Energy Audit Summary Report

AEE INTEC

Audit no. 65 – UK09

Brewery

30th of June 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. 65 – UK09

1. Data of the auditor

1.1. Contact data of the auditor

Jürgen Fluch, Matthäus Hubmann

Number of audits preformed: 20

Date of the audit: 16.05.2012

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 2011.

3.1. General information of the company

Sector	brewery
Products	beer
No. of employees	n.a. (not available)
Current primary energy consumption	12,440 [MWh/a]

3.2. Flow sheet of the whole manufacturing side

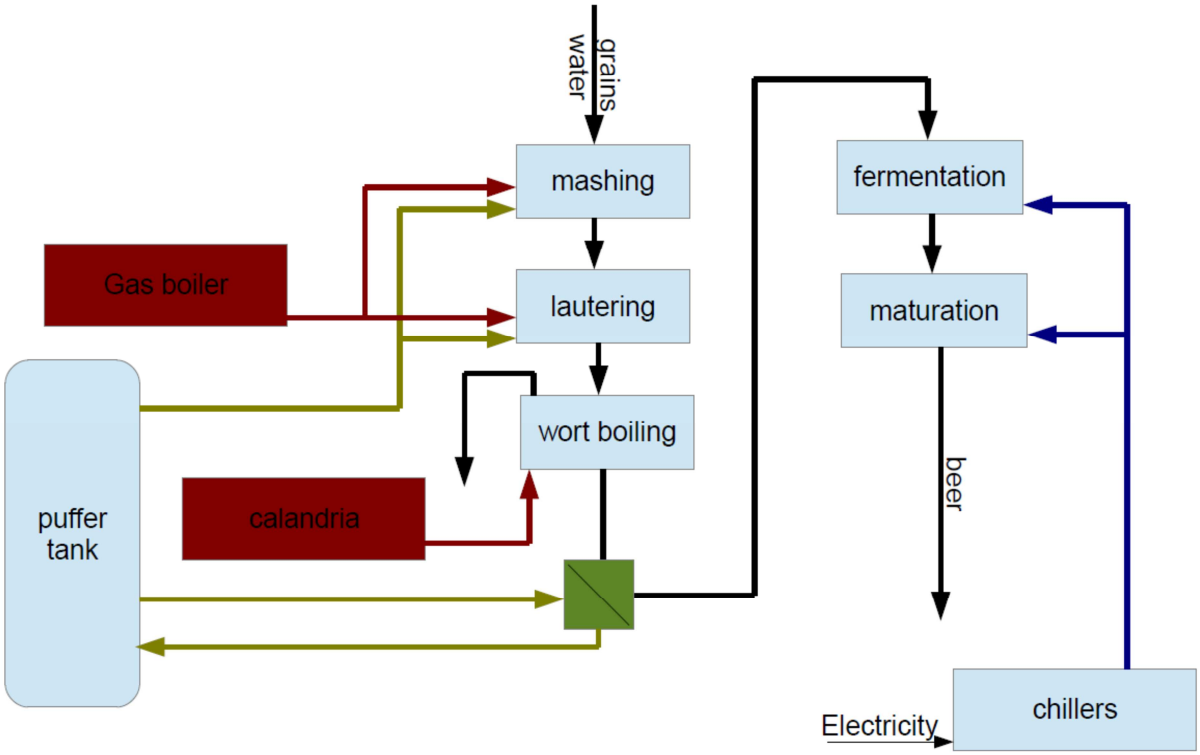

Figure 1: Simplified flow sheet of the factory

3.3. Description of the existing system

- **Energy Supply:**

The factory is mainly consuming energy for heating purposes during the production. In addition it has electrical consumption for cooling all year long.

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	2,869	23.07	2,843	76.25
Total electricity	9,571	76.93	885	23.75
Total (fuels + electricity)	**12,440**	**100.00**	**3,728**	**100.00**

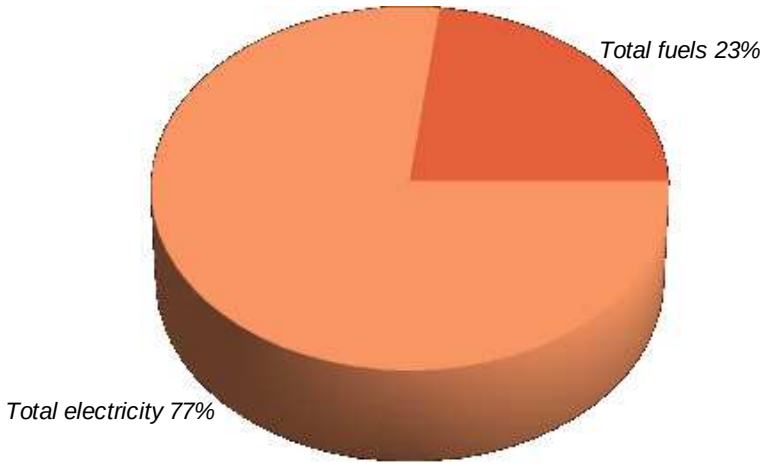

Figure 2: distribution of PEC by fuel type

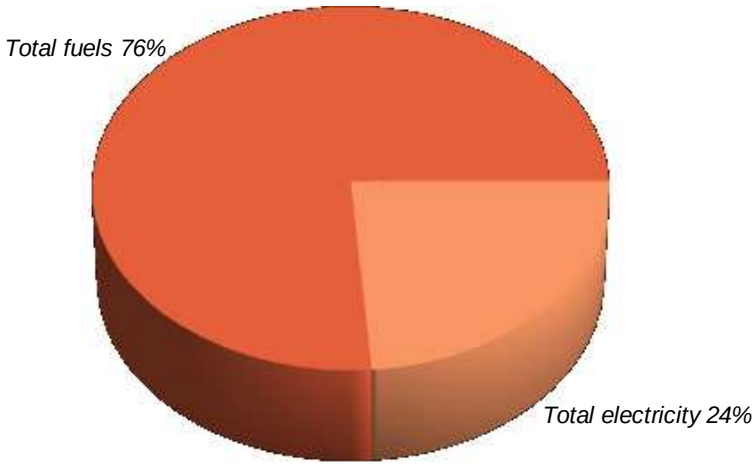

Figure 3: distribution of PET by fuel type

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

Fuel type	FEC		FET	
	[MWh]	[% of Total]	[MWh]	[% of Total]
Natural gas	2,609	44.98	2,585	89.75
Electricity	3,190	55.02	295	10.25
Total	5,799	100.00	2,880	100.00

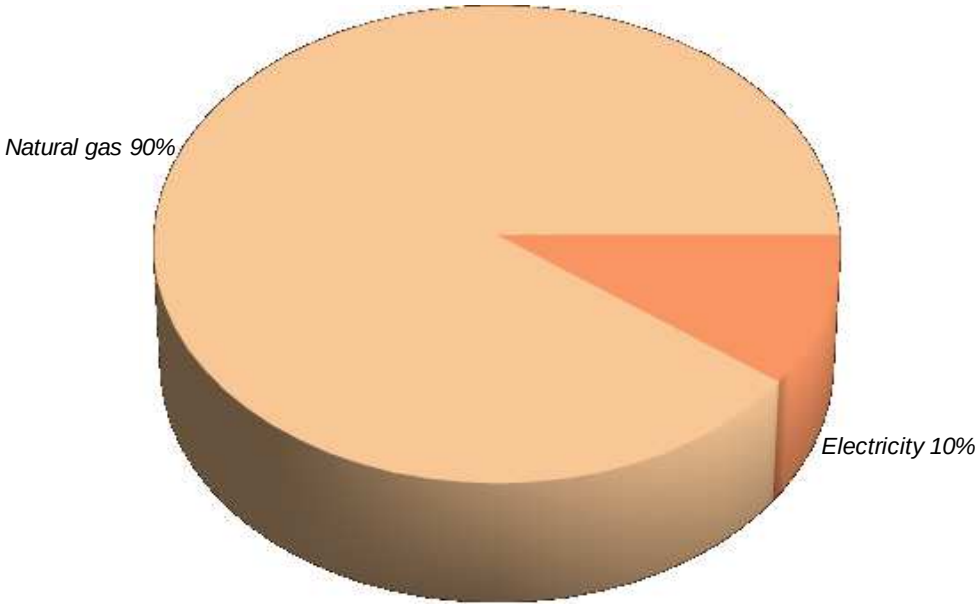

Figure 4: Total final energy consumption for thermal use (FET)

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

Equipment	Fuel type	FET by equipment	
		[MWh]	[% of Total]
steam boiler	Natural gas	1,161	43.11
calandria	Natural gas	1,214	45.07
chiller 1	Electricity	195	7.25
chiller 2	Electricity	123	4.57
Total		**2,694**	**100.00**

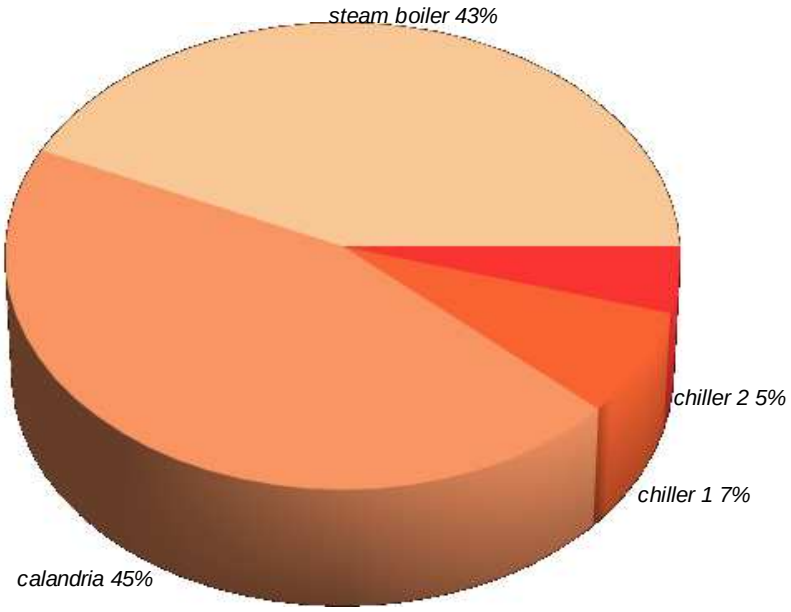

Figure 5: Final energy consumption for thermal use (FET) by equipment

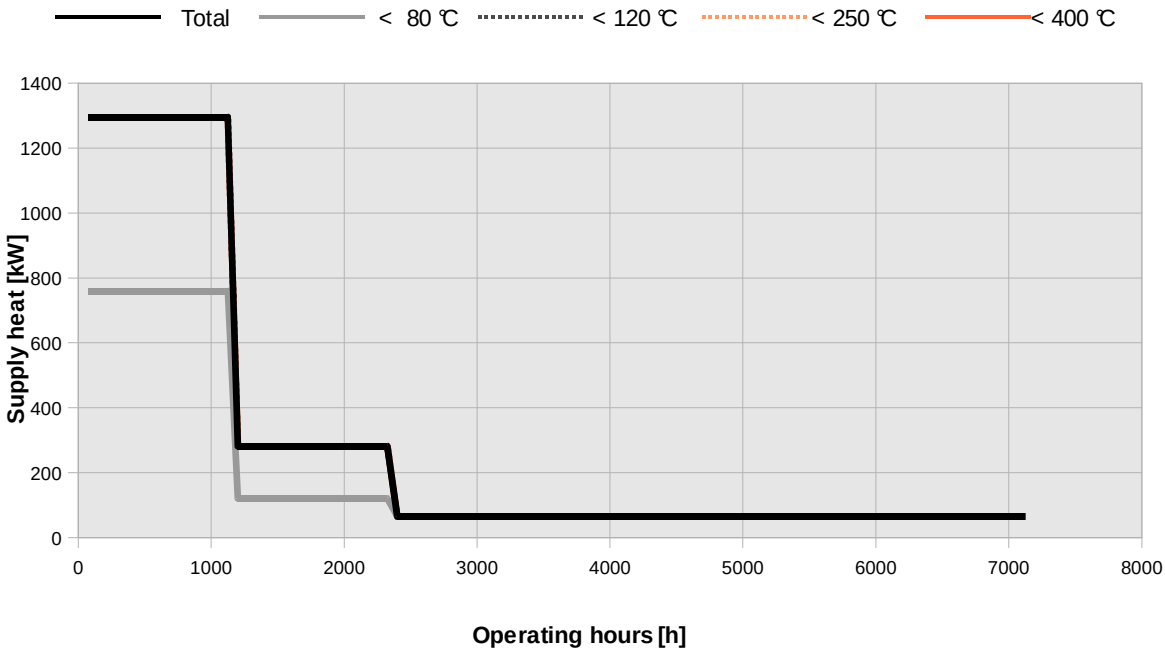

Figure 6: Distribution of supply heat by temperature levels and annual operating hours. Present state.

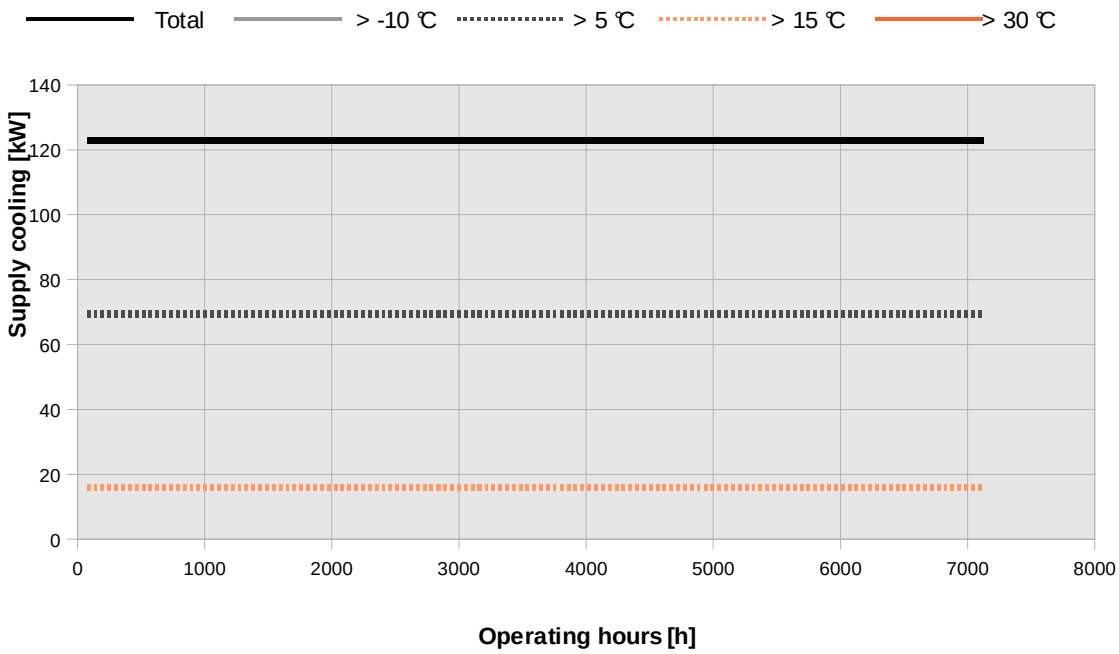

Figure 7: Distribution of supply cooling by temperature levels and annual operating hours. Present state.

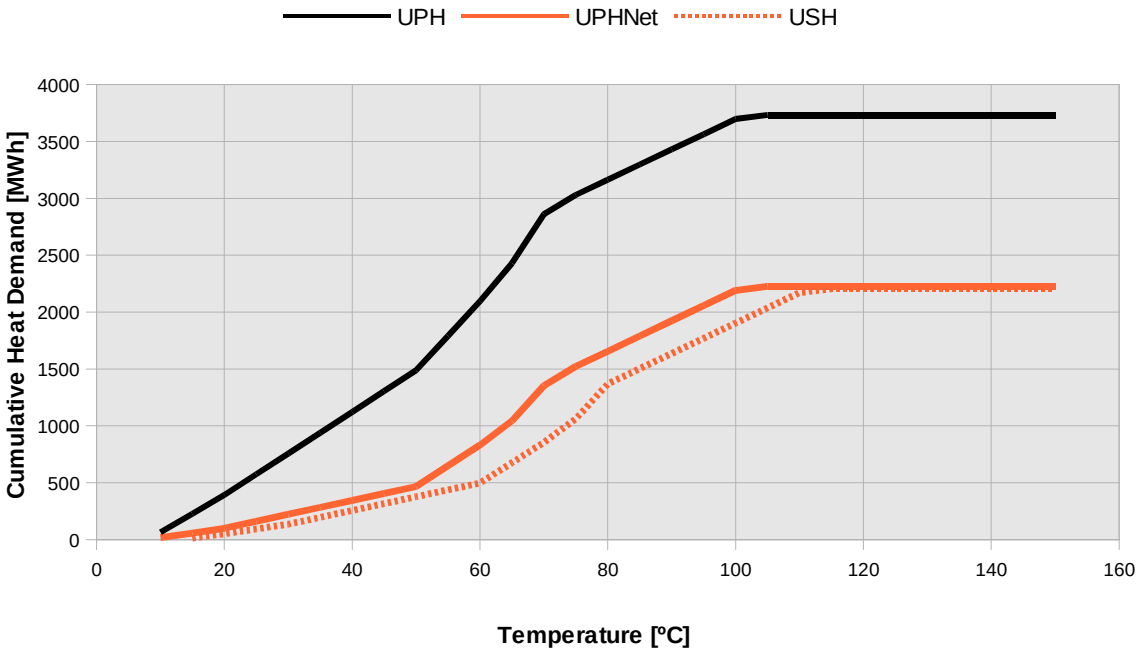

Figure 8: Distribution of the heat demand by temperature levels

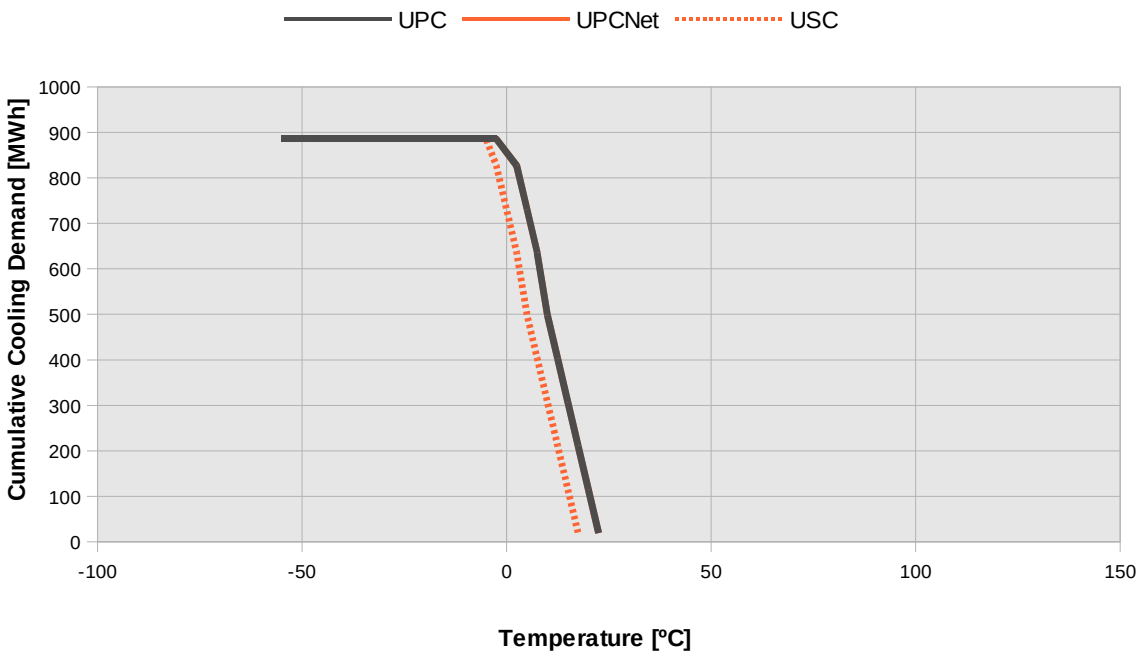

Figure 9: Distribution of the cooling demand by temperature levels

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

Equipment	USH by equipment	
	[MWh]	[% of Total]
steam boiler	1,197	55.25
calandria	969	44.75
Total	**2,166**	**100.00**

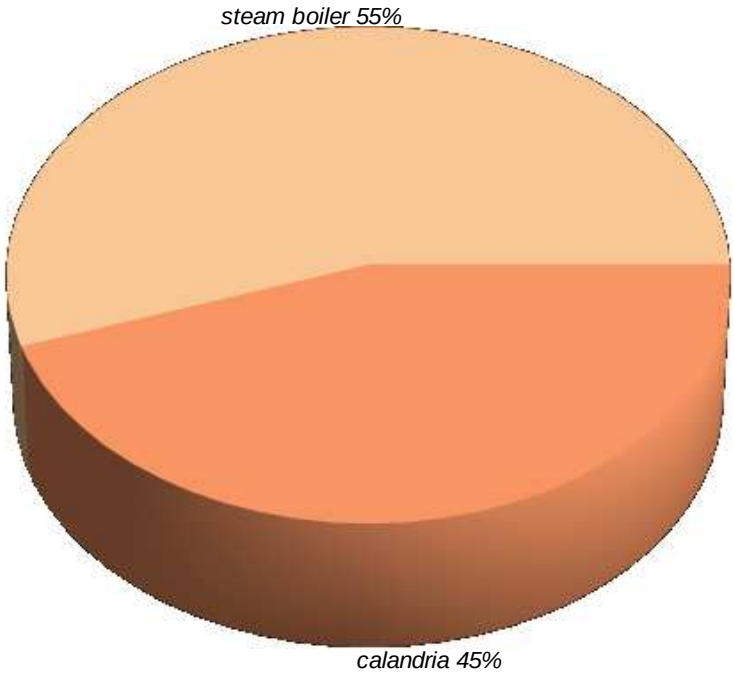

Figure 10: Useful supply heat (USH) by equipment. Present state

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

Equipment	USC by equipment	
	[MWh]	[% of Total]
chiller 1	542	61.07
chiller 2	345	38.93
Total	**887**	**100.00**

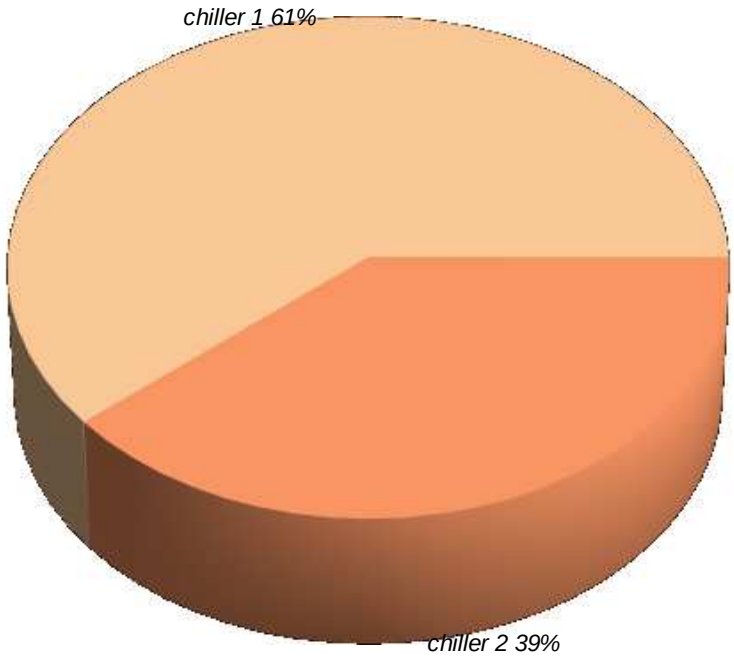

Figure 11: Useful supply cooling (USC) by equipment. Present state

Table 6: Heat exchangers and amount of recovered energy

Heat Exchanger	Power	Heat Source	Heat Sink	Heat transferred	
	[kW]			[MWh]	[%]
HX brew water	1,256	wort boiling	mashing	1,507	100.00
	1,256			**1,507**	**100**

Table 7: Useful process heat (UPH) by process

Process	Total	Circulation	Maintenance	Start-up
	[MWh]	[MWh]	[MWh]	[MWh]
mashing	2,185	1,697	2	486
wort boiling	970	962	8	0
lautering	109	105	4	0
hot water brew house	468	468	0	0
Total	**3,732**			

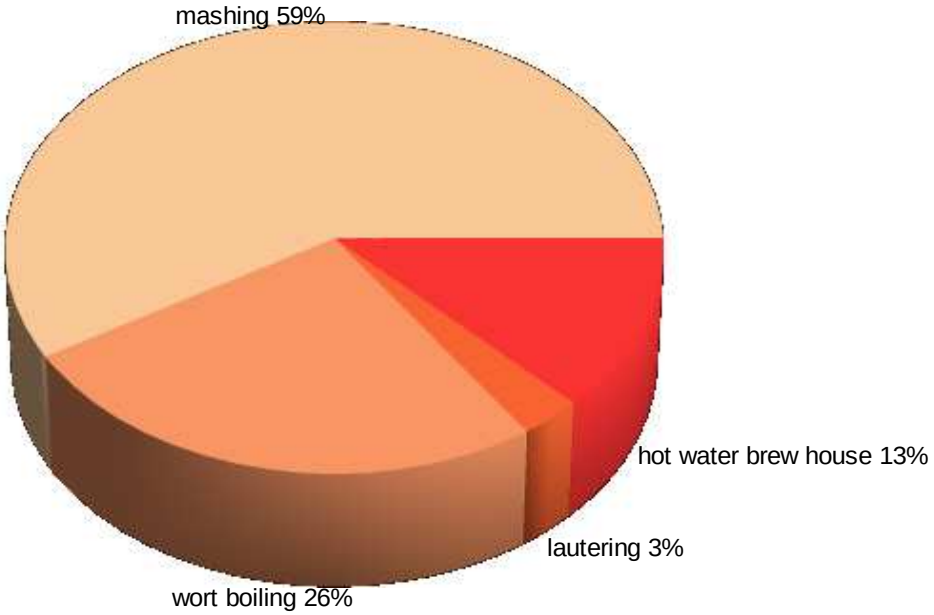

Figure 12: Useful process heat (UPH) by process

Table 8: Useful process cooling (UPC) by process

Process	Total	Circulation	Maintenance	Start-up
	[MWh]	[MWh]	[MWh]	[MWh]
fermentation	539	537	2	0
maturation	346	345	1	0
Total	**885**			

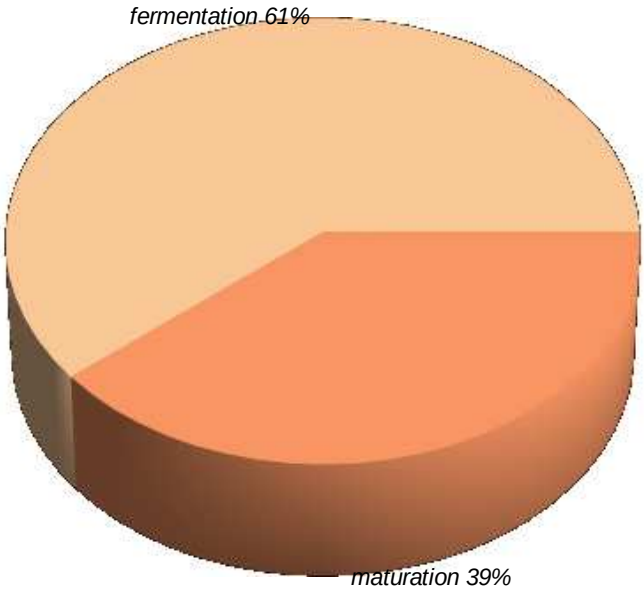

Figure 13: Useful process cooling (UPC) by process

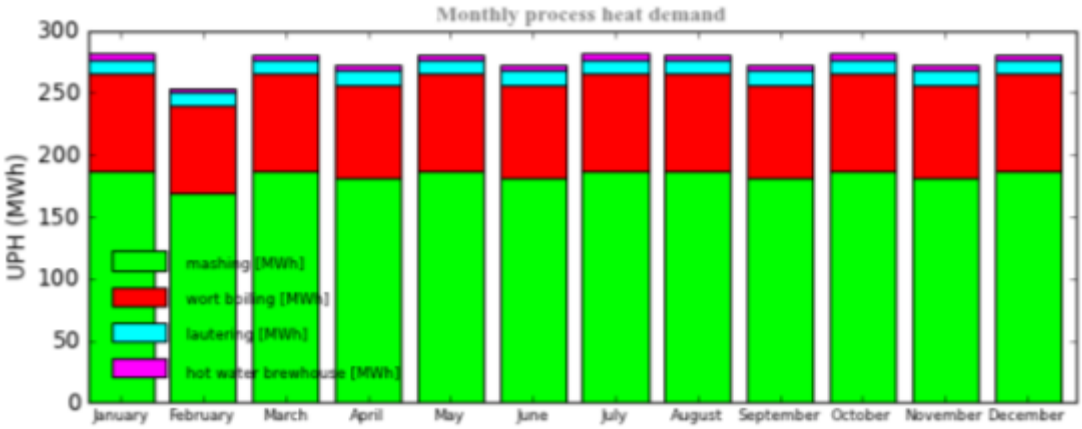

Figure 14: Distribution of useful process heat demand per month

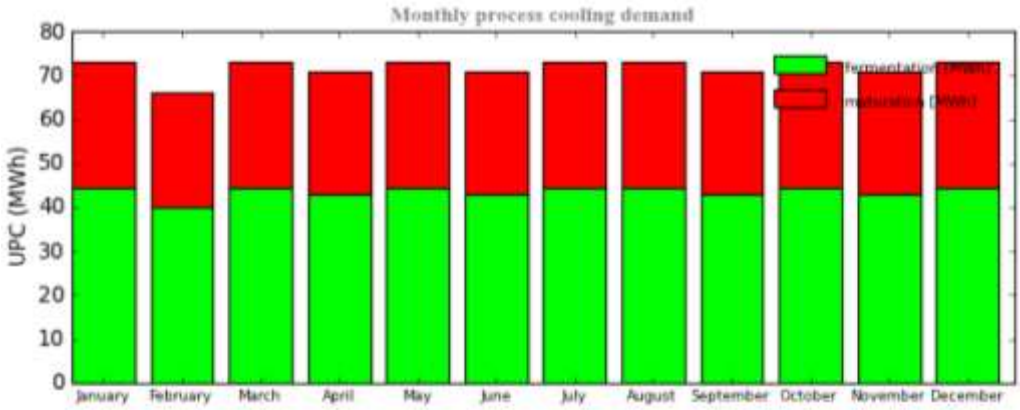

Figure 15: Distribution of useful process cooling demand per month

3.4. General

- The total output of the brewery is 245,000 hl/a of beer, 90% of these beers correspond to one type of beer, the main product. The calculations in this report are based on the brewing data and requirements of the main beer type and 24 brews per week and 300 days per year of production.

4. Comparative study

4.1. Proposed alternatives

There are four proposals made in this study. In the first proposal additional heat exchangers are proposed to be installed. The second proposal is a solar thermal system using flat plate collectors. The third proposal focuses on the installation of additional heat exchangers and the implementation of solar thermal system. In the fourth proposal a new CHP (combined heat and power plant) is installed.

Table 9: Overview of the alternative proposals studied

Short Name	Description
new boiler	based on present state the installation of a new boiler is proposed
solar	based on present state the installation of a solar thermal system is suggested
CHP (176kW)	based on present state the implementation of a CHP (combined heat and power plant) is proposed
CHP (375kW)	based on present state the implementation of a CHP (combined heat and power plant) is proposed
solar (300kW)	based on present state the installation of a solar thermal system is suggested

4.1.1. Heat Supply

- **New boiler:**

Type	steam boiler
Nominal thermal power	1,396 kW
Thermal efficiency	0.91
Operating hours	7,200 h

Table 10: Heat exchangers and amount of recovered energy

Heat Exchanger	Power	Heat Source	Heat Sink	Amount of recovered energy	
	[kW]			[MWh]	[%]
HX brew water	1,256	wort boiling	mashing	1,507	100.00
Total	1,256			**1,507**	**100**

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

Equipment	Type	Heat and cooling supplied to pipe/duct	Nominal capacity	Contribution to total heat and cooling supply	
			[kW]	[MWh]	[%]
New boiler 1	steam boiler	steam-mashing steam-lautering steam-hot water steam-boiling	1,396	2,205	100.00
steam boiler	steam boiler	steam-mashing steam-lautering steam-hot water	1,000	0	0.00
calandria	steam boiler	steam-boiling	500	0	0.00
chiller 1	compression chiller (air cooled)	glycol 1	238	540	60.94
chiller 2	compression chiller (air cooled)	glycol 2	238	346	39.06
Total			**3,372**	**3,091**	**200**

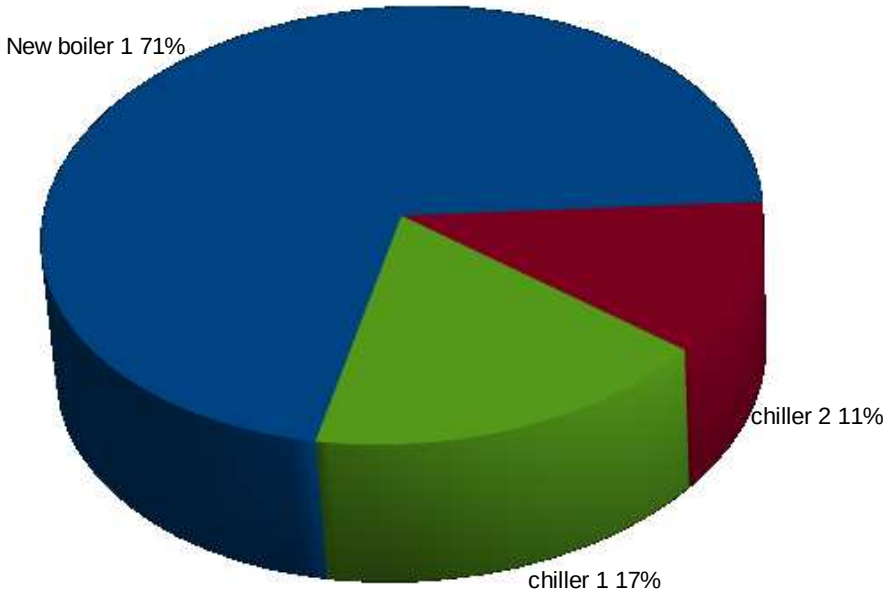

Figure 16: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).

- graphic: heat demand covered by equipment:

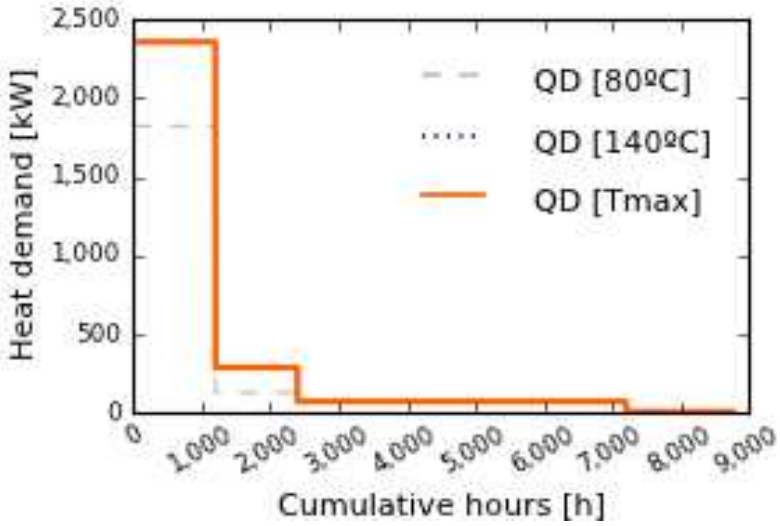

Figure 17: Cumulative heat supply to be covered by equipment

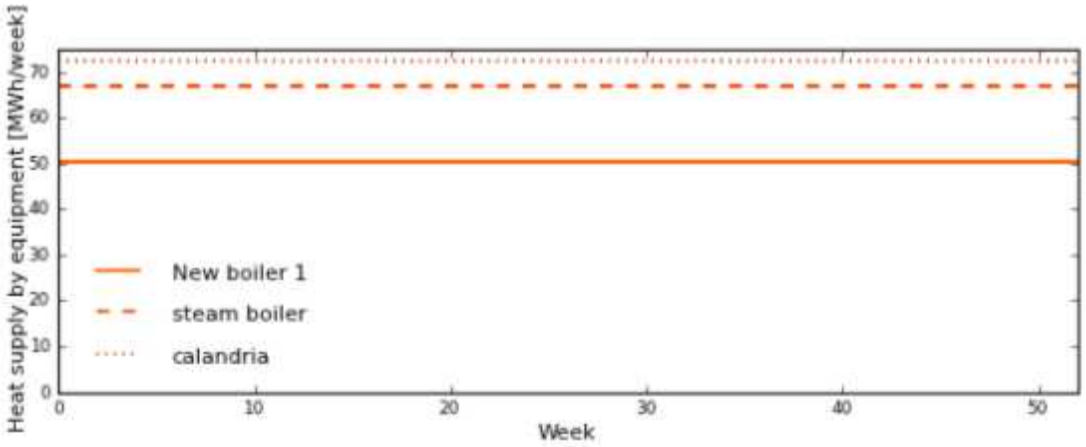

Figure 18: Daily heat supply by equipment

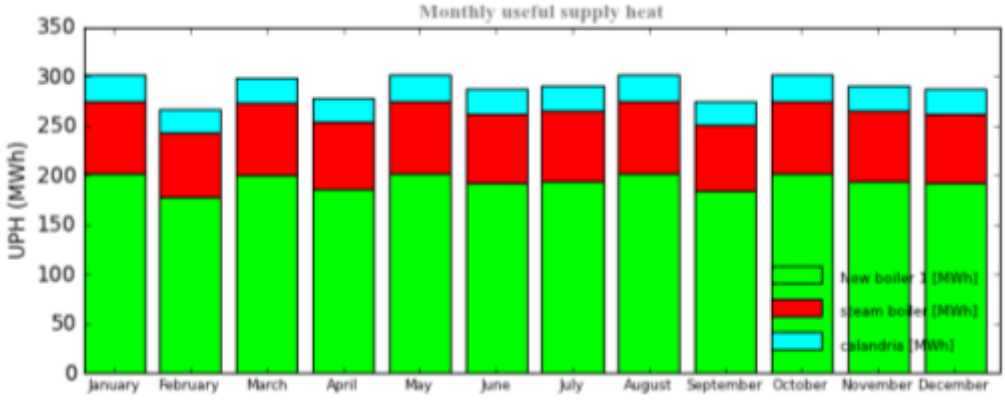

Figure 19: Distribution of useful process heat supply per month

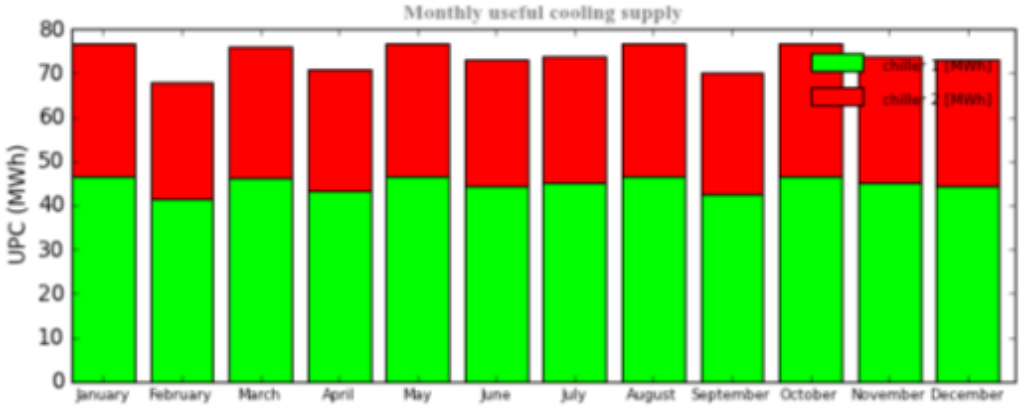

Figure 20: Distribution of useful process cooling supply per month

- **Solar (FPC):**

Collector type:	FPC (flat plate collectors)
Installed capacity:	847 kW
Installed collector area:	1,210 m²
Solar buffer storage volume:	60 m³
Solar fraction:	15.81 %
Annual energy yield:	468.61 kWh/kWa

Table 12: Heat exchangers and amount of recovered energy

Heat Exchanger	Power	Heat Source	Heat Sink	Amount of recovered energy	
	[kW]			[MWh]	[%]
HX brew water	1,256	wort boiling	mashing	1,507	100.00
Total	1,256			**1507**	**100**

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

Equipment	Type	Heat and cooling supplied to pipe/duct	Nominal capacity	Contribution to total heat and cooling supply	
			[kW]	[MWh]	[%]
Solar thermal system	solar thermal (flat-plate)	steam-mashing steam-lautering steam-hot water	848	254	12.35
steam boiler	steam boiler	steam-mashing steam-lautering steam-hot water	1,000	981	47.65
calandria	steam boiler	steam-boiling	500	824	40.01
chiller 1	compression chiller (air cooled)	glycol 1	238	540	60.94
chiller 2	compression chiller (air cooled)	glycol 2	238	346	39.06
Total			**2,824**	**2,945**	**200**

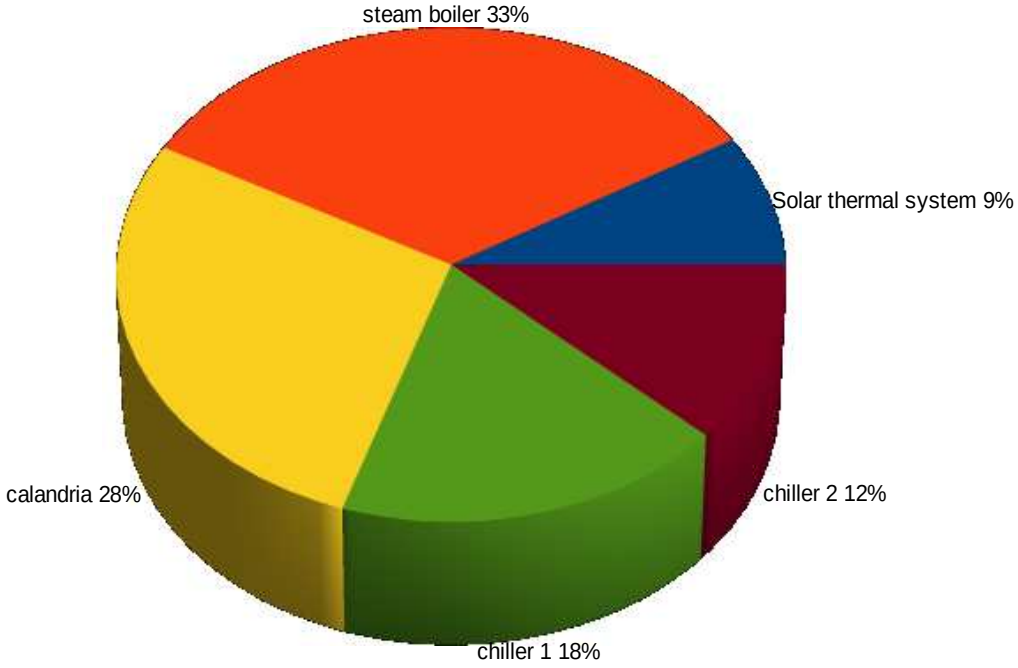

Figure 21: Final energy consumption for thermal use (FET) by equipment

- graphic: heat demand covered by solar thermal system:

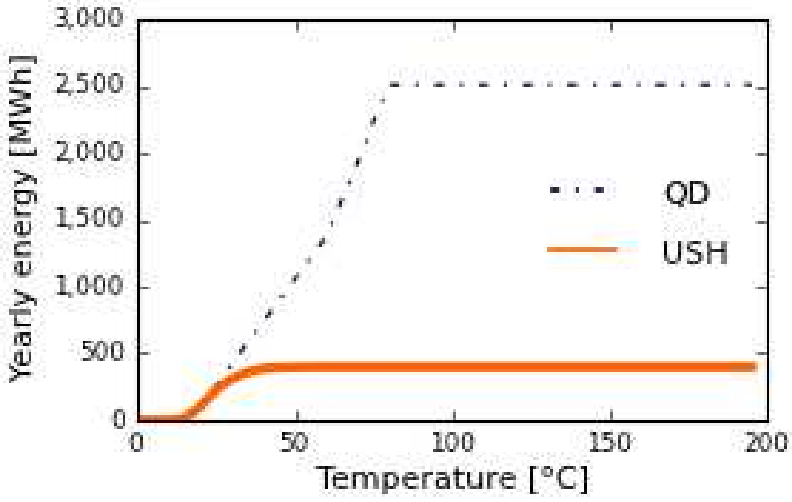

Figure 22: Heat demand and solar contribution

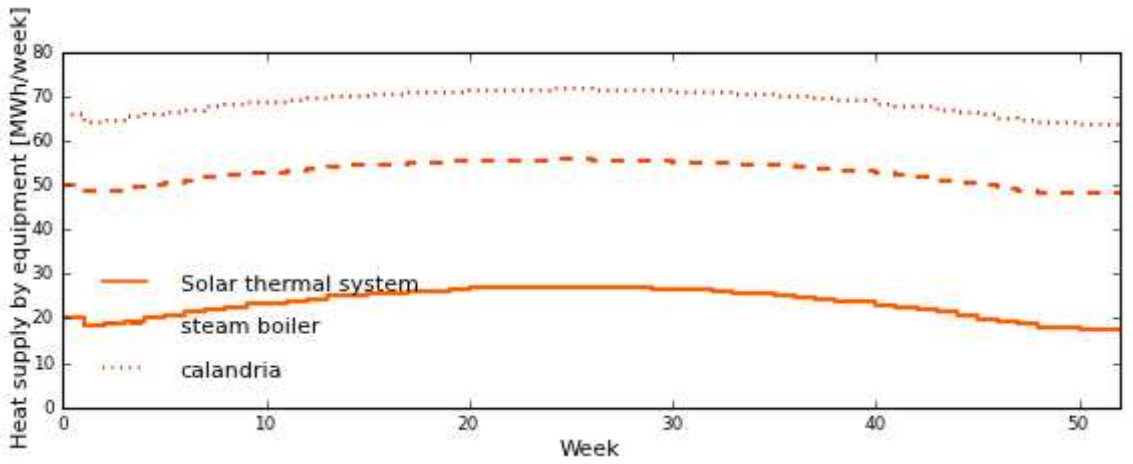

Figure 23: Daily heat supply by equipment

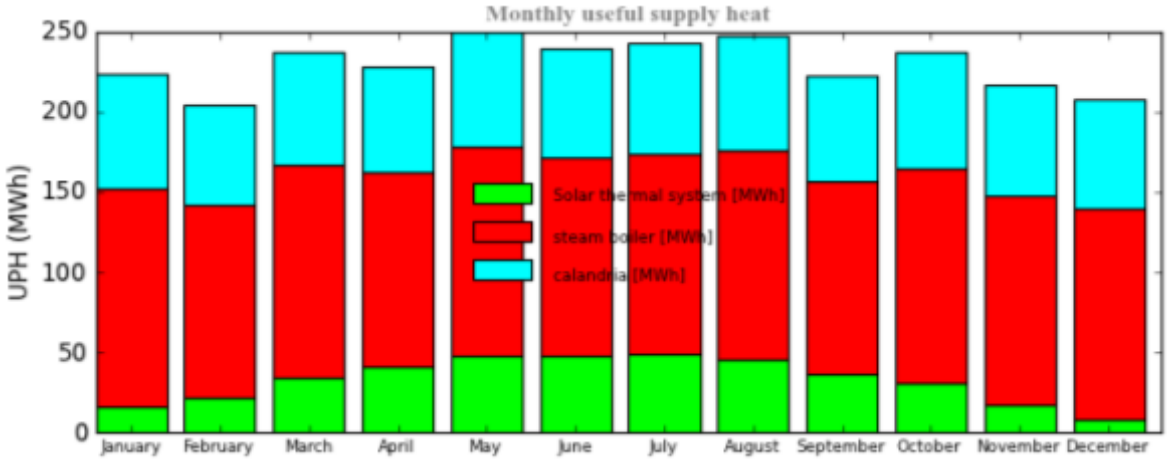

Figure 24: Distribution of useful process heat supply per month

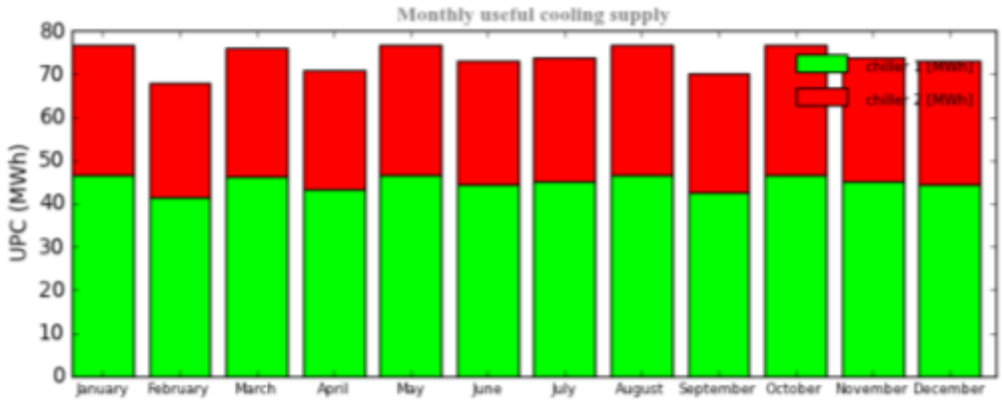

Figure 25: Distribution of useful process cooling supply per month

- **CHP (176 kW):**

Type	CHP engine
Nominal thermal power	176 kW
Nominal electrical power	100 kW
Thermal efficiency	0.51
Electrical efficiency	0.29
Operating hours	7,200 h

Table 14: Heat exchangers and amount of recovered energy

Heat Exchanger	Power	Heat Source	Heat Sink	Amount of recovered energy	
	[kW]			[MWh]	[%]
HX brew water	1,256	wort boiling	mashing	1,507	100.00
Total	1,256			**1,507**	**100**

Table 15: Heat and cooling supply equipment and contribution to total heat and cooling supply

Equipment	Type	Heat and cooling supplied to pipe/duct	Nominal capacity	Contribution to total heat and cooling supply	
			[kW]	[MWh]	[%]
New CHP 1	CHP engine	steam-mashing steam-lautering steam-hot water steam-boiling	176	1,198	54.32
steam boiler	steam boiler	steam-mashing steam-lautering steam-hot water	1,000	527	23.89
calandria	steam boiler	steam-boiling	500	480	21.79
chiller 1	compression chiller (air cooled)	glycol 1	238	540	60.94
chiller 2	compression chiller (air cooled)	glycol 2	238	346	39.06
Total			**2,152**	**3,091**	**200**

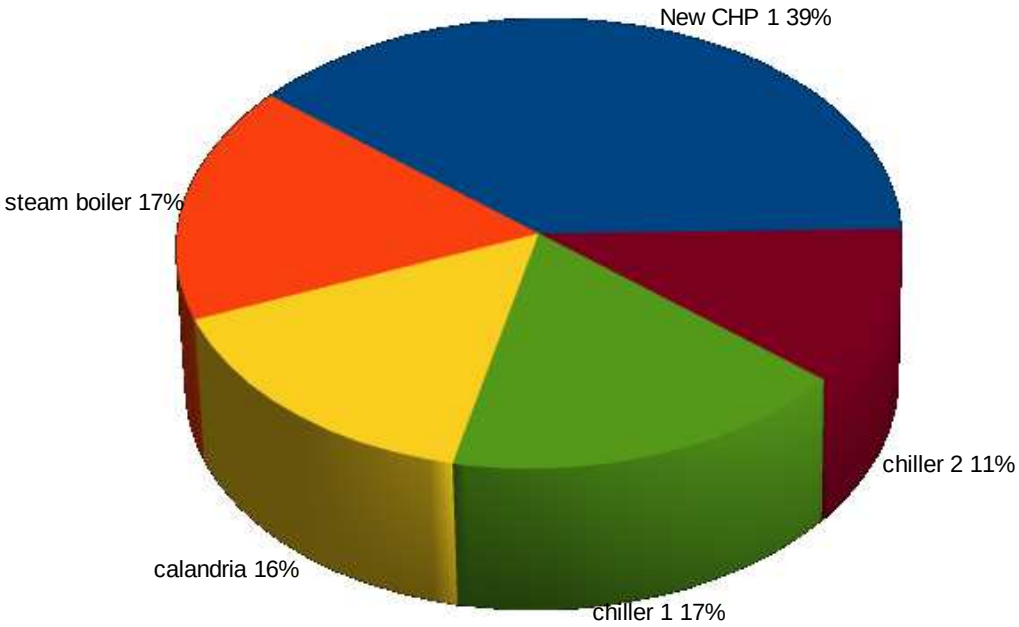

Figure 26: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).

- graphic: heat demand covered by CHP:

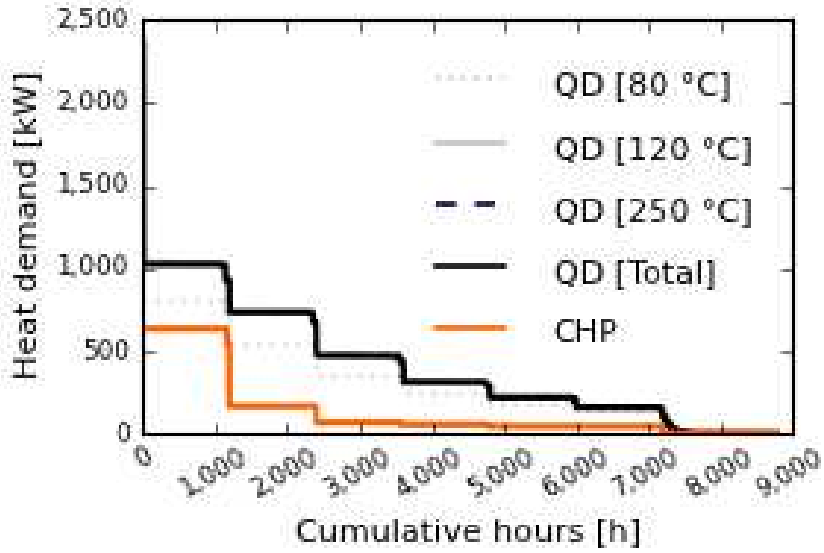

Figure 27: Cumulative heat supply to be covered by CHP

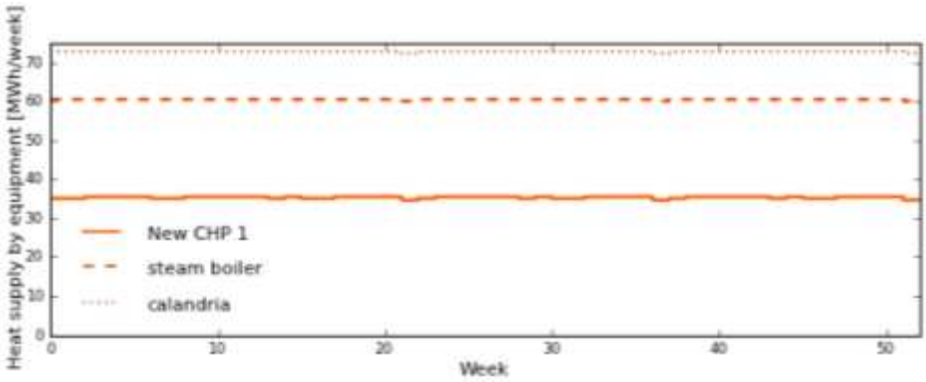

Figure 28: Daily heat supply by equipment

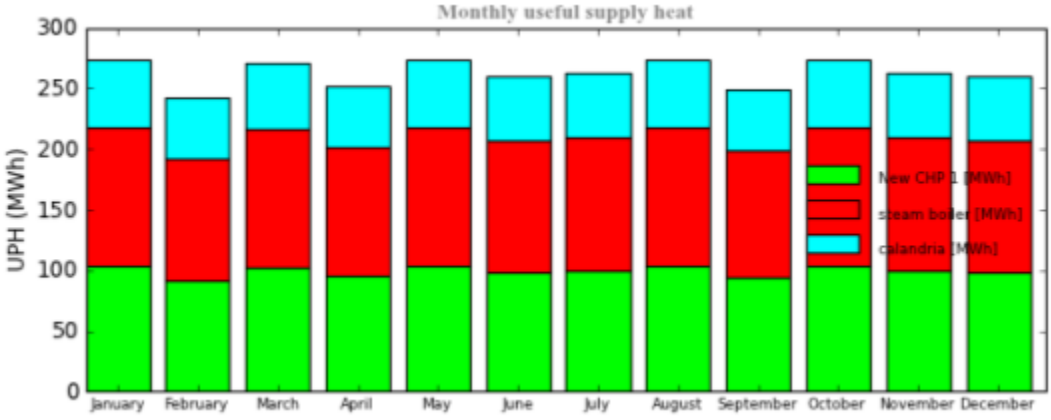

Figure 29: Distribution of useful process heat supply per month

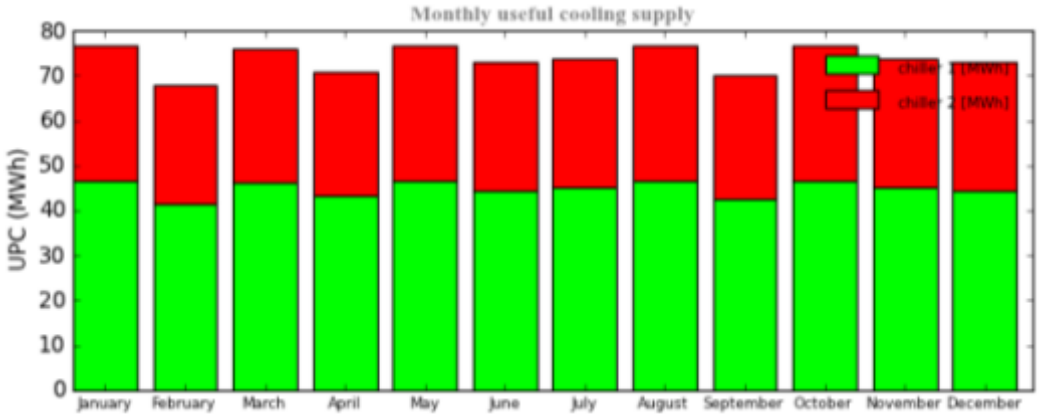

Figure 30: Distribution of useful process cooling supply per month

- **CHP (375 kW):**

Type	CHP engine
Nominal thermal power	375 kW
Nominal electrical power	200 kW
Thermal efficiency	0.60
Electrical efficiency	0.32
Operating hours	7,200 h

Table 16: Heat exchangers and amount of recovered energy

Heat Exchanger	Power	Heat Source	Heat Sink	Amount of recovered energy	
	[kW]			[MWh]	[%]
HX brew water	1,256	wort boiling	mashing	1,507	100.00
Total	1,256			**1,507**	**100**

Table 17: Heat and cooling supply equipment and contribution to total heat and cooling supply

Equipment	Type	Heat and cooling supplied to pipe/duct	Nominal capacity	Contribution to total heat and cooling supply	
			[kW]	[MWh]	[%]
New CHP 2	CHP gas turbine	steam-mashing steam-lautering steam-hot water steam-boiling	375	1,465	66.42
steam boiler	steam boiler	steam-mashing steam-lautering steam-hot water	1,000	382	17.32
calandria	steam boiler	steam-boiling	500	359	16.26
chiller 1	compression chiller (air cooled)	glycol 1	238	540	60.94
chiller 2	compression chiller (air cooled)	glycol 2	238	346	39.06
Total			**2,351**	**3,091**	**200**

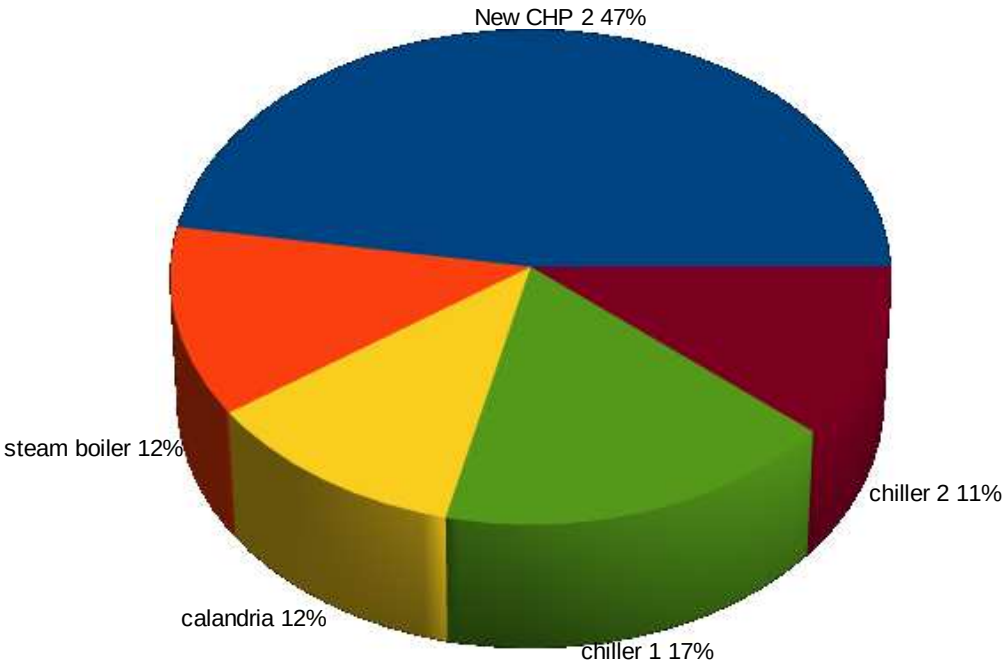

Figure 31: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).

- graphic: heat demand covered by CHP:

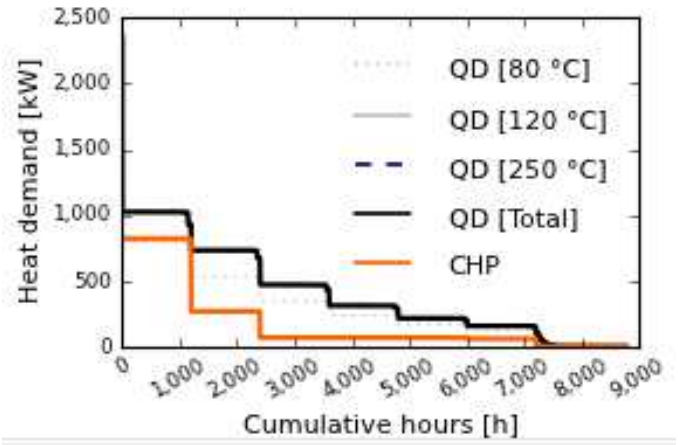

Figure 32: Cumulative heat supply to be covered by CHP

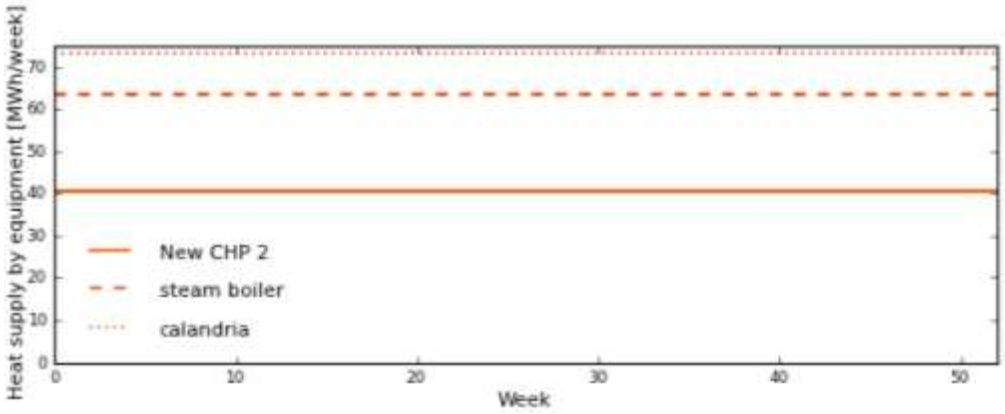

Figure 33: Daily heat supply by equipment

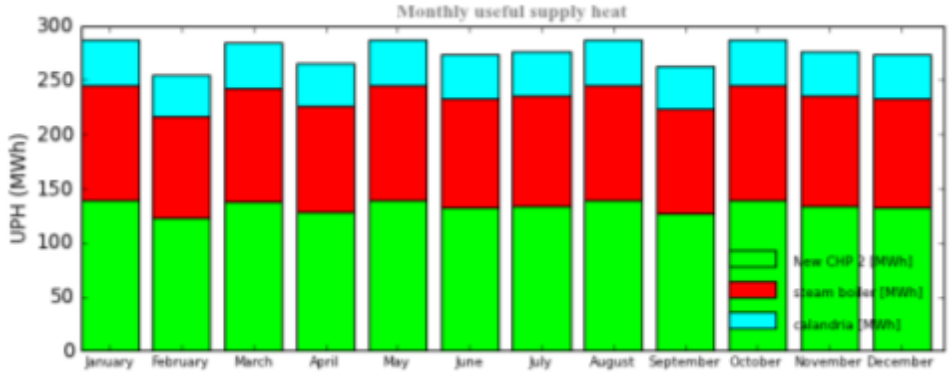

Figure 34: Distribution of useful process heat supply per month

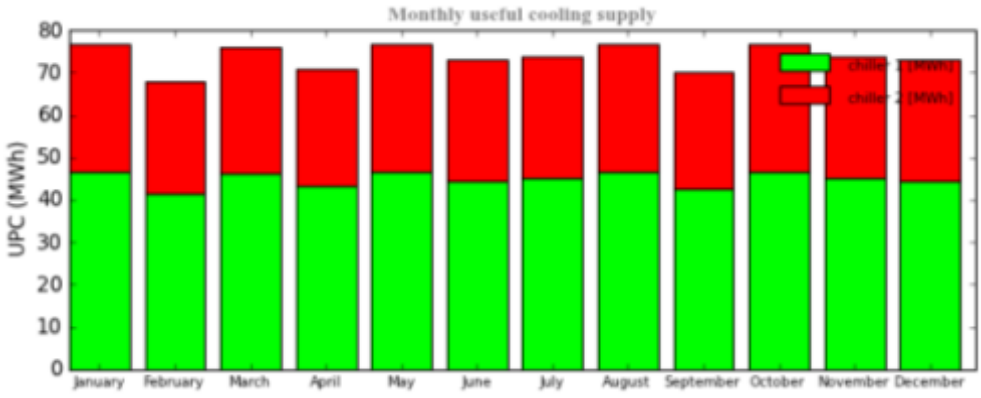

Figure 35: Distribution of useful process cooling supply per month

- **Solar (300 kW):**

Collector type:	FPC (flat plate collectors)
Installed capacity:	300 kW
Installed collector area:	429 m²
Solar buffer storage volume:	60 m³
Solar fraction:	11.29 %
Annual energy yield:	464.76 kWh/kWa

Table 18: Heat exchangers and amount of recovered energy

Heat Exchanger	Power	Heat Source	Heat Sink	Amount of recovered energy	
	[kW]			[MWh]	[%]
HX brew water	1,256	wort boiling	mashing	1,507	100.00
Total	1,256			**1,507**	**100**

Table 19: Heat and cooling supply equipment and contribution to total heat and cooling supply

Equipment	Type	Heat and cooling supplied to pipe/duct	Nominal capacity	Contribution to total heat and cooling supply	
			[kW]	[MWh]	[%]
Solar thermal system	solar thermal (flat-plate)	steam-mashing steam-lautering steam-hot water	300	139	6.77
steam boiler	steam boiler	steam-mashing steam-lautering steam-hot water	1,000	1,096	53.22
calandria	steam boiler	steam-boiling	500	824	40.01
chiller 1	compression chiller (air cooled)	glycol 1	238	540	60.94
chiller 2	compression chiller (air cooled)	glycol 2	238	346	39.06
Total			**2,276**	**2,945**	**200**

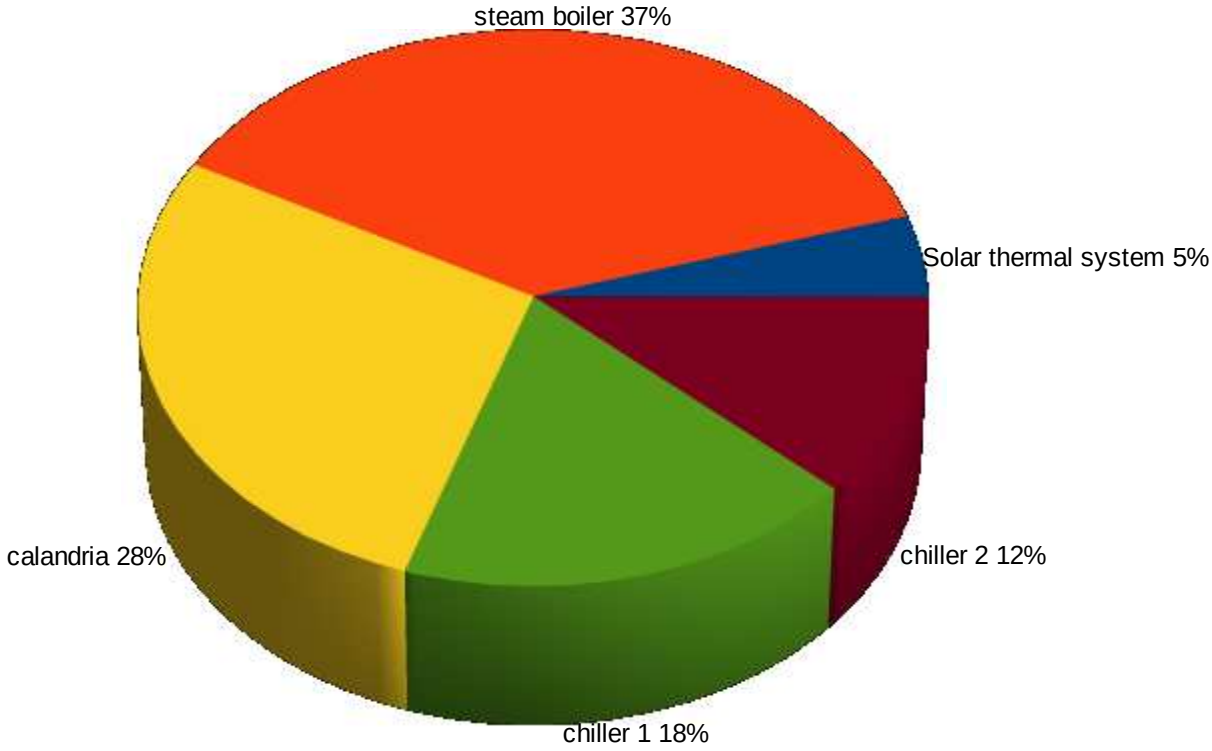

Figure 36: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).

- graphic: heat demand covered by solar thermal system:

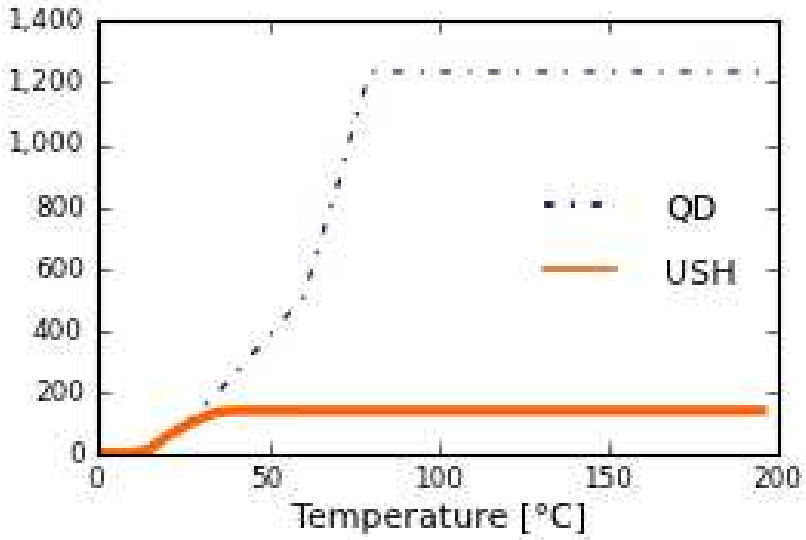

Figure 37: Heat demand and solar contribution

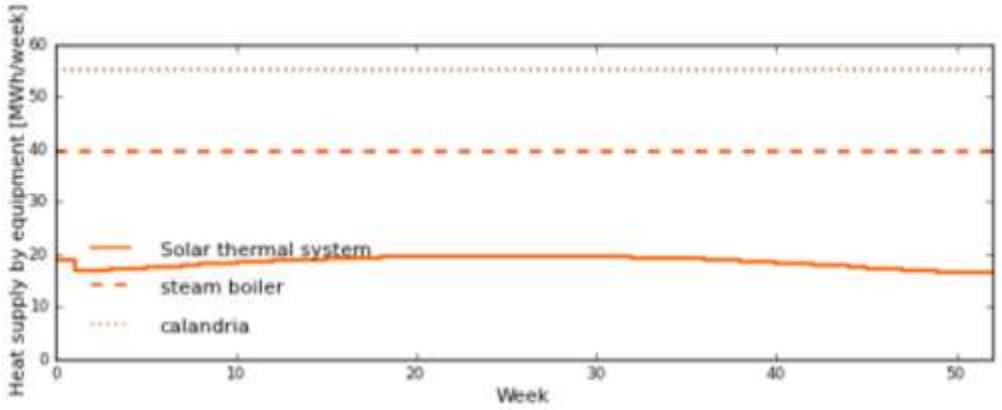

Figure 38: Daily heat supply by equipment

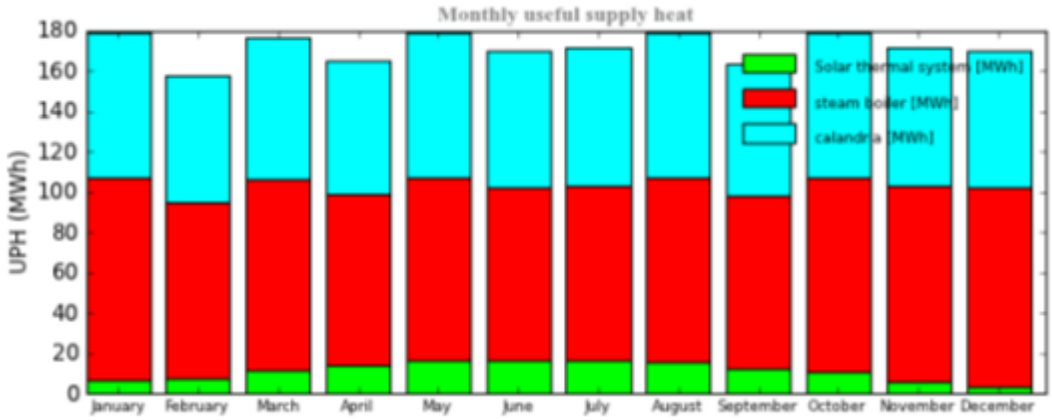

Figure 39: Distribution of useful process heat supply per month

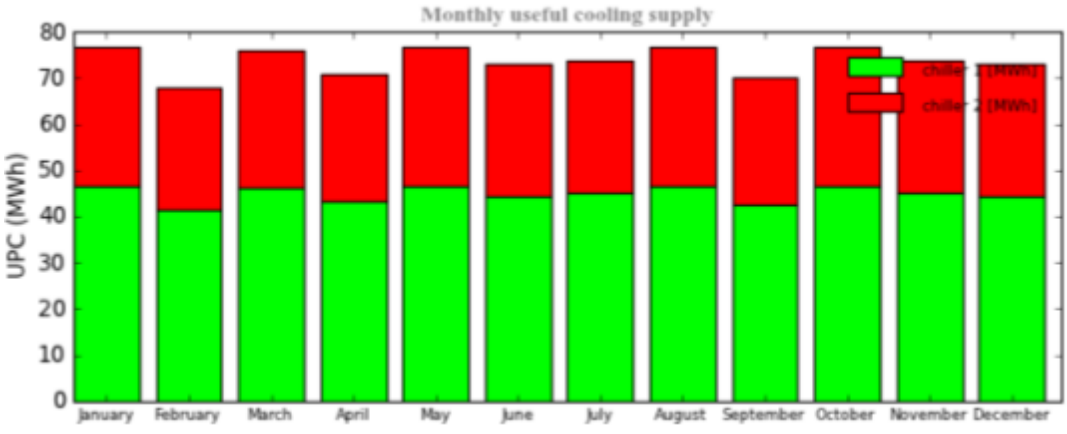

Figure 40: Distribution of useful process cooling supply per month

- Primary energy consumption (PEC)

Table 20: primary energy consumption and savings

Alternative	Primary energy consumption	Savings	
	[MWh]	[MWh]	[%]
Present State (checked)	12,440	---	---
new boiler	12,277	163	1.31
solar	12,092	348	2.80
CHP (176kW)	11,506	935	7.51
CHP (375kW)	10,976	1,464	11.77
solar (300kW)	12,251	189	1.52

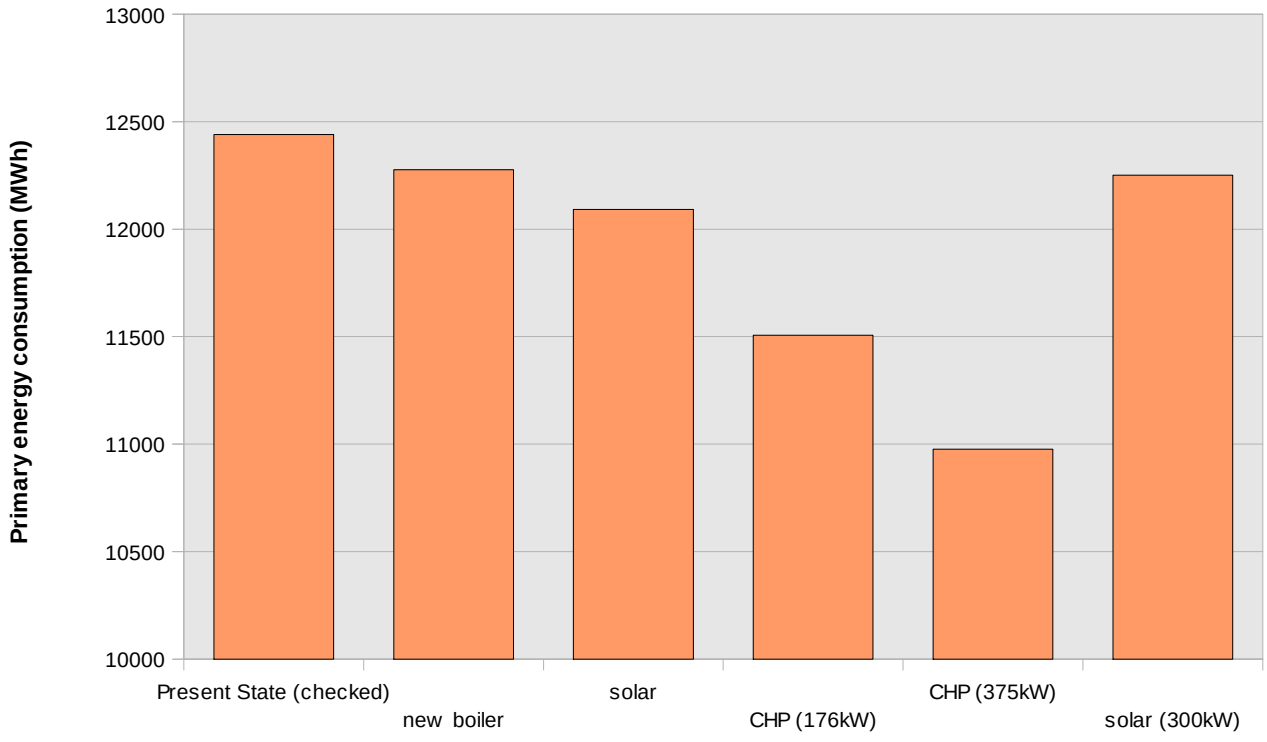

Figure 41: Comparison of alternatives: primary energy consumption

- 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 21: Useful process and supply heat: present state and alternative proposals.

Alternative	Useful process heat (UPH) [MWh]	Savings UPH [MWh]	Useful supply heat (USH) [MWh]	Savings USH [MWh]
Present State (checked)	3,732	---	2,144	---
new boiler	3,732	0	2,144	-61
solar	3,732	0	2,144	85
CHP (176kW)	3,732	0	2,144	-61
CHP (375kW)	3,732	0	2,144	-61
solar (300kW)	3,732	0	2,144	85

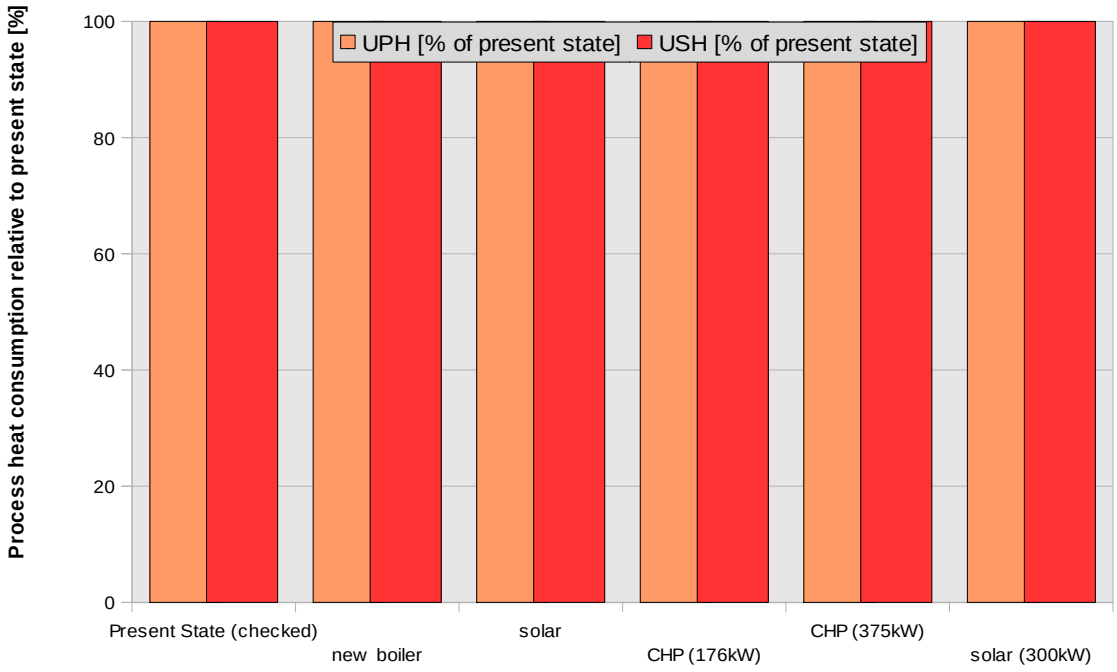

Figure 42: Comparison of alternatives: useful process heat supply

- Environmental impact

Table 22: CO2 production and CO2 savings per year

Alternative	Production of CO2	CO2 savings	Water consumption
	[t]	[%]	[m3]
Present State (checked)	2247.29		0.00
new boiler	2207.71	1.76	0.00
solar	2165.82	3.63	0.00
CHP (176kW)	2159.97	3.89	0.00
CHP (375kW)	2078.20	7.52	0.00
solar (300kW)	2201.84	2.02	0.00

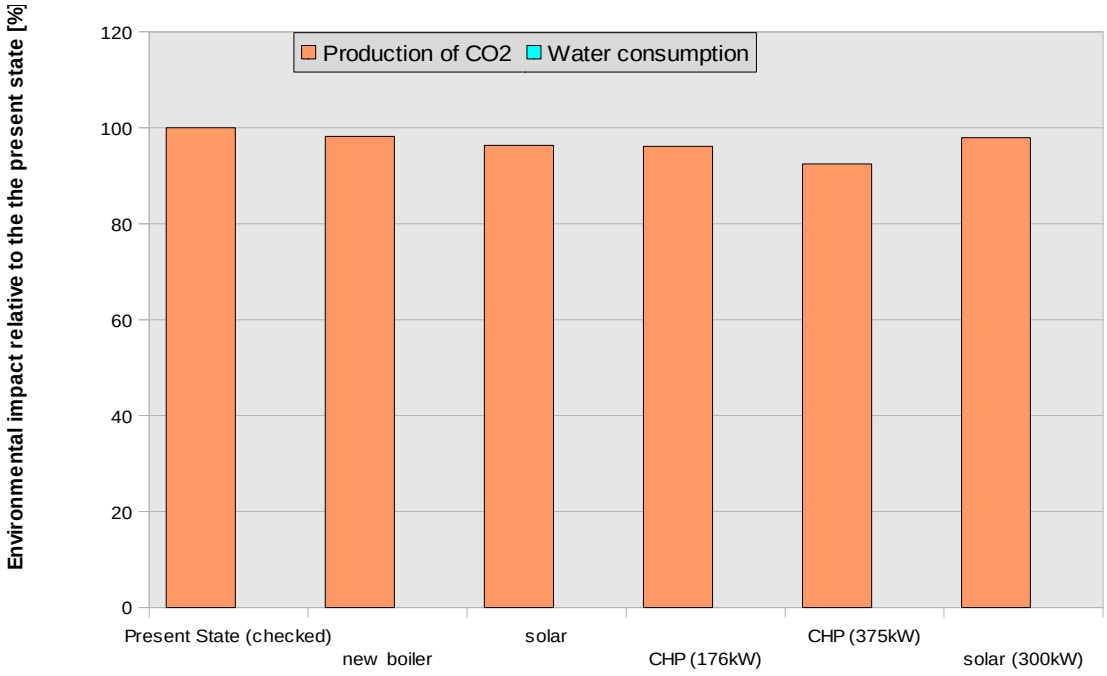

Figure 43: Comparison of alternatives: environmental impact

Table 23: Investment costs and subsidies of the proposals

Alternative	Total investment [€]	Own investment [€]	Subsidies [€]
Present State (checked)	---	---	---
new boiler	180,000	180,000	0
solar	544,500	381,150	163,350
CHP (176kW)	180,000	180,000	0
CHP (375kW)	360,000	360,000	0
solar (300kW)	192,000	134,400	57,600

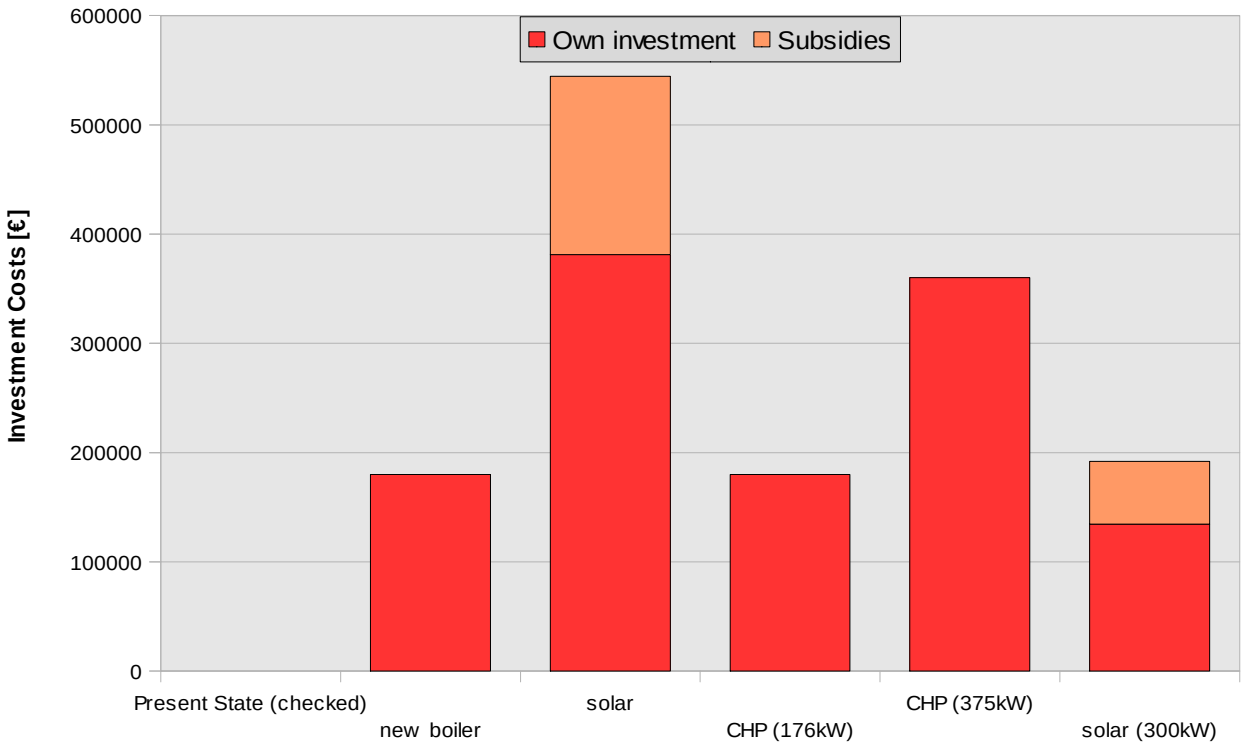

Figure 44: Comparison of alternatives investment cost

5. Selected alternative(s) and conclusions

5.1. Selected alternative

As selected alternative the "CHP (375 kW)" 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

CHP (375 kW):

Type	CHP engine
Nominal thermal power	375 kW
Nominal electrical power	200 kW
Thermal efficiency	0.60
Electrical efficiency	0.32
Operating hours	7,200 h

Table 24: Heat exchangers and amount of recovered energy

Heat Exchanger	Power	Heat Source	Heat Sink	Heat transferred	
	[kW]			[MWh]	[%]
HX brew water	1,256	wort boiling	mashing	1,507	100.00
	1,256			**1,507**	**100**

Table 25: Heat and cooling supply equipment and contribution to total supply. Final proposed solution.

Equipment	Type	Heat / cooling supplied to pipe/duct	Nominal capacity	Contribution to total heat / cooling supply	
			[kW]	[MWh]	[%]
New CHP 2	CHP gas turbine	steam-mashing steam-lautering steam-hot water steam-boiling	375	1,465	66.42
steam boiler	steam boiler	steam-mashing steam-lautering steam-hot water	1,000	382	17.32
calandria	steam boiler	steam-boiling	500	359	16.26
chiller 1	compression chiller (air cooled)	glycol 1	238	540	60.94
chiller 2	compression chiller (air cooled)	glycol 2	238	346	39.06
Total			**2,351**	**3,091**	**200**

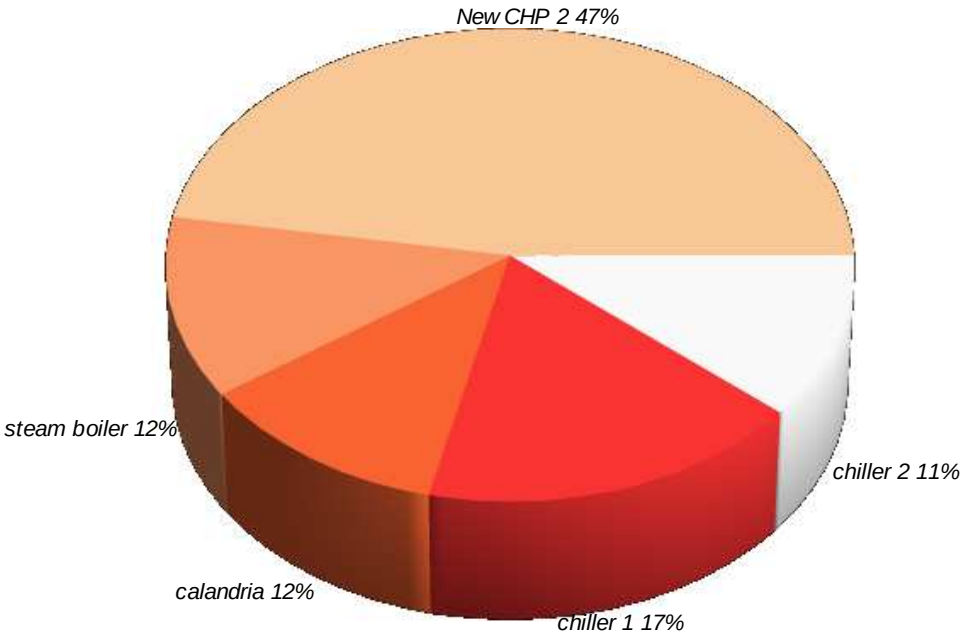

Figure 45: Contribution of each equipment to the total useful heat and cooling supply (USH + USC). Final proposed solution.

5.1.3. Energy Consumption

Table 26: 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	4,106	37.41	4,106	180.40
Total electricity	6,870	62.59	-1,830	-80.40
Total (fuels + electricity)	**10,976**	**100.00**	**2,276**	**100.00**

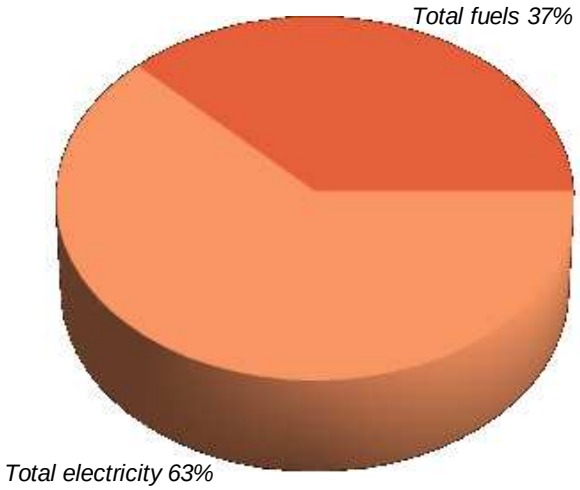

Figure 46: Distribution of PEC by fuel type

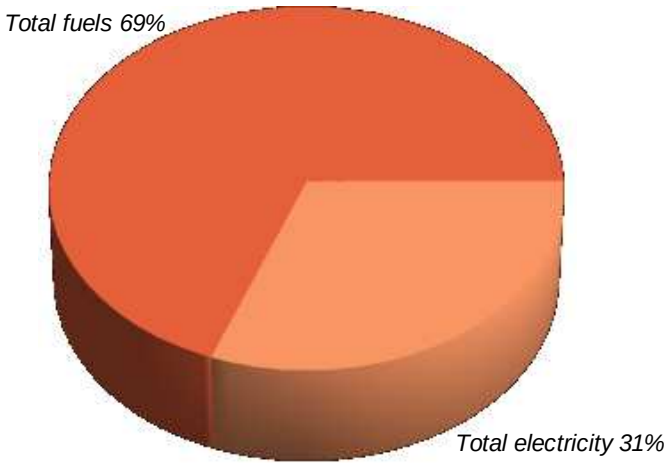

Figure 47: Distribution of PET by fuel type

Table 27: Total final energy consumption (FEC) and final energy consumption for thermal use (FET)

Fuel type	FEC		FET	
	[MWh]	[% of Total]	[MWh]	[% of Total]
Natural gas	3,733	61.98	3,733	119.53
Electricity	2,290	38.02	-610	-19.53
Total	6,023	100.00	3,123	100.00

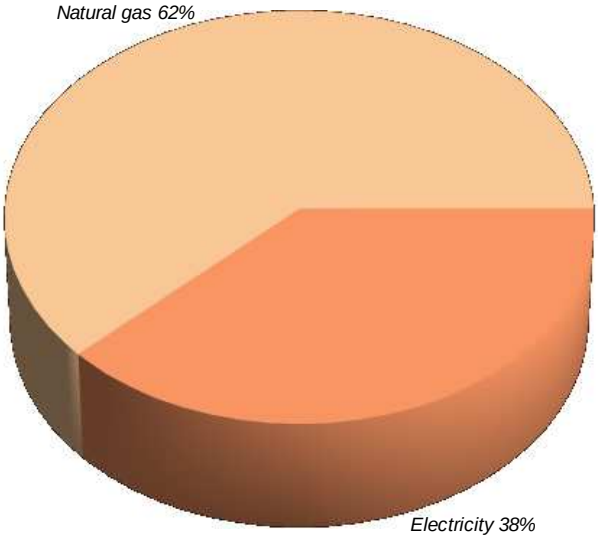

Figure 48: Distribution of PEC by fuel type

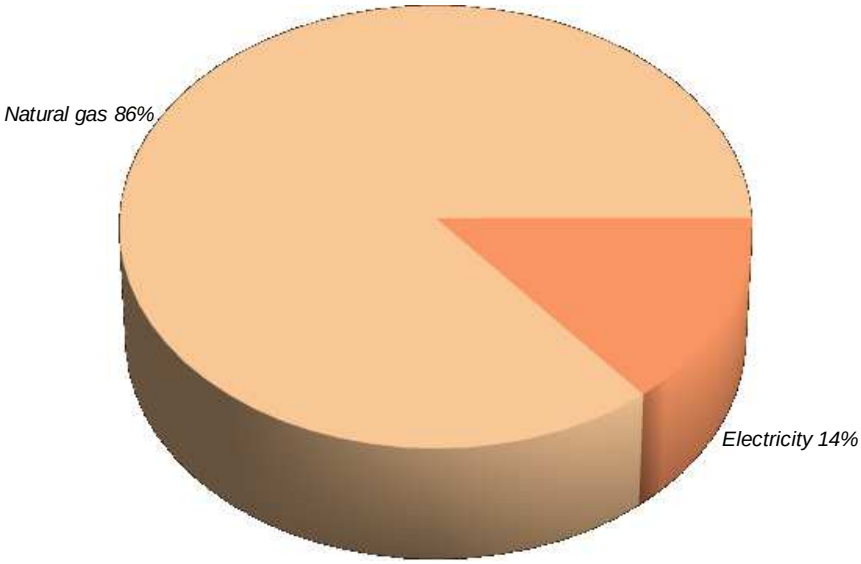

Figure 49: Total final energy consumption for thermal use (FET). Proposed final solution.

Table 28: Final energy consumption for thermal use (FET) by equipment. Proposed final solution.

Equipment	Fuel type	FET by equipment	
		[MWh]	[% of Total]
steam boiler	Natural gas	482	15.44
calandria	Natural gas	452	14.48
chiller 1	Electricity	159	5.11
chiller 2	Electricity	120	3.84
New CHP 2	Natural gas(- gen.elect.)	1,909	61.12
Total		**3,123**	**100**

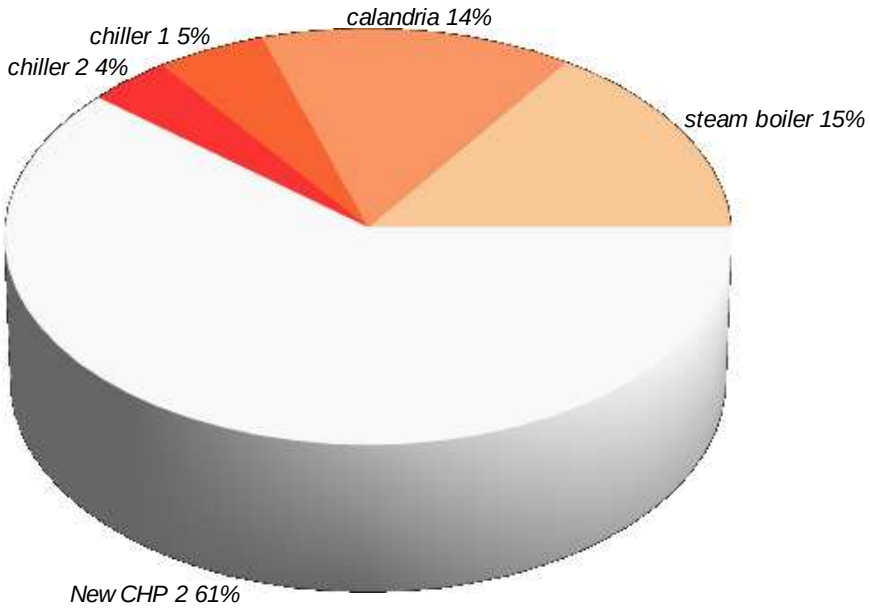

Figure 50: Final energy consumption for thermal use (FET) by equipment

Table 29: Useful supply heat (USH) by equipment. Proposed final solution.

Equipment	USH by equipment	
	[MWh]	[% of Total]
steam boiler	382	17.32
calandria	359	16.26
New CHP 2	1,465	66.42
Total	**2,205**	**100**

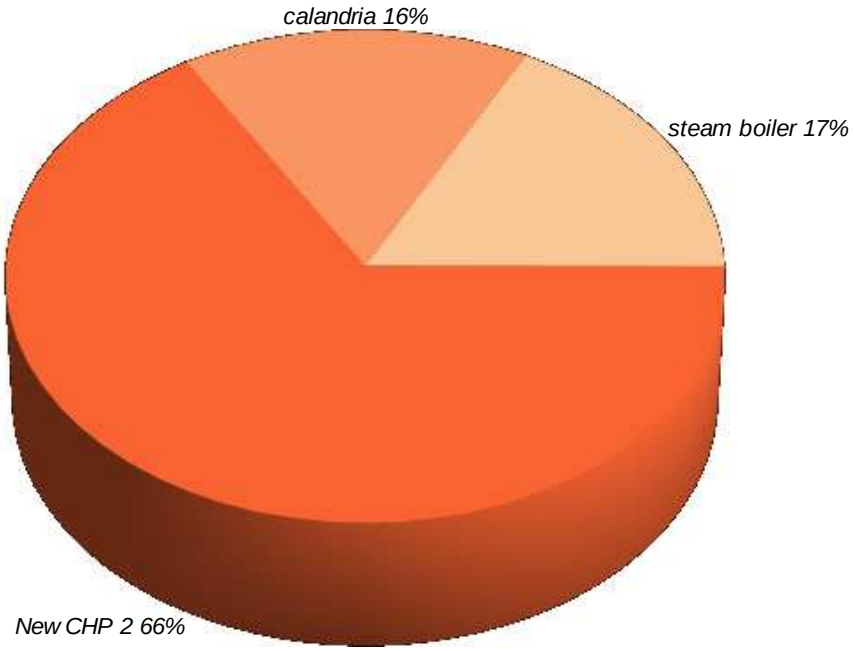

Figure 51: Useful supply heat (USH) by equipment. Proposed final solution.

Table 30: Useful supply cooling (USC) by equipment. Proposed final solution.

Equipment	USC by equipment	
	[MWh]	[% of Total]
chiller 1	540	60.94
chiller 2	346	39.06
Total	**886**	**100**

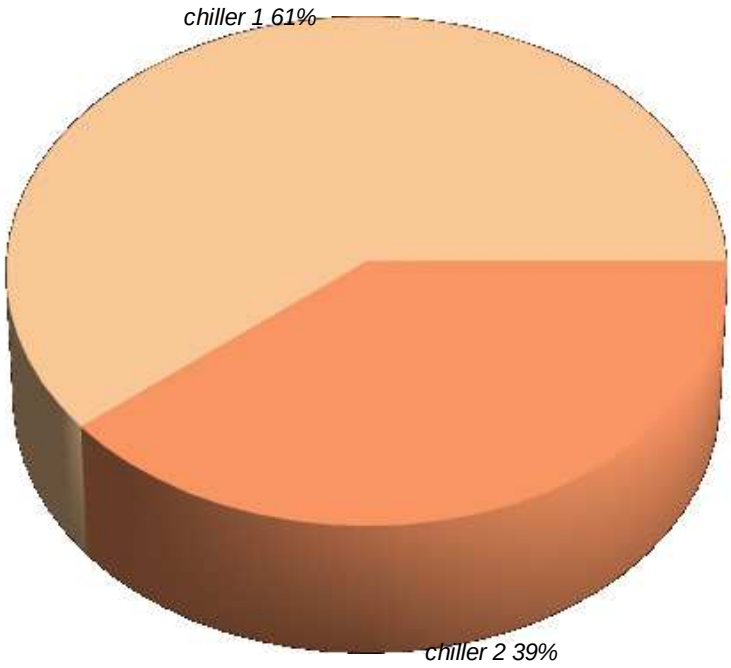

Figure 52: Useful supply cooling (USC) by equipment. Proposed final solution.

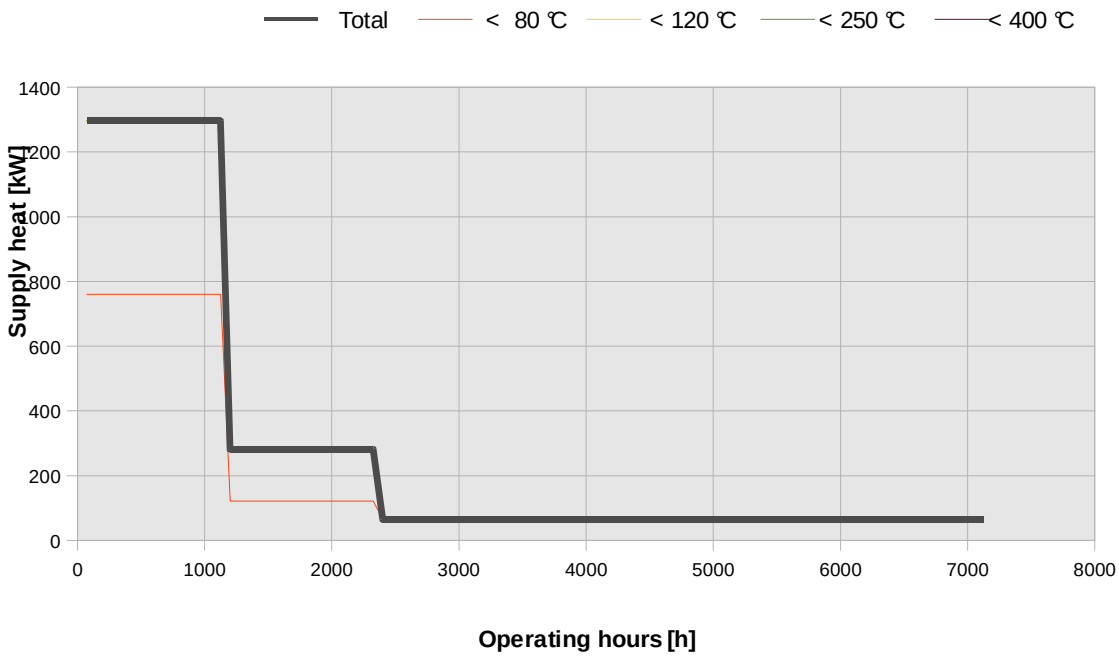

Figure 53: Distribution of supply heat by temperature levels and annual operating hours. Proposed final solution.

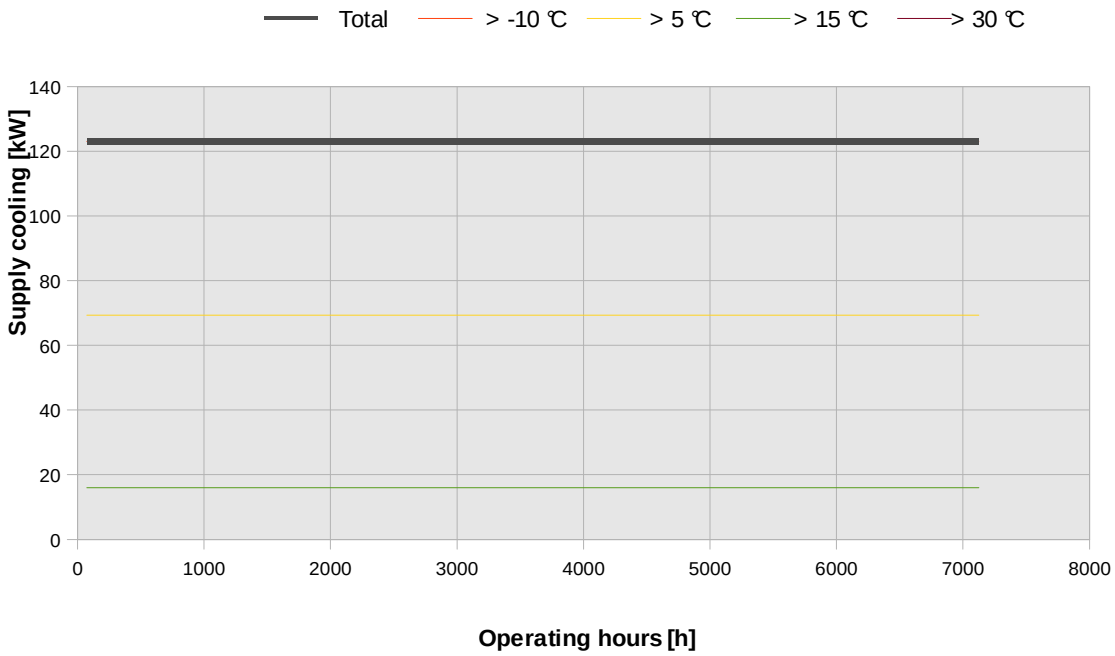

Figure 54: Distribution of supply cooling by temperature levels and annual operating hours. Proposed final solution.

Table 31: Useful process heat demand (UPH) by process. Proposed final solution.

Process	Total [MWh]	Circulation [MWh]	Maintenance [MWh]	Start-up [MWh]
mashing	2,185	1,697	2	486
wort boiling	970	962	8	0
lautering	109	105	4	0
hot water brew house	468	468	0	0
Total	**3,732**			

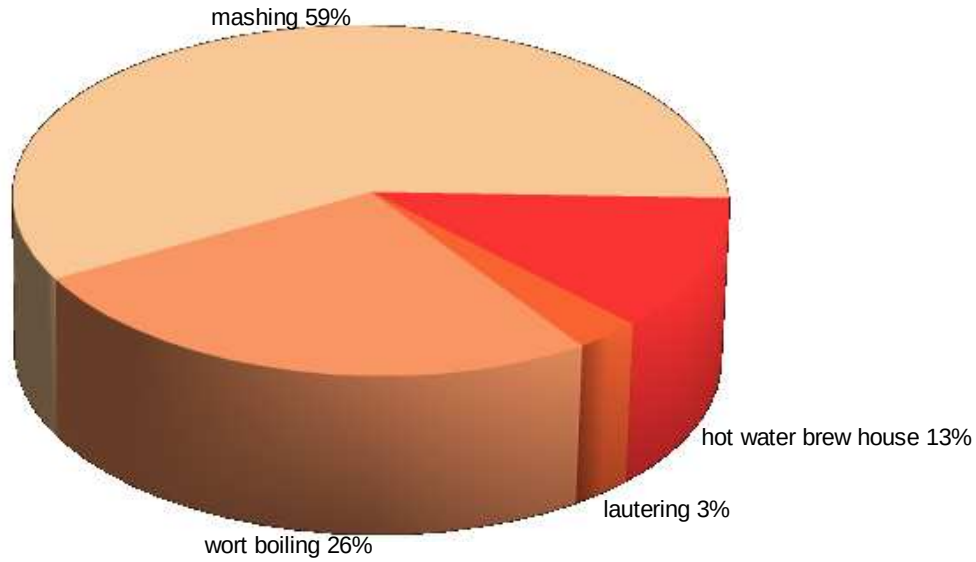

Figure 55: Useful process heat (UPH) by process. Proposed final solution.

Table 32: Useful process cooling demand (UPC) by process. Proposed final solution.

Process	Total [MWh]	Circulation [MWh]	Maintenance [MWh]	Start-up [MWh]
fermentation	539	537	2	0
maturation	346	345	1	0
Total	**885**			

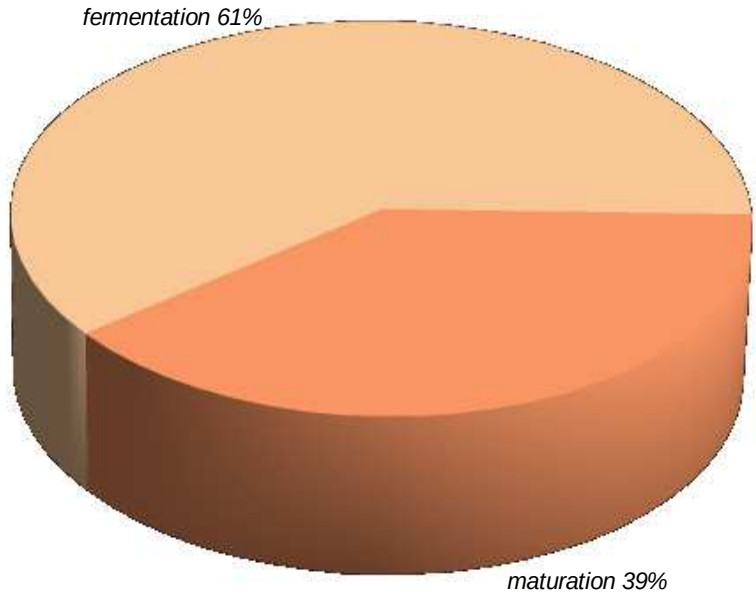

Figure 56: Useful process cooling (UPC) by process. Proposed final solution.

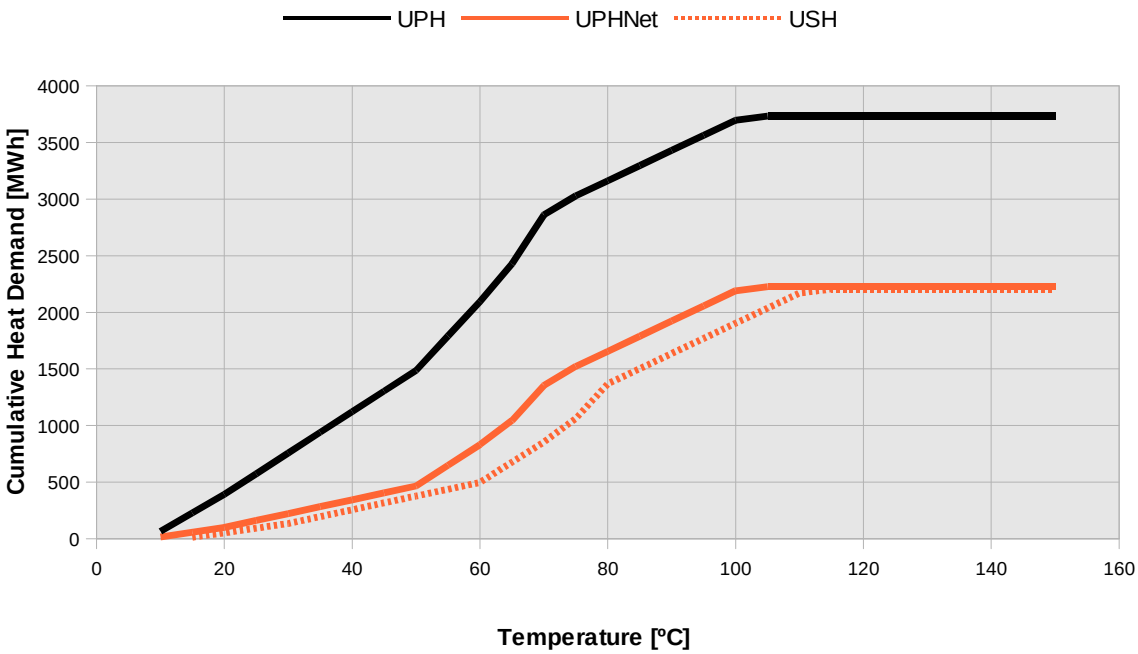

Figure 57: Distribution of the heat demand by temperature levels

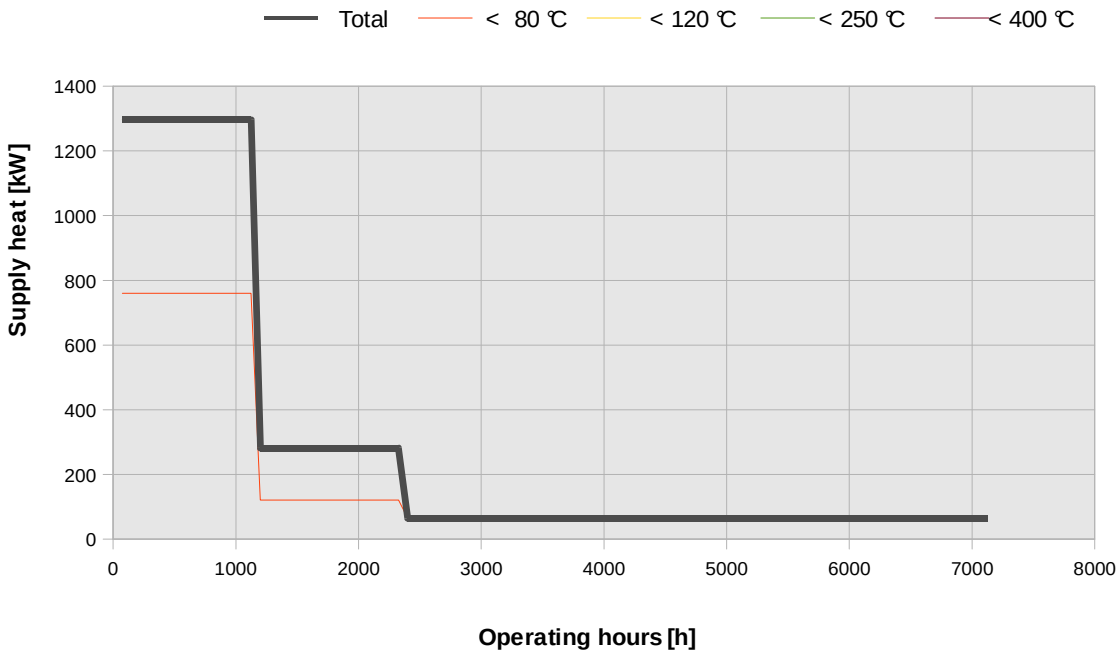

Figure 58: Distribution of supply heat by temperature levels and annual operating hours. Proposed final solution.

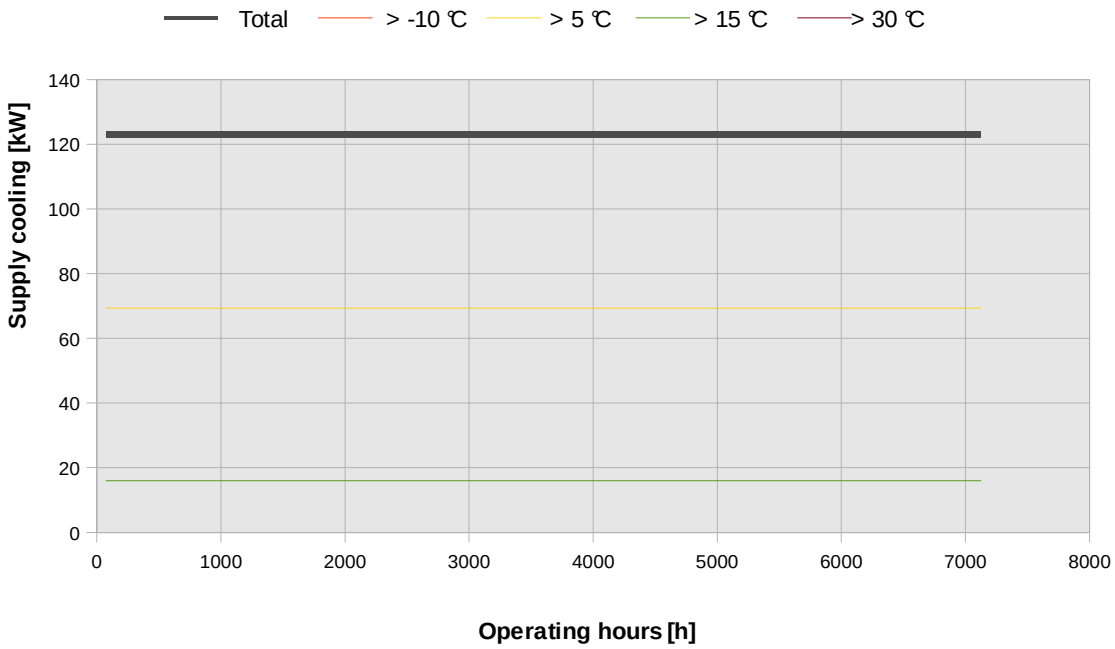

Figure 59: Distribution of supply cooling by temperature levels and annual operating hours. Proposed final solution.

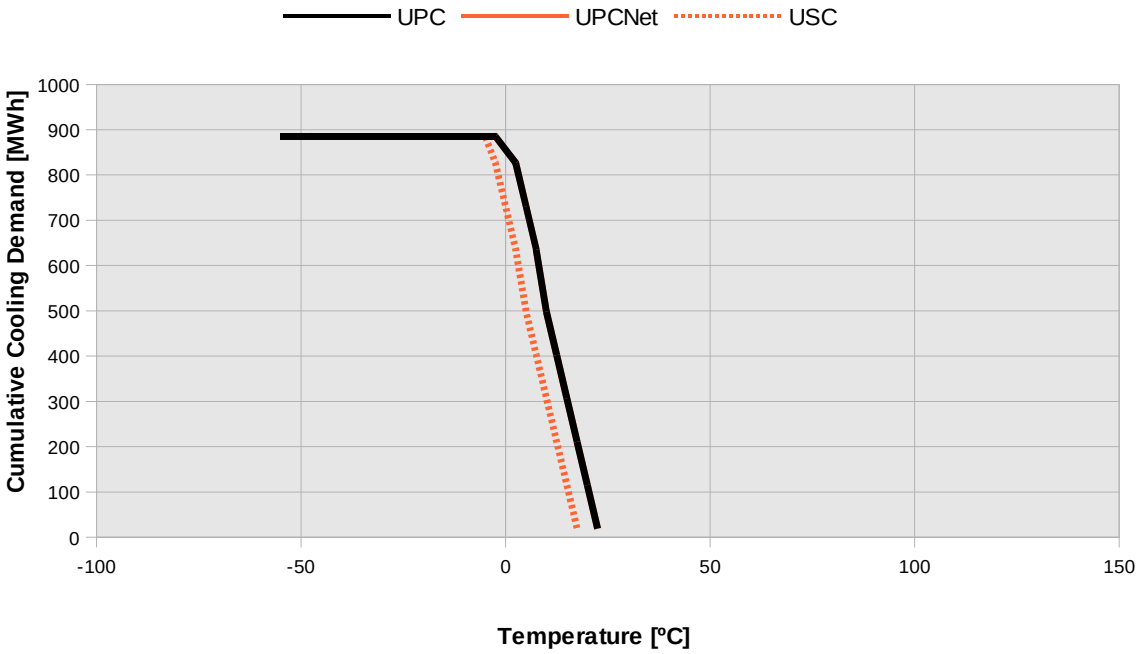

Figure 60: Distribution of the cooling demand by temperature levels

5.2. Comparative study and conclusions

5.2.1. Energy and environmental analysis

In the proposed alternative around 12 % of the CO_2 pollution can be saved.

5.2.2. Economic analysis

The payback period of about 12 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 solar thermal plant of the investment costs and have to be revised.

As no information about the actual energy prices could be obtained, the calculations were done with assumed energy costs (natural gas: 46 €/MWh and electricity: 0.12 €/kWh).

Table 33: Savings of the proposed alternative in comparison to the present state

		Present state	Alternative	Saving	[% savings]
Total primary energy consumption (1)					
- total	[MWh]	12,440	10,976	1,464	12%
- fuels	[MWh]	2,869	4,106	-1,237	-43%
- electricity	[MWh]	9,571	6,870	2,701	28%
Primary energy saving due to renewable energy	[MWh]		0		
CO2 emissions	[t/a]	2,311	2,026	285	12%
Annual energy system cost (2)	[EUR]	439,283	400,710	38,573	9%
Total investment costs	[EUR]		360,000		
Payback period (3)	[years]		12		

(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

- Due to the lack of information about the actual energy prices the calculations were done with assumed energy costs (natural gas: 46 €/MWh and electricity: 0.12 €/kWh).
- The consumption of the different boilers, burners (equipment) is based on the yearly overall energy consumptions, these figures and data have to be revised and adapted to the actual figures.
- In order to gain savings as high as calculated, the calculations have to be adapted to the actual thermal efficiency of the new equipment 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.