BIOENERGIESYSTEME GmbH

Your partner for energy utilisation from biomass and energy efficiency
Research • Development • Engineering

Heat Recovery + Improvement of Efficiency

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SUSTAINABLE ENERGY BIOMASS ASH ECONOMY

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BIOS BIOENERGIESYSTEME GmbH
Key information

- **Founded in 1995 as a spin-off of the Graz University of Technology Re-organisation to a limited liability company in 2001**
- **2015 opening of the BIOS Innovation Centre**
- **General manager: Prof. Dr. Ingwald Obernberger**
- **Present staff: 25 (21 graduated engineers)**
- **Annual turnover in 2020: approx. 5.0 Mio €**
- **Markets:** Austria, Germany, Italy, Switzerland but also Belarus, Belgium, Croatia, Czech Republic, Denmark, Estonia, France, Greece, Hungary, Ireland, Montenegro, Norway, Russia, Serbia, Slovakia, Spain, The Netherlands, United Kingdom, Barbados, Canada, Chile, Honduras, USA, Bangladesh, Taiwan, South Africa

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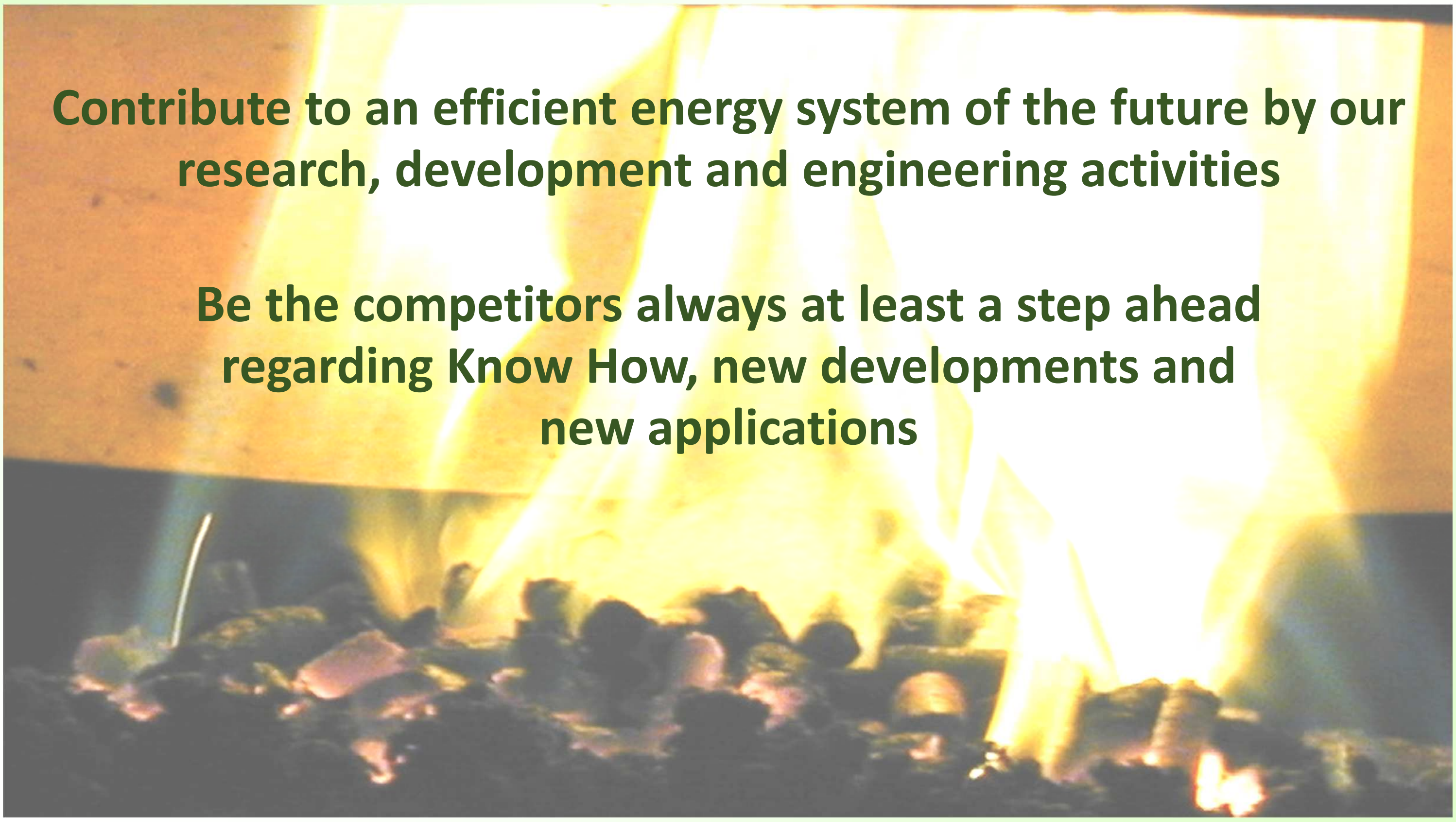
Mission



Contribute to an efficient energy system of the future by our research, development and engineering activities

Be the competitors always at least a step ahead regarding Know How, new developments and new applications

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Themenbereiche

- Heat recovery systems
- Efficiency improvement by process optimisation
- Efficiency improvement by optimisation of hydronic circuits of customers

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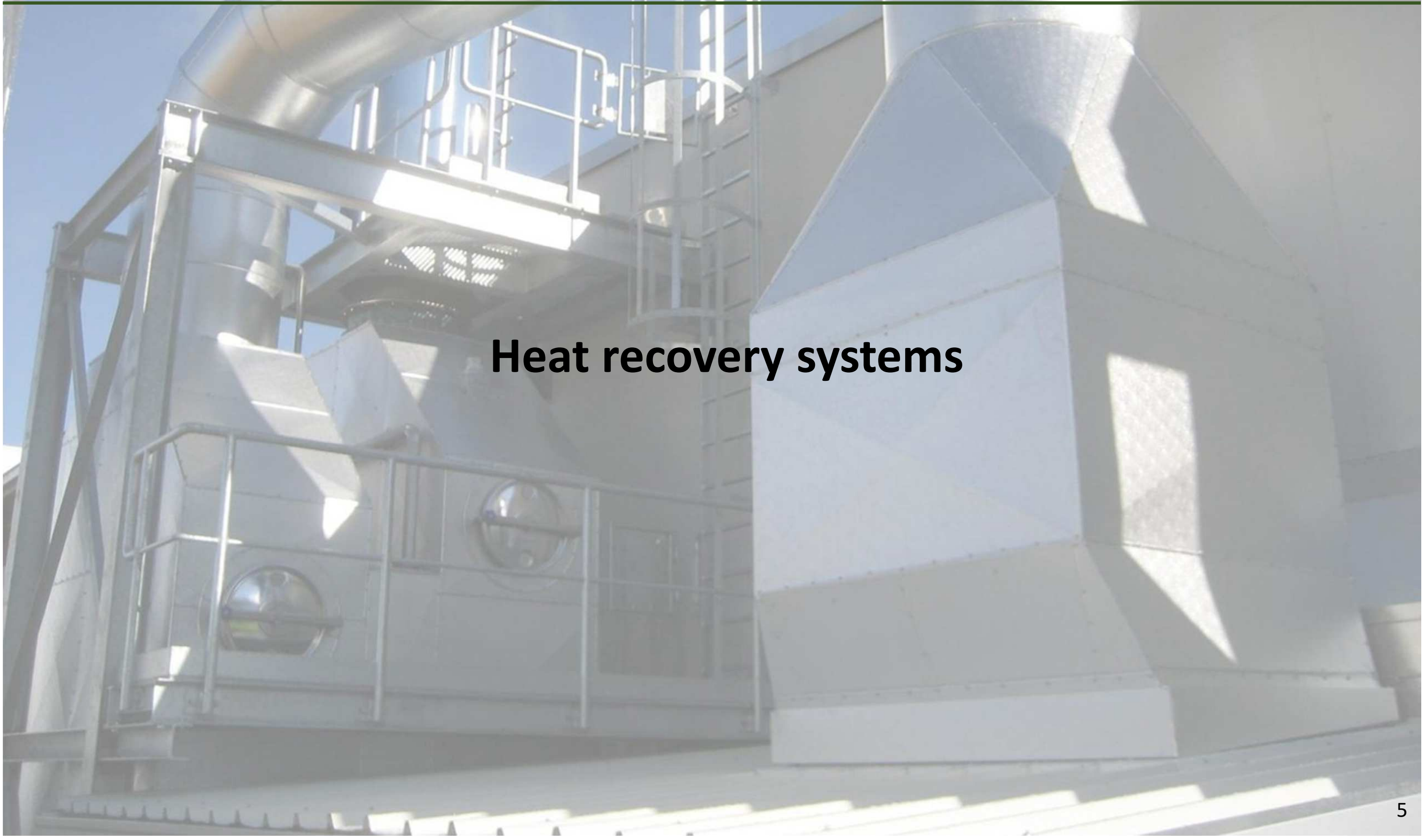

Heat recovery systems

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Framework conditions

- Reduction of operating costs by heat recovery from waste heat streams or industrial processes → improved economy
- Economisers and combustion air pre-heaters are widely spread
- Flue gas cooling below the dew point → increased potential for heat recovery by utilisation of latent heat
- No heat consumers available with appropriate return temperatures to condense the flue gas? → utilisation of heat pumps
- Frequent problems and damages by corrosion, abrasion and ash depositions → appropriate selection of process technology, process parameters and material necessary

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Optimised selection of the plant technology depending on the framework conditions given

Relevant parameters:

- Waste heat source (e.g. flue gas from a biomass furnace, flue gas from an industrial furnace, …)
- Type of fuel used (e.g. bark, waste wood, natural gas, …)
- Upstream processes (e.g. electrostatic precipitator, bag-house filter, …) result in different flue gas parameters
- Temperature level of the heat sink (e.g. return temperatures of 50°C from district heating network or 85°C from drying kilns)
- Availability of heat sources and heat sinks
- Economic parameters (e.g. heat price, electricity price, fuels price, …)

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Avoidance of problems / damages by corrosion, abrasion and deposits → to be considered:

→ to be considered:

- Flue gas temperature
- Surface temperature of the heat exchanger
- Flue gas composition
  - water and acid dew point
  - content and composition of dust
  - hygroscopic salts

→ relevant influence on the selection

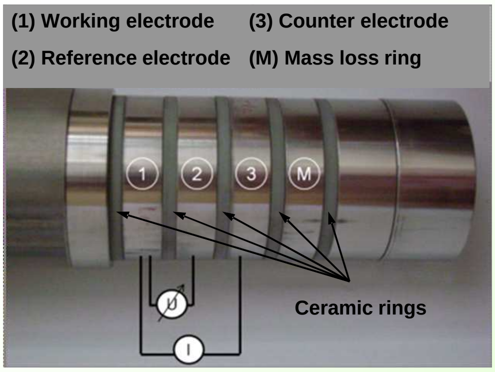
- of the process and its parameters
- of the materials used
- of the cleaning systems
- of the waste water treatment systems

Deposit on economiser tubes

Corrosion on economiser tubes

Reducing the risk of corrosion damages by measurements with an online low-temperature corrosion probe

- Surface temperature of the probe can be controlled
- Multiple passing through relevant temperature ranges is possible
- Online recording of the corrosion rate
- Determination of the acid dew point of flue gases and of the influence of hygroscopic salts (deliquescence corrosion) is possible



Corrosion sensor with three measuring electrodes

→ Possibility to evaluate the influence of different fuels and operating conditions on the corrosion rate

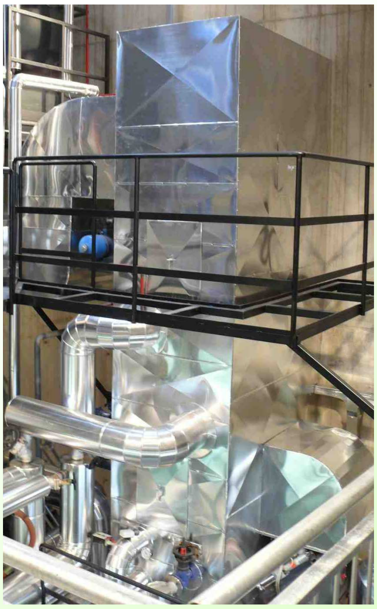
→ Definition of appropriate materials and operating parameters

Heat recovery from flue gases with economisers

- Heat carriers: water, thermal oil, steam, air, …
- Materials: carbon steel, various stainless steels, carbon, various coatings
- Cleaning systems: without, pressurised air, water, mechanical systems, shot cleaning, …

ECO with wet cleaning system in a biomass CHP plant

Thermal oil ECO for waste heat utilisation downstream an industrial furnace



ECO with a pressurised air cleaning system in a biomass CHP plant

Heat recovery from flue gases with condensers

- **Heat carriers: water, air, coolant**
- **Materials: various stainless steels, composite materials, various coatings**
- **Cleaning systems: water**
- **Kind of heat transfer**
  - via tube bundles (different flow principles)
  - via water droplets (water injection, quench)
  - via packed columns with wet surfaces
- **Kind of heat utilisation**
  - Directly in a low-temperature system
  - Indirectly → increase of the temperature level by a heat pump (compression or absorption heat pump)

Flue gas condensation test rig with directly coupled heat pump, project ICON

Heat recovery by flue gas condensation

2019, FGC plant Stadtwerke Lienz, (A) 1,500 kW condenser heat utilisation by a compression heat pump

2014, FGC plant Stadtwerke Wörgl, (A), 380 kW ECO, 1,000 kW condenser heat utilisation by a compression heat pump

2012, FGC plant Sunstore (DK) project, 1,000 kW condenser, heat utilisation by a low-temperature district heating network

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Technological options
Compression heat pump

Increase of the temperature level by a compression heat pump

- **Operating principle of a compression heat pump:**
  - Liquid coolant is expanded in the evaporator
    → takes up heat at a low temperature level
  - The evaporated coolant is compressed in the compressor → needs electric energy
  - The compressed coolant is liquefied in the condenser → the heat taken up before is released at a higher temperature level
- **Interesting when low electricity prices are available**

2014, project ICON, development of a heat pump with direct evaporator for flue gas condensation thermal output 60 kW

2019, Stadtwerke Lienz, thermal output 1,800 kW

2015, Stadtwerke Wörgl, thermal output 1 x 1,150 and 2 x 1,500 kW

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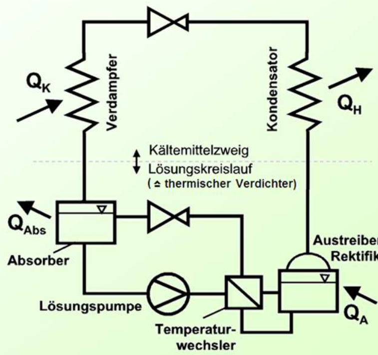
Technological options
Absorption heat pump

Increase of the temperature level by an absorption heat pump:

- **Operating principle of an absorption heat pump:**
  - A liquid coolant is evaporated at low pressure
    → takes up waste heat at a low temperature level
  - In the absorber the evaporated coolant is absorbed from a solvent
  - In the regenerator the coolant is separated from the solvent at an increased pressure level → use of thermal energy at a higher temperature level (thermal compressor)
  - The vaporised coolant is liquefied in the condenser
    → heat is released at a medium temperature level
- **Waste heat or cheap heat sources (e.g. steam) at about 180°C are needed**

Lithium bromide absorption heat pump



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Project implementation

- Preliminary design and economic pre-evaluation
- Feasibility study including the definition of the most suitable technology and a detailed economic evaluation
- Preparation of permit applications – focus on flue gas dispersion after stack exit, water vapour formation, noise emissions and waste water treatment
- Funding application, consideration of energy efficiency laws (if applicable)
- Call for bids and project implementation
- Construction supervision
- Support at start-up
- Commissioning and plant take-over
- Performance optimisation

BIOS is able to support projects regarding efficiency improvement by heat recovery in all phases of the project.

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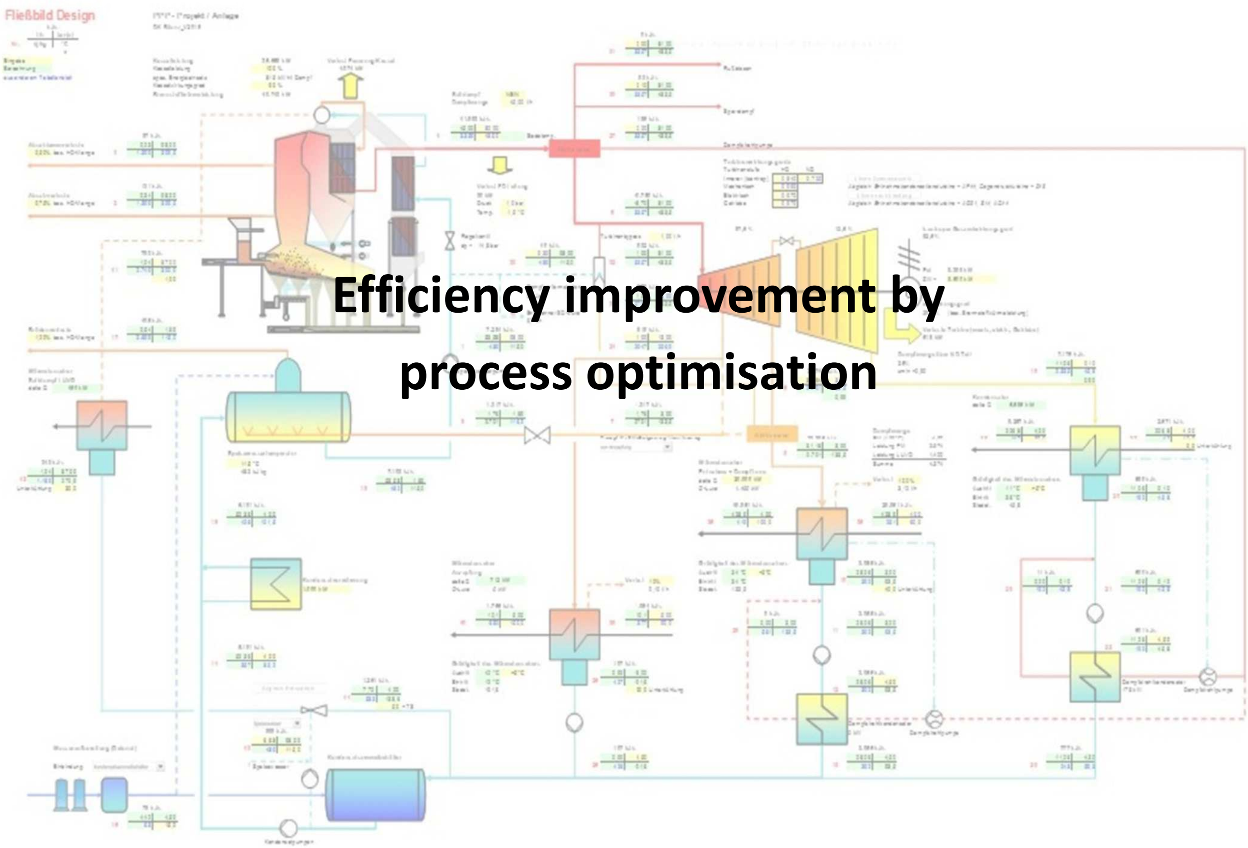

Efficiency improvement by process optimisation

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Framework conditions

- **Why process optimisation?**
  - Changed external framework conditions such as expired feed-in tariffs or influences of energy efficiency laws
  - Increase of thermal output without plant extension
  - Changed economic framework conditions (e.g. fuel price)
- **Aim: Improvement of the efficiency of an existing plant**
  - Cost savings of fuel and electricity
  - Reduction the emissions
  - Use of unused potentials such as waste heat from flue gases
- **Use of numerous commercial and in-house developed tools for techno-economic analyses, design and documentation**
- **Special focus on the consideration of the whole plant with often complex inter-relations (e.g. hydraulic simulations under consideration of annual energy balances)**

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Overview of tools used

SE-Bilanz:	**Mass and energy balance calculations for entire plants over a whole year on an hourly basis**
BIOBIL:	**Mass and energy balance calculations for biomass combustion plants**
DK-Bilanz:	**Mass and energy balance calculations for steam cycles (based on water and organic working media)**
Hydraulic Design:	**Dimensioning of hydraulic components such as pumps, control valves, etc. based on the simulation of the entire plant**
BIOS design:	**Economic evaluations (according to VDI 2067 and to calculations of the dynamic amortisation period) including tools for sensitivity analysis**
AutoCAD Plant3D:	**Preparation of P&I diagrams and of 3D layout and piping plans**
R-Design:	**Design and optimisation of district heating networks, calculation of annual load curves and annual heat losses**

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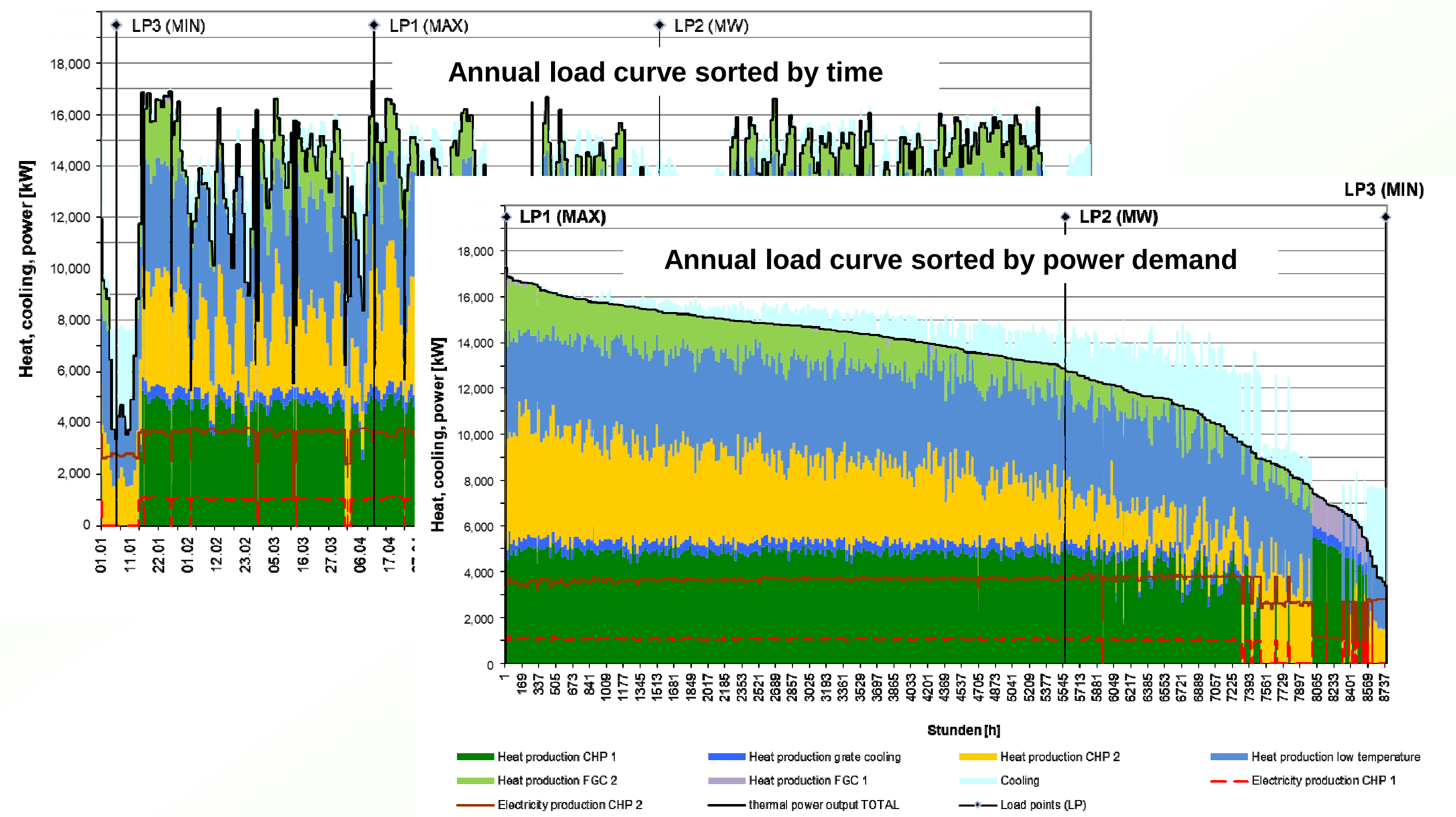
Balances for entire plants over a whole year on an hourly basis



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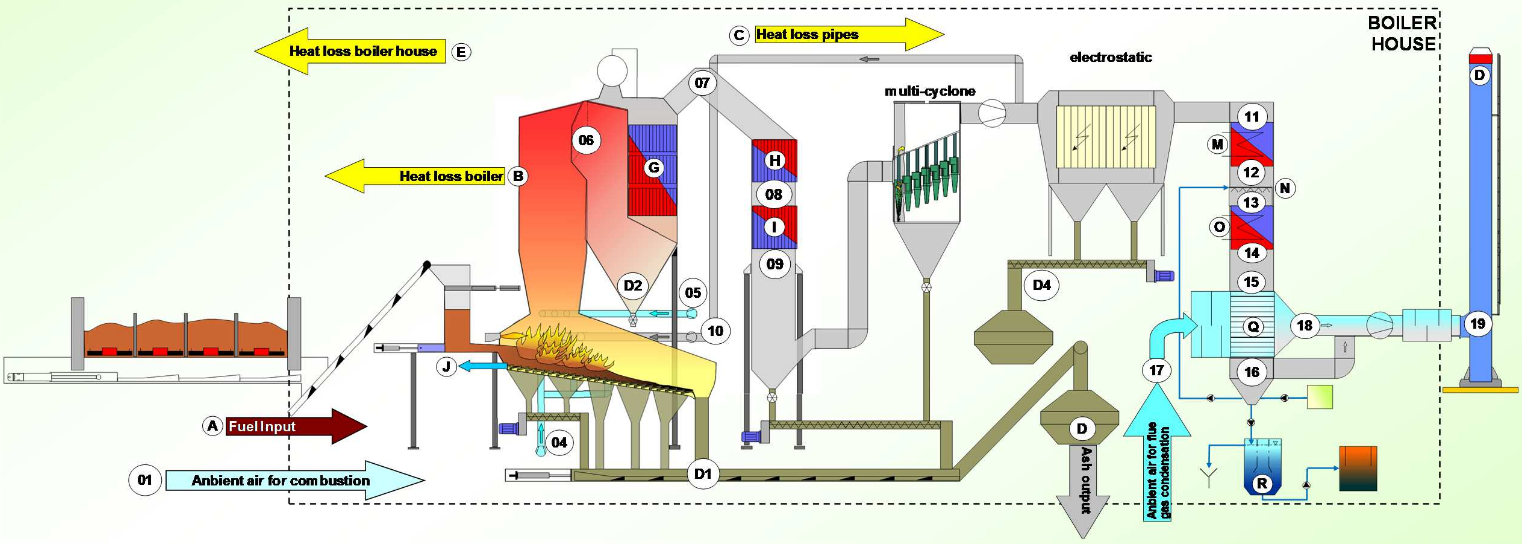
Scheme for mass and energy balances of biomass heating and CHP plants



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BIOBIL (II)

Mass and energy balance of biomass heating and CHP plants (excerpt)

Refer. Point	Description Gasoeus flow	Temp. [°C]	Dry gaseous flows Mass flow [kg/h]	Volume flow [Sm³/h]	[m³/h]	Density [kg/m³]
01	Ambient air	0.0	61,507	47,785	50,877	1.209
02	Boiler house air	63.5	61,507	47,785	62,703	0.981
03	Combustion air	63.5	61,507	47,785	62,703	0.981
04	Primary air	63.5	26,712	20,752	27,232	0.981
05	Secundary air	63.5	34,795	27,032	35,472	0.981
06	FG in furnace (adiab. FG-Temp.)	950.0	79,848	58,940	281,012	0.284
07	FG out of the TO-Boiler	350.0	79,848	58,940	143,165	0.558
08	FG out of the TO-ECO HT	270.0	79,848	58,940	124,786	0.640
09	FG out of the TO-ECO LT	180.0	79,848	58,940	104,109	0.767
10	FG recirculation	150.0	15,341	11,324	18,678	0.821
11	FG into the economiser	150.0	64,506	47,616	85,430	0.755
12	FG out of the enconomiser	75.0	64,506	47,616	64,618	0.998
13	FG into the condenser	61.1	64,506	47,616	62,037	1.040
14	FG out of the condenser	55.0	64,506	47,616	60,906	1.059
15	FG into the air pre-heater	55.0	64,506	47,616	60,906	1.059
16	FG out of the air pre-heater	35.0	64,506	47,616	57,194	1.128
17	Devaporisation air into the air pre-heater	0.0	259,379	201,511	214,552	1.209
18	Devaporisation airout of the air pre-heater	52.5	259,379	201,511	255,812	1.014
	Drying air into the air pre-heater					
	Drying air out of the air pre-heater					
19	FG stack	48.9	323,885	249,127	312,735	1.036

Refer. Point	Description	*Efficiency based on LHV*	Capacity [kW]
Total energy input (furnace)			**30,467.2**
A	**Fuel input (LHV)**	*100.0%*	**29,196.8**
	Heat fuel	-	98.1
03	Heat combustion air		669.6
10	FG recirculation		698.9
Total energy output (furnace)			**30,467.2**
07	Enthalpy of FG after TO-ECO 2		9,685.6
	Chemical bound heat FG		19.8
D	Enthalpy of ash		2.5
	Chemical bound heat ash		9.3
B+J	Heat losses boiler + grate cooling		750.0
G	Useful heat of: TO-Boiler, TO-ECO HT, TO-ECO LT		20,000.0
Heat use / heat recovery		*useful heat*	**25,609.8**
G	TO-Boiler	*68.5%*	20,000.0
H	TO-ECO HT	*8.4%*	2,456.6
I	TO-ECO LT	*9.3%*	2,703.2
J	Grate cooling	*1.5%*	450.0

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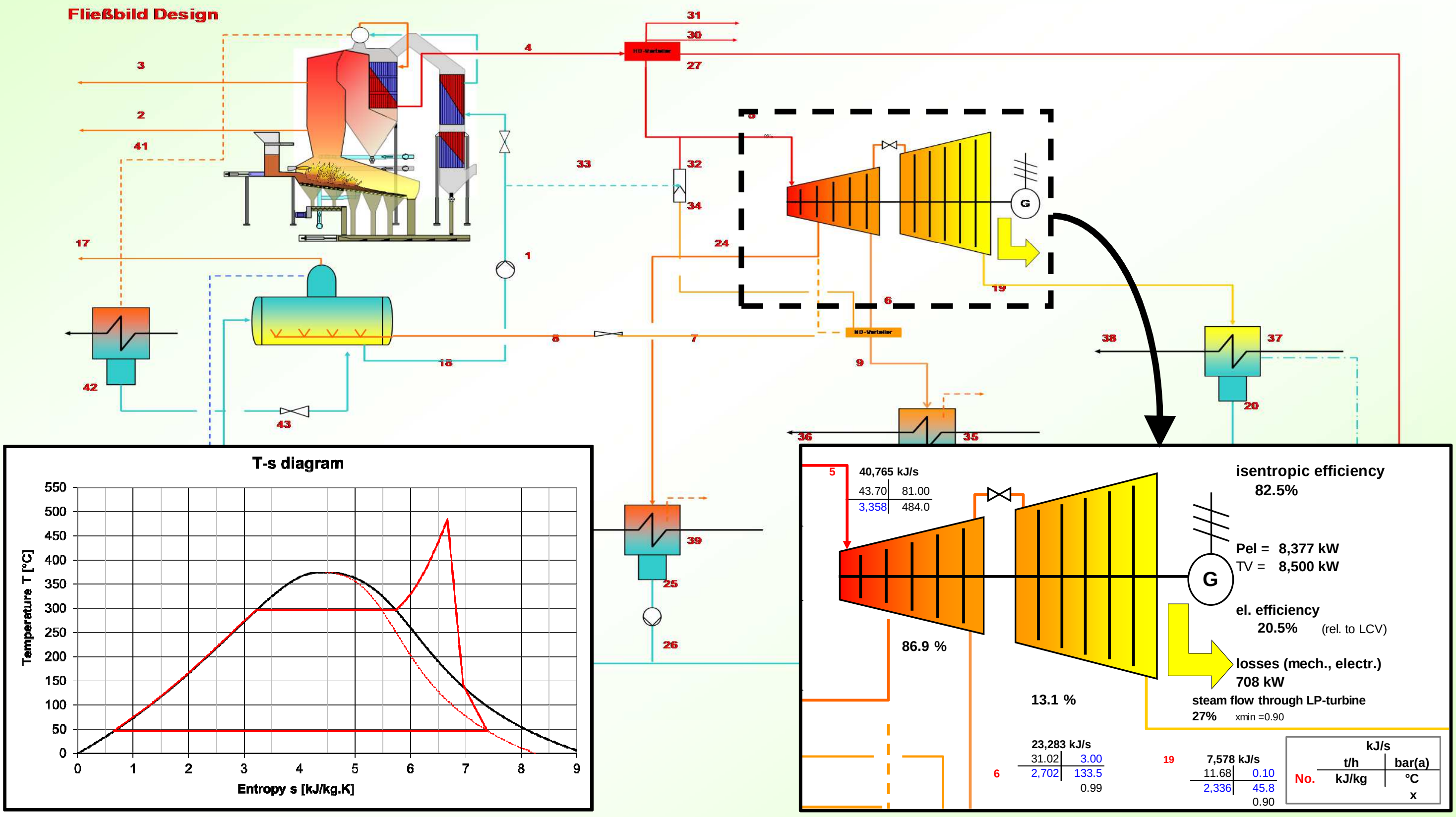
DK-Bilanz

Mass and energy balances for steam cycles (based on water and organic working media)



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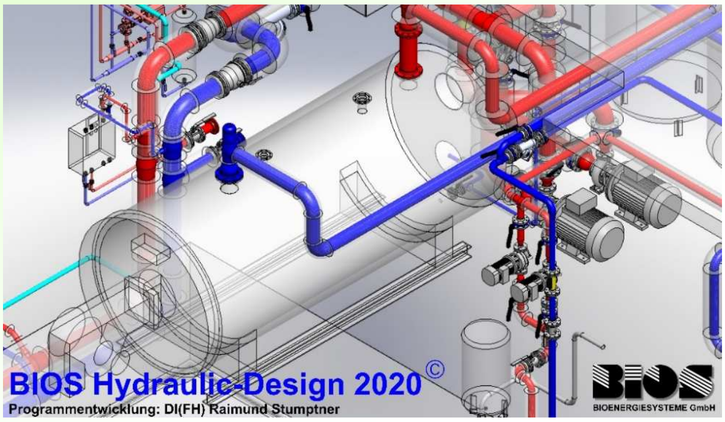
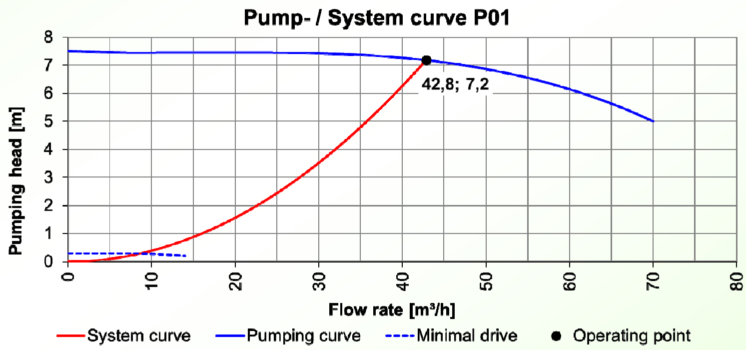
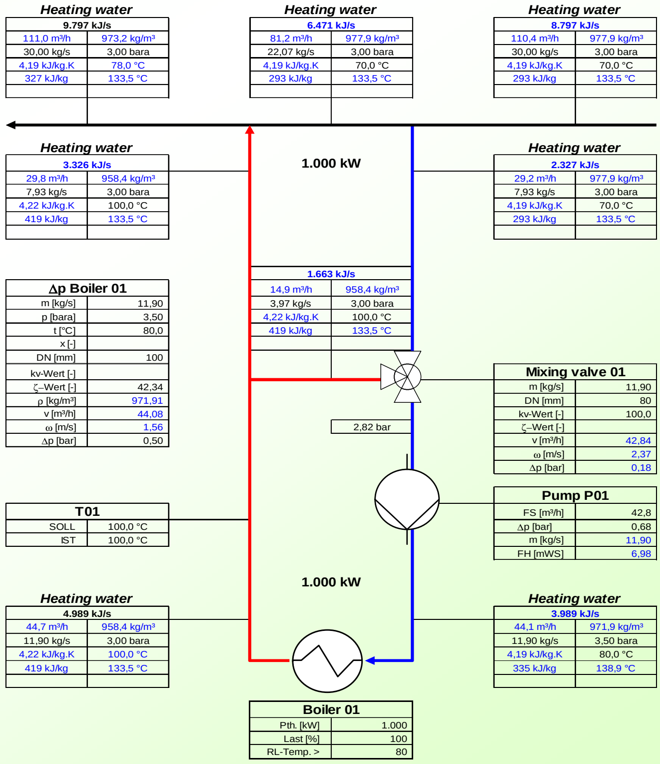
Hydraulic Design

Dimensioning of hydraulic components such as pumps, control valves, etc. based on the simulation of the entire plant







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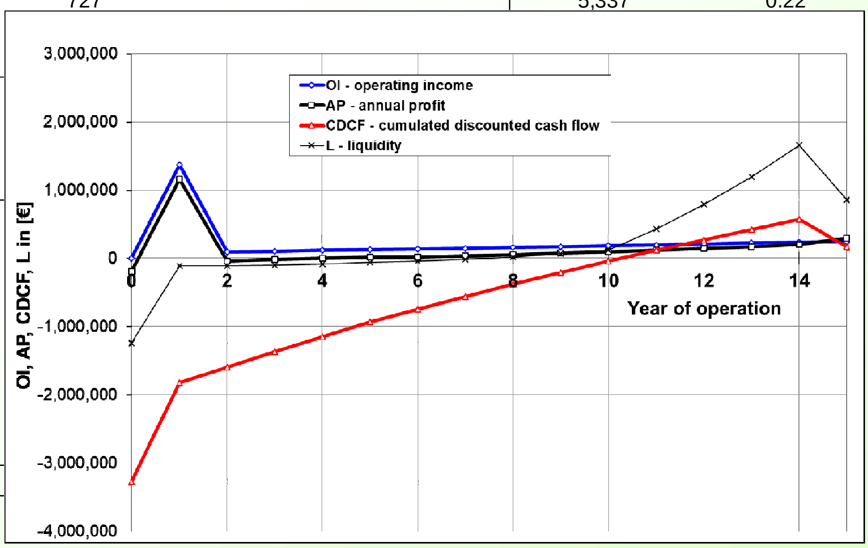
BIOS-Design

Economic evaluations (according to VDI 2067 and calculations of the dynamic amortisation period) including tools for sensitivity analysis

Economic calculation according to VDI 2067

	Investment costs €	capital bound costs € p.a.	maintenance costs € p.a.	consumption based costs € p.a.	operating costs € p.a.	total energy costs € p.a.	specific energy costs € / MWh sold
Construction costs							
Building	312,493	19,826	3,125			22,951	0.95
Storage area	72,673	4,611	727			5,337	0.22
Outside facility	21,802	1,383					
Infrastructure	7,267	461					
Network of pipes							
Pipes	130,811	8,464					
Trenching / backfilling	36,336	2,351					
Heat transfer stations	-	-					
Mechanical equipment							
Combustion and boiler	639,521	55,756					
Electricity							
Other costs							
Operational supplements CHP							
Rental fee (property)							
Sum of costs	**3,277,030**	**271,761**					
specific energy costs (w/o subsidies)		11.20					



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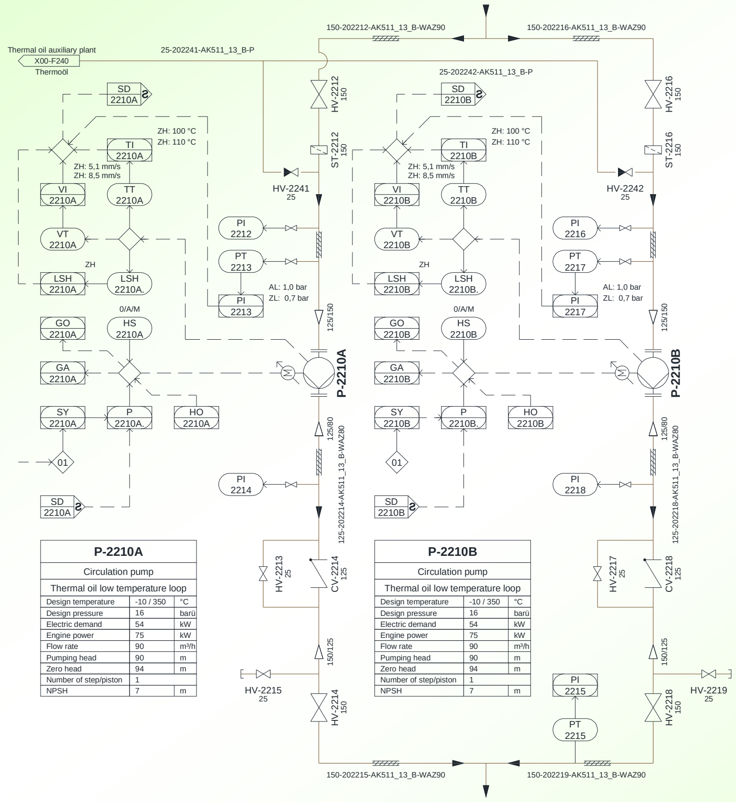
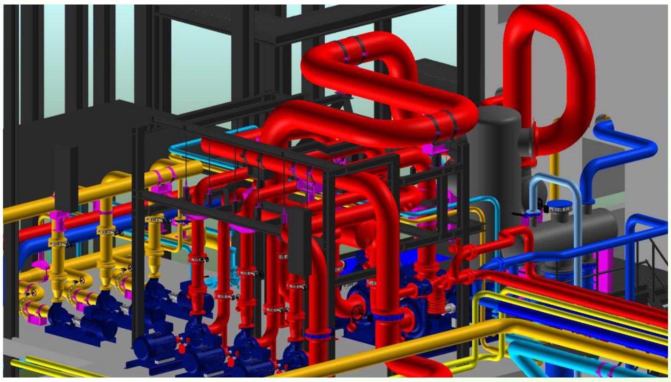
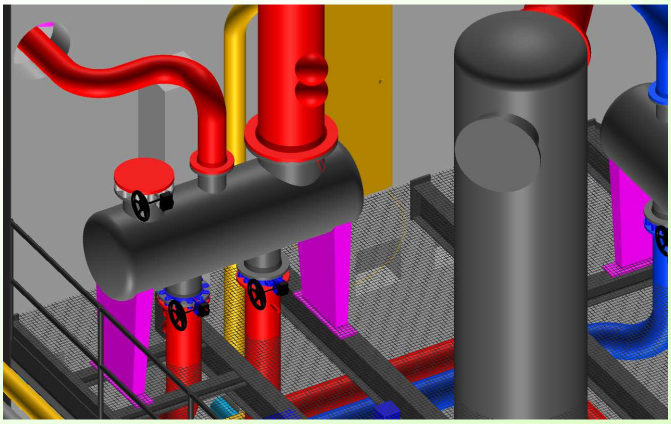
Preparation of P&I diagrams and of 3D layout and piping plans







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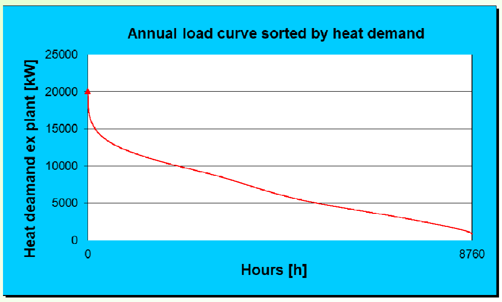
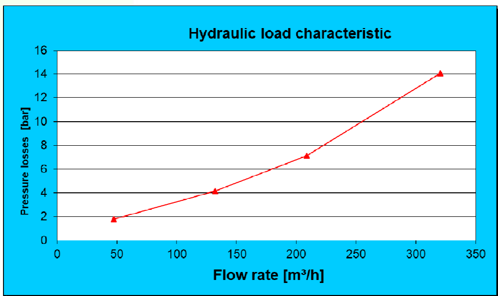
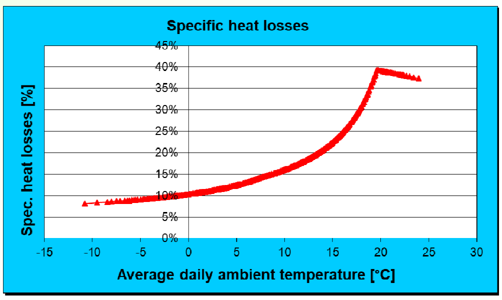
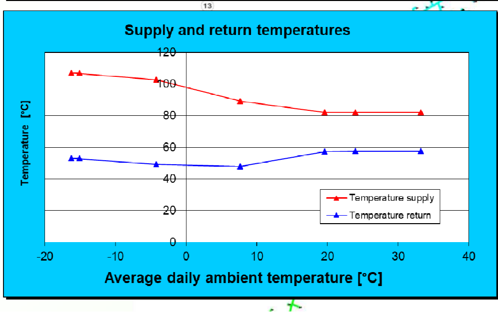
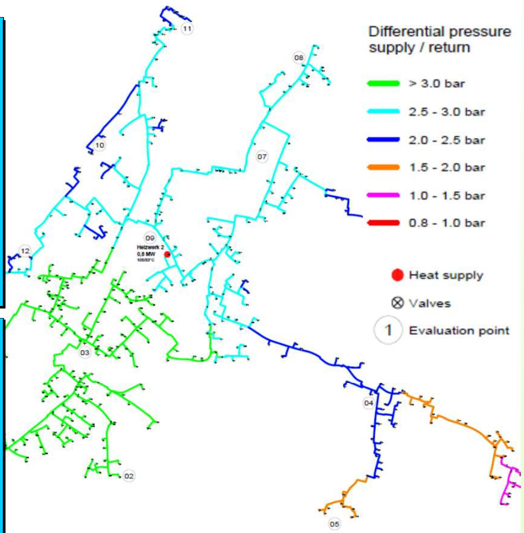
Design and optimisation of district heating networks, calculation of annual load curves and annual heat losses











Pressure analyses at minimum ambient temperture (AT -16°C)

DH-Network Point analysed	Sea level [m]	Geodesic pressure [bar]	Static pressure [bar]	Dynamic pres. supply [bar]	Dynamic pres. return [bar]	Differential pressure [bar]	Total pressure [bar]	max. pressure at valve shut off [bar]
1	675	3.6	5.8	14.3	0.2	**14.1**	20.1	**21.3**
2	712	-	2.2	9.7	5.2	**4.5**	11.9	**17.7**
3	658	5.3	7.5	9.6	5.3	**4.3**	17.1	**23.0**
4	658	5.3	7.5	8.6	6.5	**2.0**	16.1	**23.0**

Selected case studies (I)

Municipal biomass CHP plant

- **Evaluation of different options for a steam-based CHP plant**
  - New turbine
  - Exchange of the core of the turbine (turbine without transmission and generator)
  - Retrofit from extraction condensing turbine to backpressure turbine
- **Techno-economic evaluation of different operating conditions of the CHP plant**
  - Power controlled mode
  - Heat controlled mode
  - Heat only supply

Selected case studies (II)

Industry

- **Combined heat, power and chilling plant**
  - Waste wood-fired
  - Fuel pre-treatment
  - Biomass-fired thermal-oil boiler
  - ORC process
  - Absorption chiller
  - Air cooler (glycol-water)
  - Open wet cooling tower
- **Energetic and economic optimisation**

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Selected case studies (III)

Timber industry

- Retrofit and expansion of the heat distribution system
- Techno-economic evaluation of expansion scenarios
- Development of an appropriate concept for process control
- Retrofit of the flue gas condenser

Steel industry

- Heat recovery from industrial flue gases for power generation based on the ORC process including thermal oil heat storage
- Techno-economic evaluation of different options
- Development of an appropriate concept for process control

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Selected case studies (IV)

District heat supply based on industrial waste heat

- Waste heat utilisation from compression chillers
  - directly by a refrigerant cooler
  - indirectly by refrigerant condensation coupled with a compression heat pump
- Waste heat utilisation from the flue gas of a biomass boiler
  - Directly by an economiser
  - Indirectly by flue gas condensation coupled with a compression heat pump
- Process steam extraction for peak load coverage
- Gas-fired boiler for peak load coverage and back-up
- Heat storage tank

Selected case studies (V)

Retrofitting heat recovery systems in existing systems

- **Analysis of the existing system due to operational data evaluations**
- **Prediction concerning the future developement of the heat demand**
- **Techno-economic evaluation of expansion scenarios**
- **Waste heat utilisation from the flue gas of biomass boilers**
  - Directly by an economiser
  - Indirectly by flue gas condensation coupled with a compression heat pump

Selected case studies (VI)

Municipal district heat supply

- **Hybrid CHP system based on biomass and solar energy**
  - Biomass-fired thermal-oil boiler
  - ORC module
  - Flue gas condensation unit
  - Compression heat pump using CO_2
  - Long-term heat storage
  - Solar collectors
- **Development of a concept for the process control of the entire plant**

BIOS provides support for your project from the conceptual phase over the planning and erection phase till the start-up of the plant.

Efficiency improvement by optimisation of hydronic circuits of customers

Framework conditions

- **Why to optimise secondary circuits in district heating networks**
  - Efficient tool to increase the efficiency by
    - increasing the output ex heating plant
    - saving energy for pumping
    - reduction of heat losses
    - increasing the capacity of heat storage systems
    - realisation of increased potentials for heat recovery
- **Cooperation of operators of district heating networks with heat consumers, installers and engineers → advantages for all parties involved**

Within the project „Local Heat Store“, funded by the Austrian Climate and Energy Fund, BIOS already realised and demonstrated these measures successfully.

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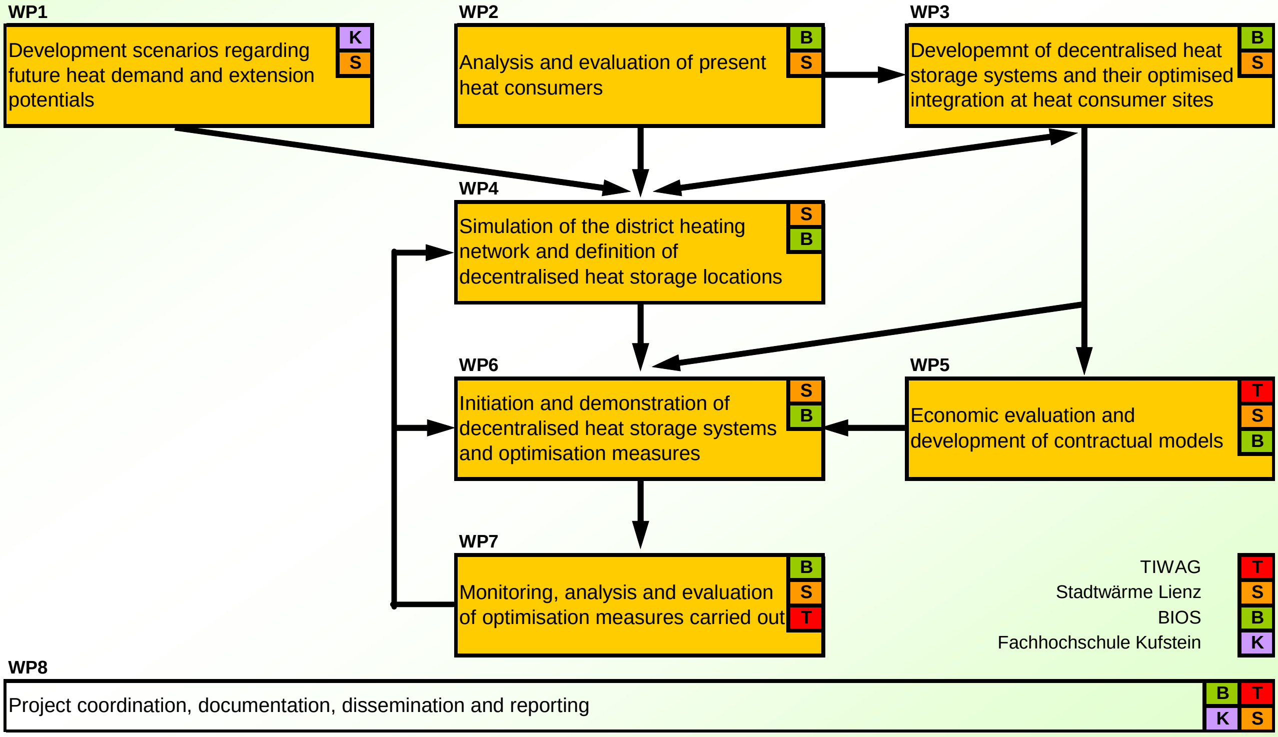
Project „Local Heat Store“ Work packages

Project „Local Heat Store“ (Project duration: 10/2011 until 09/2014): Investigation and evaluation of efficiency improvement measures by the optimisation of hydronic circuits of selected heat consumers



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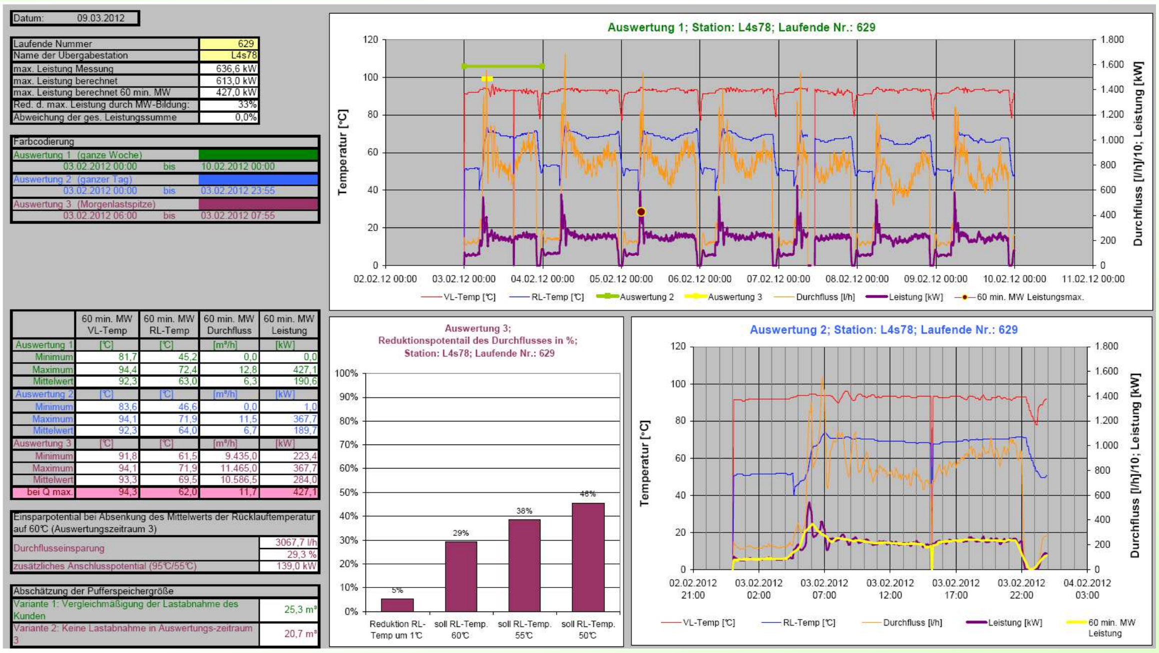
Analysis and evaluation of heat consumers (I)

- **Development of a systematic procedure and a respective software for the characterisation and evaluation of heat transfer stations**
- **Possibility for a simple ranking of the heat transfer stations according to a defined optimisation criteria**

Evaluation heat transfer stations winter 2011/2012				Evaluation period:		03.02.2012 06:00 – 03.02.2012 07:55		sort criterion: Flow rate saving		
Optimisation-priority	Name of heat transfer station (ID)	Limitation of capacity	max. capacity	Return temp. (RT) measured Average [°C]	Flow rate measured Average [l/h]	Heat demand measured Average [kW]	min. avg. return temp. Maximum [°C]	Flow rate saving at RT 60°C related to average RT [l/h]	[%]	Additional conncection potential (95/55°C) [kW]
1	L6s97	1,000	1,000	70.3	25,484.6	682.5	70.9	7,769.0	30.5	352.0
2	L6s37	360	400	72.7	11,399.0	270.7	73.1	4,270.7	37.5	193.5
3	L5s69	70	-	83.4	4,503.1	50.7	84.7	3,167.3	70.3	143.5
4	L4s78	500	750	69.8	10,467.5	277.0	71.9	3,067.7	29.3	139.0
5	L3s10	640	750	67.2	12,380.0	375.3	67.6	2,627.5	21.2	119.0
6	L2s85	820	750	64.9	16,002.5	513.6	66.8	2,338.6	14.6	105.9
7	L6s28	400	400	69.0	8,655.0	246.5	69.4	2,281.4	26.4	103.4
8	L2s154	720	500	67.2	9,579.0	288.6	68.0	2,030.3	21.2	92.0
9	L1s103	1,200	1,500	63.2	19,736.7	684.0	63.5	1,853.0	9.4	83.9
10	L6s15	260	200	71.4	5,189.2	130.9	71.8	1,744.2	33.6	79.0

Analysis and evaluation of heat consumers (II)

- The evaluation software based on MS Excel provides a clear overview for each heat transfer station for the selected evaluation period
- A quick overview of the consumer characteristics, the weak points and the optimisation possibilities is provided

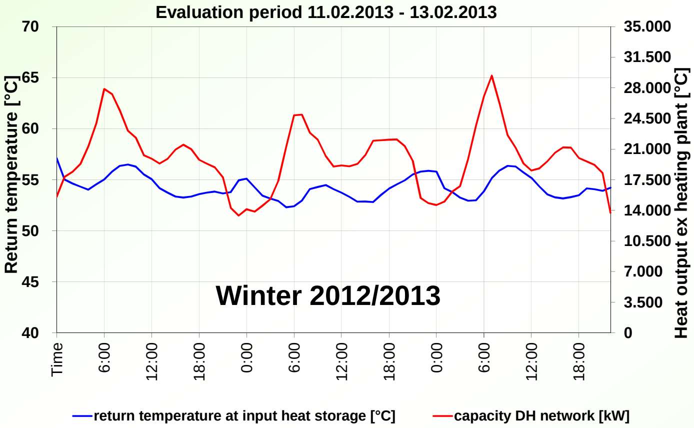


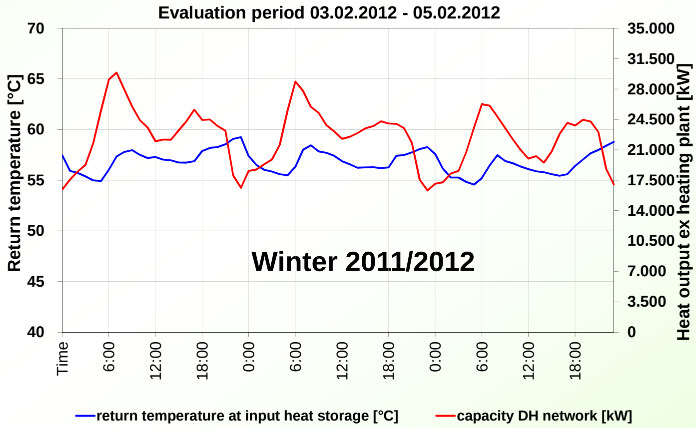
Return temperature district heating network

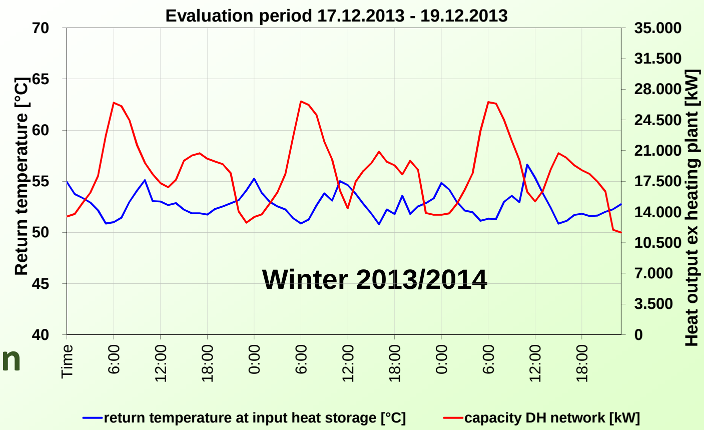
Monitoring, analysis and evaluation of optimisation measures carried out

Results „Local Heat Store“:

- return temperature – district heating network Lienz







- Reduction of the return temperature by about 2°C per year achieved by optimisation measures

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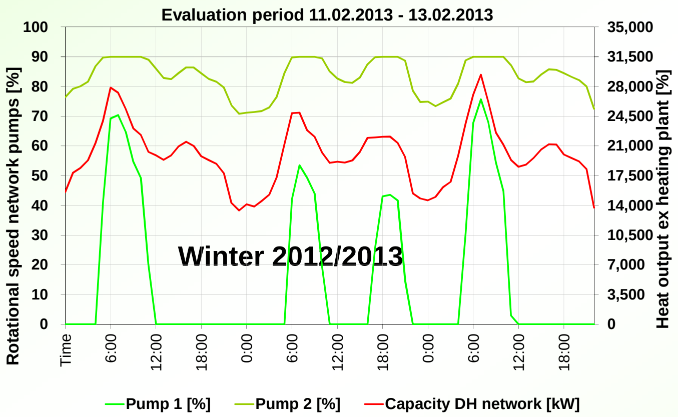
Rotational speed of the network pumps

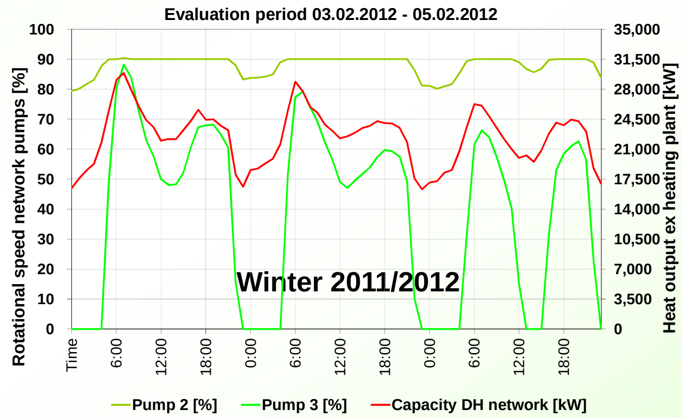
Monitoring, analysis and evaluation of optimisation measures carried out

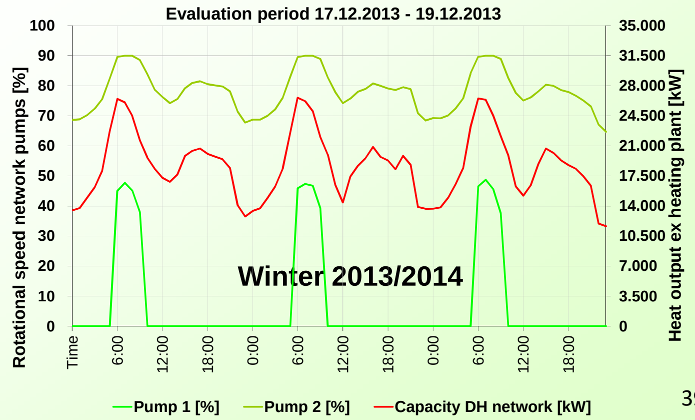
Results „Local Heat Store":

- rotational speed of the network pumps – district heating network Lienz



- → Annual reduction of the rotational speed needed to supply district heat achieved despite a network extension





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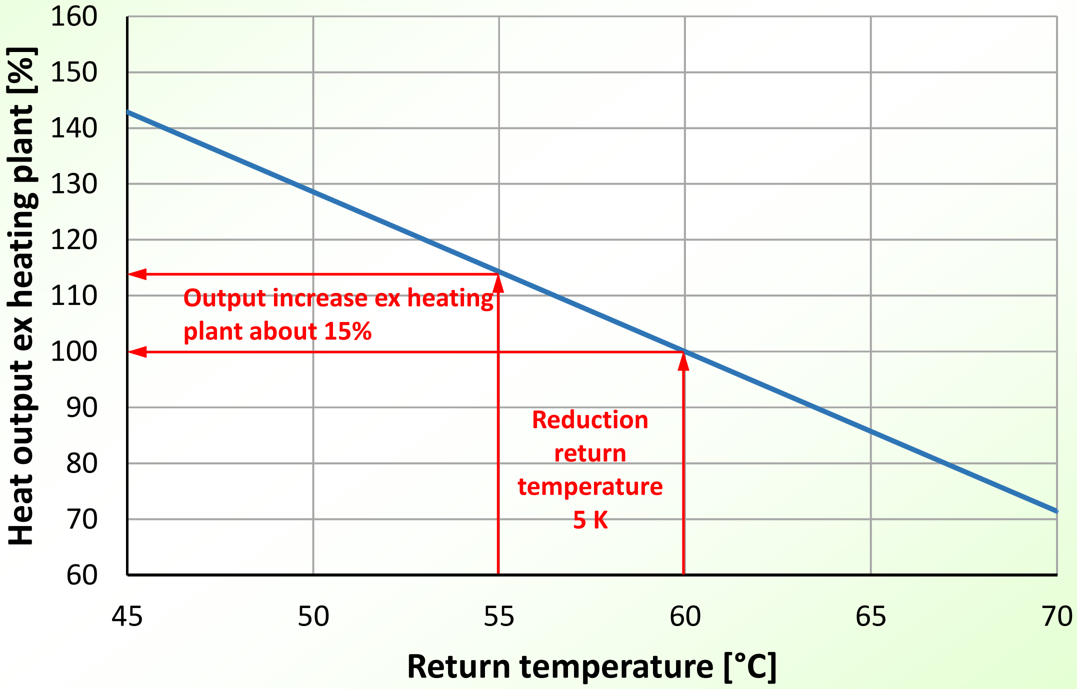
Influence of the return temperature on the heat output ex heating plant

Heat output ex heating plant versus return temperature



Assumption:

Constant feed temperature of 95°C, district heating network and pump capacity constant; a return temperature of 60°C is related to 100% heat output ex heating plant

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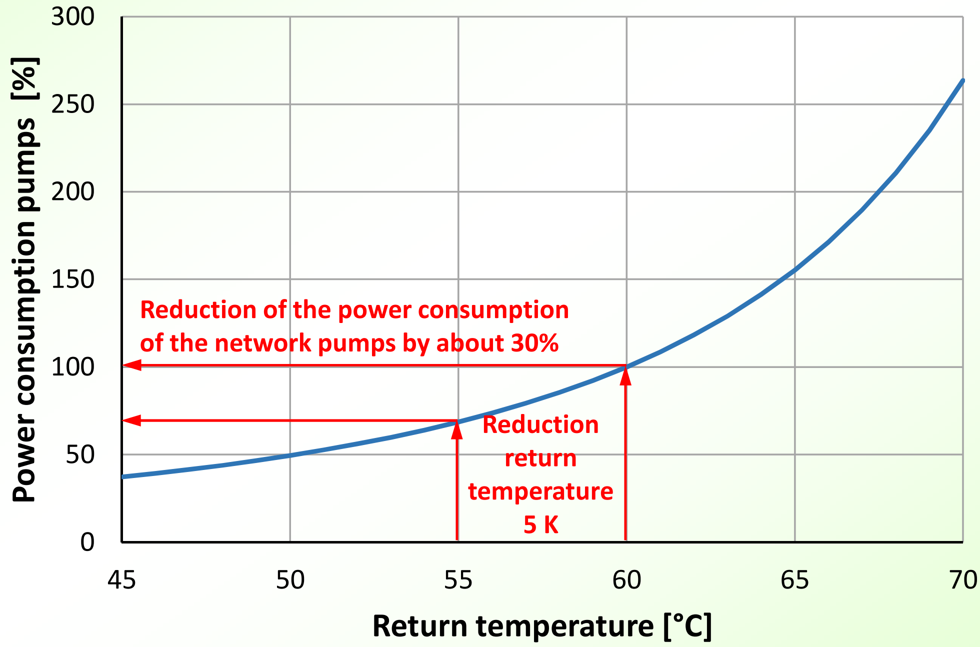
Influence of the return temperature on the power consumption of the network pumps

Power consumption of the network pumps versus return temperature



Assumption:

Constant feed temperature of 95°C, district heating network and thermal output constant; a return temperature of 60°C is related to 100% el. power

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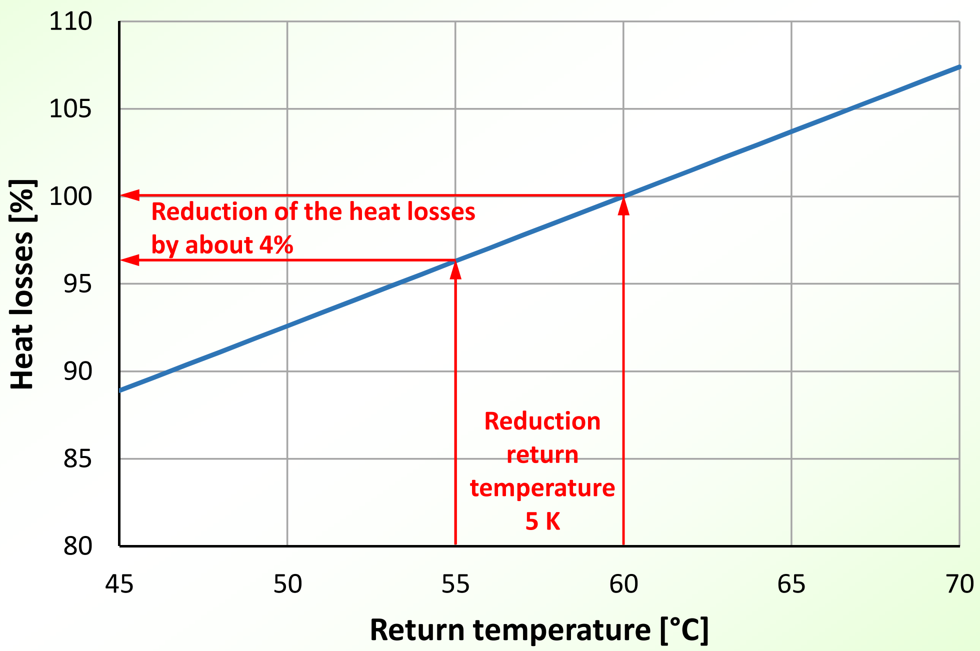
Influence of the return temperature on the heat losses of the district heating network

Heat losses of the district heating network versus return temperature



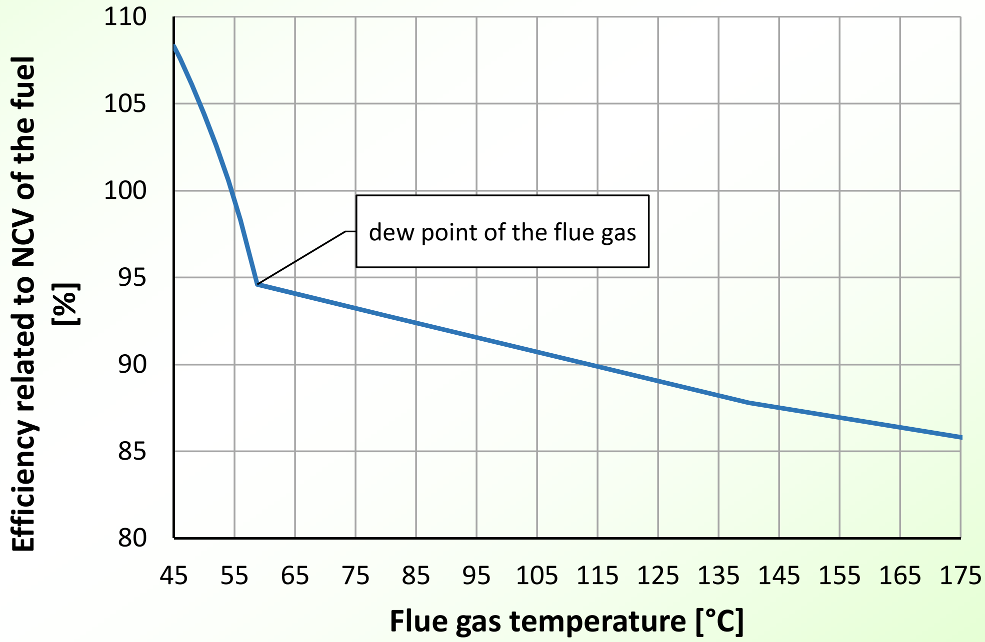
Assumption:

Constant feed temperature of 95°C, district heating network and thermal output constant; a return temperature of 60°C is related to 100% heat losses of the district heating network

Influence of the return temperature on the potential for heat recovery

Potential for heat recovery due to reduced return temperature

- Wirkungsgrad Feuerungsanlage in Abhängigkeit der Rauchgasaustrittstemperatur



Assumption:
Fuel moisture content 50 wt.% w.b., air ratio (lambda) 1.7, 500 m above sea level

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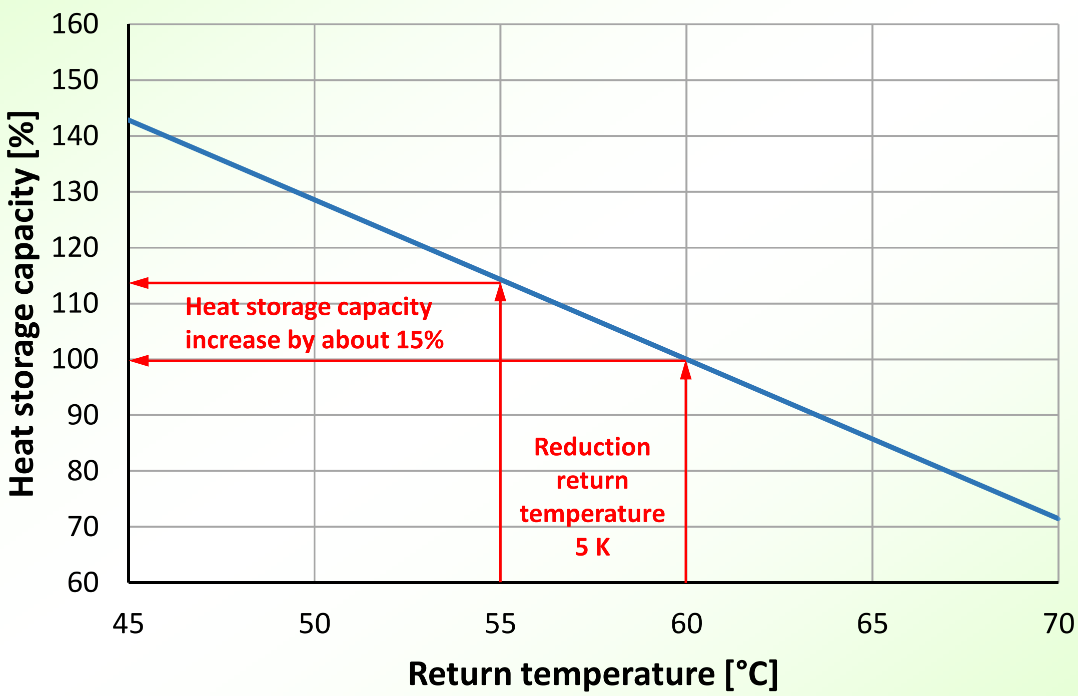
Influence of the return temperature on the heat storage capacity

Heat storage capacity versus return temperature



Assumption:
Constant feed temperature of 95°C, storage volume constant;
a return temperature of 60°C is related to 100% heat storage capacity

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Implementation of optimisation measures for secondary circuits (I)

- **Design / modification of heat supply contracts**
  - Define requirements regarding return temperatures
  - Define an incentive scheme for low return temperatures
  - Give instructions for planning and realisation of hydronic circuits
- **Systematic and periodic (e.g. annual) analysis and evaluation of all heat consumers → definition of heat consumers with the greatest optimisation potentials**
  - For large district heating networks with many heat consumers the use of the analysis and evaluation programmes developed can be of great advantage
  - For small district heating networks a "manual" evaluation by the use of the visualization system can be useful

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Implementation of optimisation measures for secondary circuits (II)

Cooperation with heat consumers – induce a win-win situation

- Equal treatment of all heat consumers should be intended
- E.g. analyses of the secondary systems could be offered for free, for complex systems hydronic engineers should be involved
- Many improvements can be realised at low costs (e.g. adjustments of the control system, avoidance of shortcut flows)
- Compliance of the requirements according to the heat supply contract should be controlled
- Possible funding schemes should be considered (in particular for major modifications)
- Consideration of energy efficiency laws (if applicable)

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Implementation of optimisation measures for secondary circuits (III)

- **Local installers should be trained regarding the correct installation of secondary hydronic systems for district heating networks**
  - Offer information material and informative meetings
  - Point out the specifications according to the heat supply contract
  - Point out the importance of low return temperatures for the district heating system
  - Point out measures to achieve low return temperatures (e.g. secondary feed temperature as low as possible, hydraulic balancing, avoidance of bypass flows, …)
- **Attention to buildings which have been equipped with thermal insulation**
  - Has the hydronic system been adapted to the reduced heat demand?
  - Significantly lower return temperatures should be achievable

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Summary of the most important findings

- **The realisation of optimisation measures to reduce the return temperature at heat consumer sites is an effective measure to increase the efficiency of the entire district heating system**
- **Secondary optimisation measures are able to:**
  - create additional potentials for the connection of new heat consumers
  - reduce the electricity consumption of the network pumps
  - reduce the heat losses of the district heating network
  - create better possibilities for heat recovery
  - increase the capacity of heat storage tanks and consequently reduce the operating time of the peak load boiler
- **The cooperation of operators of district heating networks with heat consumers, installers and hydronic engineers can lead to a win-win situation for all parties involved**

BIOS is able to support the realisation of optimisation measures for a return temperature reduction in all relevant phases.

BIOENERGIESYSTEME GmbH
Your partner for energy utilisation from biomass and energy efficiency
Research • Development • Engineering

Heat recovery + Improvement in efficiency

Honored by the government of Styria

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