→ **experiment was stopped**

Photos: REICHERT/ HFR

Combustion of spelt husks in an underfeed stoker



Combustion of spelt husks in an underfeed stoker



Conclusions and outlook

- Bioenergy will make an indispensable contribution to a future mix of renewables.
- Biomass resources are limited, therefore
  - the efficiency along the entire value chain needs to be optimized.
  - alternative feedstocks need to be utilized.
- Combustion technology for wood is state of the art, for alternative feedstocks further development is needed (process control, reduction of emissions, ash handling), especially for smaller units.
- CHP technologies need to become available for smaller units with high availability, higher electrical efficiency at reasonable costs.
- The future of energy supply will be more complex the it was in the past: More professional actors and educated consumers are needed to find creative solutions.

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Thank you for your attention !

Sources

- OBERNBERGER, I.: The present state and future development of industrial biomass combustion for heat and power generation, ASME- UIT 2010 Conference on Thermal and Environmental Issues in Energy Systems, Sorrento Italy, 16 – 19 May 2010
- WEICK – HANSEN, K.: Co firing coal and straw in PF boilers – performance impact of straw with emphasis on SCR catalyst for deNOx catalysts, Proceedings of the 16 th Annual International Pittsburgh Coal Conference, October 11 – 15, 1999
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