Future Perspectives of renewable heat supply from biomass in Germany – SmartBiomassHeat as one possible pathway

Dr. Volker Lenz

Re³build ICU Seminar, 18. December 2014, Tokyo
**BMELV:** Federal Ministry of Food, Agriculture and Consumer Protection

**BMU:** Federal Ministry for the Environment, Nature Conservation and Reactor Safety

**BMBF:** Federal Ministry of Education and Research

**BMVBS:** Federal Ministry of Transport, Building and Urban Development

**SMUL:** Saxon Ministry of the Environment and Agriculture

Organisation

DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH

BMELV

Sole shareholder

Supervisory Board (BMELV, BMU, BMBF, BMVBS, SMUL)

Most senior decision-making committee, appoints Research Advisory Council

Research Advisory Council

Consultative function
The Research Departments

Deutsches Biomasseforschungszentrum
Prof. Dr. mont. Michael Nelles

Bioenergy Systems
Prof. Dr.-Ing. Daniela Thran
- UFZ Bioenergy Department - system analysis

Biochemical Conversion
Dr.-Ing. Jan Liebetrat
- UFZ- Working Group „MicAS”

Thermo-chemical Conversion
Dr.-Ing. Volker Lenz

Biorefineries
Dr.-Ing. Franziska Muller-Langer

UFZ = Helmholtz Centre for Environmental Research (UFZ)
Research Focus

- New and improved fuels
- Primary and secondary emission reduction for small combustion systems: CO, VOC, PAH, Dust, PCD/F, NOx...
- Control technology for small plants.
- Use of alternative biomass fuels in small plants.
- Development of small scale CHP units
- Development of object and local network control units.
Motivation for the promotion of Bioenergy in Germany

- **Climate protection**
  - EU-15: 8% reduction of GHG emissions (2008-2012),
  - EU-27: 20% reduction until 2020
  - Germany: 40% reduction until 2020 (compared to 1990)
  - Worldwide 2 K – Aim: reduction of at least 80% (industrial countries up to 95%)

- **Energy security**
  - reduction of energy imports
  - reduction of dependencies from fossil energy carriers

- **Creation of income/jobs**
  - direct: creation of income in rural areas → started as a measure to use overcapacities in agricultural production
  - indirect: development of a Biomass-/Bioenergy based Economy
What is so special about bioenergy?

**Chances**

- most frequently used renewable energy worldwide
- any kind of energy solution
- storable and demand-oriented usable
- local value chains
- GWP reduction compared to fossil fuels
- ...

**Challenges**

- Limited potential – conflicting use
- Non-sustainable use of resource
- Limited standardization – high prices for technology
- Low energy density – demanding logistics
- Price impacts on coupled markets
- GWP reduction often less than 80%
- ...
Use of wood in Germany

With increased demand prices for wood resources increased also.

Biomass in the energy system worldwide

Use of harvested forest and agricultural biomass worldwide in 2008

- 58%: Food
- 11%: Wood, material
- 10%: Wood, energy
- 3.3%: Renewable resources, material
- 2.7%: Renewable resources, energy
- 15%: Animal feed

total biomass: approx. 13 billion tonnes

Source: nova (2012) / Own presentation
Biomass in the German energy system

Percentage of final energy consumption generated from renewables in 2013

- Water power: 0.8 %
- Wind power: 2.1 %
- Photovoltaic: 1.2 %
- Biomass: 7.6 %
- Solar, geothermal energy: 0.6 %

Total: 9.288 PJ

2013 renewable shares: 12.3 %

Percentage of final energy consumption generated from renewables in 2013:

- Total: 9.288 PJ
- 62%*

Source: Renewable energy in figures, BMU 2013 / own presentation
* according to primary energy demand 75%
Biomass use for different energy purposes

Structure of final energy supply from all biomass in the power, heat and motor fuel sector in Germany in 2012

Share of biomass in the renewable final energy consumption: 65.5%

Until now almost all of the solid biofuel is wood.
Development of renewable heat in Germany

Solid biofuels
Liquid biofuels
Gaseous biofuels
Bio-waste

Solarthermal
Geothermal
Heat pump

Heat from solid biofuels in Germany

- 14 to 16 million single room heaters: integration in hot water system and pellet stoves were used only since a few years; in average 8 kW nominal power for log wood; use of roughly 14 million $t_{atro}$ wood

- 0.7 to 0.9 million wood log and wood pellet boilers with a nominal heat output of 15 to 300 kW as central heating system

- less then 10,000 wood chip boilers with nominal heat output of 100 to 3,000 kW as local heat supply
State of the art small scale heating technologies

Small scale boilers

Single room heaters

Quelle: DBFZ, Herstellerprospekt

Quelle: Pellematic Plus; Ökofen

Quelle: ETA

Wood chip boilers

Quelle: DBFZ, Herstellerprospekt, Heizomat

Quelle: wodtke

Heating system integration
Development of pellet market and pellet plants in Germany

Quelle: Lenz et al., BWK, 05/2014
Policy instruments for the promotion of Biomass for Energy

**Biomass for electricity**

- renewable Energies Act (EEG) since 2000 – economic: operational subsidy (feed-in tariff system)
- biomass electricity sustainability ordinance (BioSt-NachV) 2009
- biomass ordinance

**Biomass for heating**

- market incentive programme (MAP) 1999 – economic: financial subsidy
- renewable Energies Heat Act (EEWärmeG) 2009 – regulatory: building regulation
Regulatory constraints for Bioenergy from solid biomass

**Biomass for electricity**
- renewable Energies Act (EEG) 2014 with only very few options for further power plants for solid fuels
- except of CO₂-trading no special incentives for biomass co-combustion
- no capacity fees for biomass

**Biomass for heating**
- small scale furnace ordinance (1.BlmSchV) – pellet and wood chip as well as agricultural boilers 0.02 g/m³ PM installed after 31.12.2014 every two years in full load measurement
- precipitators on chimney top hard to measure by chimney sweepers until now
Development of heating systems in new buildings (Renewable Heat Act)


1% of the buildings
Summary status of bioenergy in general in Germany

- Renewables in sectors 2013: 24.5 % electricity; 11.6 % heat, 5.2 % fuels

- Bioenergy is the most important renewable energy source in Germany (more than three quarters of primary energy).

- There is a potential of 1200 to 1500 PJ/a and a usage of about 1000 PJ/a.

- Better prices for wood and agricultural products; additional income for biomass producers.

- BUT:
  - Biomass feed-in-tariffs are among the highest ones!
  - Biodiversity targets were not reached!
  - Need for more flexibility in power production
  - CO$_2$-reduction for first stage biofuels is sometimes poor
Restrictions for further bioenergy development in Germany

• Biomass gets more and more scarce.

• Basic (quantity) supply of renewable energy will come from Wind and Solar – for electricity; but together with geothermal also for heat.

• High fluctuation of these technologies need more storage and flexible energy production.

• Germany keeps to its target of 80 to 95% of GWP-reduction until 2050, therefore
  • the energy sector will have to change almost totally to renewable energies
  • demand of heating sector has to be reduced by at least 80%
Is there a future for solid biomass combustion?

- Use of biomass for energetic purposes is possible and feasible also in the future! BUT:
  - Quantitative increase without massive imports is very limited.
  - Change to higher quality of use is necessary.

Sustainable biomass (residues and waste, as well as by-products)

GWP-decrease in systeme at least 90%

minimum of environmental impacts by exhaust gases and wastes

maximum of efficiency

Economic advantages compared to other RE-solutions

highly flexible, regional adjusted use with high additional value for the total energy systeme

Smart Bioenergy
We need a reallocation of the used biomass potentials from the traditional quantitative and often base-load bioenergy over a technical improved use to an into the material and energy system integrated use.

The exact target is at the moment not totally describable, but a development process has to be started, which is based on the following criteria:

- smaller biomass throughput per system (higher regionality, lower negative mass effects)
- more efficient and environmentally sound conversion technologies and pathways (innovation potential und GWP-reduction)
- much better integration into the material and energy system (coupling to material production chains; stability of the energy system by combination with other RES)
Smart Bioenergy for heat production

- smaller biomass throughput per system (higher regionality, lower negative mass effects)
- more efficient and environmentally sound conversion technologies and pathways (innovation potential and GWP-reduction)
- much better integration into the material and energy system (coupling to material production chains; stability of the energy system by combination with other RES)

first use of solarthermal and geothermal as well as waste heat + small scale units

(pre-)gasification, CHP, intelligent buffer control, catalytic gas cleaning

Use residues and by-products as fuel; adjust to heat demand and then stabilize power grid with co-electricity
Result
Heat production from biomass

- There is a stable demand for „nice“ heat, for self-sufficiency and a stable willingness to pay for that.
- 100% renewable heat production is only possible with a massive reduction of heat demand (insulation) and a very significant increase of the use of all possible RES.

⇒ In mid term: High flexibility of all biomass heating systems is required

⇒ In long term: Highly flexible micro-CHP-heating systems have to be established, which can close heat gaps very flexible and demand oriented and that will stabilize the regional power net
Central Research Topic of Department Thermo-Chemical Conversion at DBFZ

SmartBiomassHeat
flexible, ressource securing, power-net-stabilizing, emission free heat

Conditioning of biowaste und by-products to high-end solid biofuel pellets

Flexibel and emission free furnaces and micro-CHP-systems

Innovative controllers for system integration

renewable heat supply

genrele power grid
Central Research Topic of Department Thermo-Chemical Conversion at DBFZ

**SmartBiomassHeat**
- Flexible, resource securing, power-net-stabilizing, emission free furnaces and micro-CHP systems
- Upgraded fuels to enable a very flexible operation of conversion technologies
- Advanced and smart system controller
- Innovative controllers for system integration
- Renewable heat supply

- Conditioning of biowaste and by-products to high-end solid biofuel pellets
- Emission reduction also during flexible operation
- Very flexible micro-CHP
- Renewable power grid
Up-graded Fuels: Lab-scale Torrefaction

Torrefaction reactor:
- Rotary batch reactor
- Indirectly heated (electric)
- Capacity approx. 5 kg per sample

200 to 300 °C for 10 to 30 minutes
Up-graded fuels: Other new treatment options

Three different solid fuels:

Wheat straw pellets, torrefied ($\text{STR}_{\text{TOR}}$ - Torrefication)
- raw material was pelletized ($\varnothing = 20\text{mm}$) and subsequently torrefied
- new technology, not fully optimized yet

Brewer’s spent grain, carbonized ($\text{BSG}_{\text{HTC}}$ - Hydrothermal Conversion)
- Treated with a commercially available HTC process (min. plant size 8000 t/yr)
- Sieved to solid fuel fraction of 15> $x <$3.5mm

Foliage, mechanically leached ($\text{FOL}_{\text{ML}}$)
- Raw material was washed, ground and mechanically dewatered
- Leached material was pelletized ($\varnothing = 4\text{mm}$)
Upgraded fuels: Conclusions at the time

- Torrefication can improve storability (reducing off-gasing and self-ignition risks) and grindability for dust firing or gasification.
- Torrefaction can probably not improve emission behaviour of ash rich fuels (no reduction of ash).
- Torrefied biomass from clean wood can be used in small scale boilers having a significantly higher heating value.
- Without boiler adaptions slagging, clogging of air nozzels and higher PME can occur.
- Possibly higher annual efficiencies can occur with torrified wood pellets.
- Washing and leaching can reduce P, Cl content significantly, so improved emissions are possible.
- HTC can handle wet residues and also can leach some ingredients.
Emission Reduction: Technical equipment for measurements

Fig.: Test Facility with Dilution Tunnel at DBFZ
Emission reduction: primary measures

**primary measures**

- **fuel**
  - fuel properties (woody/non-woody)
  - fuel preparation (size, figure, additives, fuel mix)
  - feeding (manual/automatic charge/continuous)

- **furnace construction**
  - size and geometry of the burning chamber
  - air supply (air staging, turbulence, preheating)
  - fuel bed (cooling, moving grate, ash slider)

- **control systems**
  - fuel feeding (amount, cycle)
  - air supply (amount, ratio of primary and secondary air)
  - combustion and power control
Emission Reduction: secondary measures

- electrostatic precipitators
- gravimetric precipitators (e.g. cyclone)
- absorption/scrubber
- filter (e.g. fibrous filter)
- catalyst

Al-Top
source: schraeder

Zumikr®n
source: Rüegg

DBFZ Test Facility for Precipitators

Firecat®
source: firecat
CHP-Technologies

Stirling-Engine

Heizung
Regenerator
Kühler
kalte Luft
heiße Luft
Kolben
Arbeitszylinder
Kurbelzapfen
Kurbelwelle mit
Schwinggrad
Kompressionszylinder

Fig. 16

Quelle: DBFZ

Gasification CHP

Quelle: Thermochemical Testing Ground University Zittau

Biomass ORC

Quelle: DBFZ

Wastewood Power Station

15 MWel

Quelle: hessenENERGIE

Gasification Plant Güssing

Quelle: DBFZ
Developments in solid biomass power plant technologies

Source: DBFZ 2013
Requirements of a micro-CHP system

A micro-CHP system for demand based renewable power production should fulfil the following requirements:

- electrical efficiency should be as high as possible,
- the renewable fuel should be standardized or at least standardizable,
- investment costs as low as possible,
- fast adjustable controllability, and
- optimized overall efficiency at every operating condition.

- should be primarily designed for heat supply.
Test setup at DBFZ of an updraft charcoal gasifier with gas engine

DBFZ 2014, Dennis Krüger
Flexible use of the product gas
System controller for optimising operation
Results: Pellet boiler

Increased boiler efficiency and boiler load

- Reference system
  - Boiler load: 75%
  - Boiler efficiency: 43%

- Optimized system
  - Boiler load: 84%
  - Boiler efficiency: 57%
  - Cumulated boiler load
## Results: Heating system

### 5 day continuous measurement

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>STES01</th>
<th>STES02</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel input energy</td>
<td>kWh</td>
<td>372.3</td>
<td>329.1</td>
<td>- 11.6 %</td>
</tr>
<tr>
<td>Heat output pellet boiler</td>
<td>kWh</td>
<td>329.1</td>
<td>295.7</td>
<td>- 10.1 %</td>
</tr>
<tr>
<td>DHW &amp; SH energy consumption</td>
<td>kWh</td>
<td>321.0</td>
<td>307.5</td>
<td>- 4.2 %</td>
</tr>
<tr>
<td>Solar yield</td>
<td>kWh</td>
<td>40.1</td>
<td>43.7</td>
<td>+ 9.0 %</td>
</tr>
<tr>
<td>Auxiliary energy pellet boiler</td>
<td>kWh</td>
<td>6.8</td>
<td>6.3</td>
<td>- 7.4 %</td>
</tr>
<tr>
<td>Average buffer temperature</td>
<td>°C</td>
<td>50.0</td>
<td>46.2</td>
<td>- 7.6 %</td>
</tr>
<tr>
<td>Average boiler power</td>
<td>kW</td>
<td>6.0</td>
<td>7.0</td>
<td>+ 16.6 %</td>
</tr>
</tbody>
</table>

### Annual simulation

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>STES01</th>
<th>STES02</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual boiler efficiency</td>
<td>%</td>
<td>83.0</td>
<td>89.8</td>
<td>+ 8.2 %</td>
</tr>
<tr>
<td>Annual overall efficiency</td>
<td>%</td>
<td>74.2</td>
<td>78.5</td>
<td>+ 5.8 %</td>
</tr>
</tbody>
</table>
Primary measures
Operation Control Unit (2/2)

Over the year a reduction of 6% of pellets is easily possible, including a reduction of PME!

+x% .. useless production of pellet boiler according to needed
Controller for system integration – net stability

Example of production and need of load (left) and remaining load need (right) – basis scenario 2030, week in April
Quelle: Verändert nach Consentec, IAEW (Aachen, 2011) für BDEW

Biomass as storable energy should fill the remaining gaps!

Controller should be able to start micro-CHP according to net necessities and heat demand of object without data exchange to central unit (data safety).
Controller for system integration – net stability - one possible solution
Conclusion: SmartBiomassHeat

- Biomass has a good chance to close the gap of heat supply in a renewable world.
- Especially very flexible micro-CHP technologies seem to be one of the best options entering the market by 2030.
- Up-graded fuels will probably be necessary.
- Additional flue gas cleaning or synthesis gas conversion by catalytic systems will probably gain importance.
- For a highly efficient integration of all the renewable energy sources in one system much improved controllers are necessary.
- First steps of research and development were taken (e.g. FFPRI, DBFZ ...), but further research – also for public acceptance – is required.
Need based, flexible and emission free bioenergy is one brick of our energy-future.

Contact

Prof. Dr. mont. Michael Nelles
Daniel Mayer
Prof. Dr.-Ing. Daniela Thrän
Dr.-Ing. Volker Lenz
Dr.-Ing. Jan Liebetrau
Dr.-Ing. Franziska Müller-Langer

DBFZ  Deutsches Biomasseforschungszentrum
gemeinnützige GmbH
Torgauer Straße 116
D-04347 Leipzig
Tel. +49 (0)341 2434 – 112
E-Mail: info@dbfz.de
www.dbfz.de