Energy Audit Summary Report

AEE INTEC

Audit no. 46 – BUL07

Biodiesel Company

27th of February 2012

Supported by INTELLIGENT ENERGY EUROPE

This energy audit has been carried out with cofunding of the European Commission (EACI) in the Framework of the EU funded project EINSTEIN-II (ProjectNo. IEE/09/702/SI2.558239)

AUDIT no. 46 - BUL07

1. Data of the auditor

1.1. Contact data of the auditor

Matthäus Hubmann

Number of audits preformed: 17

Date of the audit: 15.02.2012

Duration of the audit: 4 weeks

AEE INTEC, Gleisdorf, Austria

2. Introduction

2.1. Objectives

The main objectives of this audit were to verify and check the potential energy savings.

3. Status Quo: processes, distribution, energy supply

The reference data and information are taken of the year 2010.

3.1. General information of the company

Sector	Biodiesel Production
Products	Biodiesel
No. of employees	120 employees

Current total primary electrical energy consumption is 25,413 [MWh/a]

3.2. Flow sheet of the whole manufacturing side

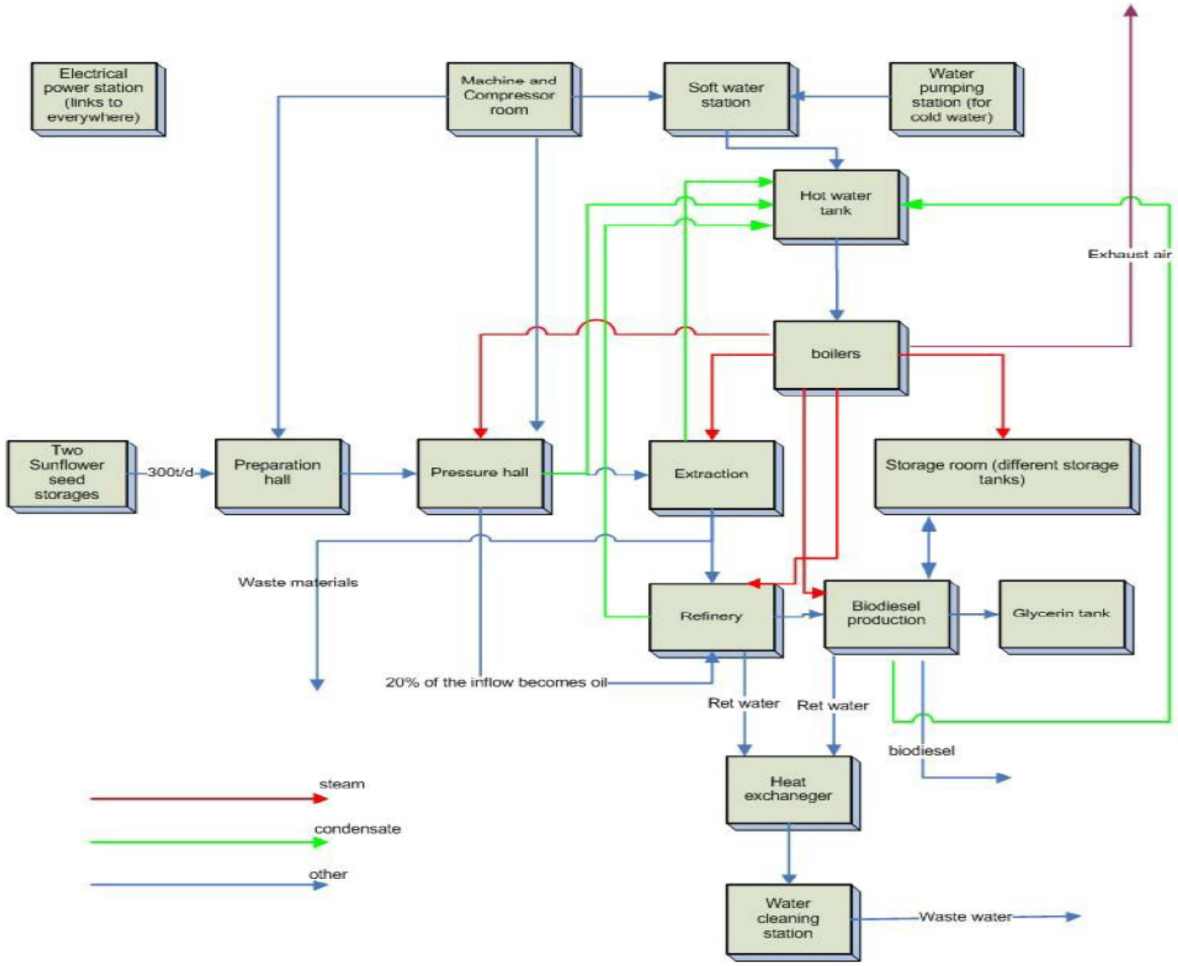

Figure 1: Flow sheet of the biodiesel production

3.3. Description of the existing system

- **Energy Supply:**

The dairy is mainly consuming energy for heating purposes during the production.

Table 1: Primary energy consumption (PEC) and primary energy consumption for thermal use (PET)

Energy type (fuels / electricity)	PEC		PET	
	[MWh]	[% of Total]	[MWh]	[% of Total]
Total fuels	14,161	55.72	14,161	93.61
Total electricity	11,252	44.28	966	6.39
Total (fuels + electricity)	**25,413**	**100.00**	**15,127**	**100.00**

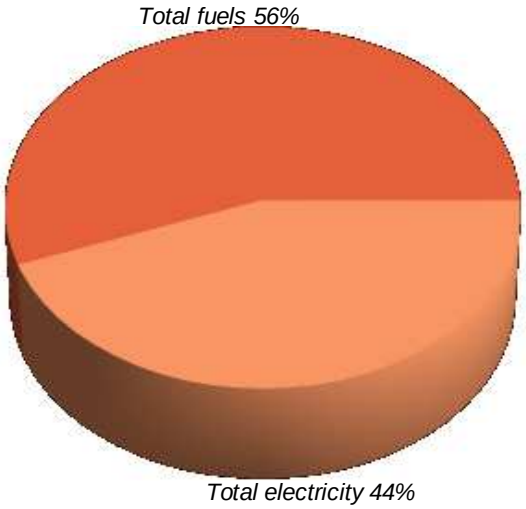

Figure 2: distribution of PEC by fuel type

Table 2: Final energy consumption (FEC) and Final energy consumption for thermal use (FET)

Fuel type	FEC		FET	
	[MWh]	[% of Total]	[MWh]	[% of Total]
sunflower seed shell	28,322	88.31	28,322	98.88
Electricity	3,751	11.69	322	1.12
Total	32,072	100.00	28,644	100.00

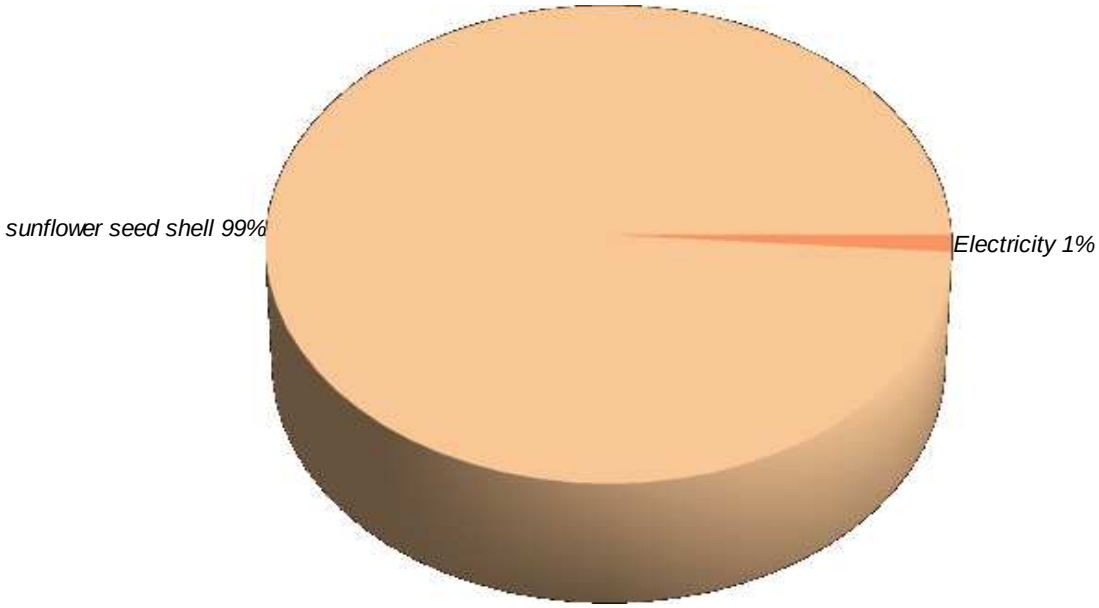

Figure 3: Total final energy consumption for thermal use (FET)

Table 3: Final energy consumption for thermal use (FET) by equipment

Equipment	Fuel type	FET by equipment	
		[MWh]	[% of Total]
small boiler	sunflower seed shell	9,435	32.94
big boiler	sunflower seed shell	18,886	65.93
heat pump 1	Electricity	124	0.43
heat pump 2	Electricity	99	0.35
heat pump 3	Electricity	99	0.35
Total		**28,644**	**100.00**

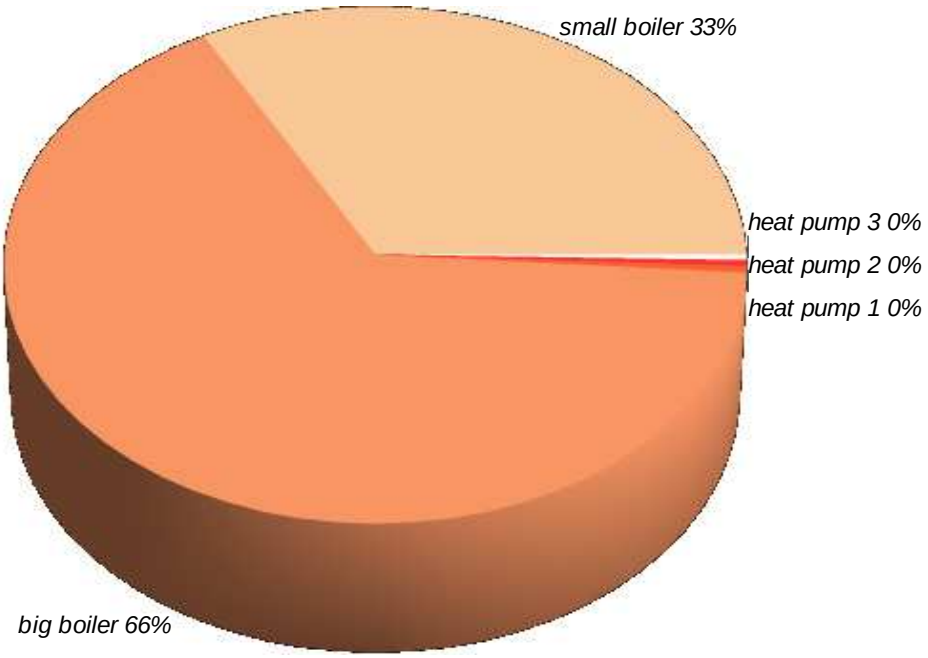

Figure 4: Final energy consumption for thermal use (FET) by equipment

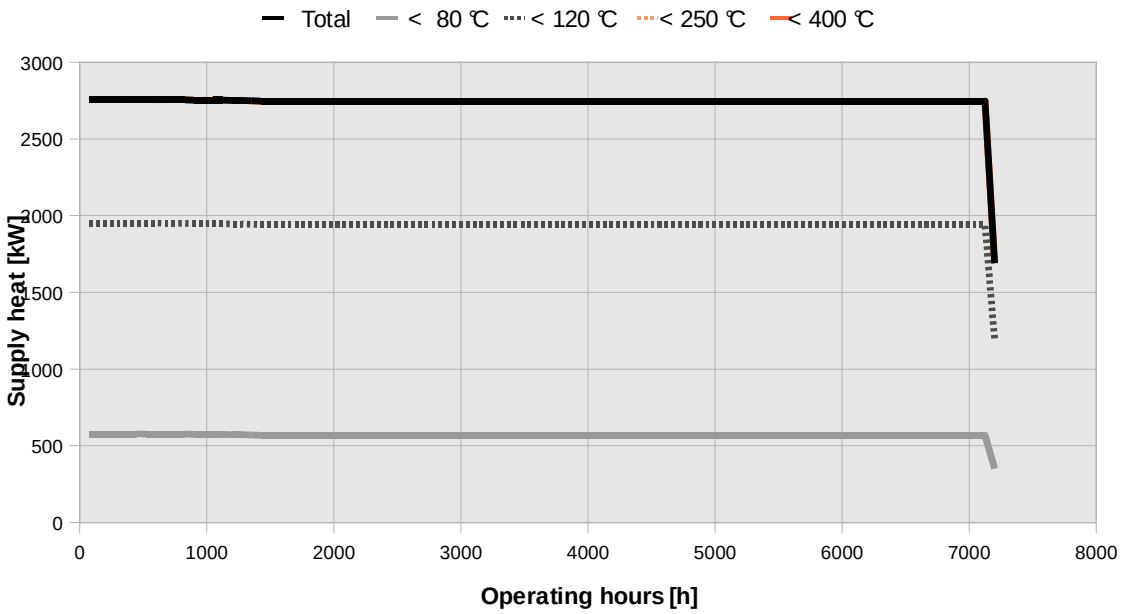

Figure 5: Distribution of supply heat by temperature levels and annual operating hours. Present state.

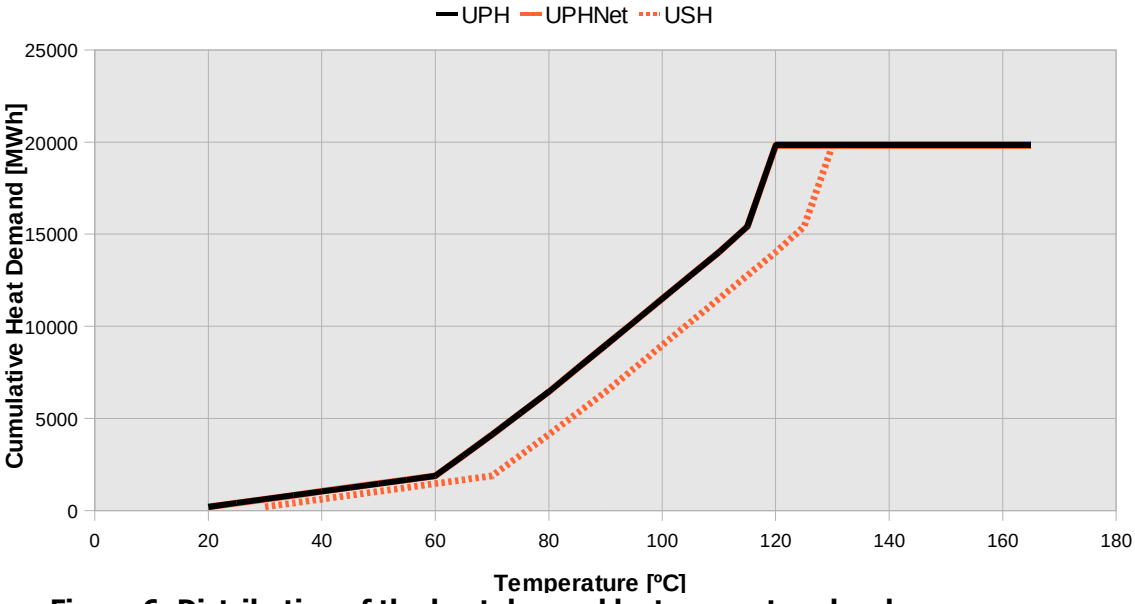

Figure 6: Distribution of the heat demand by temperature levels

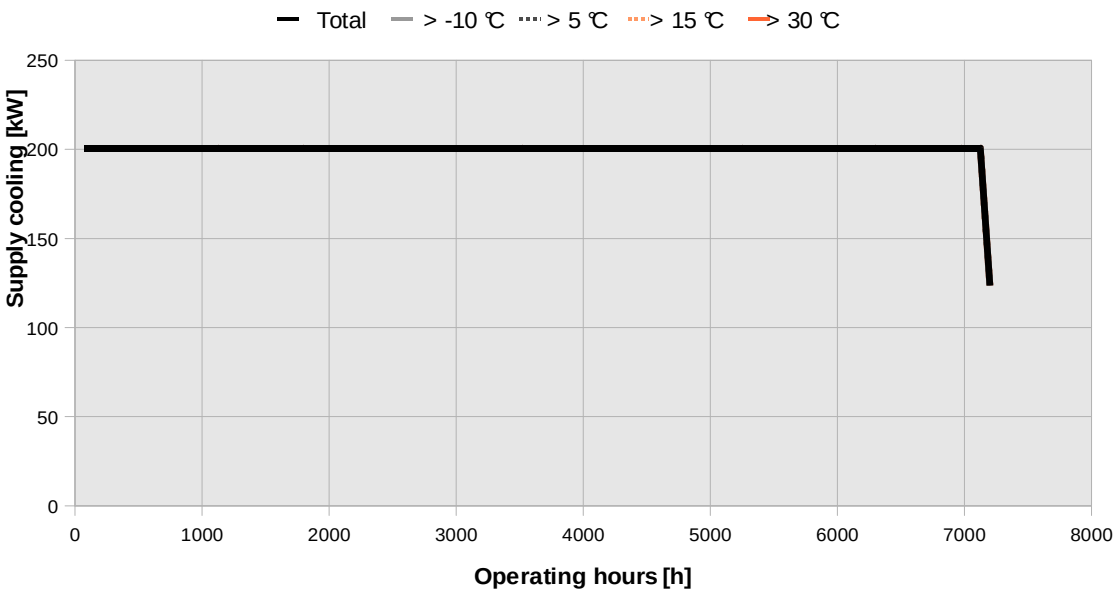

Figure 7: Distribution of supply cooling by temperature levels and annual operating hours. Present state.

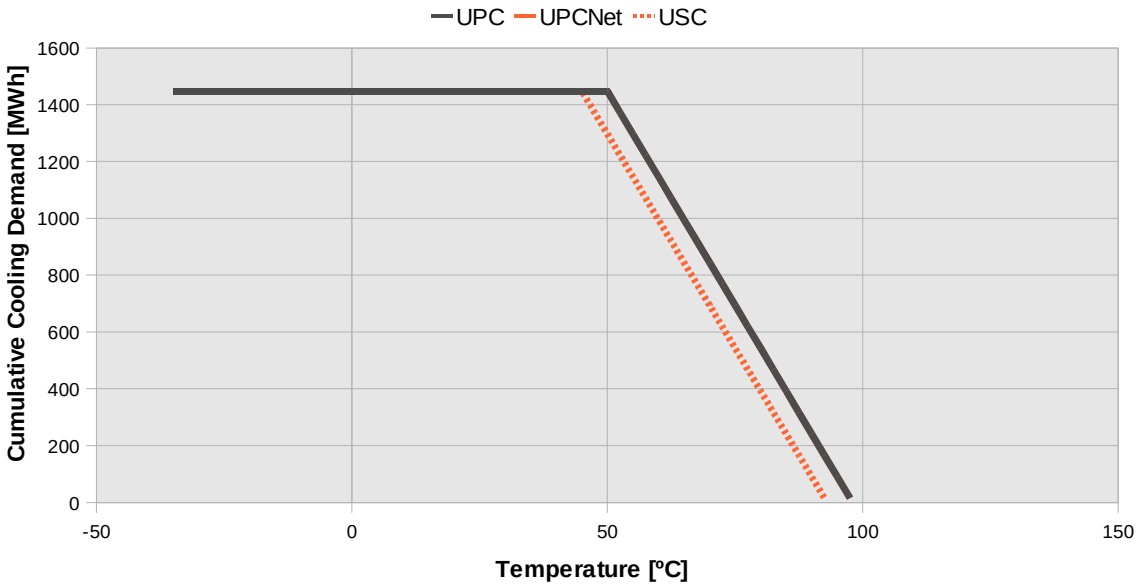

Figure 8: Distribution of the cooling demand by temperature levels

Table 4: Useful supply heat (USH) by equipment. Present state.

Equipment	USH by equipment	
	[MWh]	[% of Total]
small boiler	6,605	33.32
big boiler	13,218	66.68
Total	**19,822**	**100.00**

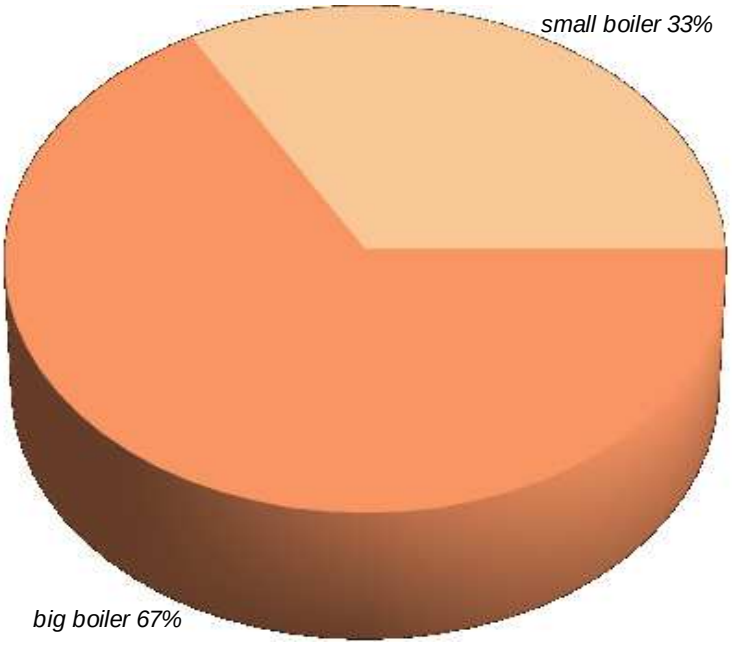

Figure 9: Useful supply heat (USH) by equipment. Present state

Table 5: Useful supply cooling (USC) by equipment. Present state.

Equipment	USC by equipment	
	[MWh]	[% of Total]
heat pump 1	542	37.42
heat pump 2	453	31.29
heat pump 3	453	31.29
Total	**1,448**	**100.00**

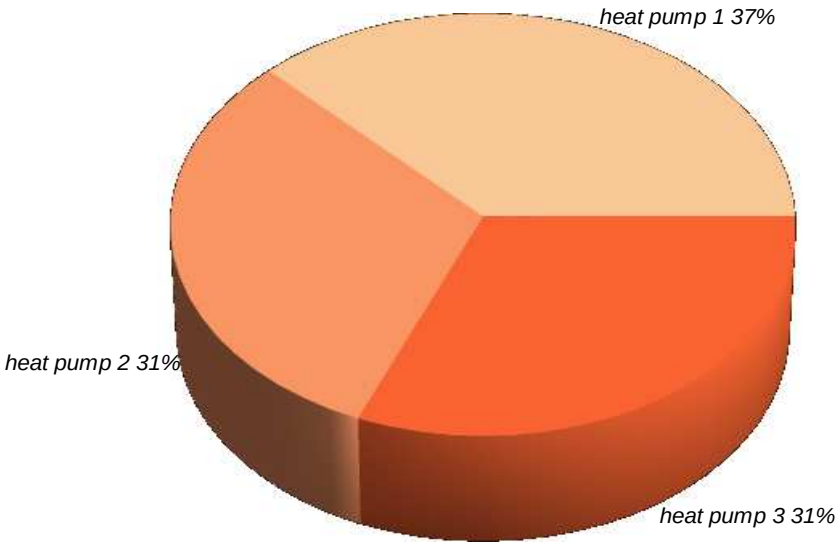

Figure 10: Useful supply cooling (USC) by equipment. Present state.

Table 6: Useful process heat demand (UPH) by process. Present state.

Process	Total	Circulation	Maintenance	Start-up
	[MWh]	[MWh]	[MWh]	[MWh]
pressure hall	6,382	5,662	720	0
extraction	3,705	2,985	720	0
refinery	5,602	4,882	720	0
biodiesel production	4,122	3,402	720	0
building_heating	10	0	10	0
Total	**19,821**			

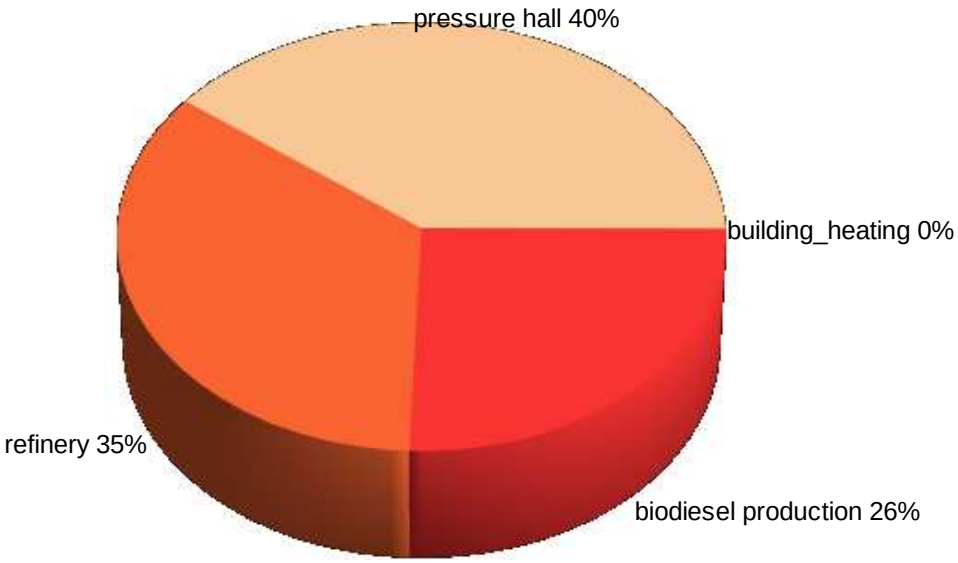

Figure 11: Useful process heat (UPH) by process

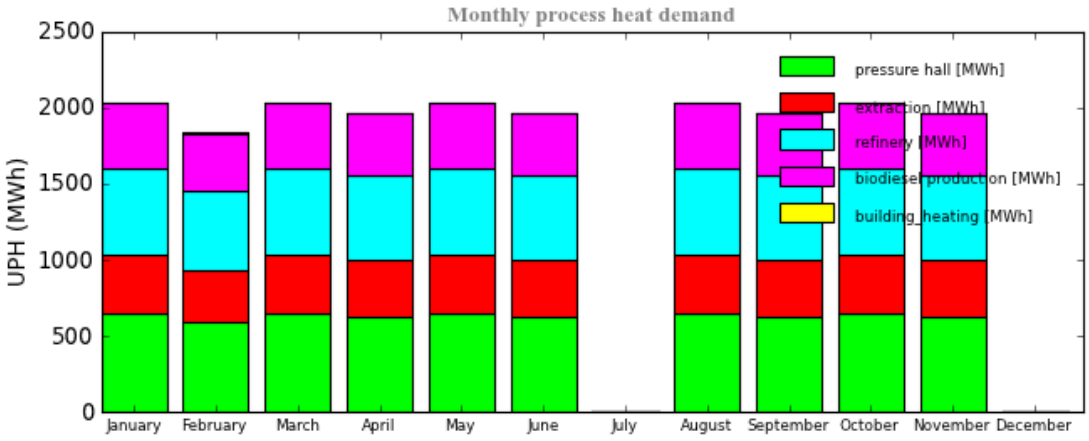

Figure 12: Distribution of useful process heat demand per month

Table 7: Useful process cooling demand (UPC) by process. Present state.

Process	Total	Circulation	Maintenance	Start-up
	[MWh]	[MWh]	[MWh]	[MWh]
refinery	724	724	0	0
biodiesel production	724	724	0	0
Total	**1,448**			

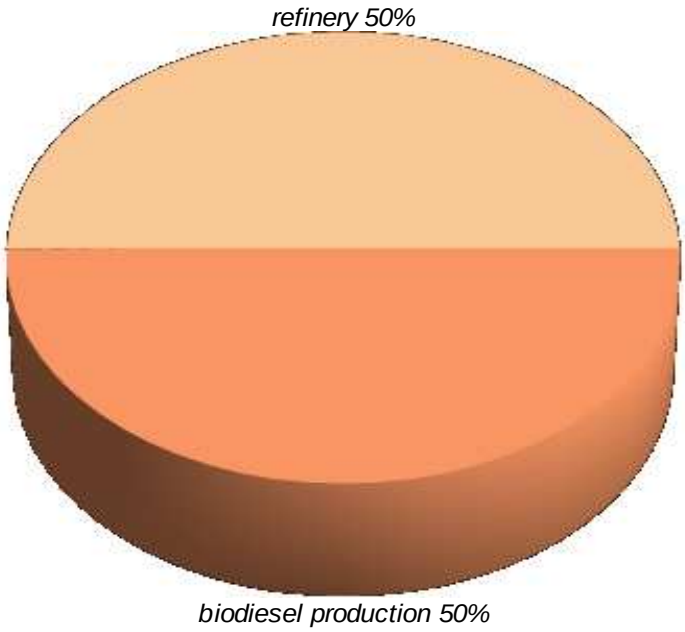

Figure 13: Useful process cooling (UPC) by process

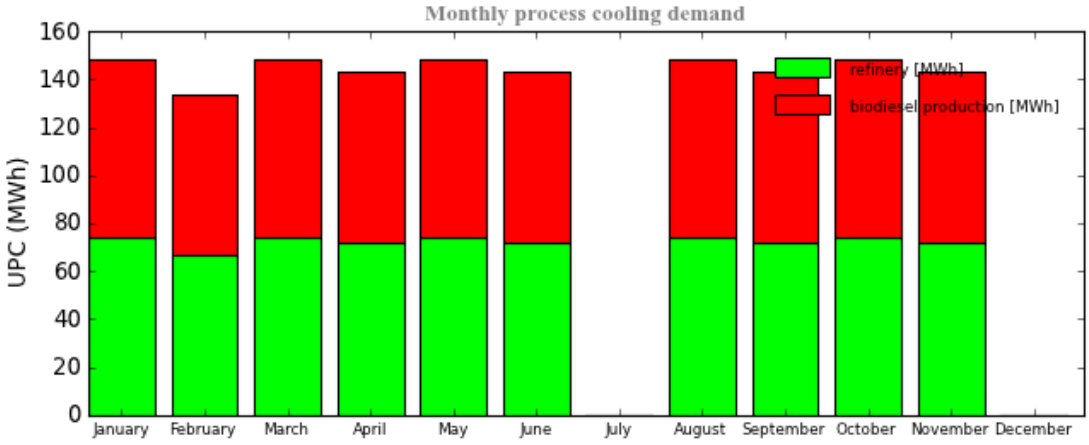

Figure 14: Distribution of useful process cooling demand per month

3.4. General

- The target room temperature during winter is 22 °C for the production hall.

4. Comparative study

4.1. Proposed alternatives

There are five proposals made in this study. In the first one five new heat exchangers are implemented into the existing system. In the second proposal a CHP (combined heat and power) system is installed additionally to the heat exchangers. The third proposal focuses on the installation of a new CHP (combined heat and power plant) without the heat exchangers. The fourth and fifth proposal "New HX mod. + steam boiler" and "New steam boiler" take a closer look at the additional installation of a new boiler with or without the heat exchangers.

Table 8: Overview of the alternative proposals studied

Short Name	Description
New HX mod.	based on present state five new heat exchangers are proposed
New HX mod. + CHP (ORC)	based on present state five new heat exchangers and additionally a CHP (combined heat and power) plant are proposed
CHP (ORC)	based on present state a CHP (combined heat and power) plant is proposed
New HX mod. + steam boiler	based on present state five new heat exchangers and additionally a new steam boiler are proposed
New steam boiler	based on present state a new steam boiler is proposed

4.1.1. Heat Supply

- **New Modified Heat Exchangers: "**New HX mod."

In Table 9 the proposed heat exchangers are listed. The heat exchangers use the waste heat of the "refinery", "biodiesel production", "pressure hall" and the "compressor" as heat sources and the following streams as heat sinks: "extraction", "pressure hall", "refinery", "biodiesel production" and "building heating". By installing these five heat exchangers up to 2,578 MWh of energy can be recovered. The heat exchanger network was based on a simple schedule and has to be adapted if the production times differ.

Table 9: Heat exchangers and amount of recovered energy

Heat Exchanger	Power	Heat Source	Heat Sink	Amount of recovered energy	
	[kW]			[MWh]	[%]
HX_AbovePinch_1	160	refinery	extraction	1,155	44.80
HX_AbovePinch_2	152	biodiesel production	pressure hall	1,093	42.40
HX_AbovePinch_4	43	pressure hall	refinery	313	12.16
HX_AbovePinch_7	2	pressure hall	biodiesel production	14	0.56
HX_AbovePinch_8	2	compressor2	building_heating	2	0.08
	359			**2,577.83**	**100**

Table 10: Heat and cooling supply equipment and contribution to total heat and cooling supply

Equipment	Nominal capacity	Contribution to total heat and cooling supply	
	[kW]	[MWh]	[%]
small boiler	3,230	14,669	100.00
big boiler	6,460	0	0.00
heat pump 1	91	660	45.58
heat pump 2	69	497	34.34
heat pump 3	69	291	20.07
Total	**9,919**	**16,117**	**200**

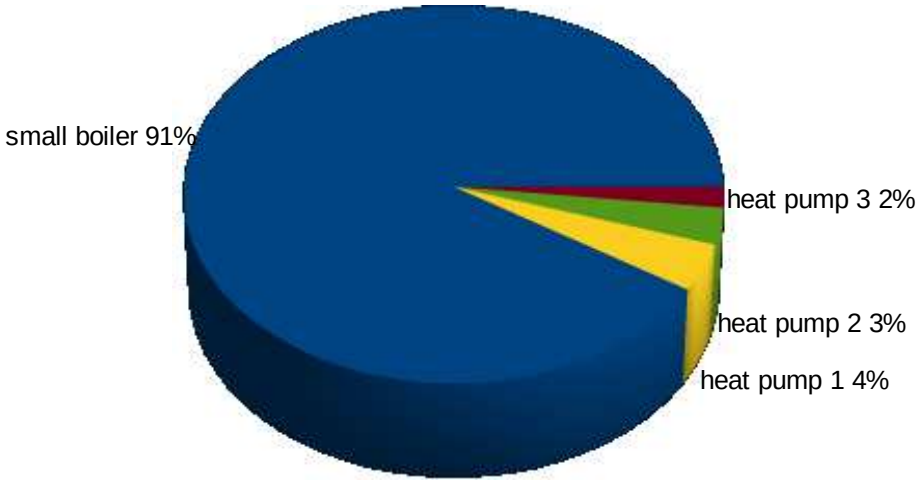

Figure 15: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).

- graphic: heat demand covered by boiler:

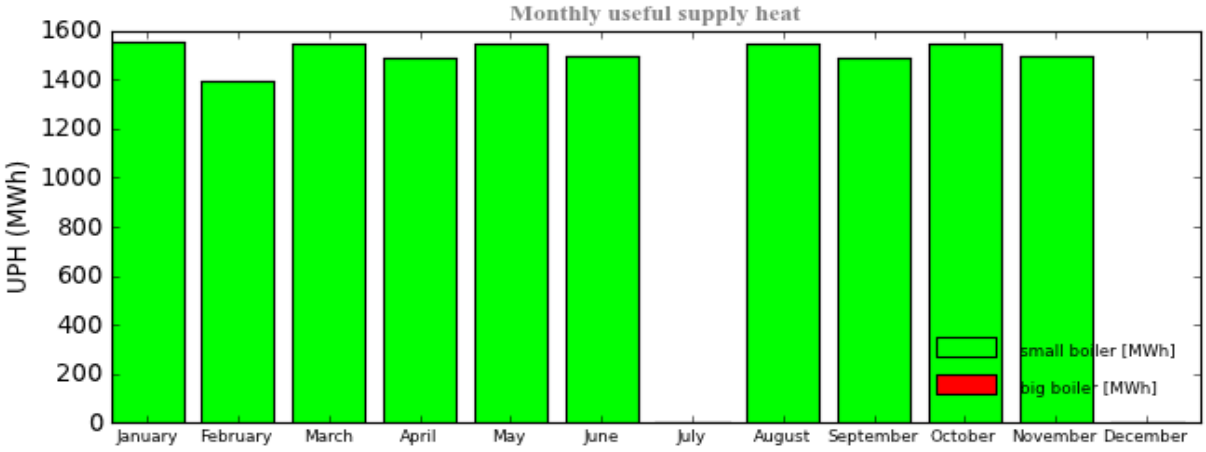

Figure 16: Distribution of useful process heat supply per month

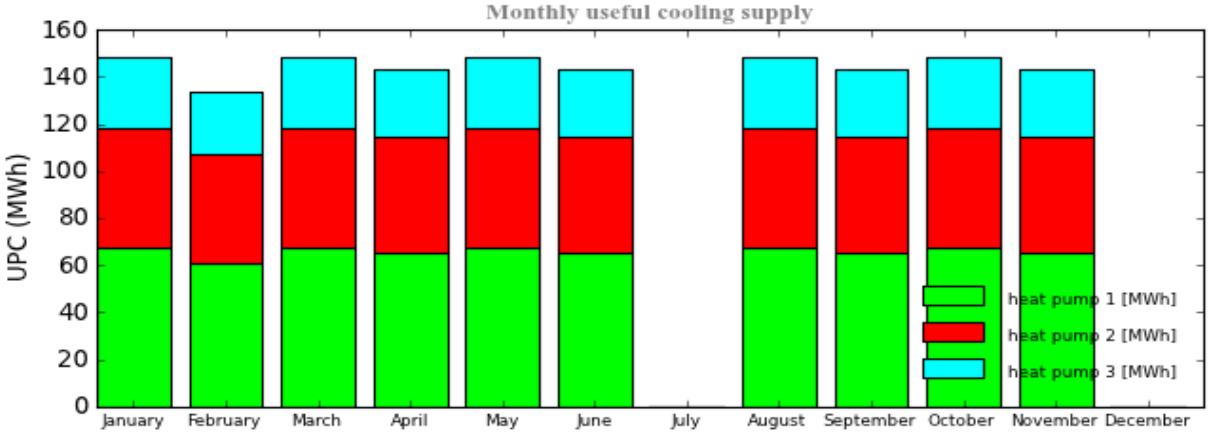

Figure 17: Distribution of useful cooling supply per month

- **New Modified HX + CHP (ORC):** "New HX mod. + CHP (ORC)"

Type	CHP engine
Nominal thermal power	500 kW
Nominal electrical power	161 kW
Thermal efficiency	0.62
Electrical efficiency	0.20
Operating hours	7,278 h

Table 11: Heat and cooling supply equipment and contribution to total heat and cooling supply

Equipment	Nominal capacity	Contribution to total heat and cooling supply	
	[kW]	[MWh]	[%]
New CHP 3	500	3,568	24.32
small boiler	3,230	11,101	75.68
big boiler	6,460	0	0.00
heat pump 1	91	660	45.58
heat pump 2	69	497	34.34
heat pump 3	69	291	20.07
Total	**10,419**	**16,117**	**200**

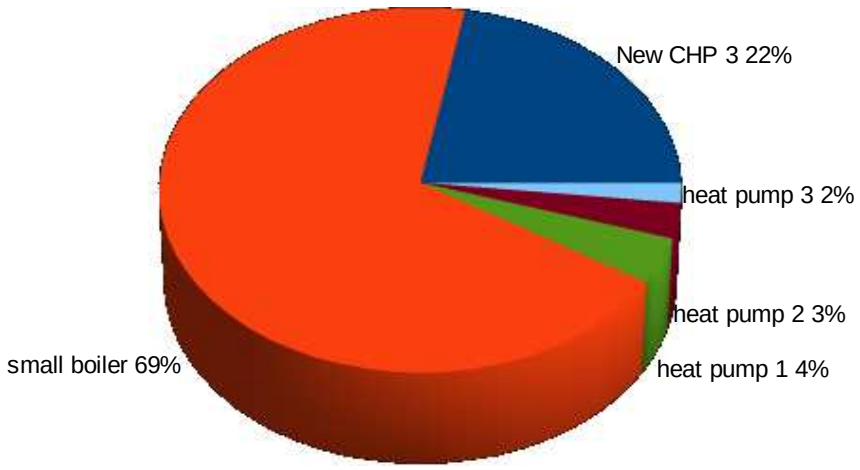

Figure 18: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).

- graphic: heat demand covered by CHP system:

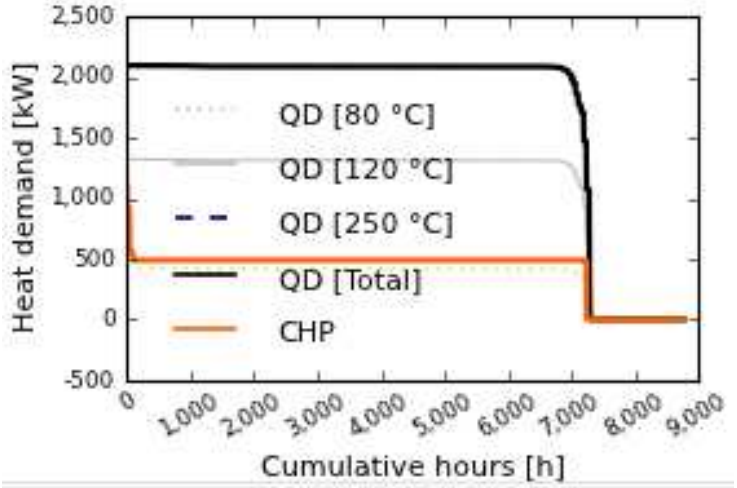

Figure 19: Heat demand and CHP contribution

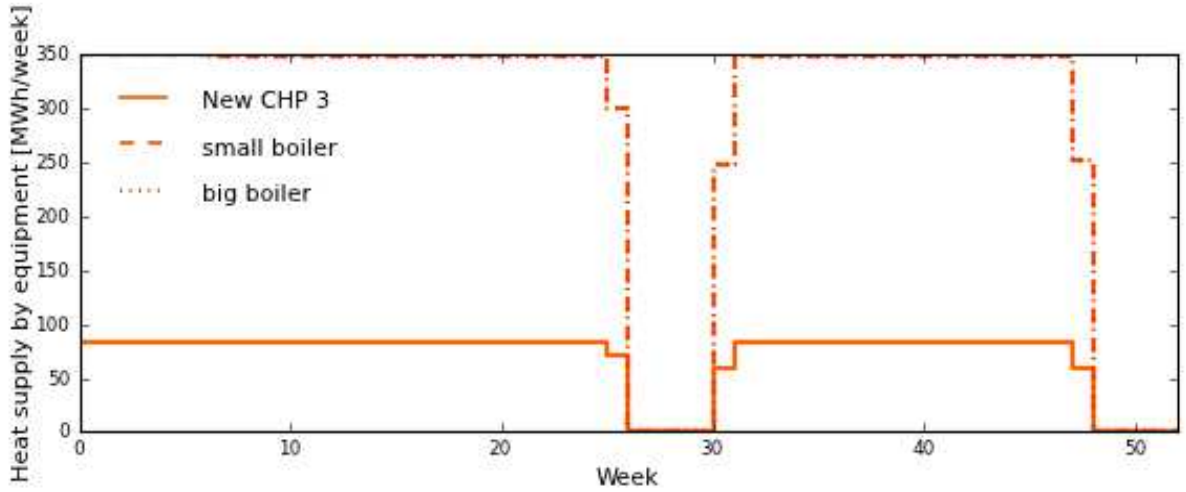

Figure 20: Daily heat supply by equipment

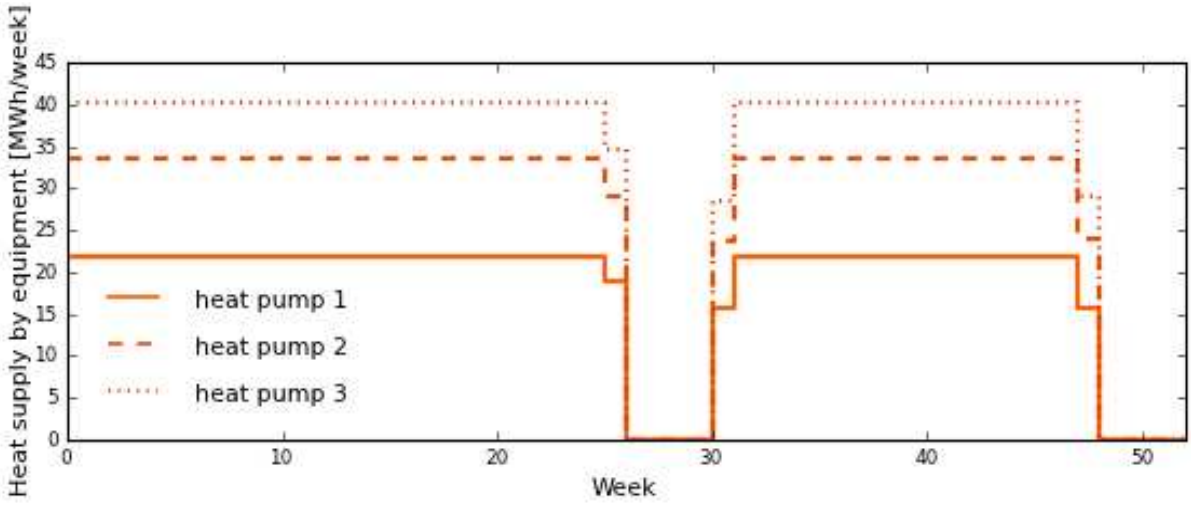

Figure 21: Daily cold supply by equipment

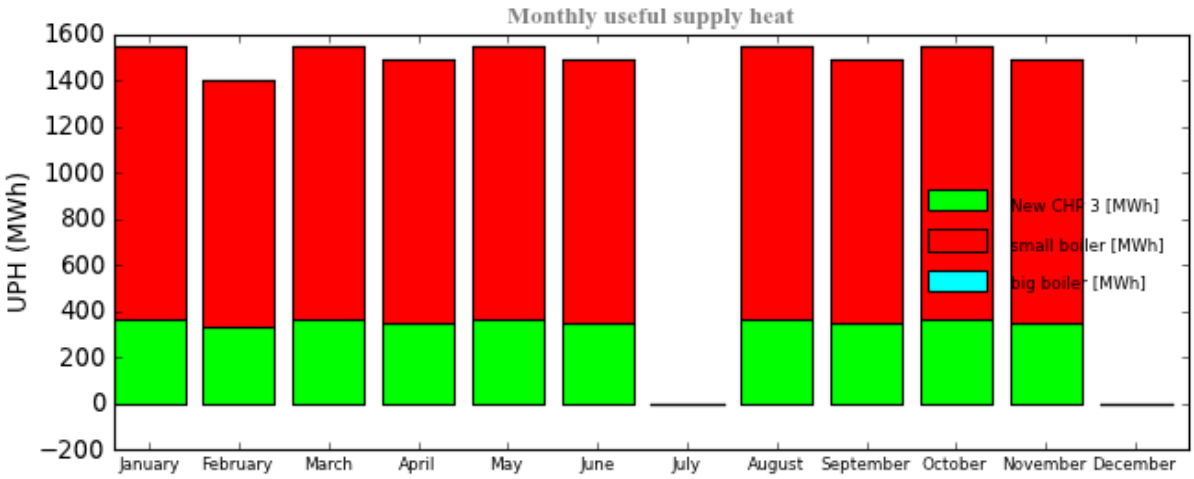

Figure 22: Distribution of useful process heat supply per month

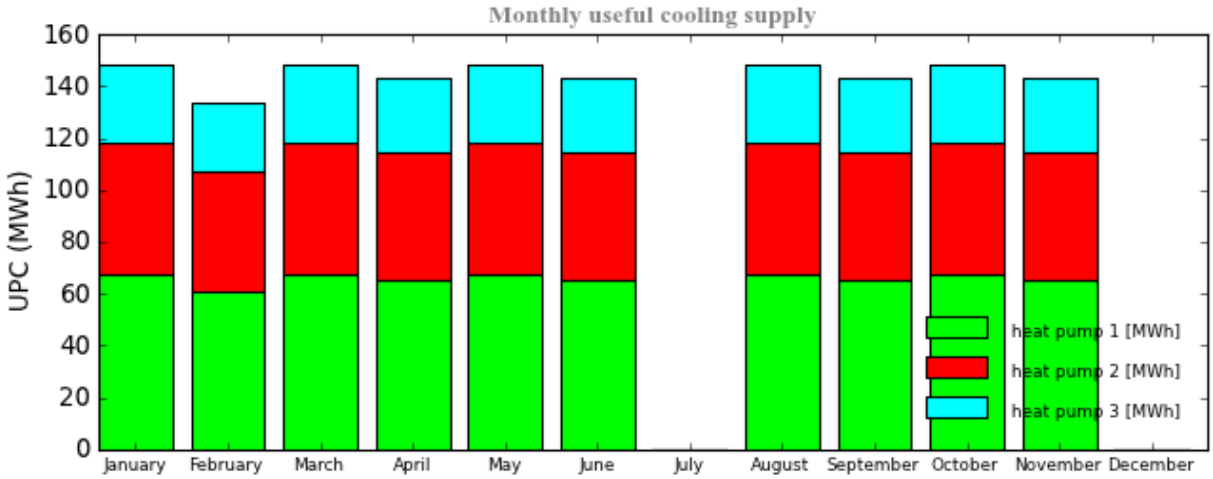

Figure 23: Distribution of useful cooling supply per month

- **CHP (ORC):**

Type	CHP engine
Nominal thermal power	700 kW
Nominal electrical power	226 kW
Thermal efficiency	0.62
Electrical efficiency	0.20
Operating hours	7,278 h

Table 12: Heat and cooling supply equipment and contribution to total heat and cooling supply

Equipment	Nominal capacity	Contribution to total heat and cooling supply	
	[kW]	[MWh]	[%]
New CHP 1	700	4,995	25.20
small boiler	3,230	14,825	74.80
big boiler	6,460	0	0.00
heat pump 1	91	660	45.58
heat pump 2	69	497	34.34
heat pump 3	69	291	20.07
Total	**10,619**	**21,269**	**200**

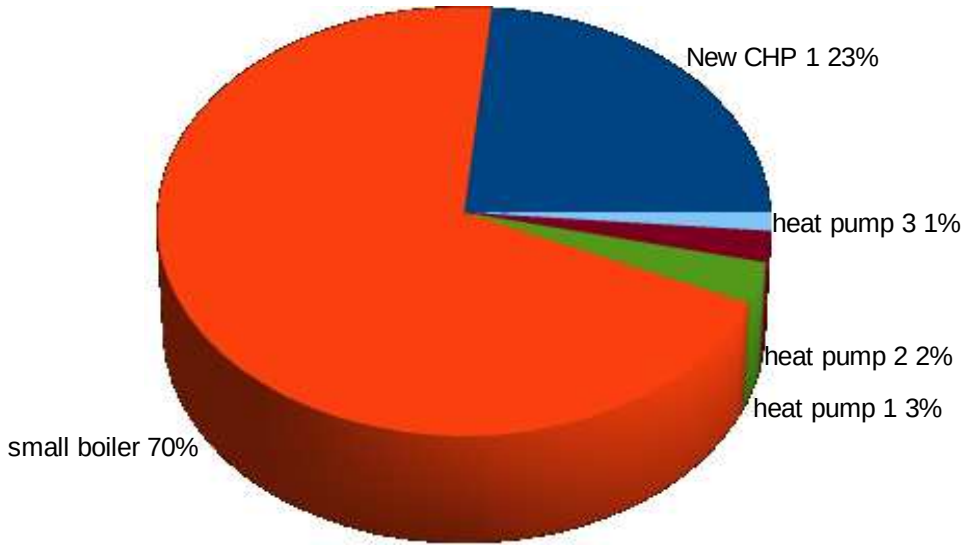

Figure 24: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).

- graphic: heat demand covered by CHP:

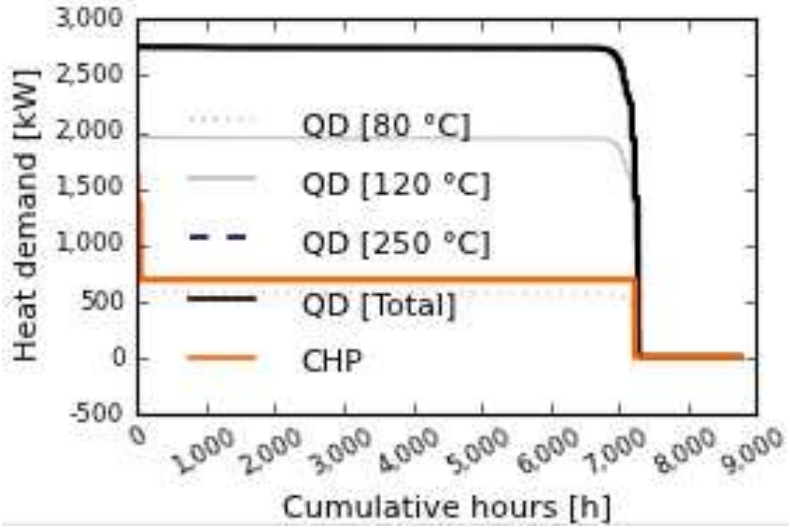

Figure 25: Cumulative heat supply to be covered by CHP

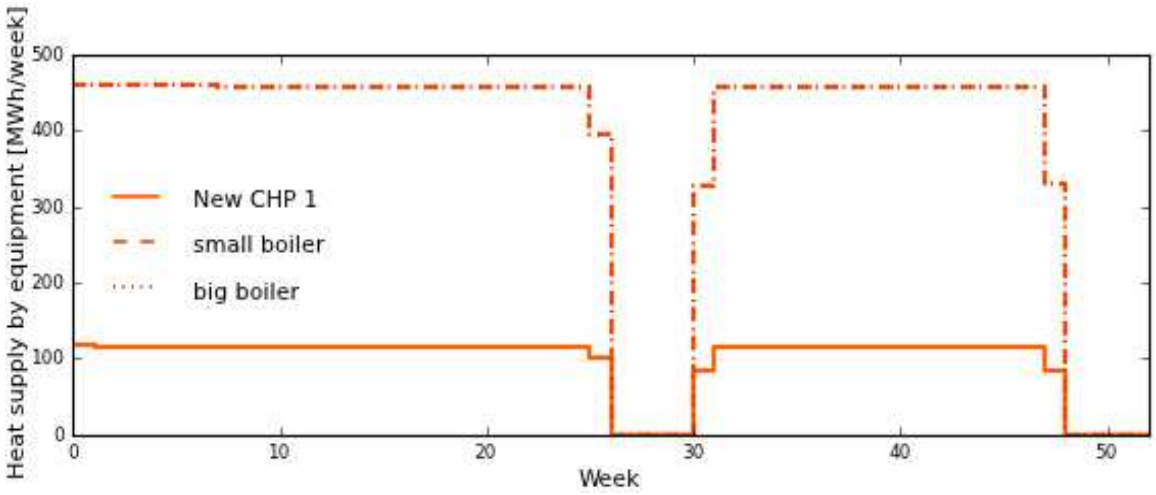

Figure 26: Daily heat supply by equipment

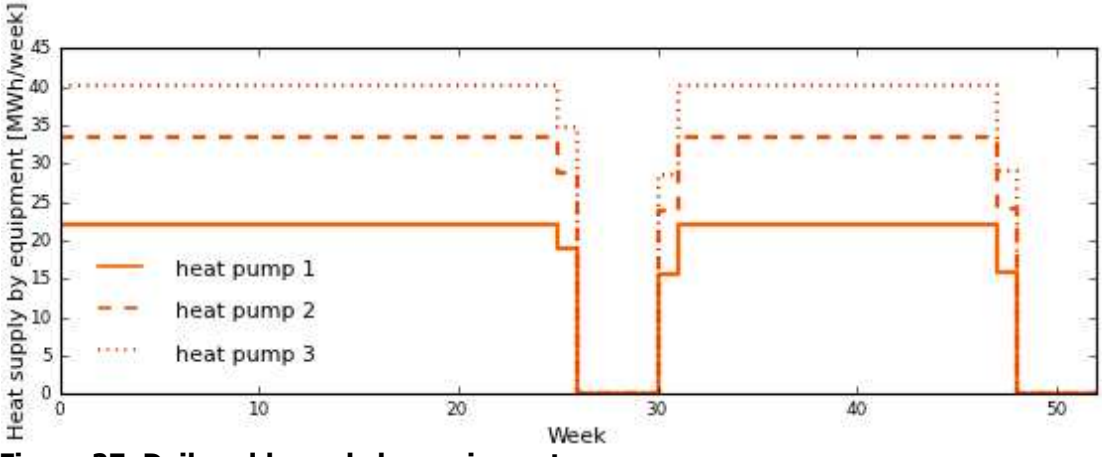

Figure 27: Daily cold supply by equipment

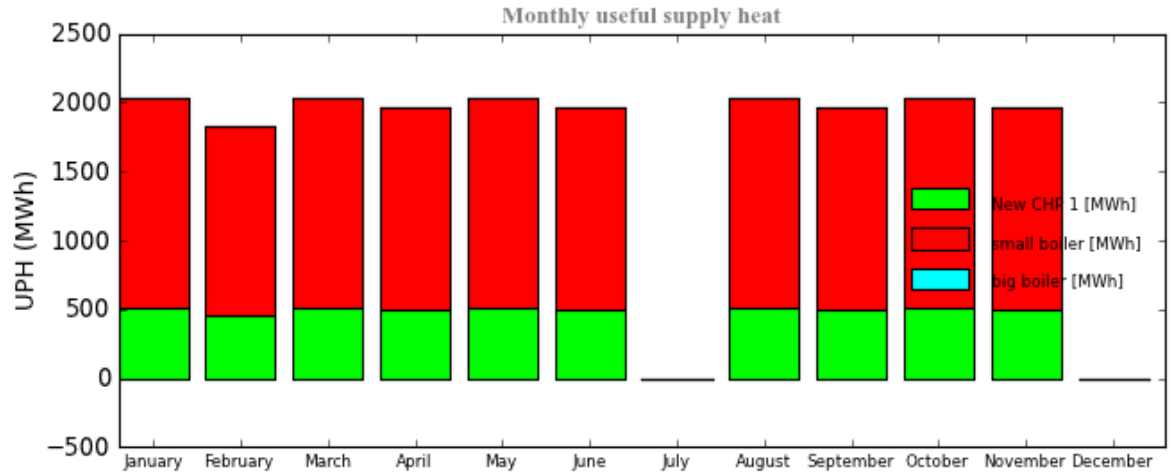

Figure 28: Distribution of useful process heat supply per month

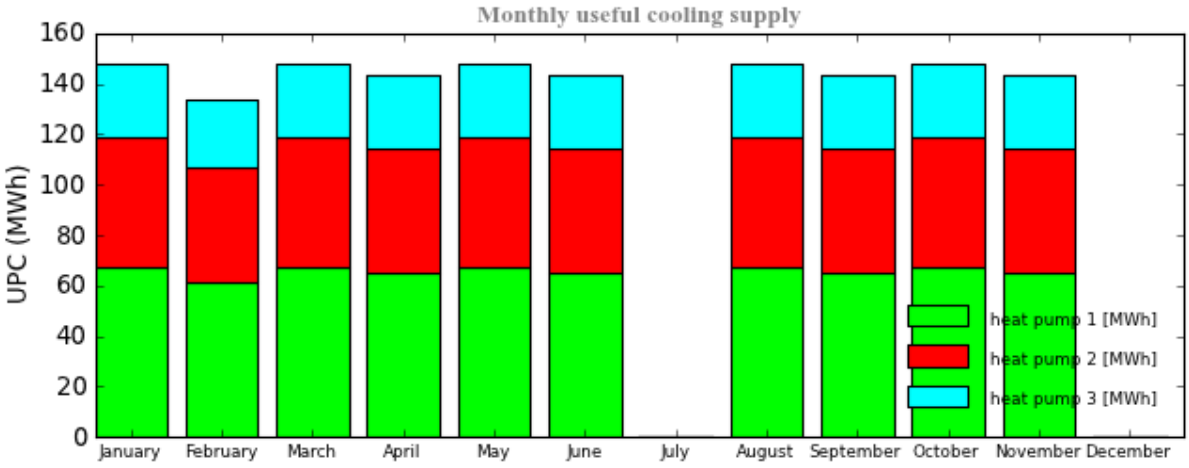

Figure 29: Distribution of useful process cooling supply per month

- **New Modified HX + Steam Boiler: "**New HX mod. + steam boiler**"**

Type of boiler	steam boiler
Nominal power	2791 kW
Thermal efficiency	0.91
Operating hours	7,238 h

Table 13: Heat and cooling supply equipment and contribution to total heat and cooling supply

Equipment	Nominal capacity	Contribution to total heat and cooling supply	
	[kW]	[MWh]	[%]
New boiler 1	2,791	14,669	100.00
small boiler	3,230	0	0.00
big boiler	6,460	0	0.00
heat pump 1	91	660	45.58
heat pump 2	69	497	34.34
heat pump 3	69	291	20.07
Total	**12,710**	**16,117**	**200**

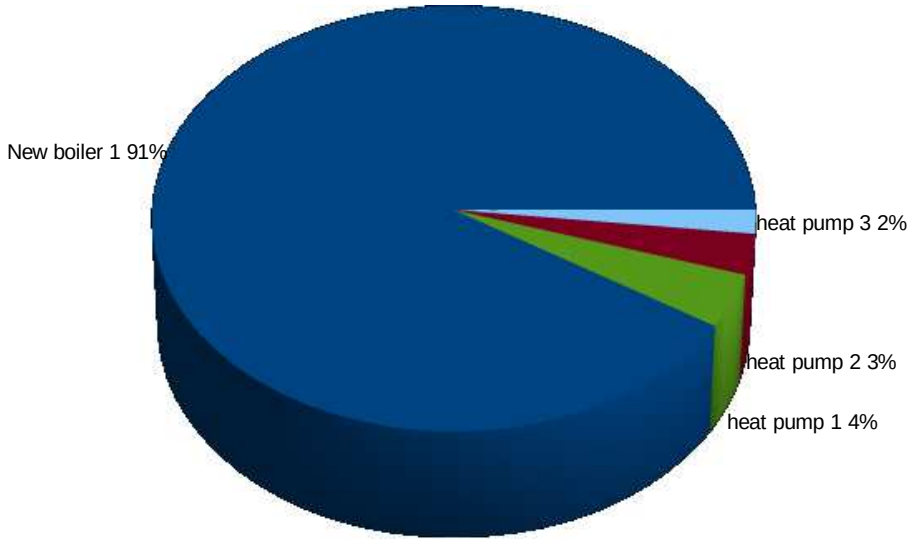

Figure 30: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).

- graphic: heat demand covered by boilers

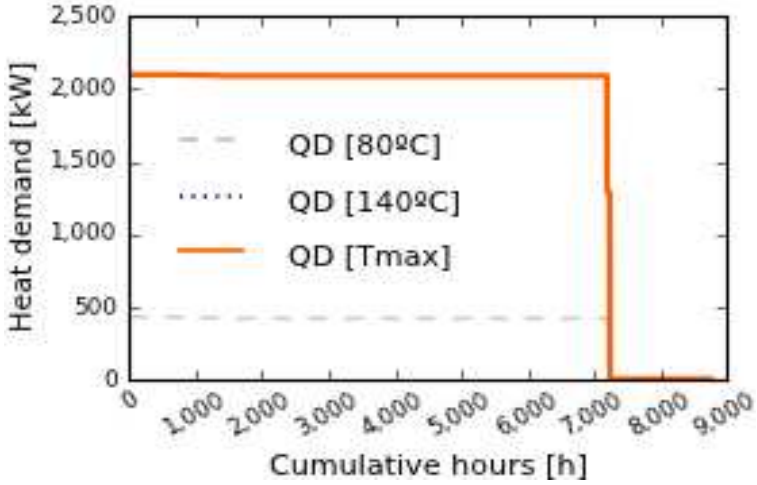

Figure 31: Cumulative heat demand to be covered by boilers

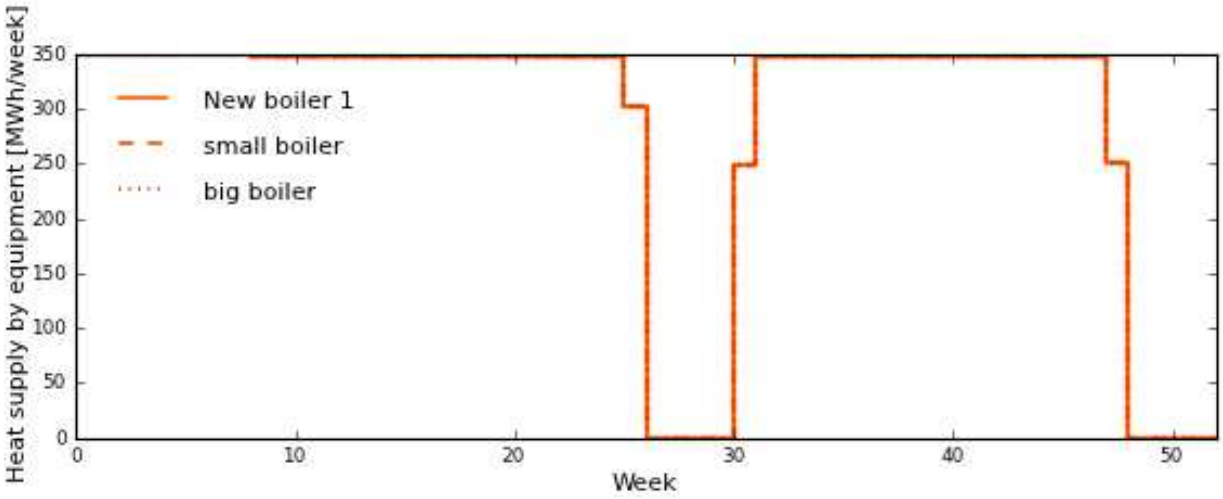

Figure 32: Daily heat supply by equipment

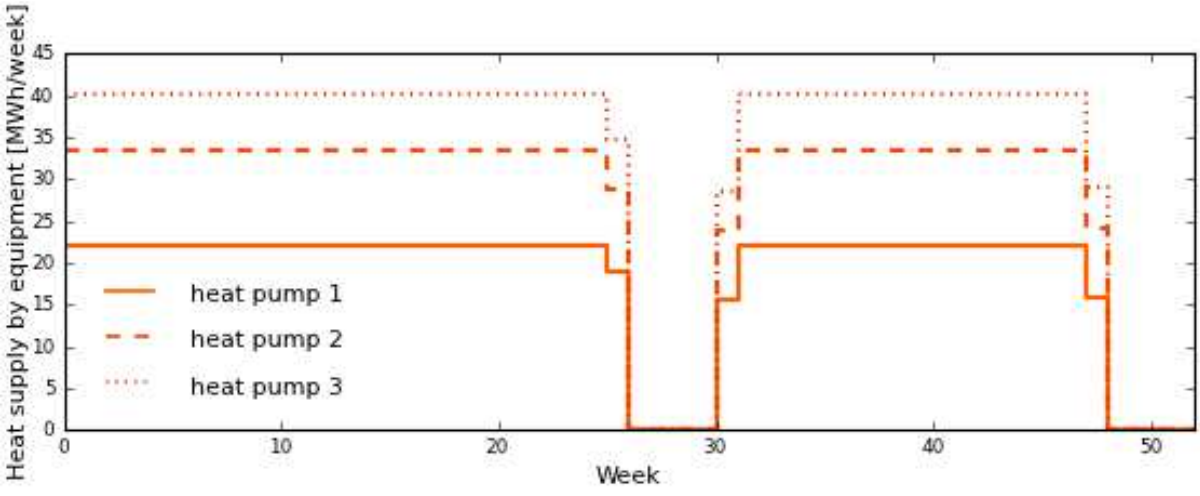

Figure 33: Daily cold supply by equipment

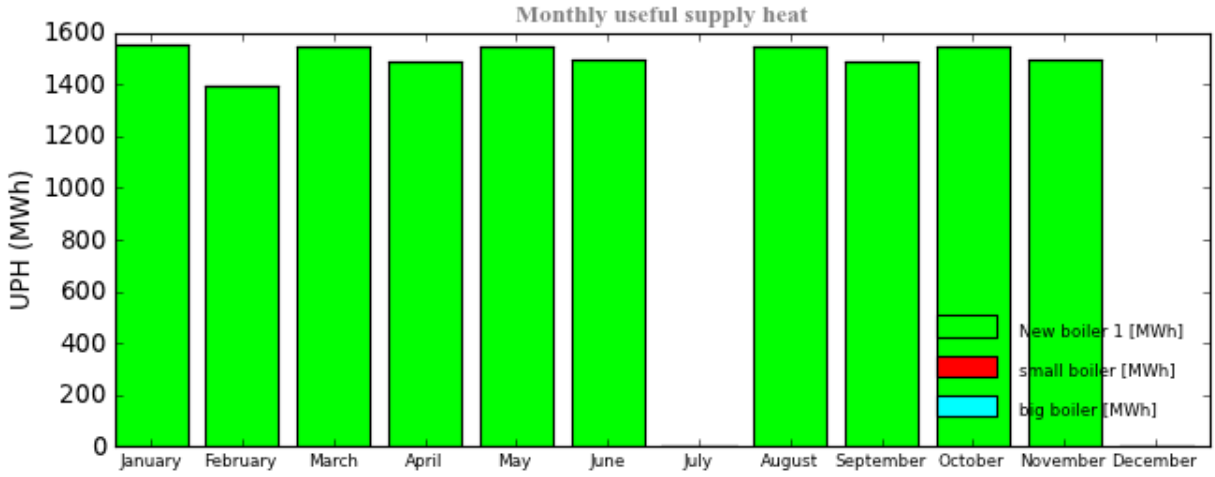

Figure 34: Distribution of useful process heat supply per month

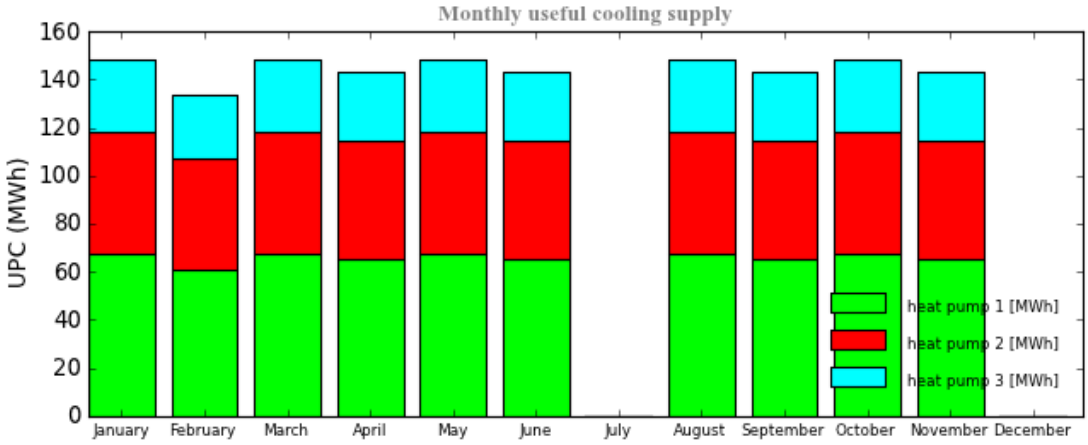

Figure 35: Distribution of useful process cooling supply per month

- **New Steam Boiler:**

Type of boiler	steam boiler
Nominal power	3418 kW
Thermal efficiency	0.89
Operating hours	7,238 h

Table 14: Heat and cooling supply equipment and contribution to total heat and cooling supply

Equipment	Nominal capacity	Contribution to total heat and cooling supply	
	[kW]	[MWh]	[%]
heat pump 1	91	660	45.58
heat pump 2	69	497	34.34
heat pump 3	69	291	20.07
New boiler 4	3,418	19,821	100.00
Total	**3,647**	**21,269**	**200**

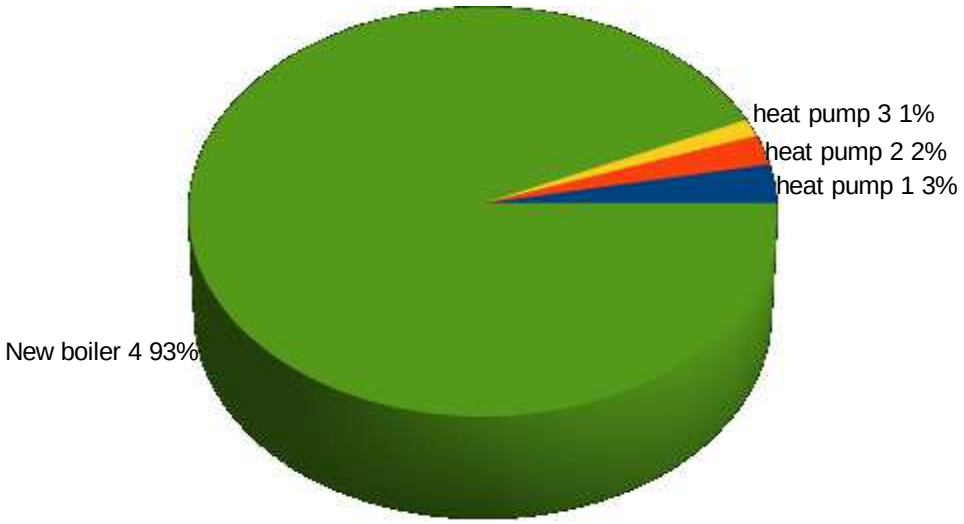

Figure 36: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).

- graphic: heat demand covered by boiler

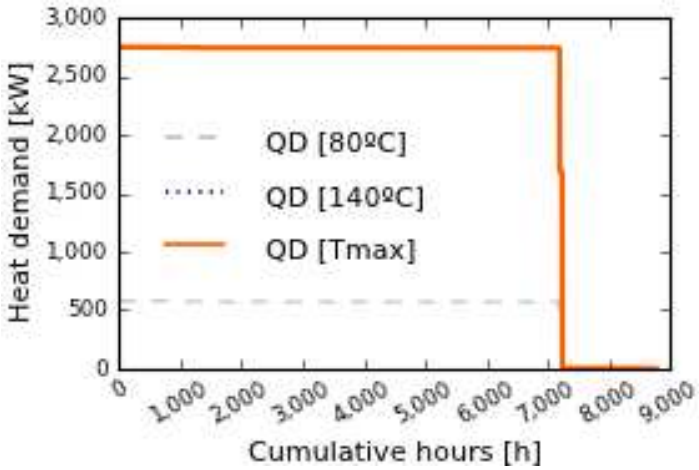

Figure 37: Cumulative heat demand to be covered by boilers

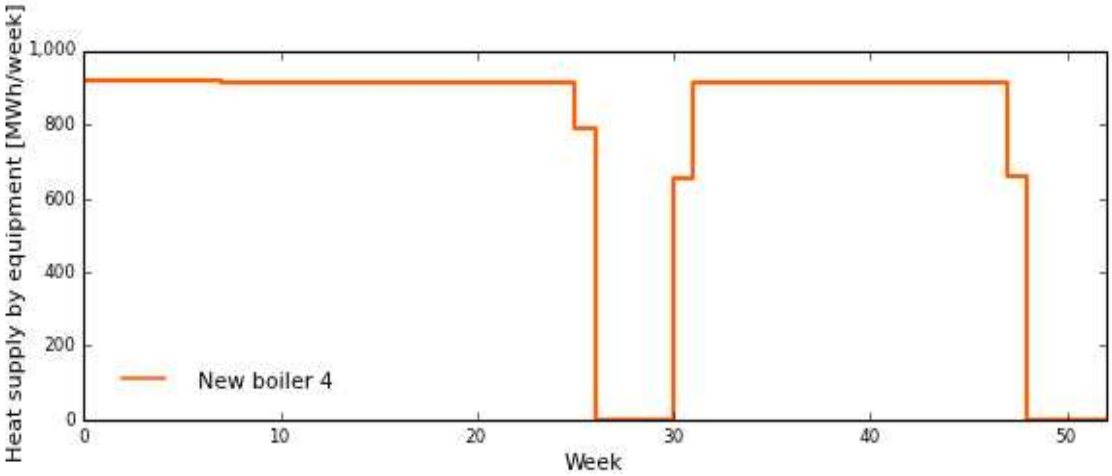

Figure 38: Daily heat supply by equipment

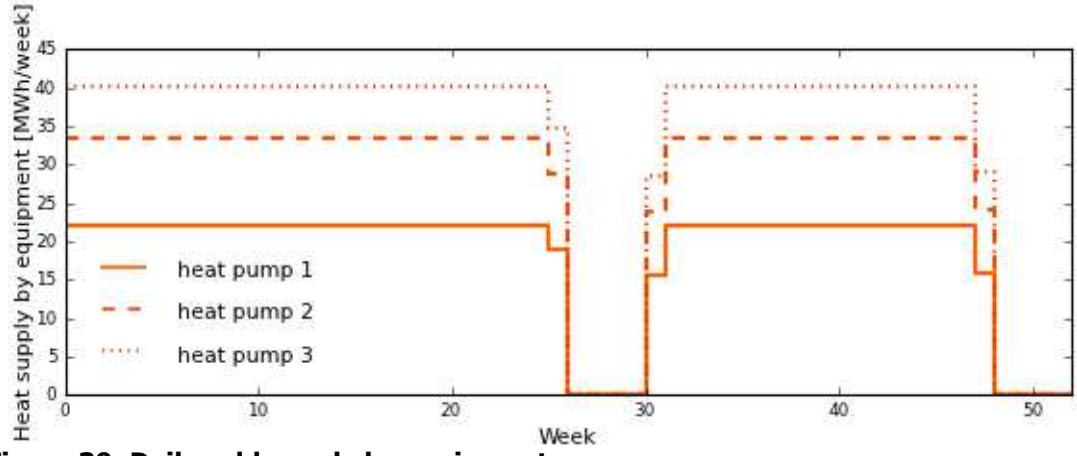

Figure 39: Daily cold supply by equipment

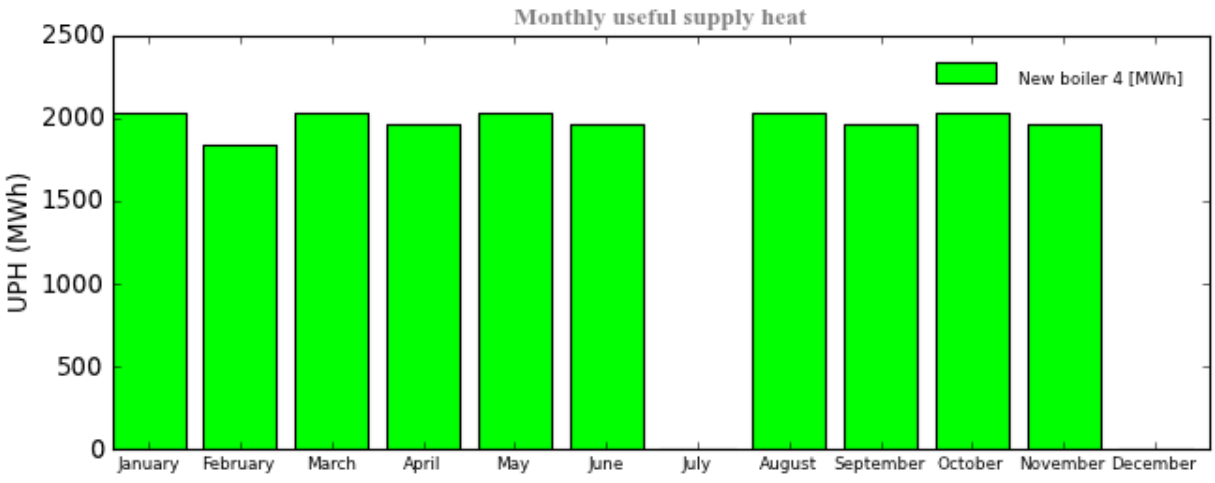

Figure 40: Distribution of useful process heat supply per month

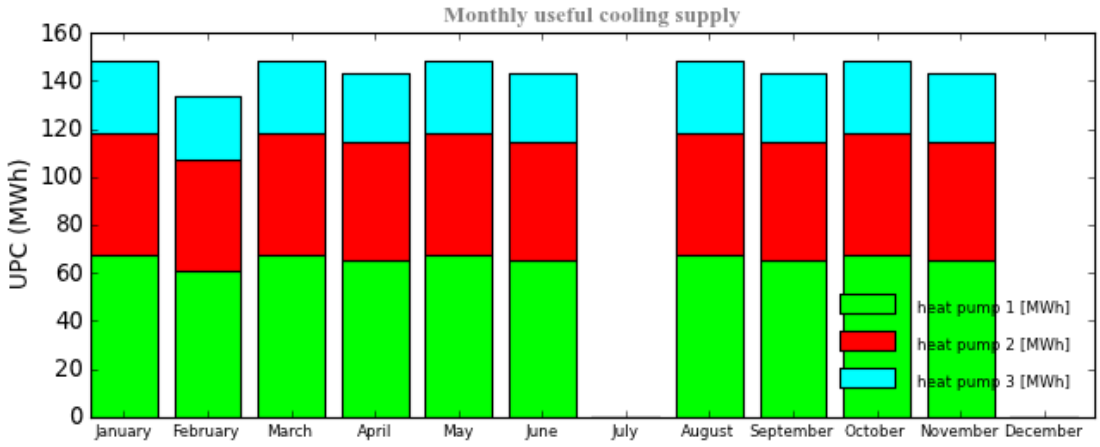

Figure 41: Distribution of useful process cooling supply per month

- Primary energy consumption (PEC)

Table 15: primary energy consumption and savings

Alternative	Primary energy consumption	Savings	
	[MWh]	[MWh]	[%]
Present State (checked)	25,413	---	---
New HX mod.	20,897	4,516	17.77
New HX mod. + CHP (ORC)	17,761	7,652	30.11
CHP (ORC)	20,187	5,226	20.57
New HX mod. + steam boiler	18,962	6,451	25.38
New steam boiler	22,223	3,190	12.55

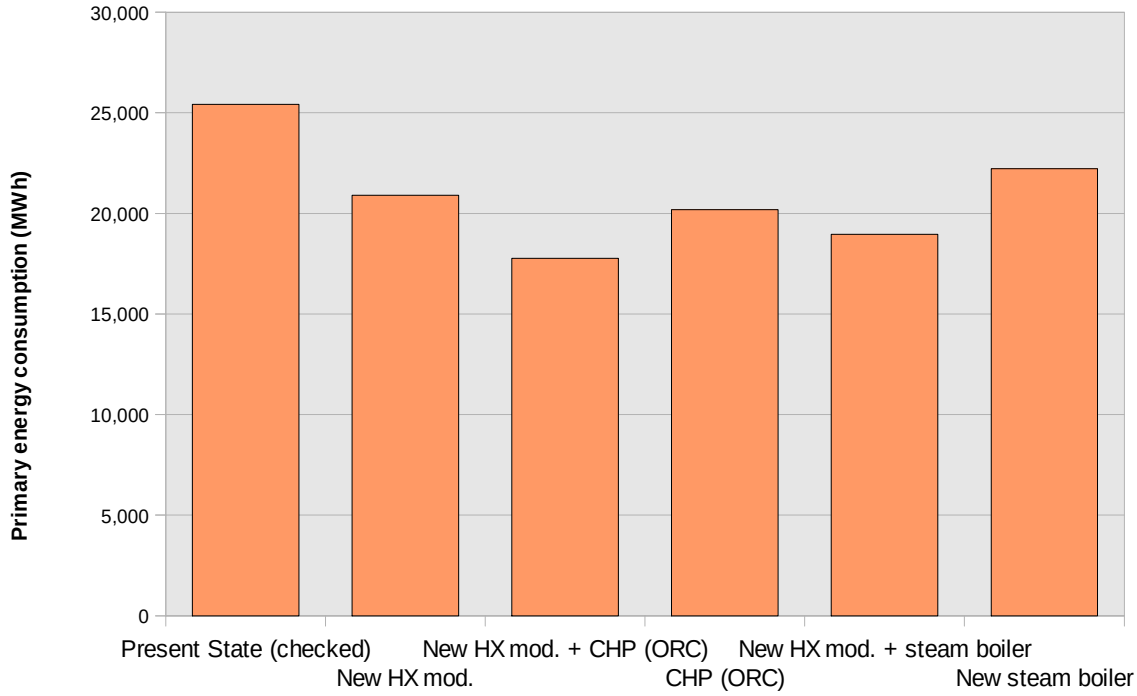

Figure 42: Comparison of alternatives: primary energy consumption

- Useful process and supply heat (UPH and USH)

  Due to the fact that the processes were not changed, the useful process heat and the supply heat stayed the same.

Table 16: Useful process and supply heat: present state and alternative proposals.

Alternative	Useful process heat (UPH)	Savings UPH	Useful supply heat (USH)	Savings USH
	[MWh]	[MWh]	[MWh]	[MWh]
Present State (checked)	19,821	---	19,825	---
New HX mod.	19,821	0	14,669	5,155
New HX mod. + CHP (ORC)	19,821	0	14,669	5,155
CHP (ORC)	19,821	0	19,821	4
New HX mod. + steam boiler	19,821	0	14,669	5,155
New steam boiler	19,821	0	19,821	4

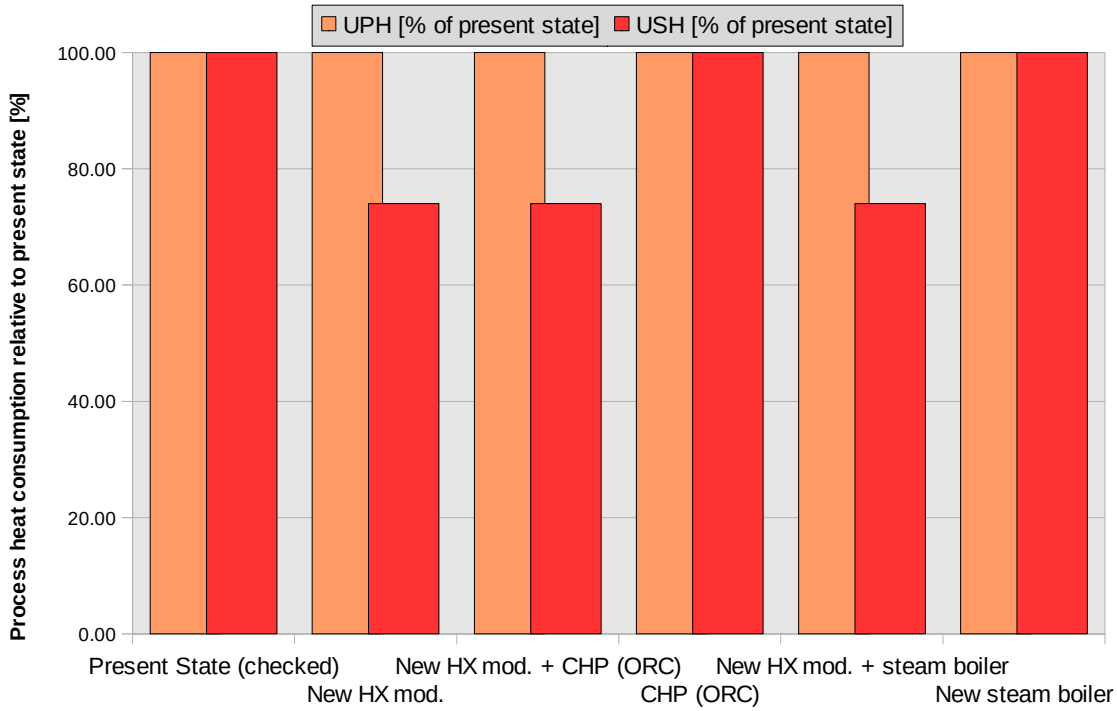

Figure 43: Comparison of alternatives: useful process heat supply

- Useful process and supply cooling (UPC and USC)

  Due to the fact that the processes were not changed, the useful process cooling and the supply cooling stayed the same.

Table 17: Useful process and supply cooling: present state and alternative proposals.

Alternative	Useful process cooling (UPC)	Savings UPC	Useful supply cooling (USC)	Savings USC
	[MWh]	[MWh]	[MWh]	[MWh]
Present State (checked)	1,448	---	1,448	---
New HX mod.	1,448	0	1,448	0
New HX mod. + CHP (ORC)	1,448	0	1,448	0
CHP (ORC)	1,448	0	1,448	0
New HX mod. + steam boiler	1,448	0	1,448	0
New steam boiler	1,448	0	1,448	0

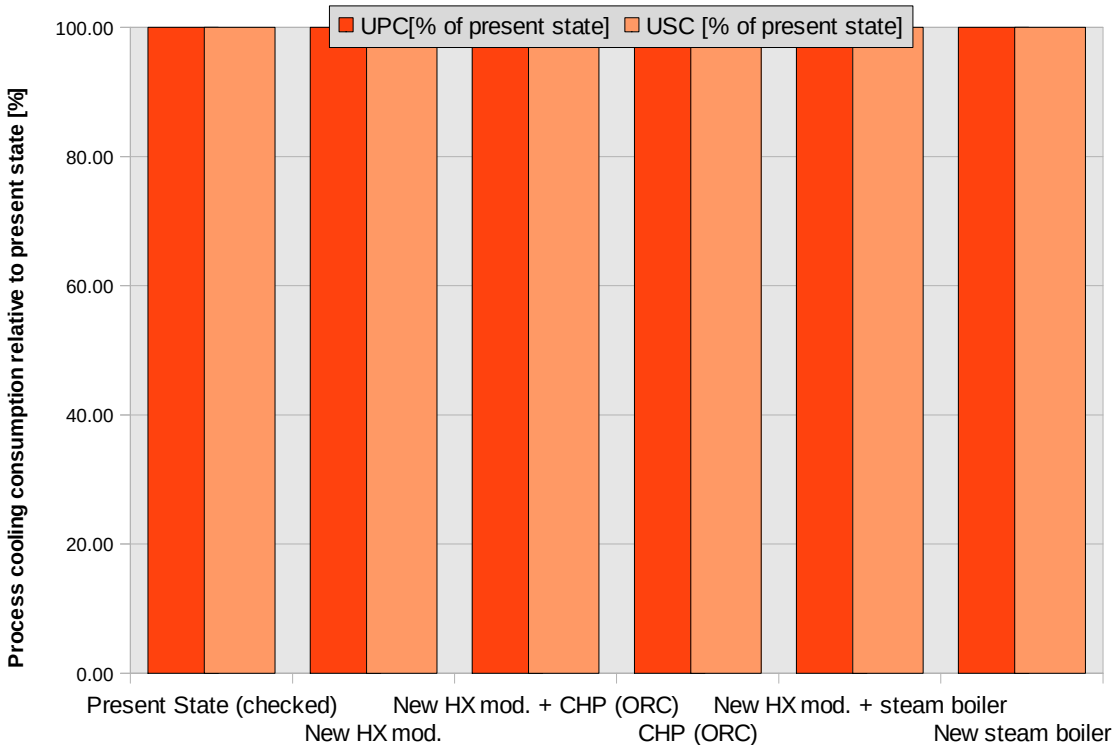

Figure 44: Comparison of alternatives: useful process cooling supply

- Environmental impact

Table 18: CO2 production and CO2 savings per year

Alternative	Production of CO2	Water consumption
	[t]	[m³]
Present State (checked)	1,875.37	3,492.67
New HX mod.	1,736.47	2,986.01
New HX mod. + CHP (ORC)	1,149.55	2,986.01
CHP (ORC)	914.78	2,986.01
New HX mod. + steam boiler	1,817.04	2,986.01
New steam boiler	1,847.89	2,986.01

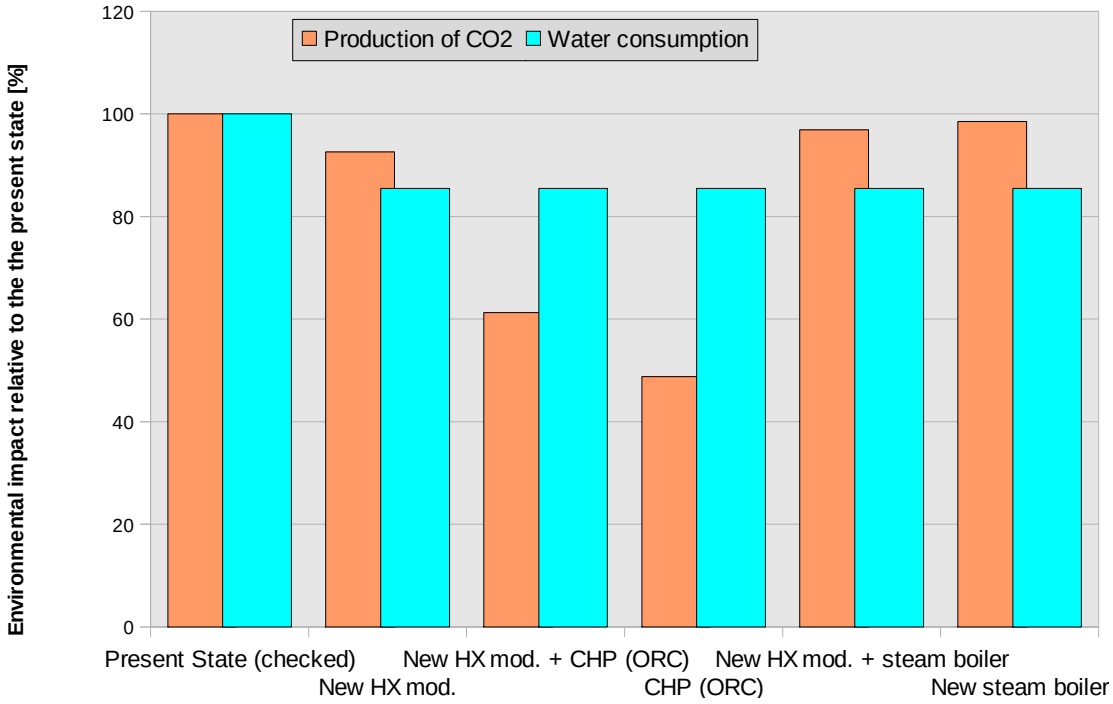

Figure 45: Comparison of alternatives: environmental impact

Table 19: Investment costs and subsidies of the proposals

Alternative	Total investment [€]	Own investment [€]	Subsidies [€]
Present State (checked)	---	---	---
New HX mod.	89,725	89,725	0
New HX mod. + CHP (ORC)	380,048	292,951	87,097
CHP (ORC)	406,452	284,516	121,936
New HX mod. + steam boiler	415,225	415,225	0
New steam boiler	512,700	512,700	0

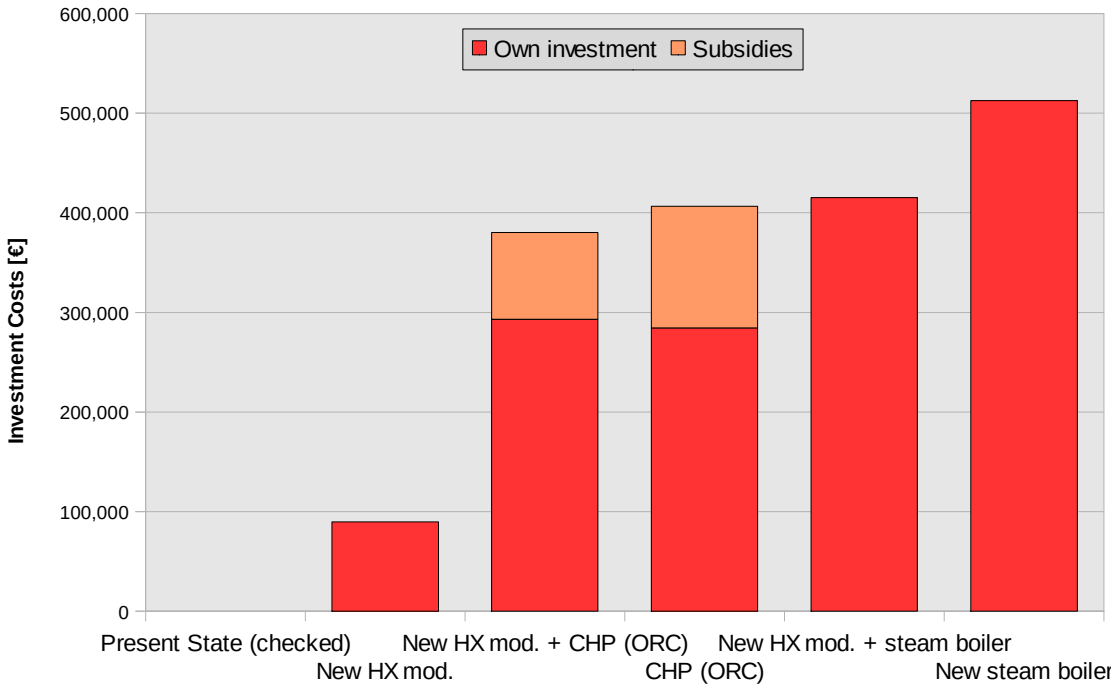

Figure 46: Comparison of alternatives investment cost

5. Selected alternative(s) and conclusions

5.1. Selected alternative

As selected alternative the "New Modified HX + CHP" proposal has been chosen, because of the short payback period and the high CO_2 savings per year.

5.1.1. Process optimisation (written proposals)

None

5.1.2. Heat Supply

- **New Modified HX + CHP (ORC):**

Type	CHP engine
Nominal thermal power	500 kW
Nominal electrical power	161 kW
Thermal efficiency	0.62
Electrical efficiency	0.20
Operating hours	7,178 h

Table 20: Heat and cooling supply equipment and contribution to total heat and cooling supply

Equipment	Nominal capacity	Contribution to total heat and cooling supply	
	[kW]	[MWh]	[%]
New CHP 3	500	3,568	24.32
small boiler	3,230	11,101	75.68
big boiler	6,460	0	0.00
heat pump 1	91	660	45.58
heat pump 2	69	497	34.34
heat pump 3	69	291	20.07
Total	**10,419**	**16,117**	**200**

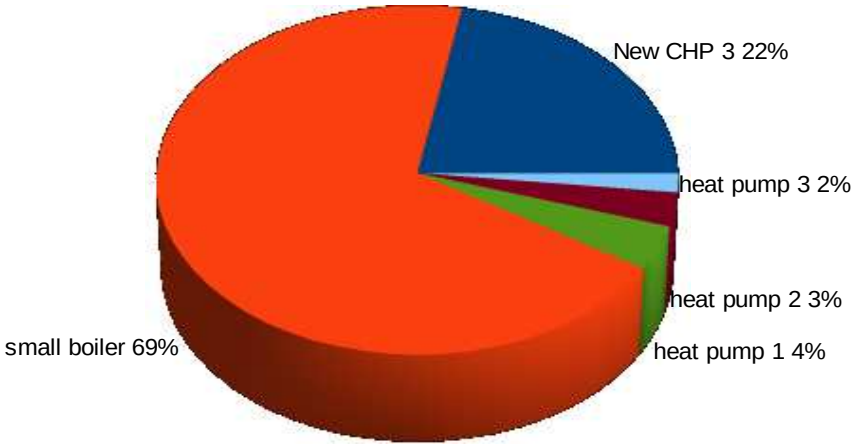

Figure 47: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).

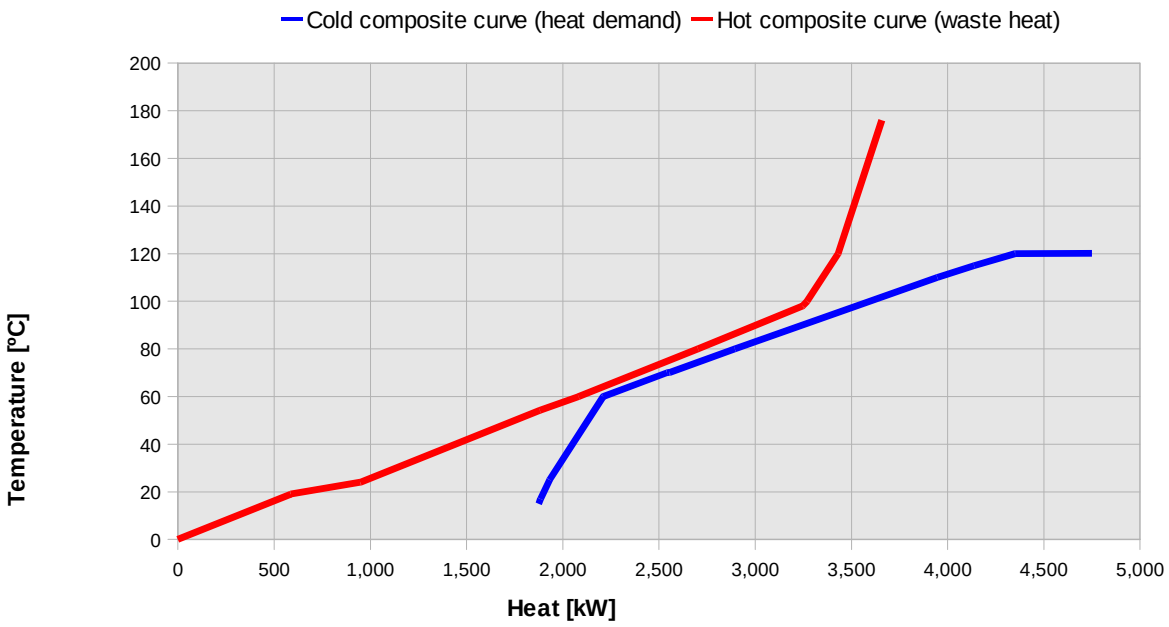

Figure 48: Pinch Analysis - Composite Curves

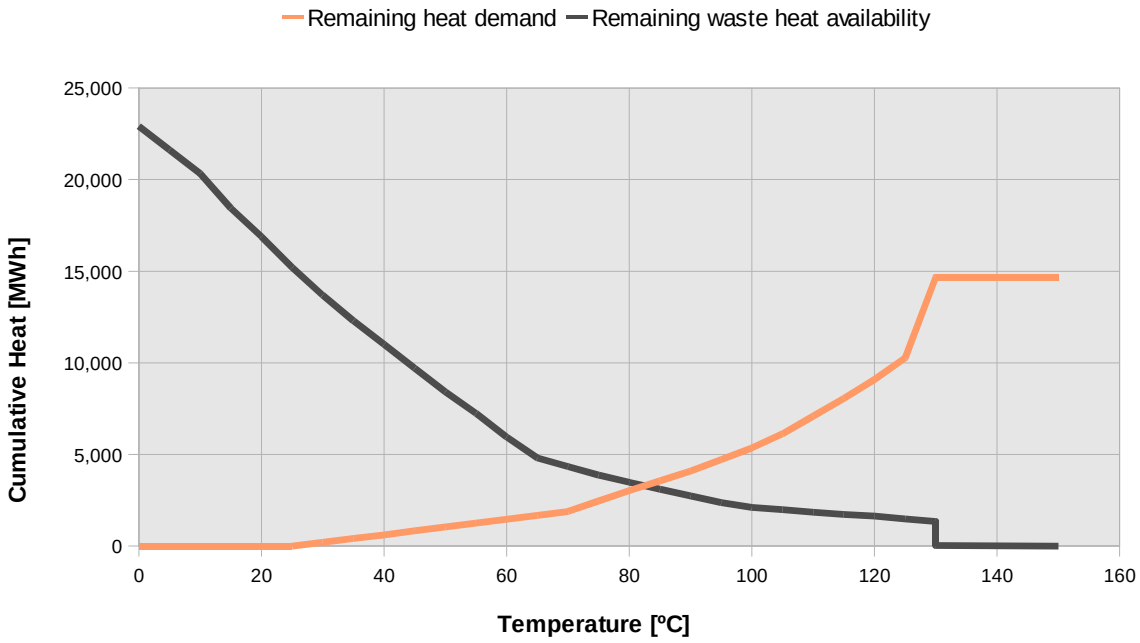

Figure 49: Pinch Analysis – Remaining yearly energy demand and energy availability

5.1.3. Energy Consumption

Table 21: Total primary energy consumption (PEC) and primary energy consumption for thermal use (PET)

Energy type (fuels / electricity)	PEC		PET	
	[MWh]	[% of Total]	[MWh]	[% of Total]
Total fuels	10,864	61.17	10,864	145.29
Total electricity	6,897	38.83	-3,387	-45.29
Total (fuels + electricity)	**17,761**	**100.00**	**7,477**	**100.00**

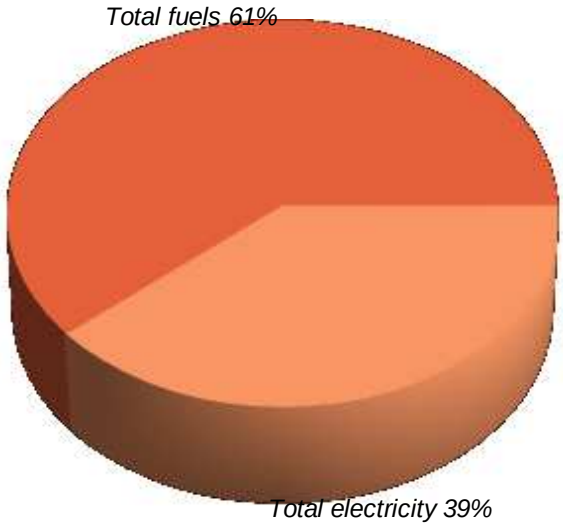

Figure 50: Distribution of PEC by fuel type

Table 22: Total final energy consumption (FEC) and final energy for thermal use (FET). Proposed final solution.

Fuel type	FEC		FET	
	[MWh]	[% of Total]	[MWh]	[% of Total]
sunflower seed shell	21,728	90.43	21,728	105.48
Electricity	2,299	9.57	-1,129	-5.48
Total	24,027	100.00	20,599	100.00

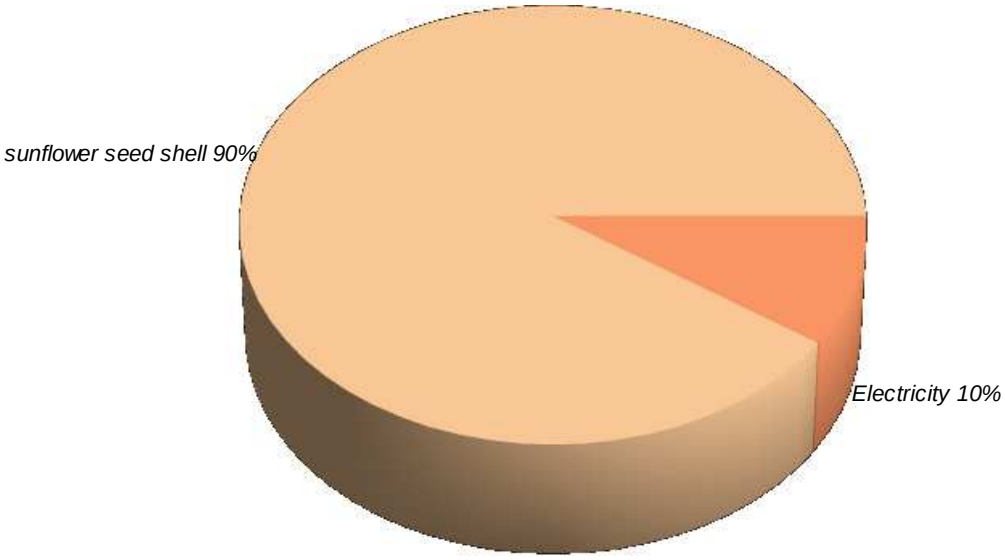

Figure 51: Total final energy consumption (FEC). Proposed final solution.

Table 23 : Final energy consumption for thermal use (FET) by equipment. Proposed final solution.

Equipment	Fuel type	FET by equipment	
		[MWh]	[% of Total]
small boiler	sunflower seed shell	15,859	76.99
big boiler	sunflower seed shell	0	0.00
heat pump 1	Electricity	20	0.10
heat pump 2	Electricity	15	0.07
heat pump 3	Electricity	9	0.04
New CHP 3	sunflower seed shell(- gen.elect.)	4,695	22.79
Total		**20,599**	**100**

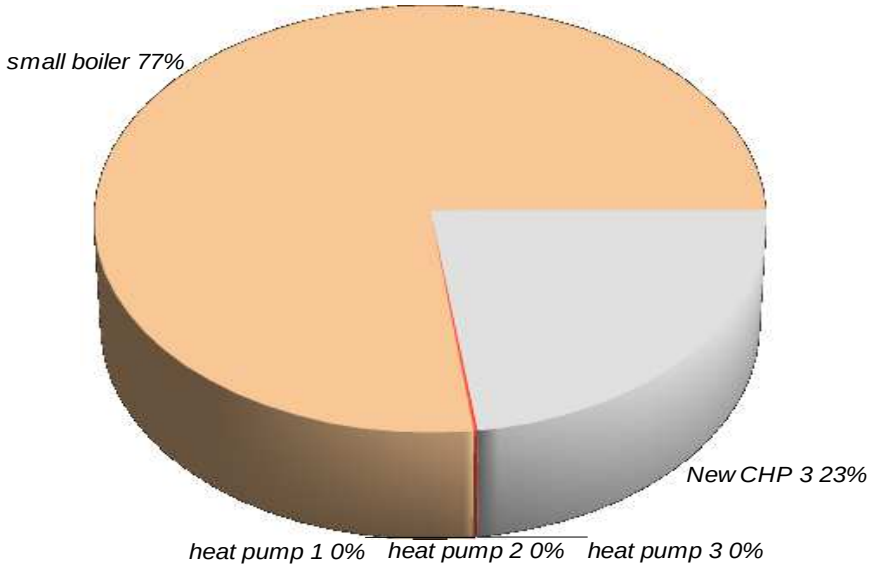

Figure 52: Final energy consumption for thermal use (FET) by equipment

Table 24 : Useful supply heat (USH) by equipment. Proposed final solution.

Equipment	USH by equipment	
	[MWh]	[% of Total]
small boiler	11,101	75.68
big boiler	0	0.00
New CHP 3	3,568	24.32
Total	**14,669**	**100**

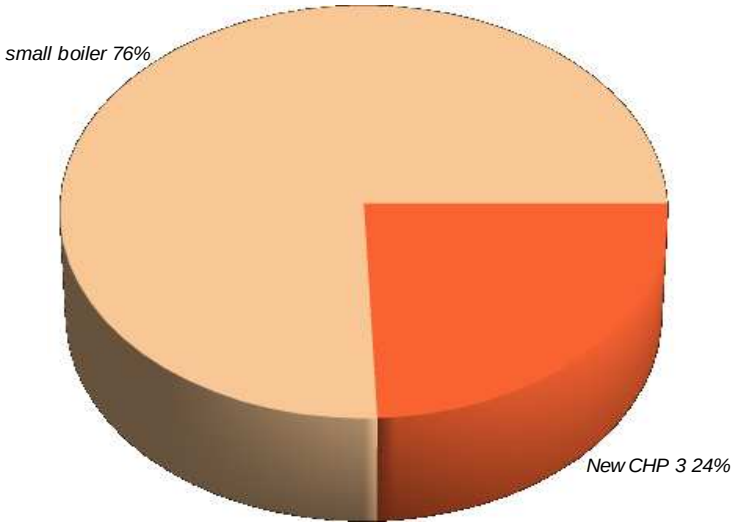

Figure 53: Useful supply heat (USH) by equipment. Proposed final solution

In the following the instantaneous demand for useful supply heat (USH) by temperature levels and annual operating hours is analysed. In Table 25 data of maximum power and yearly heat demand are given for base load (> 4000 h/a), medium load (> 2000 h/a) and peak load (< 2000 h).

Table 25: Supply heat by temperature levels and annual operating hours

Temperature levels	Base load		Medium load		Peak load	
	power [kW]	energy [MWh]	power [kW]	energy [MWh]	power [kW]	energy [MWh]
Total	**2,032**	**14,659**	**2,032**		**2,041**	**10**
< 80 °C	419	3,021	419		428	10
< 120 °C	1,259	9,079	1,259		1,268	10
< 250 °C	2,032	14,659	2,032		2,041	10
< 400 °C	2,032	14,659	2,032		2,041	10

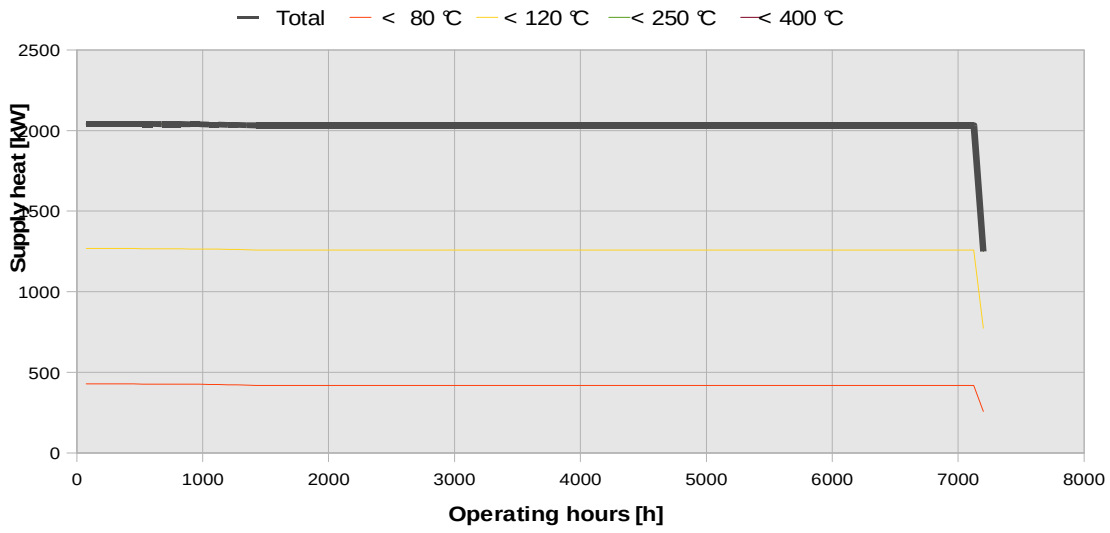

Figure 54: Distribution of supply heat by temperature levels and annual operating hours. Proposed final solution.

Table 26 : Useful supply cooling (USC) by equipment. Proposed final solution.

Equipment	USC by equipment	
	[MWh]	[% of Total]
heat pump 1	660	45.58
heat pump 2	497	34.34
heat pump 3	291	20.07
Total	**1,448**	**100**

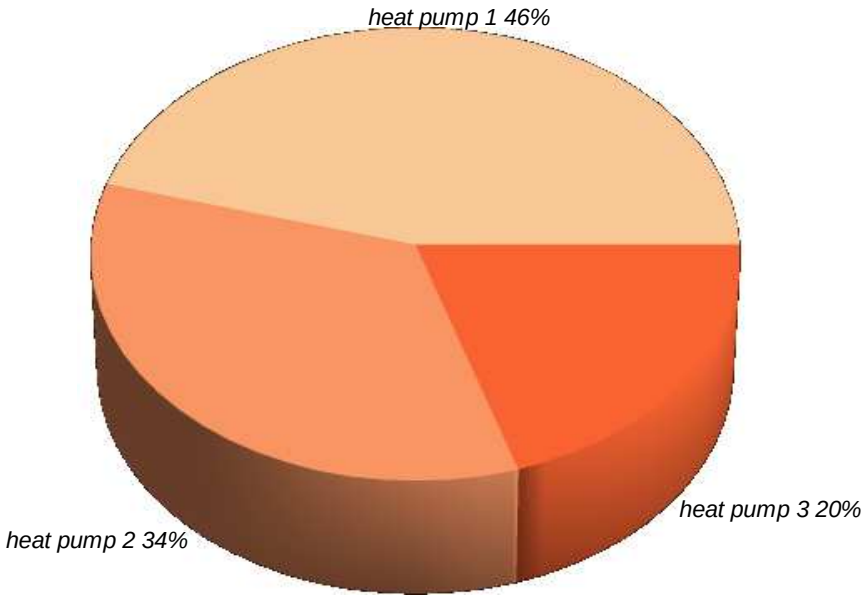

Figure 55: Useful supply cooling (USC) by equipment. Proposed final solution

In the following the instantaneous demand for useful supply heat (USH) by temperature levels and annual operating hours is analysed. In Table 27 data of maximum power and yearly heat demand are given for base load (> 4000 h/a), medium load (> 2000 h/a) and peak load (< 2000 h).

Table 27: Table 6.2.2.1 Supply heat by temperature levels and annual operating hours

Temperature levels	Base load		Medium load		Peak load	
	power [kW]	energy [MWh]	power [kW]	energy [MWh]	power [kW]	energy [MWh]
Total	**2,032**	**14,659**	**2,032**		**2,041**	**10**
< 80 °C	419	3,021	419		428	10
< 120 °C	1,259	9,079	1,259		1,268	10
< 250 °C	2,032	14,659	2,032		2,041	10
< 400 °C	2,032	14,659	2,032		2,041	10

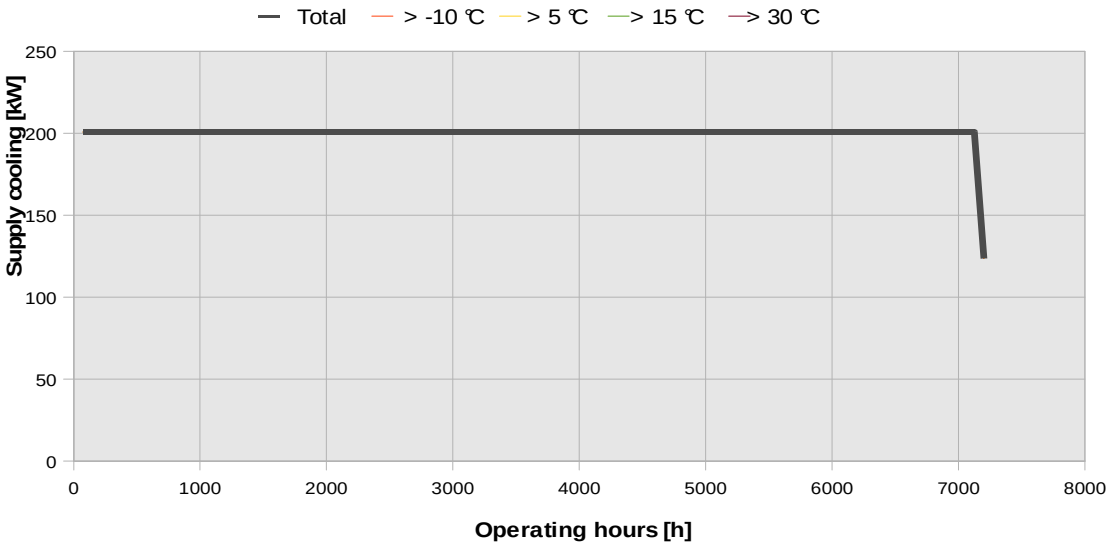

Figure 56: Distribution of supply cooling by temperature levels and annual operating hours. Proposed final solution.

Table 28: Useful process heat demand (UPH) by process. Proposed final solution.

Process	Total	Circulation	Maintenance	Start-up
	[MWh]	[MWh]	[MWh]	[MWh]
pressure hall	6,382	5,662	720	0
extraction	3,705	2,985	720	0
refinery	5,602	4,882	720	0
biodiesel production	4,122	3,402	720	0
building_heating	10	0	10	0
Total	**19,821**			

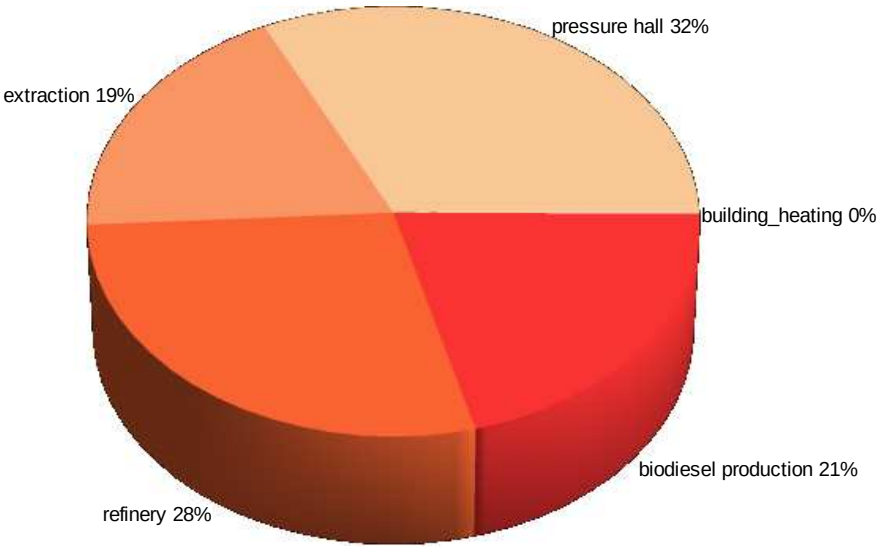

Figure 57: Useful process heat (UPH) by process. Proposed final solution.

Table 29: Useful process cooling demand (UPC) by process. Proposed final solution.

Process	Total	Circulation	Maintenance	Start-up
	[MWh]	[MWh]	[MWh]	[MWh]
refinery	724	724	0	0
biodiesel production	724	724	0	0
Total	**1,448**			

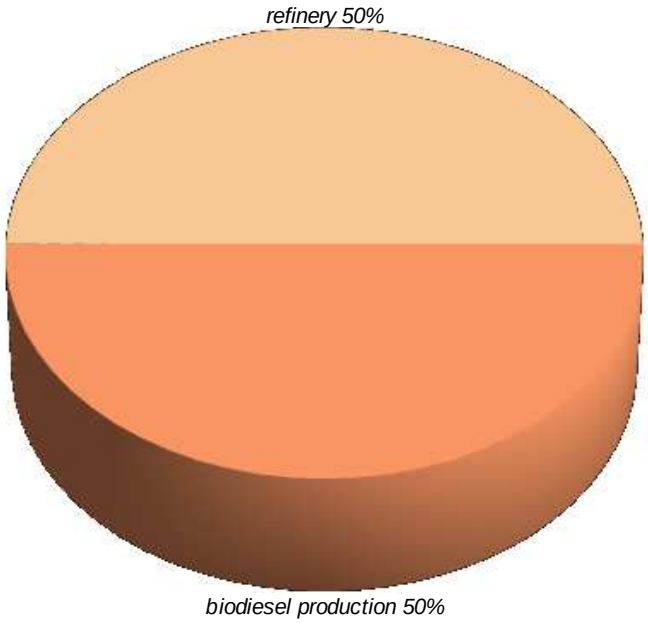

Figure 58: Useful process cooling (UPC) by process. Proposed final solution.

Table 30: Process heat demand and supply by temperature levels. Proposed final solution.

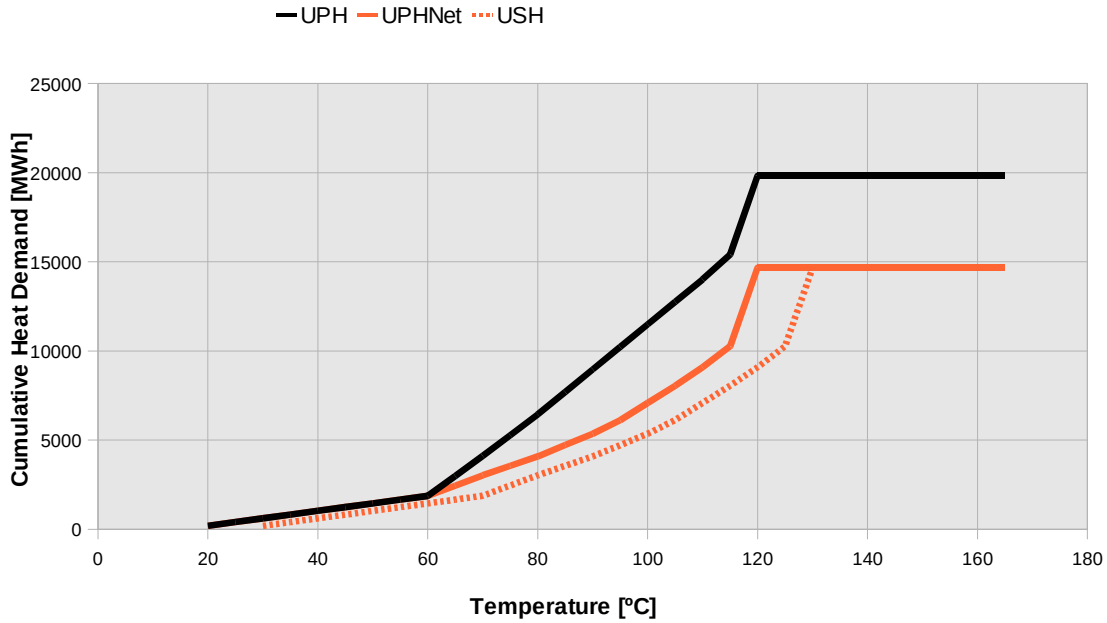

Figure 59: Figure 6.3.2.1 Distribution of the heat demand by temperature levels

Table 31: Process cooling demand and supply by temperature levels. Proposed final solution.

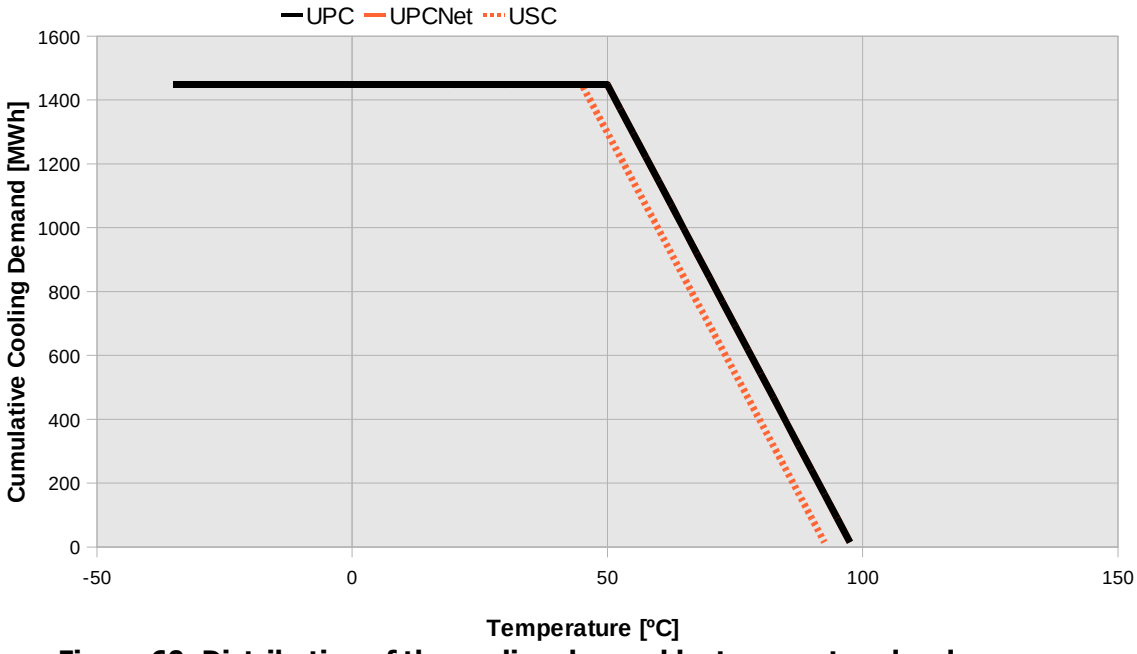

Figure 60: Distribution of the cooling demand by temperature levels

5.2. Comparative study and conclusions

5.2.1. Energy and environmental analysis

In the proposed alternative around 39 % of the CO_2 pollution (726 tons of CO_2) can be saved.

5.2.2. Economic analysis

The payback period of about 3 years has to be checked concerning the investment costs and due to the possible change of these figures the payback period will change in dependency. The calculations are based on costs and subsidies of 30 % for the biomass CHP plant of the investment costs and have to be revised. Investment and installing cost are based on actual cost in Austria and not Bulgaria.

Table 32: Savings of the proposed alternative in comparison to the present state

		Present state	Alternative	Saving	[% savings]
Total primary energy consumption (1)					
- total	[MWh]	25,413	17,761	7,652	30%
- fuels	[MWh]	14,161	10,864	3,297	23%
- electricity	[MWh]	11,252	6,897	4,355	39%
Primary energy saving due to renewable energy	[MWh]		1,644		
CO_2 emissions	[t/a]	1,875	1,150	726	39%
Annual energy system cost (2)	[EUR]	426,128	292,213	133,916	31%
Total investment costs	[EUR]		380,048		
Payback period (3)	[years]		3		

(1) including primary energy consumption for non-thermal uses

(2) including energy cost (fuel and electricity bills), operation and maintenance costs and annuity of total investment.

(3) Supposing 30% of funding of total investment (subsidies or equivalent other support mechanisms)

5.2.3. Conclusions and outlook

- In order to gain savings as high as calculated, the calculations have to be adapted to the actual thermal and electrical efficiency of the new CHP as the computed savings are based on the highest number
- Based on the available data and measurements performed the energy consumption split to the processes and equipments so that they could be calculated by EINSTEN and the results are well comparable to the present state of the company. For the economic aspects some further calculations will be necessary as final investment costs are based on first estimations.