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Technical aspects of optimization and modernization of district heating systems

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4th ENTRAIN train-the-trainer session – online - 23.06.2021

Working fields of the Energy Agency

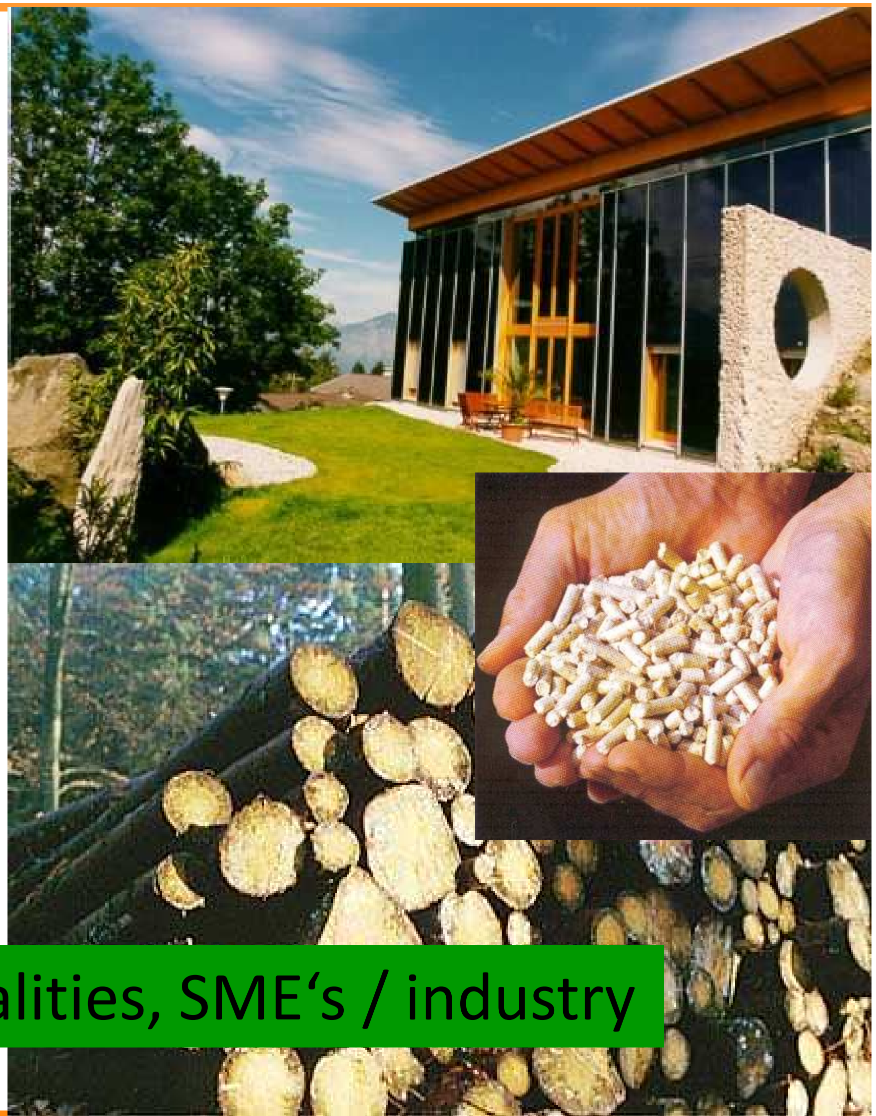
Renewable Energy
biomass, biogas, solar thermal and PV, wind, water, green electricity

Energy Efficiency
building sector and production facilities

R&D projects

Financing and Funding

Trainings

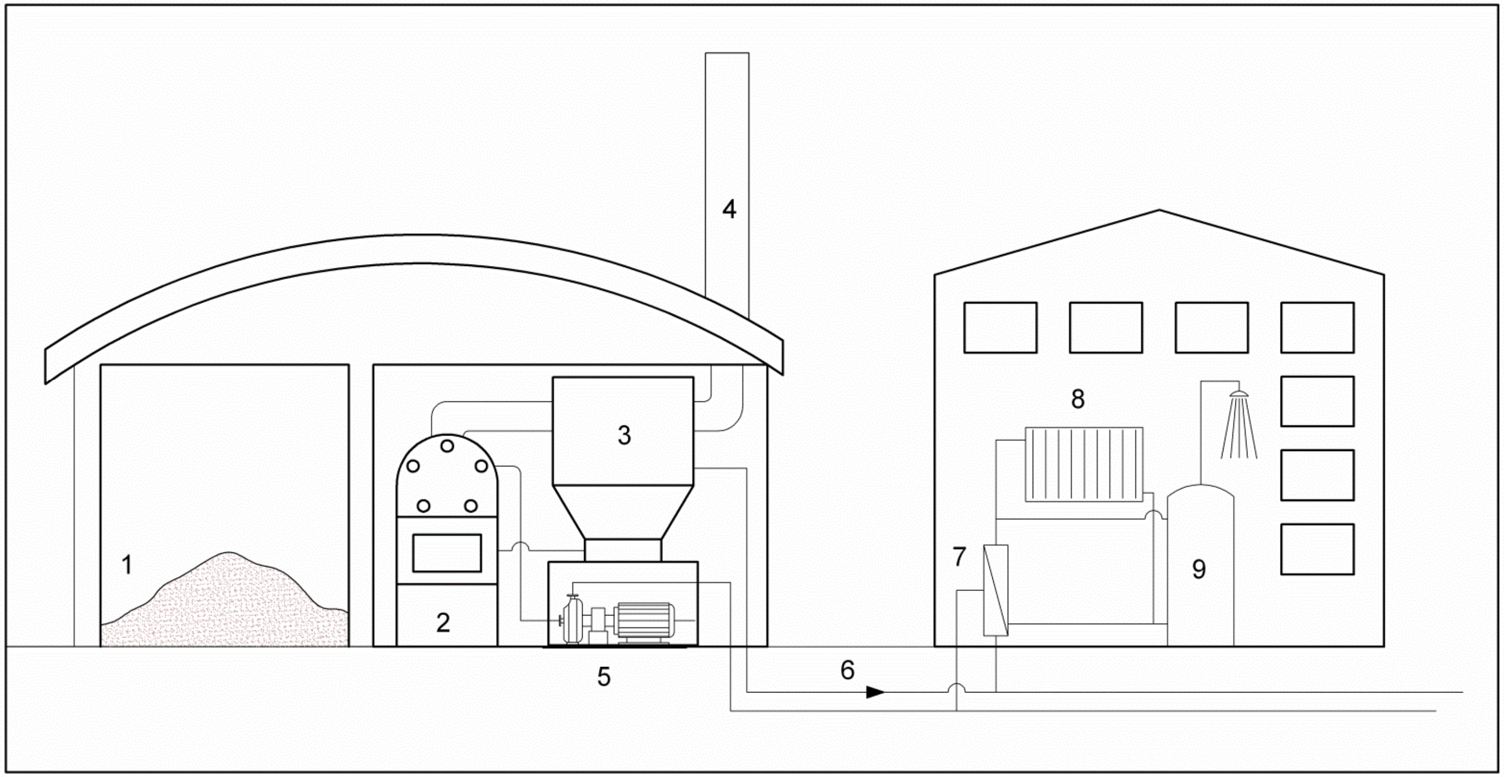


Target groups: private, municipalities, SME's / industry

Content

- Basics of efficiency optimization
- Improvement of the energy performance
- Network densification
- Load and heat storage management

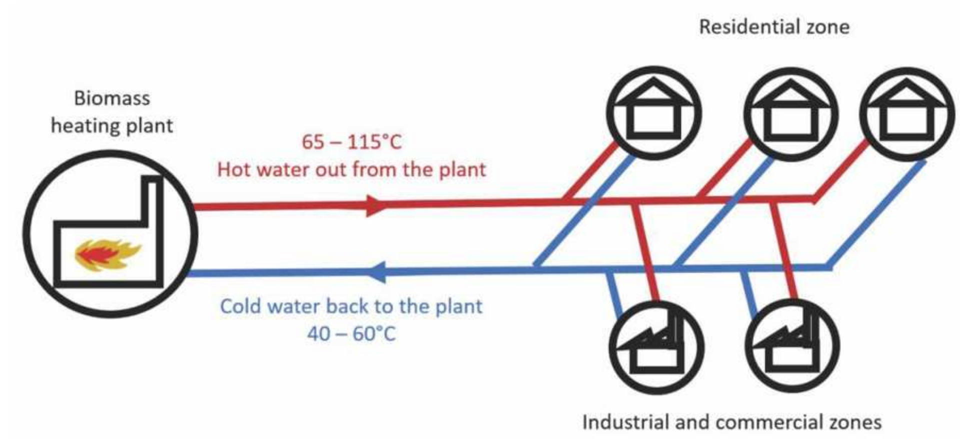
Biomass district heating (I)

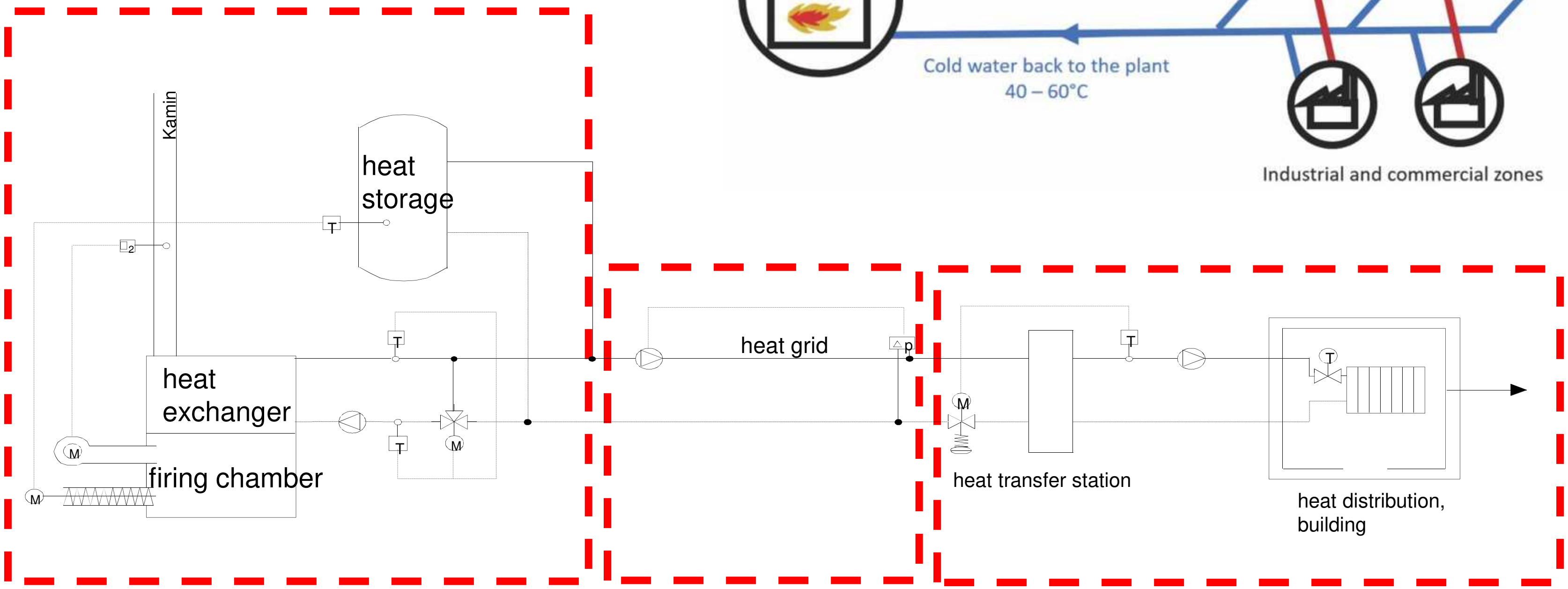


Quelle: AEE

Legend: 1 fuel deposit, 2 biomass boiler, 3 flue gas cleaning, 4 flue gas, 5 grid pump, 6 heat grid, 7 house transfer station, 8 heat delivery, 9 hot water storage tank

Biomass district heating (II)





heat supply

heat distribution

customer side

Efficiency optimization

Areas of interests are:

- **Customer side**
  - Main influences to the system temperatures
- **Heat losses of the district heating grid**
  - System temperature – fore-/back flow
  - Linear heat density [MWh/(a.Trm)]
  - Type and insulation of pipes
  - Full year operation or only in wintertime?
- **Heat production: Fuel efficiency**
  - Dimensioning of the boiler
  - Settings of the firing system (excess air, flue gas temperture)
  - cleaning the flue gas ducts / heat exchanger
  - Quality of fuel (water content)
  - Heat recovery in the flue gas flow?
  - Puffer storage for load management?

Customer side / secondary side

Influences on the required **supply flow** and **return flow temperature:**

- Type of customer
- Load characteristic
- Type of heating system
  - radiators, ground floor heating
  - use large heating surfaces!
- High efficient hot water preparation
- Hydraulic balancing of the system
- High-efficiency pumps
- Return temperature limitation in the transfer station
- Bonus tariff for low return flow temp!

Picture: heat transfer station and hot water storage

Hot water preparation

BJ1

Different types of efficient hot water preparation

High-efficiency register
Quelle: Austria Email

Fresh water module

Folie 8

BJ1 Bärnthaler Josef; 22.06.2021

Heat transfer station

How can we measure the heat-consumption?

$$Q = \dot{m} \, . \, cp \, . \, \Delta T$$

Q … heat [J/s]

$\dot{m}$ … mass flow [kg/s]

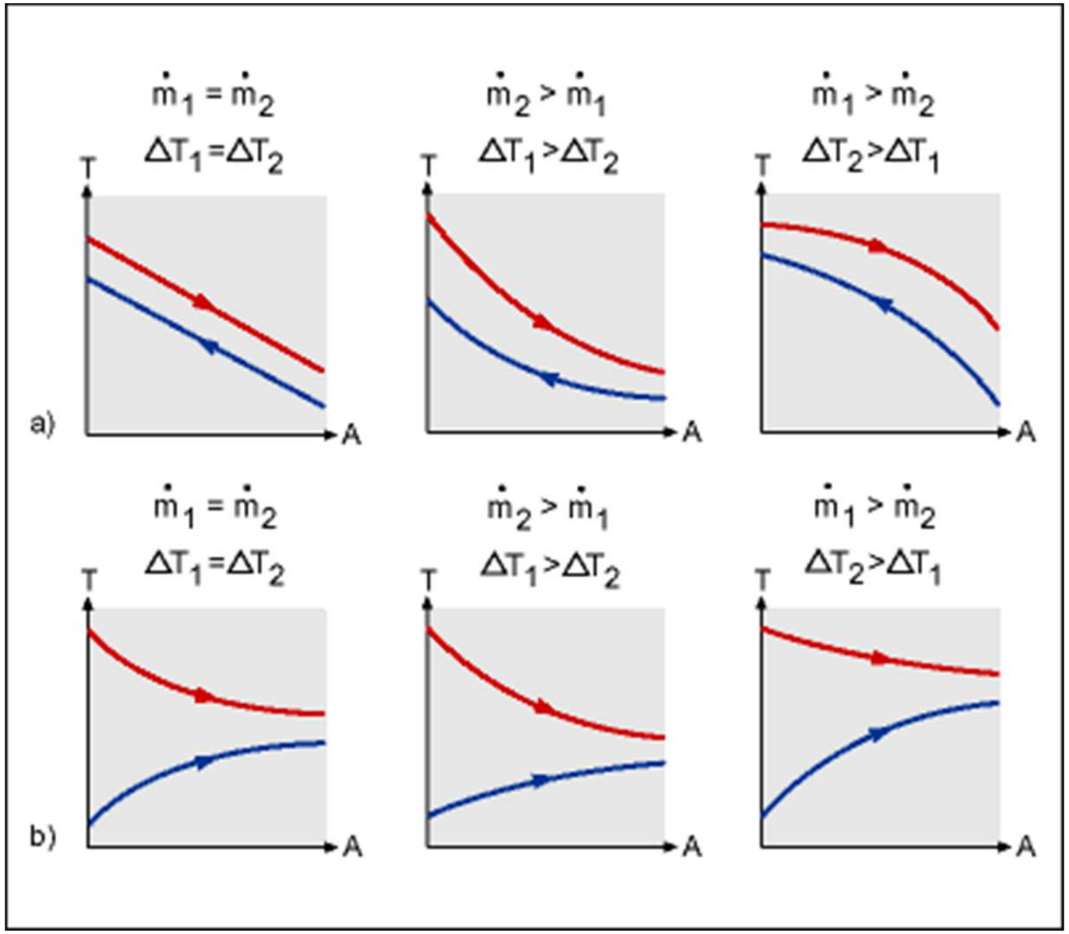
c_p … specific heat capacity [J/kg.K]

$\Delta T = T_{supply\ line} - T_{return\ line}$ [K]

Heat exchanger – hydraulic balancing

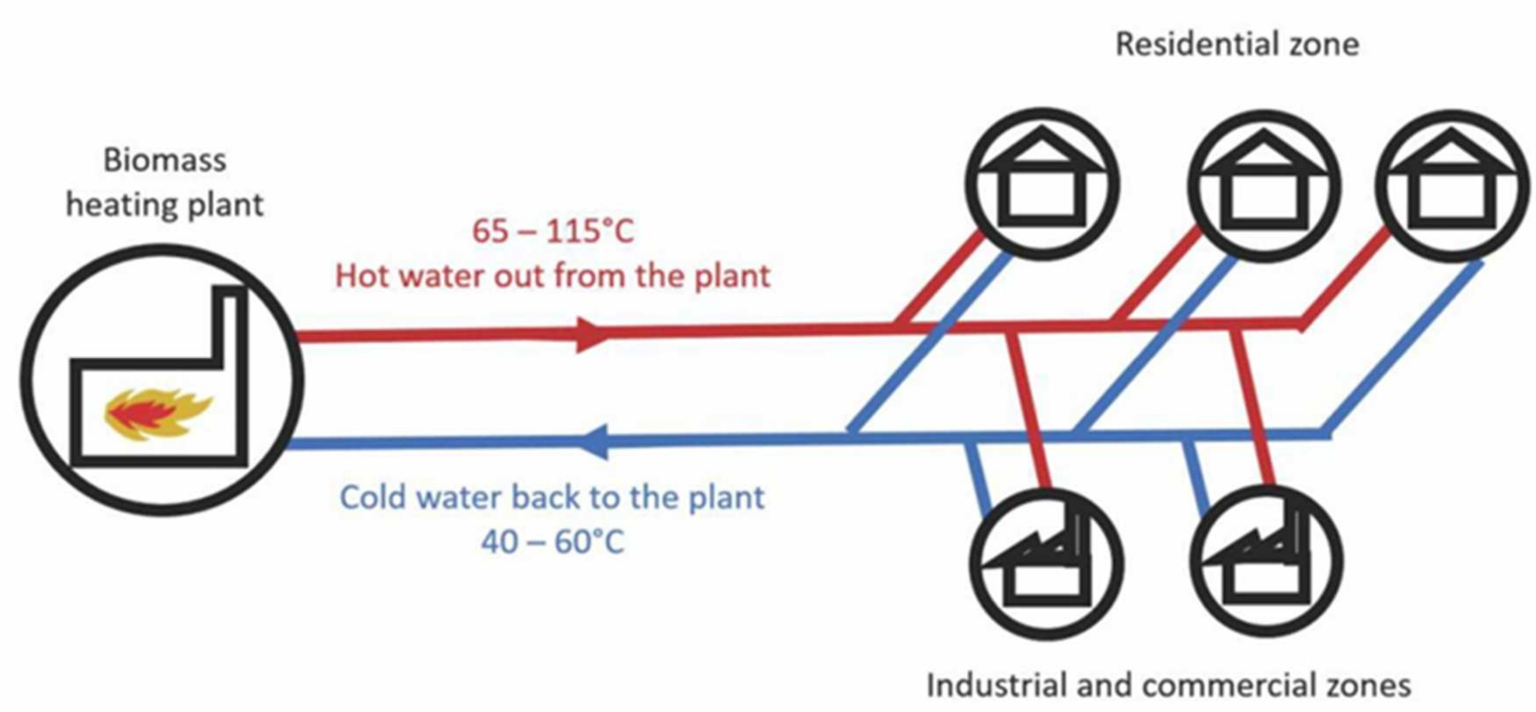
Counter flow

Parallel flow



Grid system

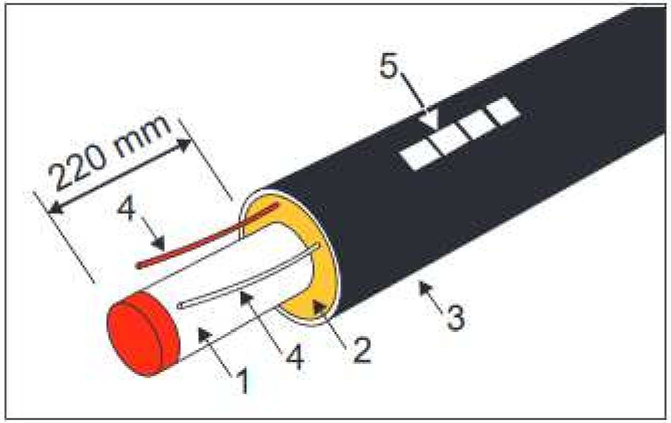
The required supply flow and return flow temperature affected by the costumers



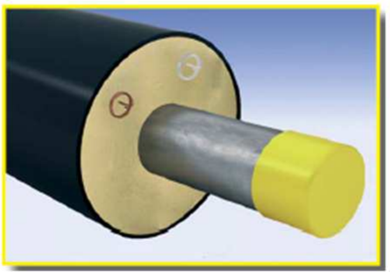
district heating grids – pipes (1)

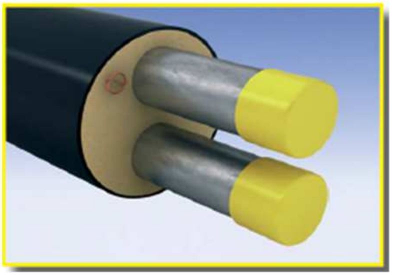
A preinsulated pipe consists of:

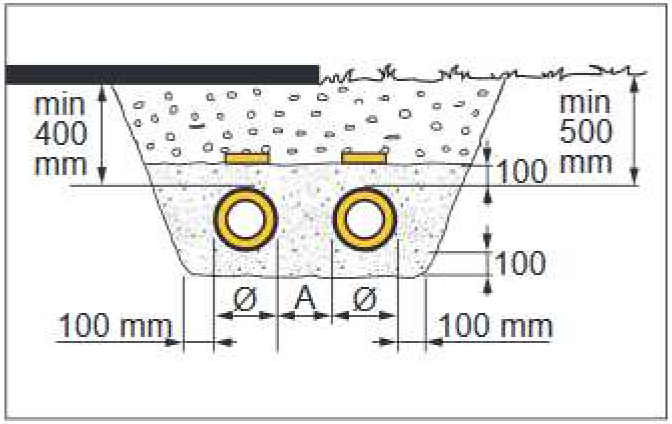
Pos.	Part	Material
1	Service pipe	Steel
2	Insulation	Polyurethane foam
3	Outer casing	Polyethylene, HDPE
4	Two 1.5 mm² copper wires for surveillance	One wire is tinned
5	Pipe label	



Single / twin steel pipe [ISOPLUS]







[LOGSTOR]

district heating grids – pipes (2)

Flexible double pipe made of polyethylene,
for micro-grids and small projects

Polyethylene Y-pipe

twin steel pipe with PU foam insulation, leak detection, diffusion barrier and plastic jacket

always use high insulation standard!

Quelle: 1,2 Kelit; 3 Isoplus

grid typology & structure (2)

Example 2

Performance indicators – grid (1)

- $$heat\ allocation = \frac{sold\ heat\ [MWh]}{grid\text{–}length\ [m]}$$
  - Recommendation: > 1,2 [MWh/m]   [QM-Heizwerke]
  - Acceptable from ~ 0,5 [MWh/m], at good conditions
- $$heat\ losses = \frac{heat\ losses\ in\ grid\ [MWh]}{heat\ feeded\ into\ grid\ [MWh]}$$
  - < 15 [%] for new projects [QM-Heizwerke; KPC-UFI]
  - Existing projects: 5 – 25 [%] (*35 in some cases*)

Performance indicators – grid (2)

- **electricity consumption** $= \dfrac{\boldsymbol{electicity\ for\ grid\ pumps\ [kWh]}}{\boldsymbol{sold\ heat\ [MWh]}}$
- $\boldsymbol{mean\ temp.difference\ (\mathrm{T_{supply}} - \mathrm{T_{return}})}$ **[K]**
- **Specific volume flow [m³/MWh]**
- **Full load hours [h]**– average of all customers

Performance indicators – grid (3)

Full Load Hours

According to the specific load characteristics, heat customer has typical full load hours.

'Full load hours' are the ratio of the used heat of a customer divided by its power demand:

$$\text{full load hours} = \frac{Q_{th}}{P_{th\ nominal}}\ [h]$$

- Residential buildings 1600 – 1800 [h]
- Hotels 1800 – 2000 [h]
- Schools 1300 – 1600 [h]
- Hospitals 2000 – 2200 [h]

=> all depending on climate data and other conditions!

Performance indicators – grid (4)

Economic indicators

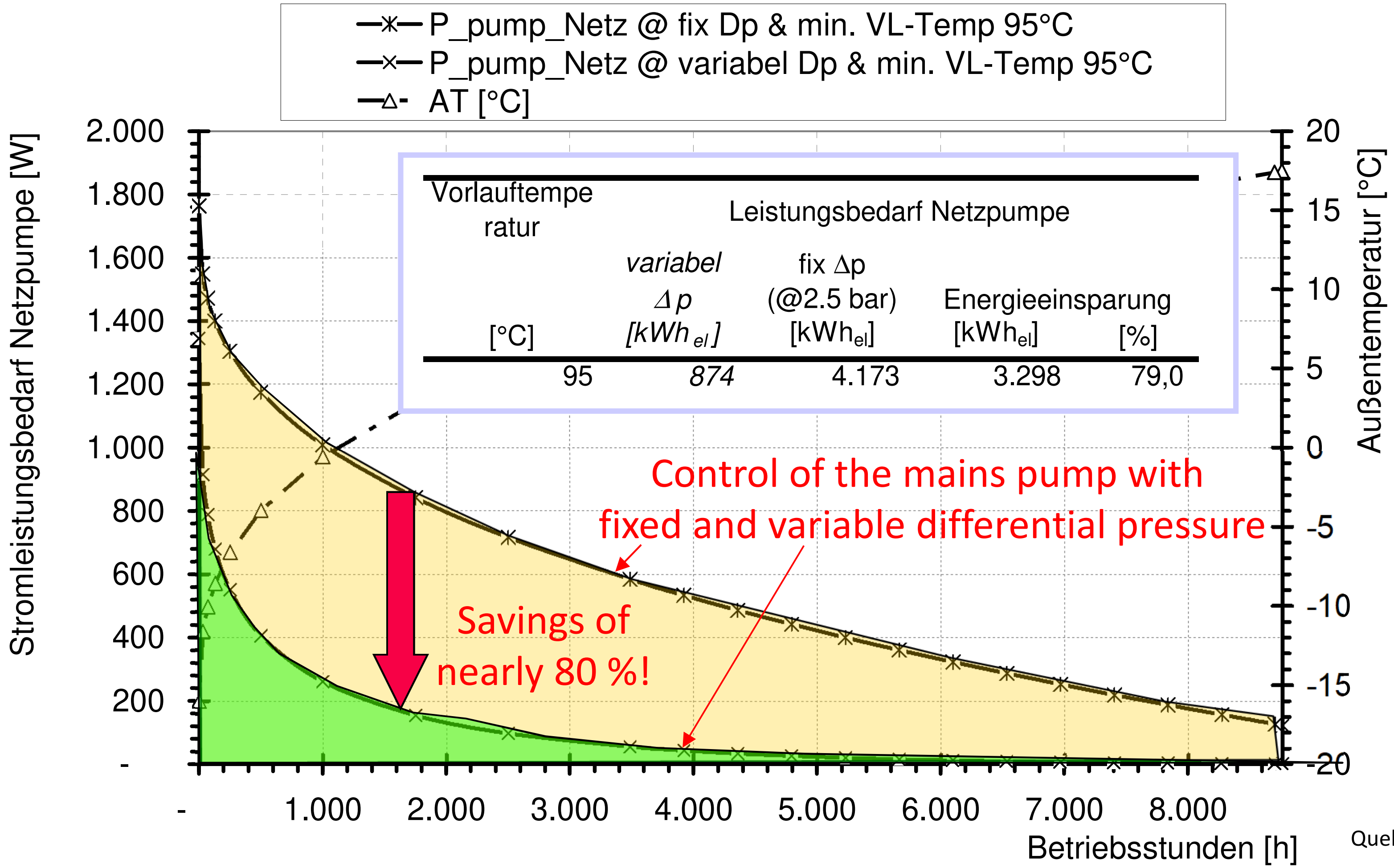
$$specific\ installation\ costs = \frac{cost\ of\ grid\ [€]}{grid\ length\ [m]}$$

- 200 – 600 [€/m], depending on green fields – roads; at countryside
- > 1000 [€/m] in cities

$$costs\ of\ heat\ distribution = \frac{cost\ of\ grid\ [€]}{sold\ heat\ [\frac{MWh}{y}]}$$

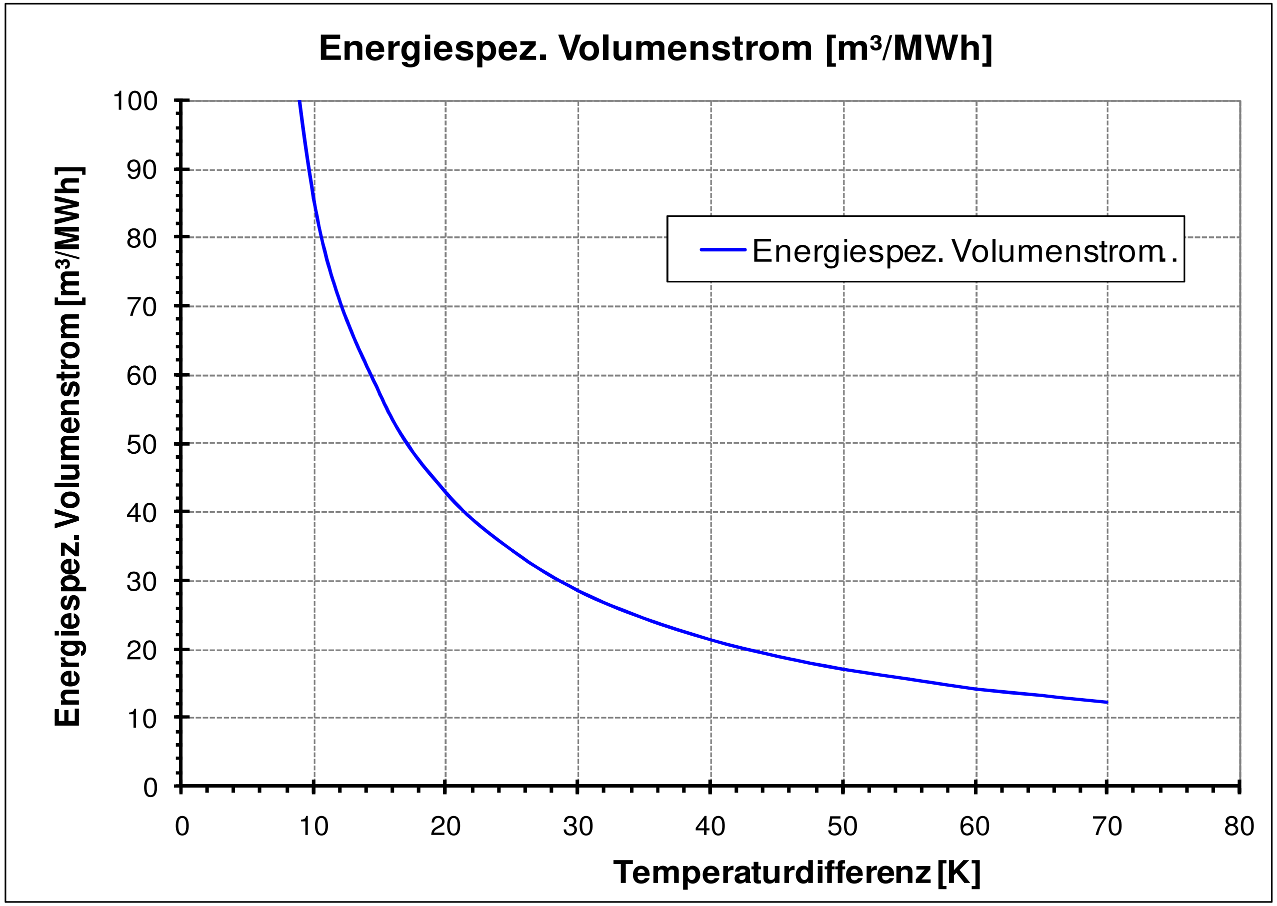
- min 50, mean 220, max. 480 [€/MWh/y] [QM-Heizwerke, KPC]
- Costs of grid: excavation, pipe laying, and restoration

electricity consumption – grid pumps



Quelle: F. Lettner

Spezific volume flow



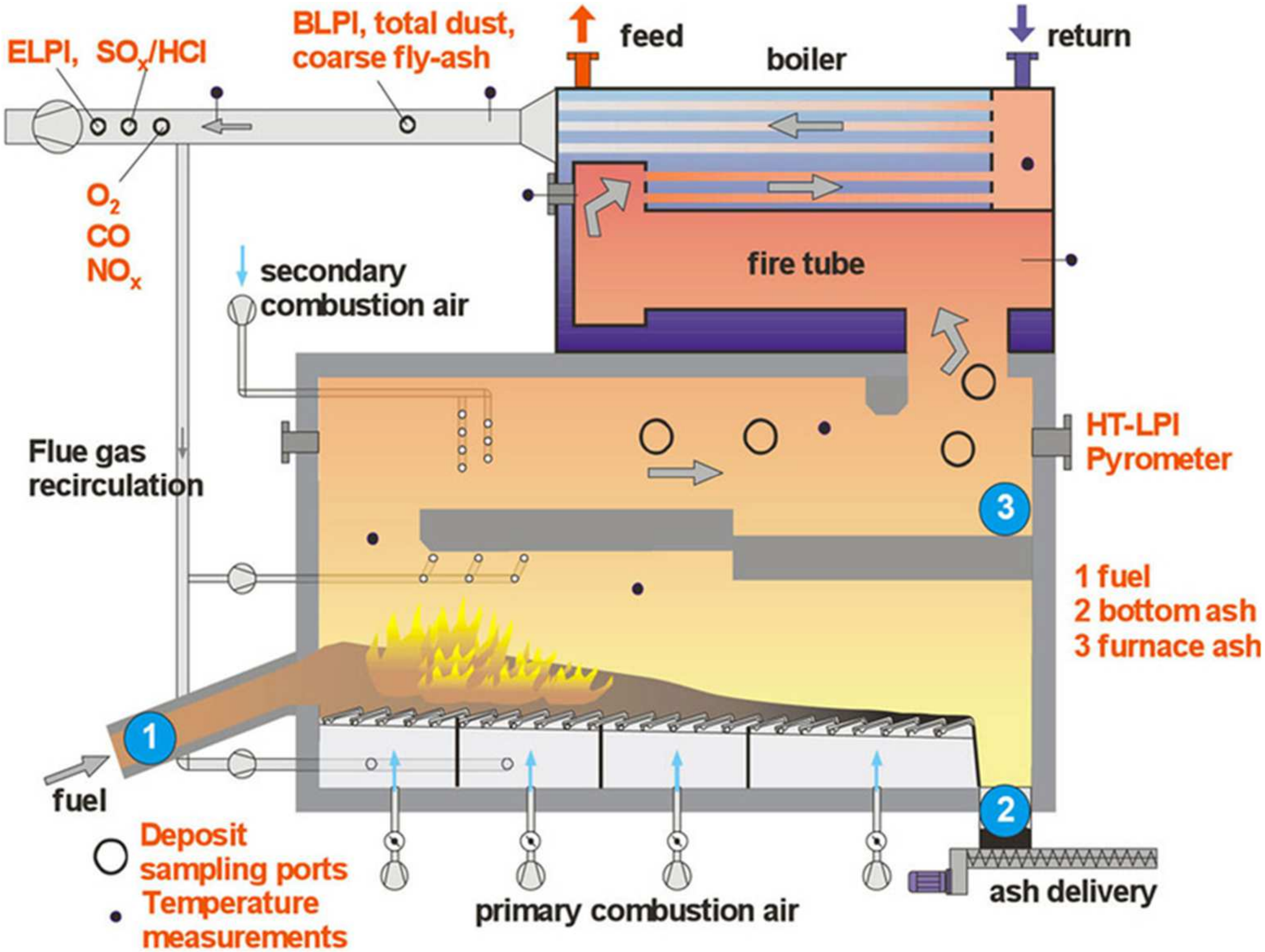
Recommendations – grid densification

- **Goal: Improvement of the heat allocation [MWh/m]**
- **Try to get the large customers, and all close to the grid line**

- **Estimation of heat demand of buildings**
  - New buildings: energy certificates
  - Existing buildings: average of heat consumption of the last ~ 3 years
  - Hot water preparation in hospitals, hotels …
  - Process heat

- **Evaluation of optimization potential for customers**
  - Planned thermal insulation in the next years?
  - Analysis of optimization potential in the heating system

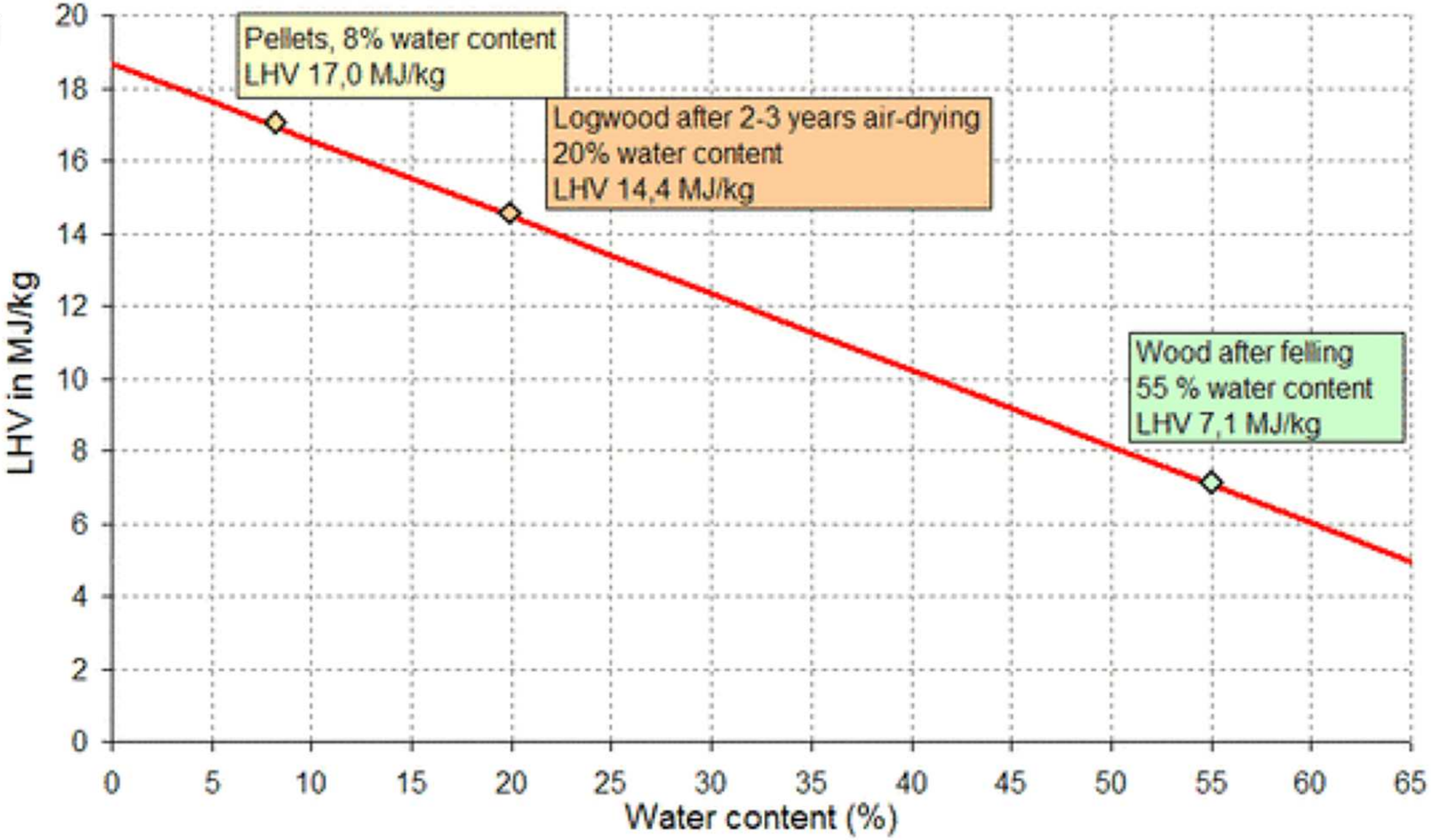
biomass grate-furnace



Water content vs. calorific value of wood

The moisture content of wood chips can vary from 25% to 60% but is most typically at 30 % in small boilers, and > 40% in large boilers.

Ef



Water or moisture content

- There are two methods used to calculate the moisture content, 'Wet Basis' and 'Dry Basis'. The most common method in energy terms is wet basis, whilst foresters tend to use the dry basis. It is important to note that the two methods will give a different result for the same piece of wood.

<u>Example</u>

A quantity of wood has a total mass of 10kg. It is dried in an oven so that all water is removed and then weighed. Its new mass is 8kg. The moisture content is calculated as:

WET BASIS

$$moisture\ content\ (MC) = \frac{mass\ of\ water\ (2kg)}{mass\ of\ wet\ wood\ (10kg)} = 20\%$$

DRY BASIS

$$moisture\ content\ (MC) = \frac{mass\ of\ water\ (2kg)}{mass\ of\ dry\ wood\ (8kg)} = 25\%$$

Calorific value

- Heating value (calorific value) is the heat released by the fuel when completely burnt, and may be determined at constant volume or constant pressure, and flue gas is cooled back to the initial temperature (ambient temperature)

- - higher/gross heating/calorific value (HHV, H_s) - assumes that the water vapor in the products condenses and thus includes the latent heat of vaporization of the water vapor in the products.
- - lower/net heating/calorific value (LHV, H_i) - does not. contain the latent heat, the water in flue gas remain in steam form at the initial temperature

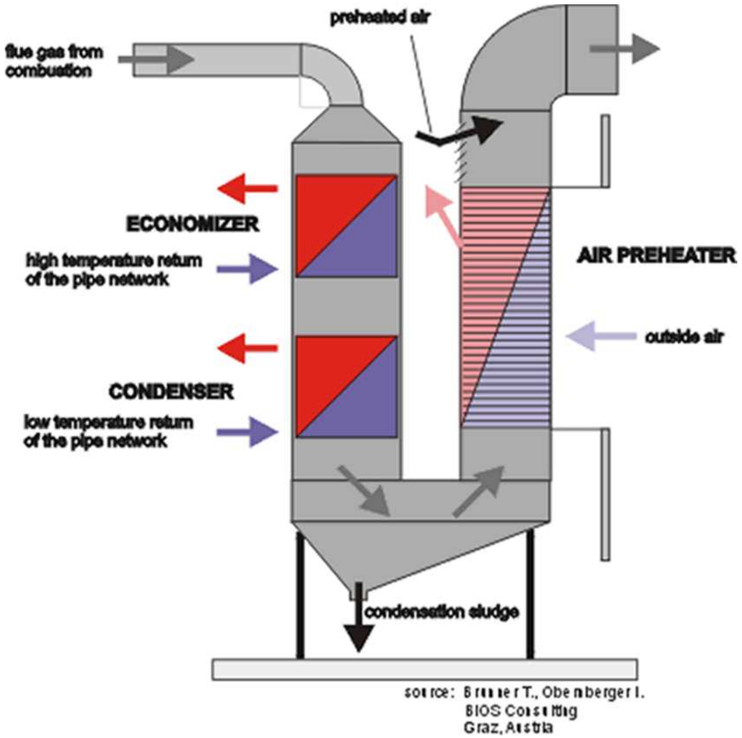
possible dimensions: MJ/kg, MJ/m³, kWh/kg, kWh/m³

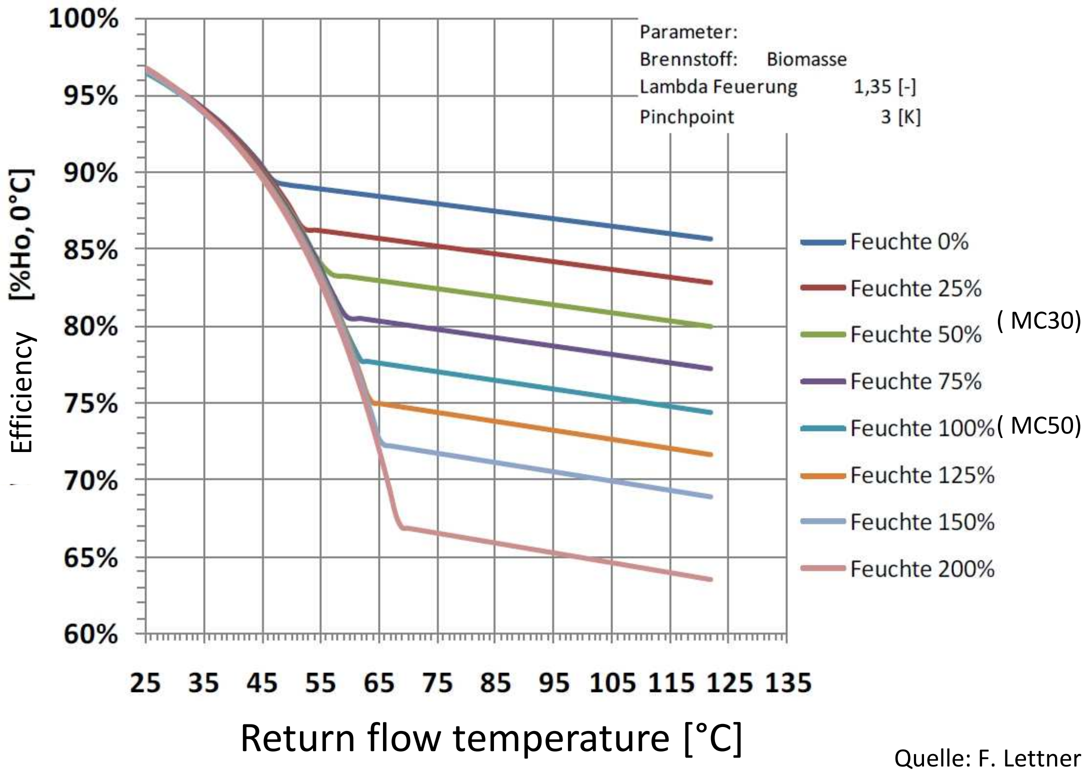
$$LHV = HHV - m_w \cdot h_{fg} - 9 \cdot m_{H_2} \cdot h_{fg}$$

m_w = mass of water vapor per unit mass of fuel
h_{fg} = latent heat of vaporization of water vapor / at its partial pressure in the combustion products [J/kg_{H2O}]
m_{H2} = mass of original hydrogen per unit mass of fuel.

Heat recovery - flue gas condensation

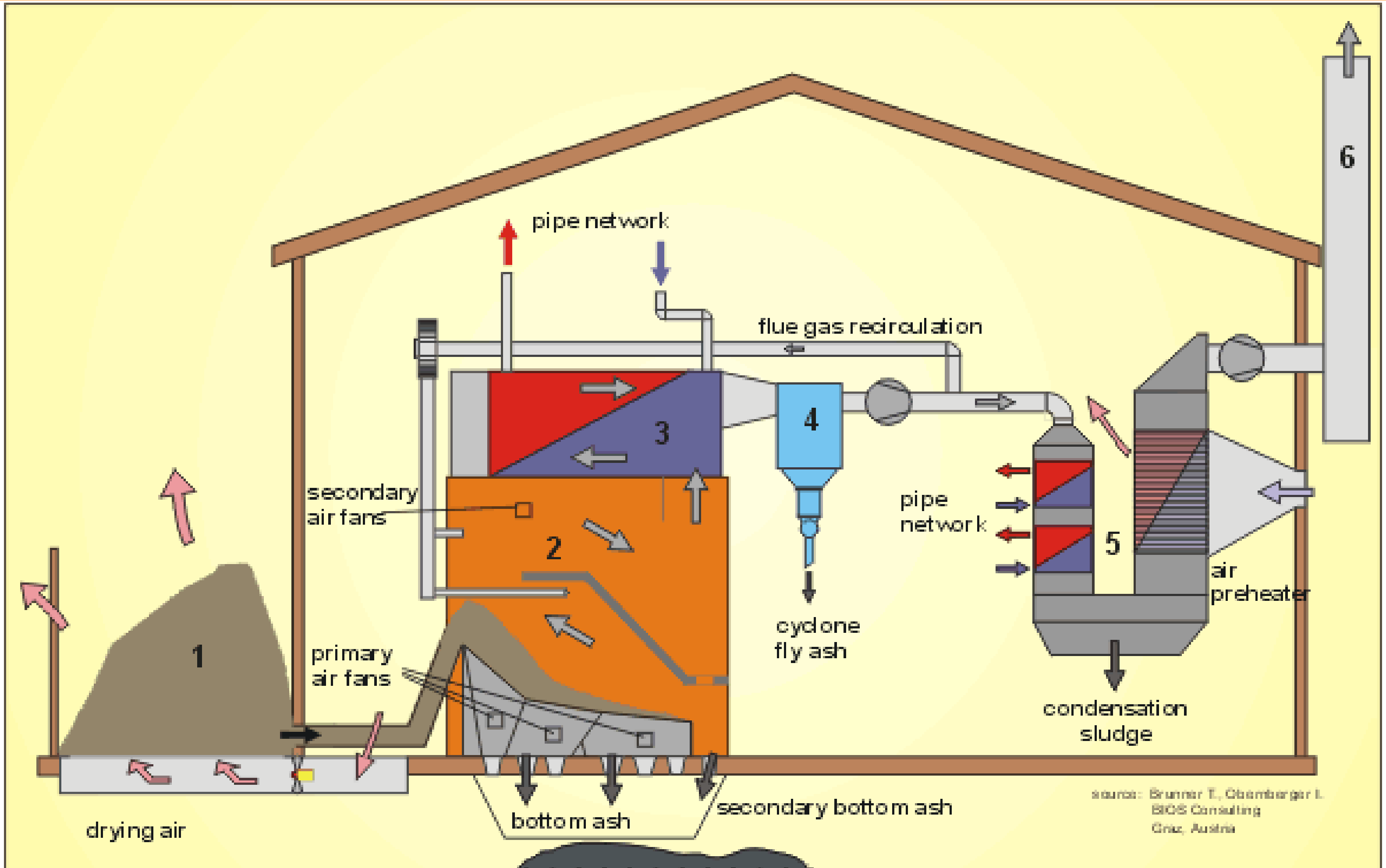
maximum fuel utilization with economizer, condenser and air preheater





Quelle: F. Lettner

Biomass heating plant with heat recovery system (flue gas condensation)



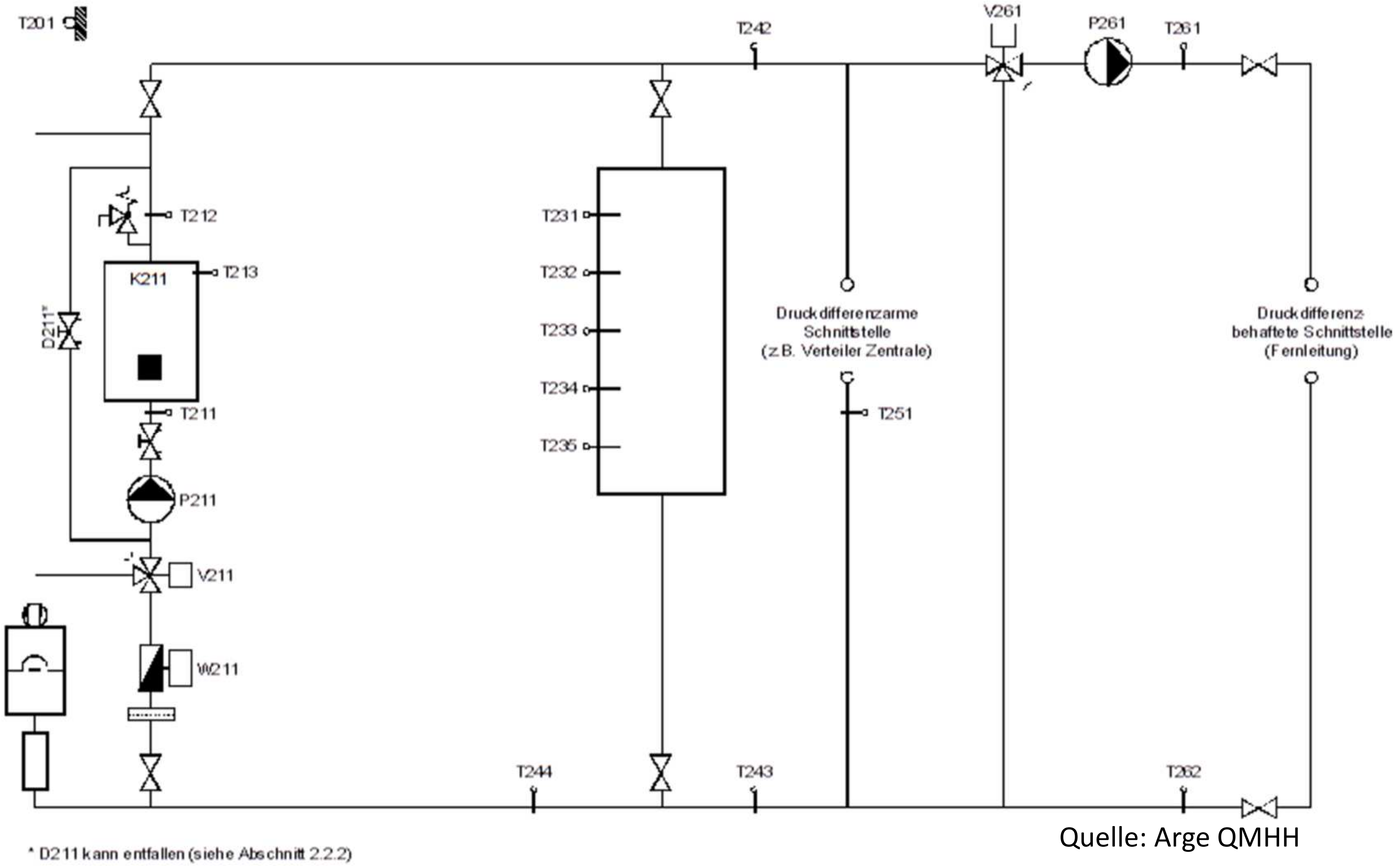
Bios-bioenergy.at

Integration of heat storage (1)

Advantages:

- Decoupling of grid and heat production
- Smoother operation of the biomass boiler
- Covering peak loads
- Better integration of industrial waste heat or other renewable heat sources

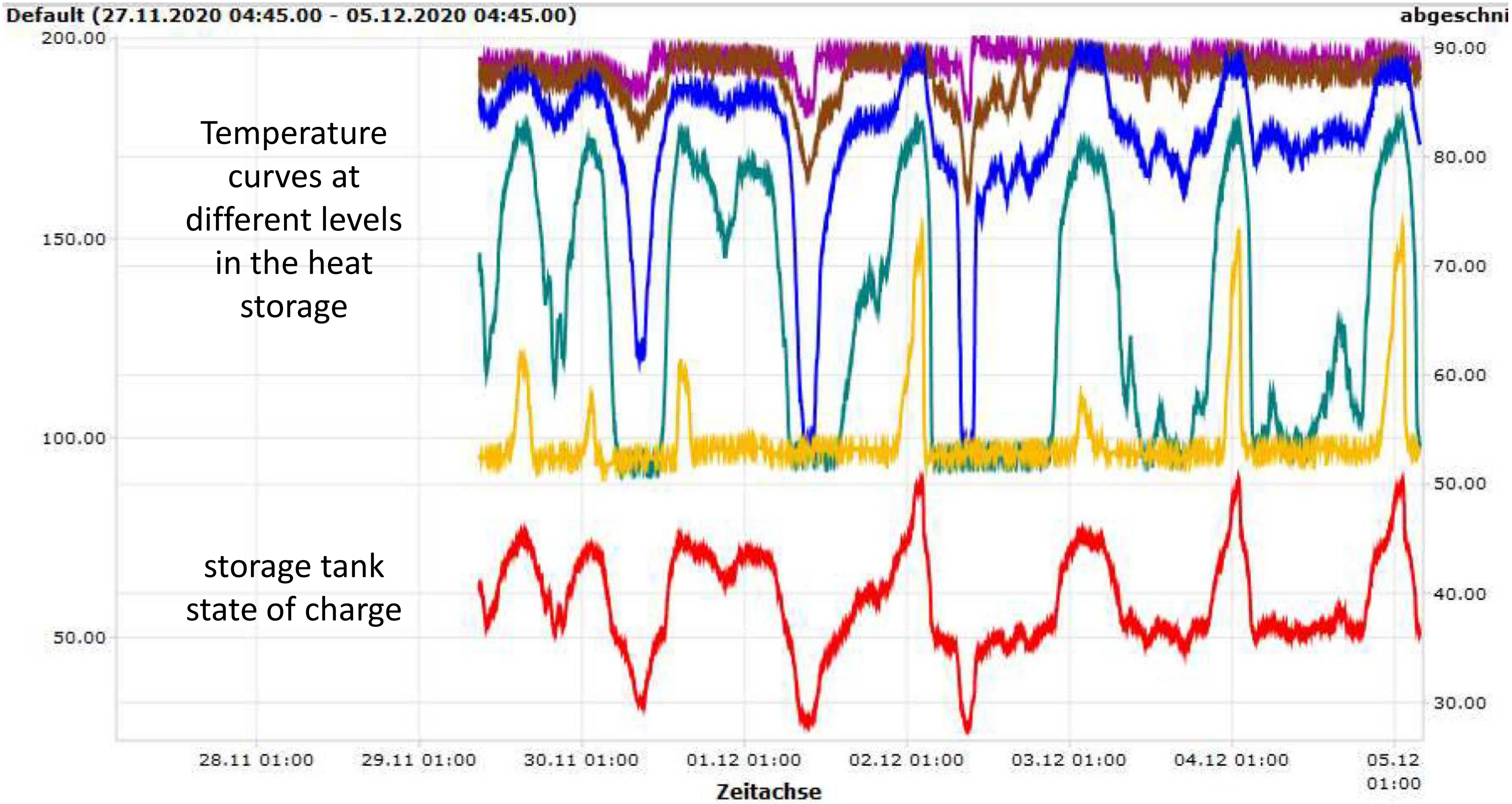
Integration of heat storage (2)



Quelle: Arge QMHH

The output of the biomass boiler must be controlled as a function of the storage tank state of charge!

Integration of heat storage (3)

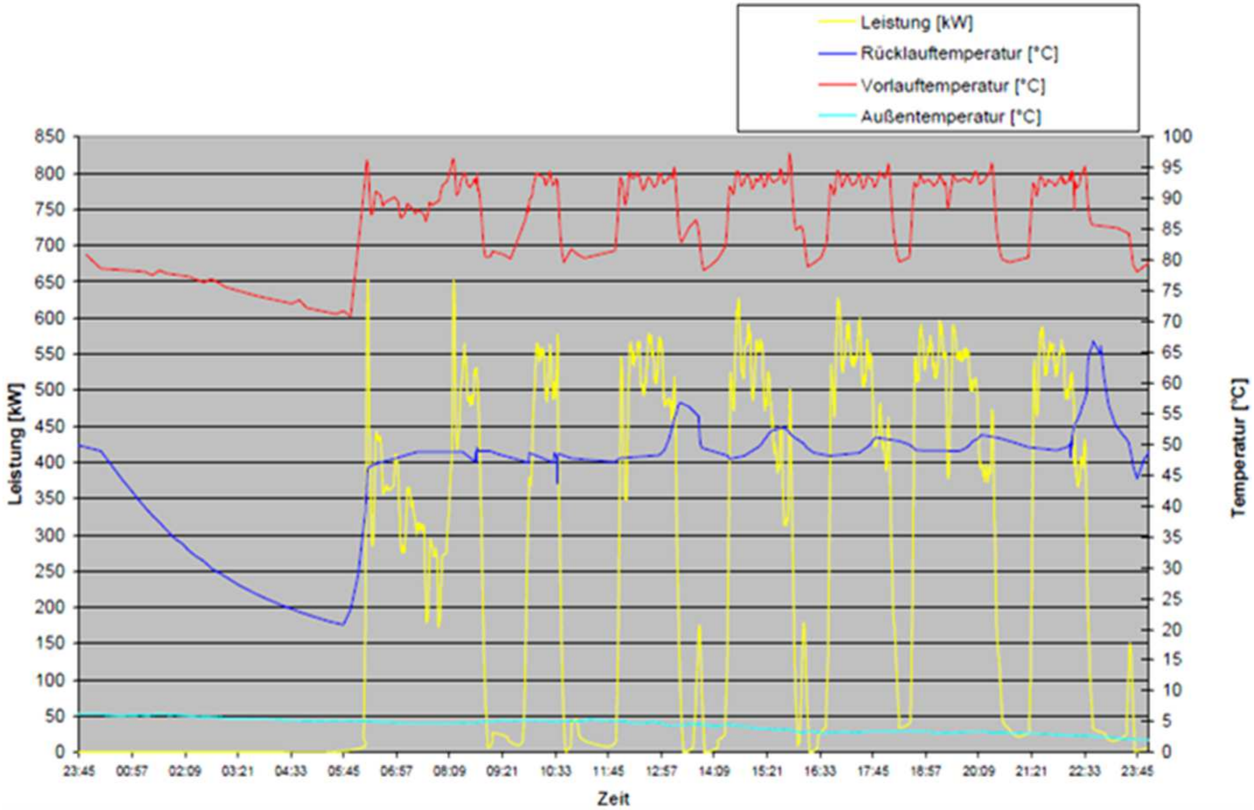


example: the storage is working well, decoupling demand and production!

Integration of heat storage (4)

Example: 800 kW biomass boiler with large load fluctuations, variation also in the supply temperature –

Potential for optimization, the boiler should operate continuously



Overall efficiency

- To determine the **degree of utilization** of the heat supply system, an annual degree of utilization of (flat rate) 85% is assumed for the boiler system (biomass and fossil fuel boiler).
- "Heat gains” from a **solar thermal system** and **from waste heat sources** can be taken into account to <u>increase</u> the degree of utilization.
- The **overall utilization rate** (heat provider and grid system) results from the multiplication of the utilization rates and may not fall below 75% according to the funding guideline (Austria).

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