Energy Audit Summary Report

AEE INTEC

Audit no. 66 – BUL10

Mushroom Factory

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. 66 – BUL10

1. Data of the auditor

1.1. Contact data of the auditor

Jürgen Fluch, Matthäus Hubmann

Number of audits preformed: 17

Date of the audit: 15.06.2012

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	Production of PV-modules
Products	Photovoltaic modules
No. of employees	150
Current primary energy consumption	14.5 [MWh/a]

3.2. Flow sheet of the whole manufacturing side

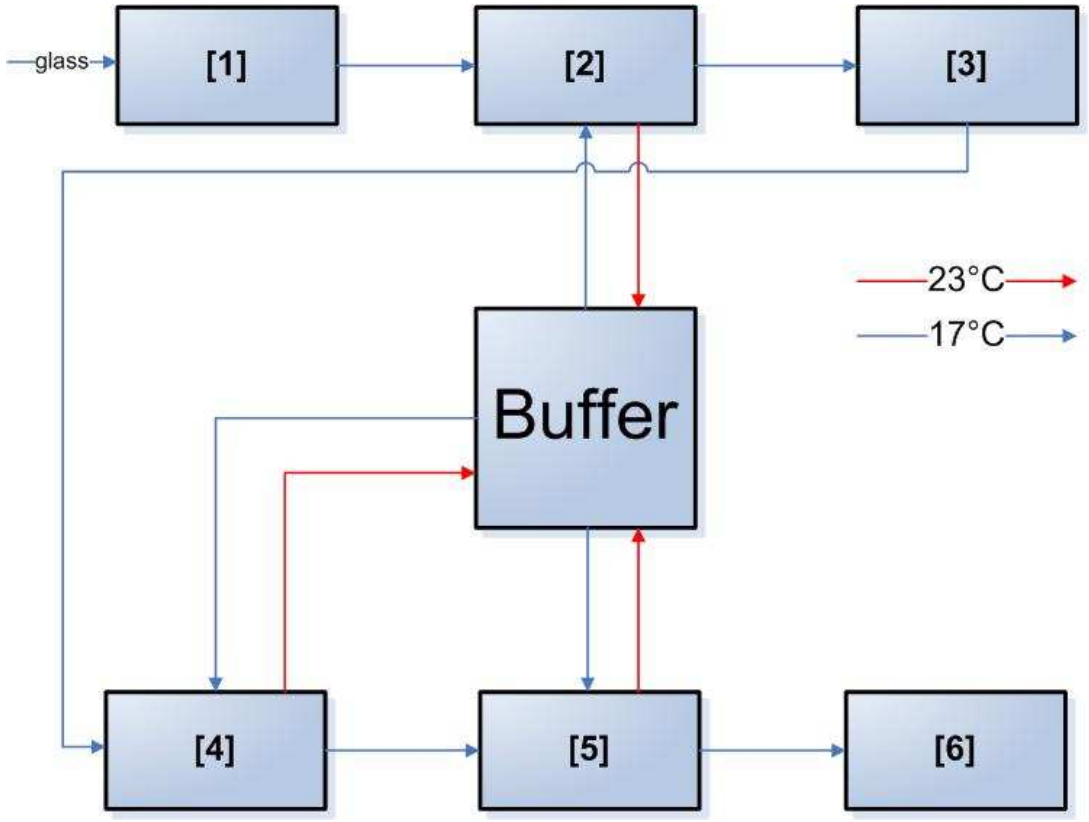

Figure 1: Flow sheet of the factory; [1] Rinsing and laser scribing of glass with TCO layer; [2] Vacuum laying down silicon layers; [3] Laser scribing; [4] Laying down ZnO and Al layers; [5] Laminating; [6] Mounting and packaging; [Buffer] buffer storage tank of 1500 l

3.3. Description of the existing system

- **Energy Supply:**

The factory is mainly consuming electric energy for heating and process maintenance purposes during the production. In addition it has a low natural gas consumption.

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	1	0.00	1	0.01
Total electricity	14,522	100.00	12,773	99.99
Total (fuels + electricity)	**14,522**	**100.00**	**12,774**	**100.00**

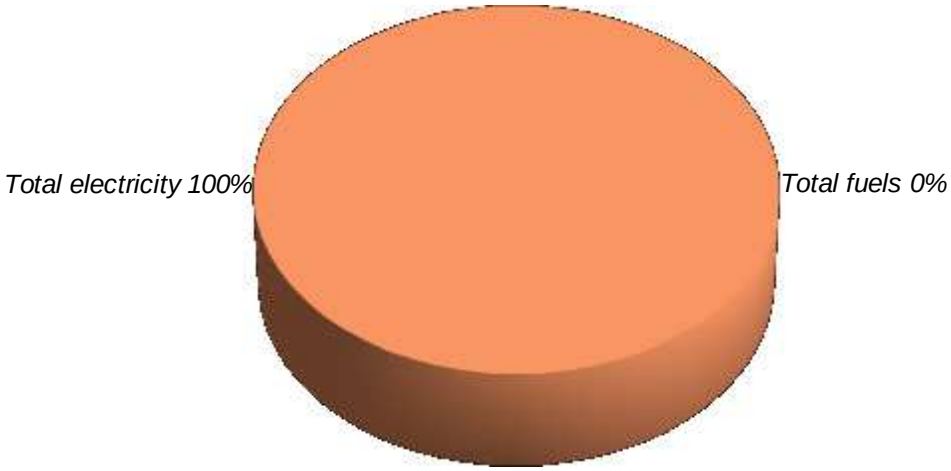

Figure 2: Distribution of PEC by fuel type

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

Fuel type	FEC		FET	
	[MWh]	[% of Total]	[MWh]	[% of Total]
Natural gas	1	0.01	1	0.01
Electricity	5,007	99.99	4,405	99.99
Total	5,008	100.00	4,405	100.00

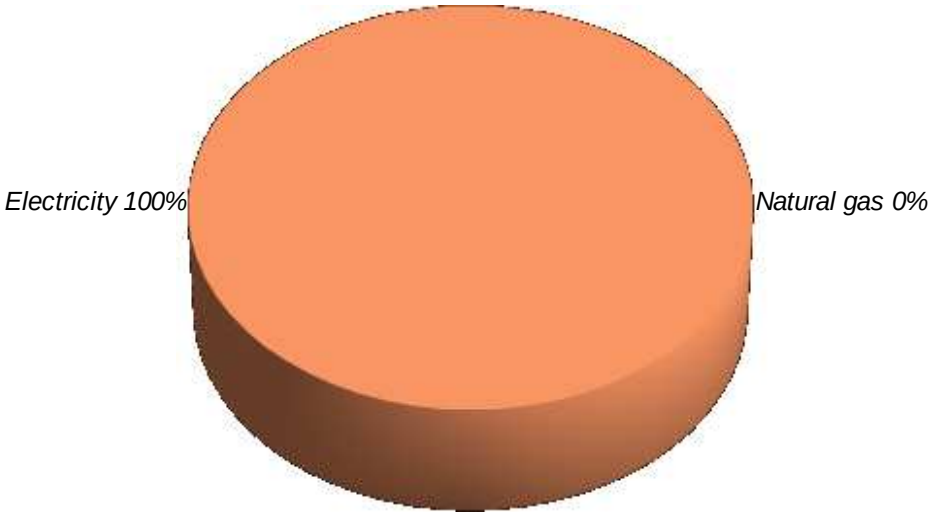

Figure 3: Total final energy consumption for thermal use (FET)

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

Equipment	Fuel type	FET by equipment	
		[MWh]	[% of Total]
El. heater 15kW	Electricity	85	1.93
El. heater 30kW	Electricity	81	1.84
Chillers	Electricity	3,971	90.11
Heating lamination	Electricity	129	2.92
Heating through plasma	Electricity	6	0.14
Hot water heating	Electricity	39	0.89
Electrical heaters	Electricity	95	2.16
Gas plasma	Natural gas	1	0.01
Total		**4,407**	**100.00**

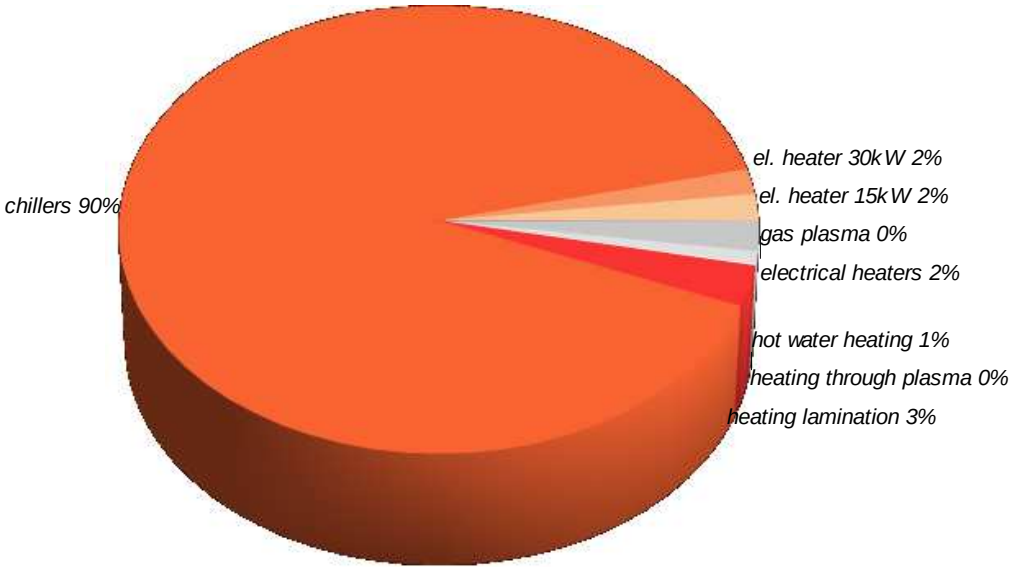

Figure 4: Final energy consumption for thermal use (FET) by equipment

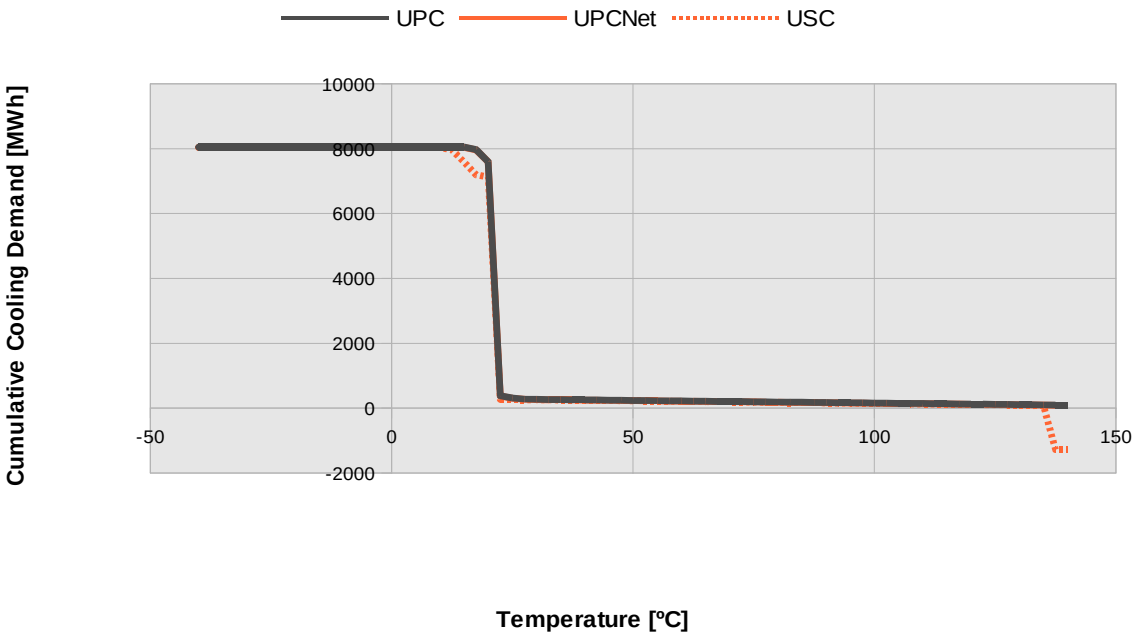

Figure 5: Distribution of supply heat by temperature levels and annual operating hours. Present state.

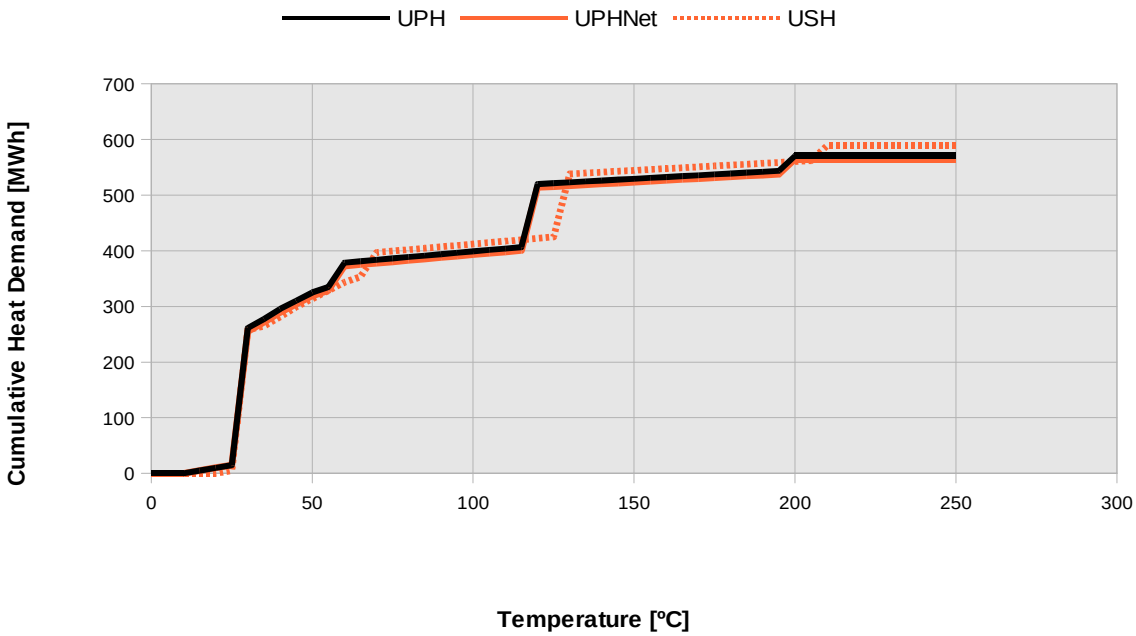

Figure 6: Distribution of the heat demand by temperature levels

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

Equipment	USH by equipment	
	[MWh]	[% of Total]
El. heater 15kW	85	20.29
El. heater 30kW	81	19.35
Heating lamination	129	30.78
Heating through plasma	6	1.48
Hot water heating	39	9.34
Electrical heaters	78	18.64
Gas plasma	1	0.13
Total	**419**	**100**

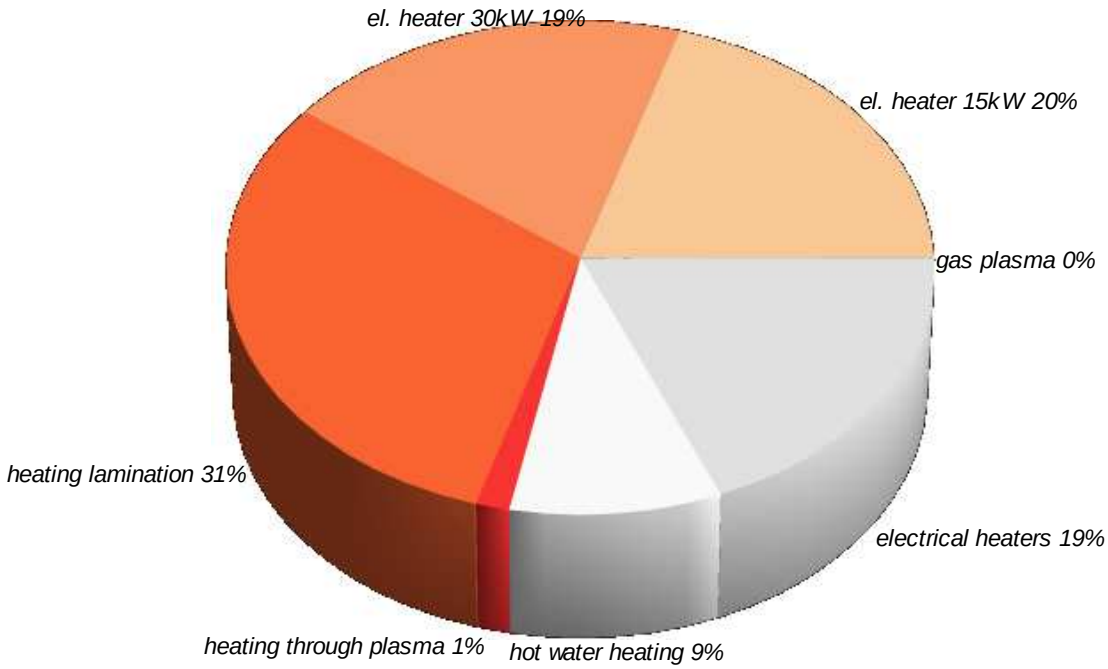

Figure 7: Useful supply heat (USH) by equipment. Present state

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

Equipment	USC by equipment	
	[MWh]	[% of Total]
Chillers	7,934	100
Total	**7,934**	**100**

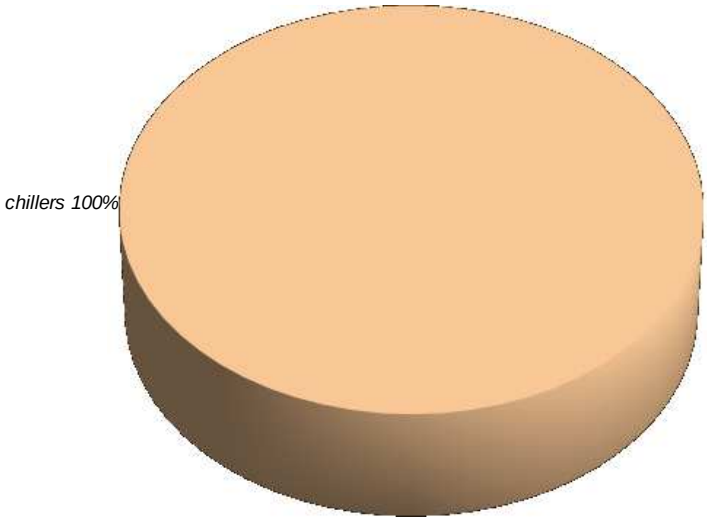

Figure 8: Useful supply cold (USC) by equipment. Present state

Table 6: Heat exchanger network and amount of recovered energy

Heat Exchanger	Power	Heat Source	Heat Sink	Heat transferred	
	[kW]			[MWh]	[%]
HR_Recuperation	38	Pre-heating vacuum I	Heating by electrical heaters_heating	136	100
	38			**136**	**100**

Table 7: Useful process heat demand (UPH) by process. Present state.

Process	Total	Circulation	Maintenance	Start-up
	[MWh]	[MWh]	[MWh]	[MWh]
Pre-heating vacuum I	81	56	25	0
ZnO and Al layers	6	5	1	0
Laminating	129	18	111	0
Hot bath rinsing and laser	85	11	34	40
Heating by electrical heaters_heating	230	0	230	0
Cooling production hall total_HW	39	39	0	0
Gas consumption	1	1	0	0
Total	**571**			

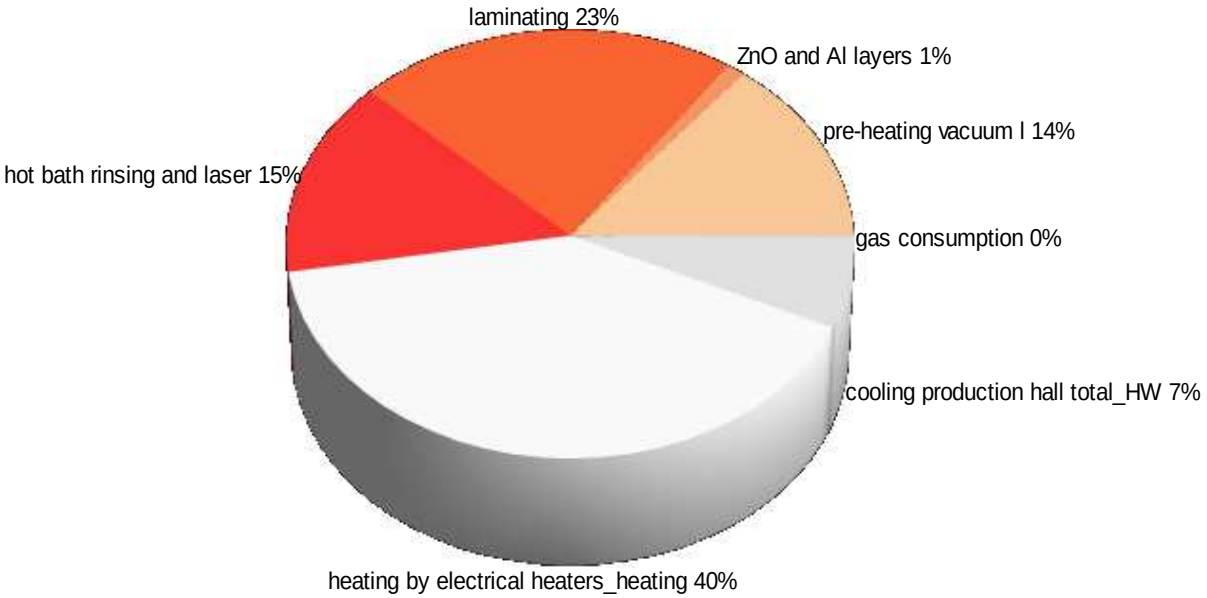

Figure 9: Useful process heat (UPH) by process

Table 8: Useful process cooling demand (UPC) by process. Present state.

Process	Total	Circulation	Maintenance	Start-up
	[MWh]	[MWh]	[MWh]	[MWh]
Equipment cooling	732	732	0	0
Cold bath rinsing and laser	35	8	20	7
Cooling production hall total_cooling	6,850	0	6,850	0
Pre-heating vacuum I	286	286	0	0
ZnO and Al layers	122	122	0	0
Laminating	21	21	0	0
Total	**8,046**			

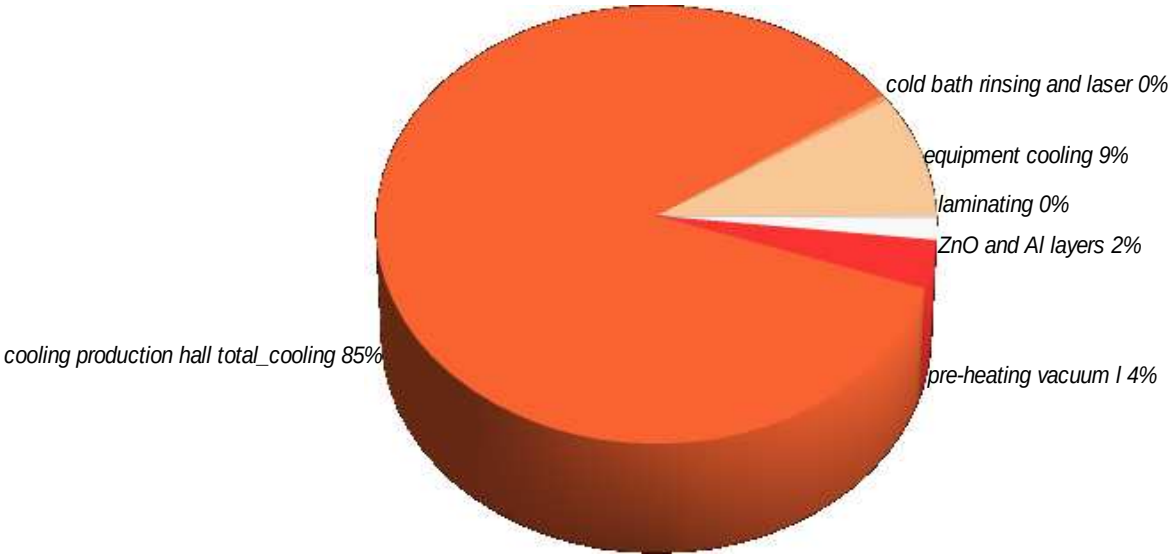

Figure 10: Useful process cooling (UPC) by process

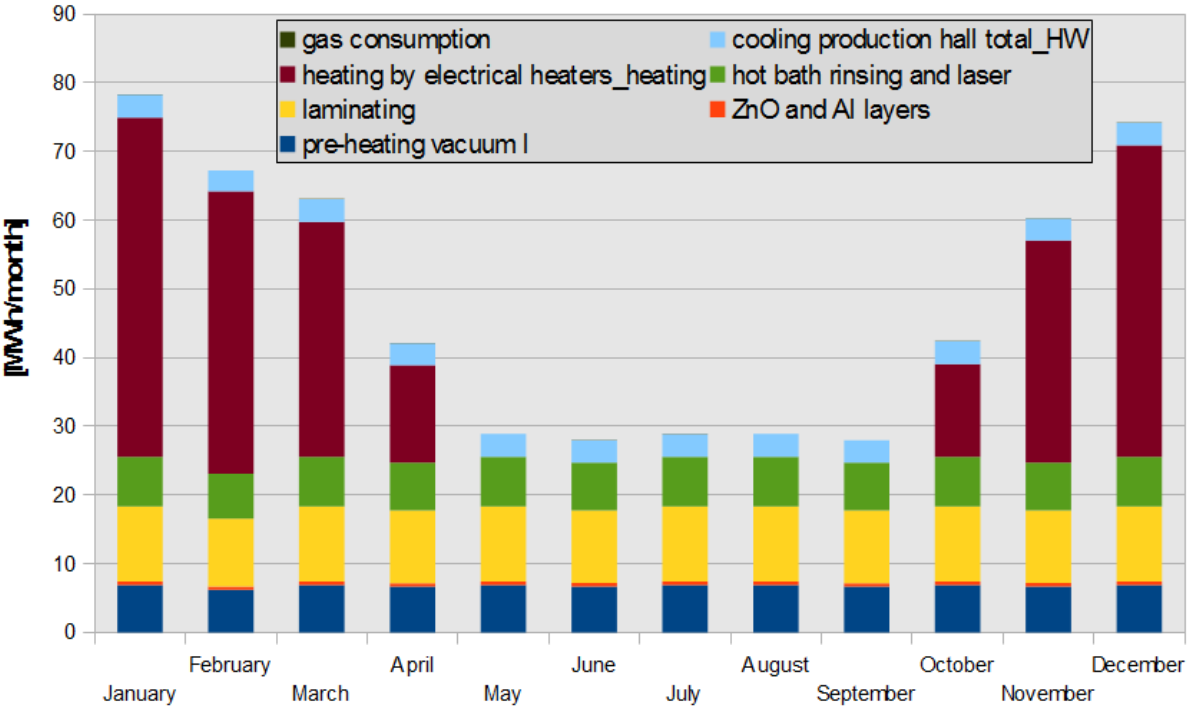

Figure 11: Distribution of useful process heat demand per month

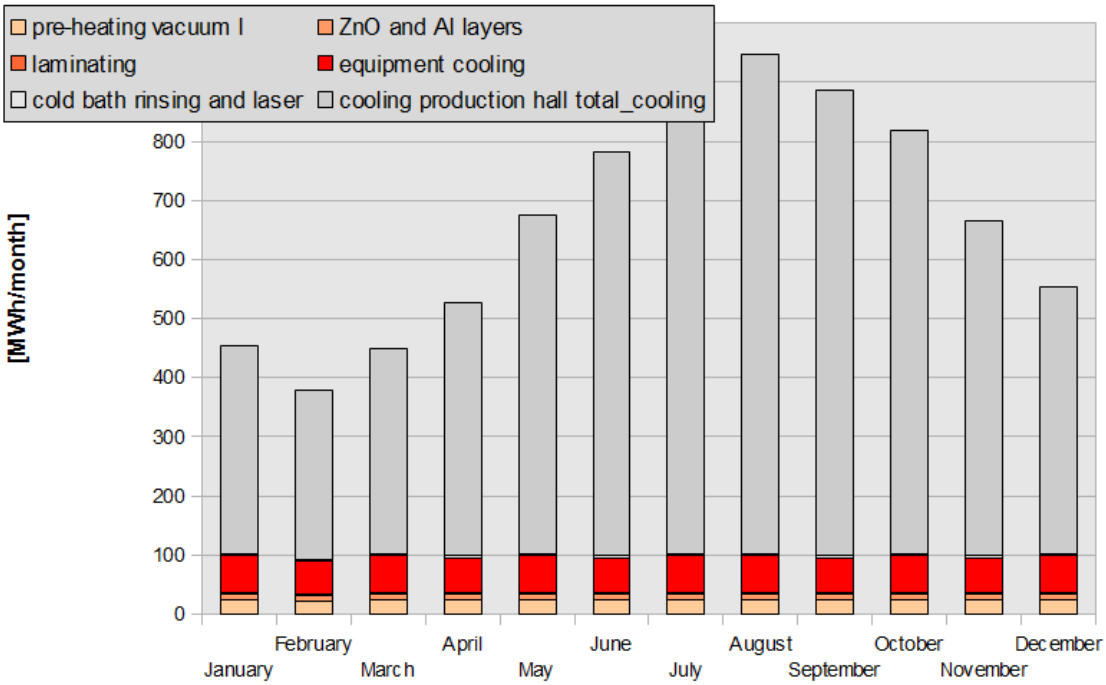

Figure 12: Distribution of useful process cooling demand per month

3.4. General

- The target room temperature during winter is 25 °C for the production.
- The hot water demand was estimated due to the number of employees.

4. Comparative study

4.1. Proposed alternatives

There are three proposals made in this study. In the first proposal a solar thermal system is installed using flat plate collectors. The second proposal is to use new heat exchanger to recover more energy from waste streams. The third proposal focuses on the installation of a new CHP (combined heat and power plant).

Table 9: Overview of the alternative proposals studied

Short Name	Description
SOLAR	based on present state a solar thermal system is proposed
HX	based on present state the installation of new heat exchangers is proposed
CHP	based on present state the installation of new heat exchangers is proposed and the installation of a combined heat and power plant is proposed

4.1.1. Heat Supply

- **Solar (FPC):**

Collector type:	FPC (flat plate collectors)
Installed capacity:	100 kW
Installed collector area:	143 m²
Solar buffer storage volume:	32 m³
Solar fraction:	24.6 %
Annual energy yield:	932.5 kWh/kWa

Table 10: 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)	o==el. heater 15kW==o o==hot water==o o==el. heating==o	100	93	1.08
El. heater 15kW	hot water boiler	o==el. heater 15kW==o	15	62	0.72
El. heater 30kW	hot water boiler	o==el. heater 30kW==o	30	81	0.94
Chillers	compression chiller (water cooled)	o==water cooling==o o==production hall cooling==o o==air AC cooling==o o==cooling rooms and hall==o	1,400	8,035	93.17
Heating lamination	hot water boiler	o==heating lamination==o	29	129	1.49
Heating through plasma	hot water boiler	o==heating through plasma==o	1	6	0.07
Hot water heating	hot water boiler	o==hot water==o	30	30	0.35
Electrical heaters	hot water boiler	o==el. heating==o	50	187	2.17
Gas plasma	hot water boiler	o==plasma==o	200	1	0.01
Total			**1,856**	**8,624**	**100**

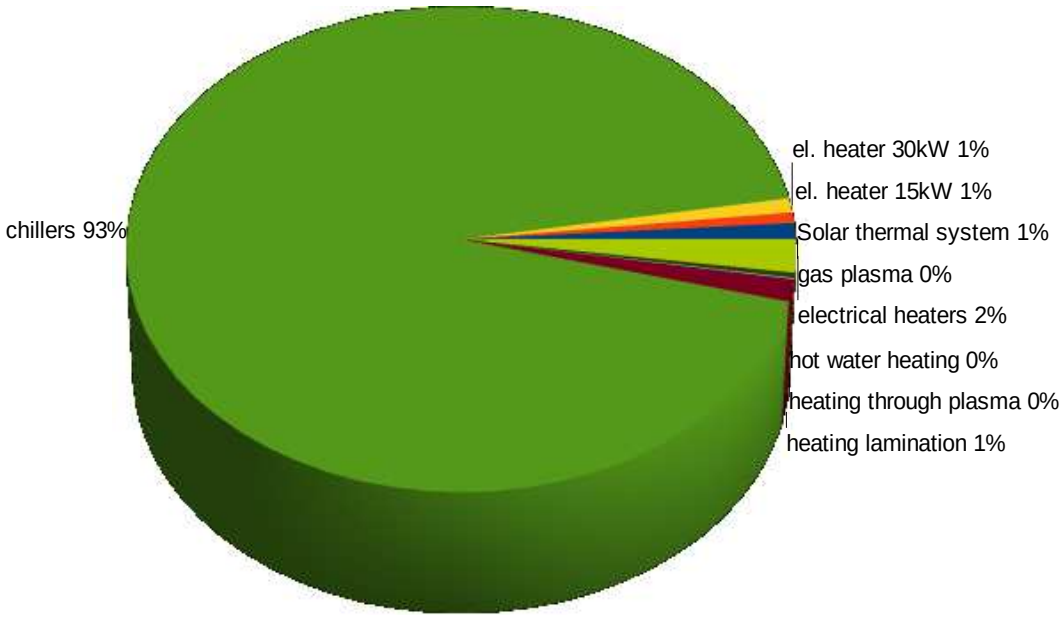

Figure 13: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).

- graphic: heat demand covered by solar thermal system:

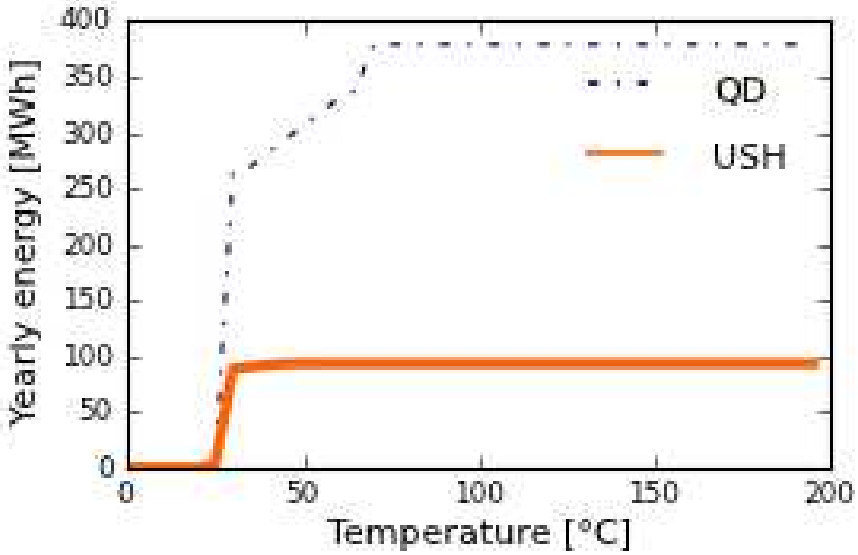

Figure 14: Heat demand and solar contribution

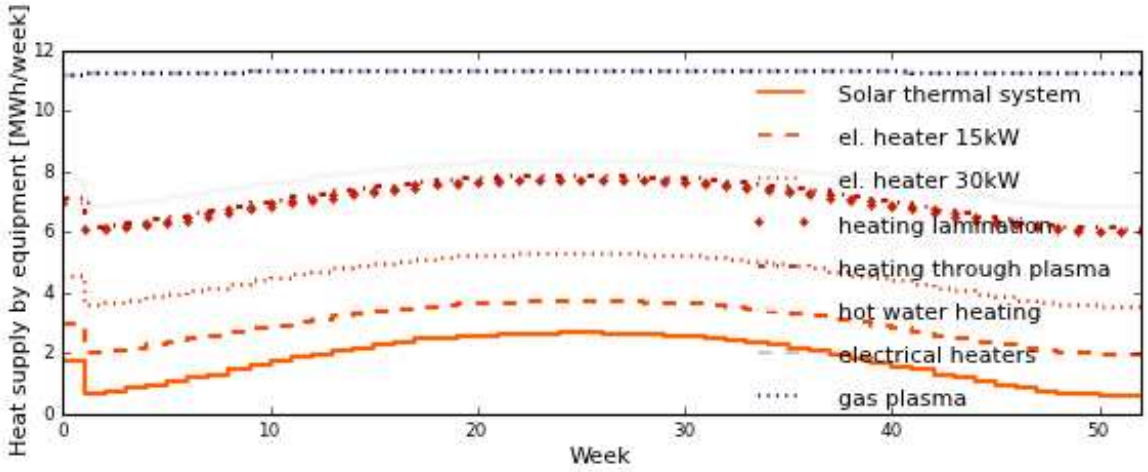

Figure 15: Daily heat supply by equipment

- **HX: heat recovery**

Heat exchanger type: plate heat exchangers

Table 11: Heat exchangers and amount of recovered energy

Heat Exchanger	Power	Heat Source	Heat Sink	Amount of recovered energy	
	[kW]			[MWh]	[%]
HX_BelowPinch_0	1	cooling production hall total_cooling	cooling production hall total_HW	5	37.16
HX_BelowPinch_2	2	cold bath rinsing and laser	hot bath rinsing and laser	8	62.06
HR_recuperation	4	pre-heating vacuum l	heating by electrical heaters_heating	0	0.78
Total	6			**12.9**	**100**

Table 12: 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]	[%]
El. heater 15kW	hot water boiler	o==el. heater 15kW==o	15	73	0.84
El. heater 30kW	hot water boiler	o==el. heater 30kW==o	30	81	0.94
Chillers	compression chiller (water cooled)	o==water cooling==o o==production hall cooling==o o==air AC cooling==o o==cooling rooms and hall==o	1,400	8,022	93.28
Heating lamination	hot water boiler	o==heating lamination==o	29	129	1.50
Heating through plasma	hot water boiler	o==heating through plasma==o	1	6	0.07
Hot water heating	hot water boiler	o==hot water==o	30	34	0.40
Electrical heaters	hot water boiler	o==el. heating==o	50	254	2.96
Gas plasma	hot water boiler	o==plasma==o	200	1	0.01
Total			**1,756**	**8,600**	**100**

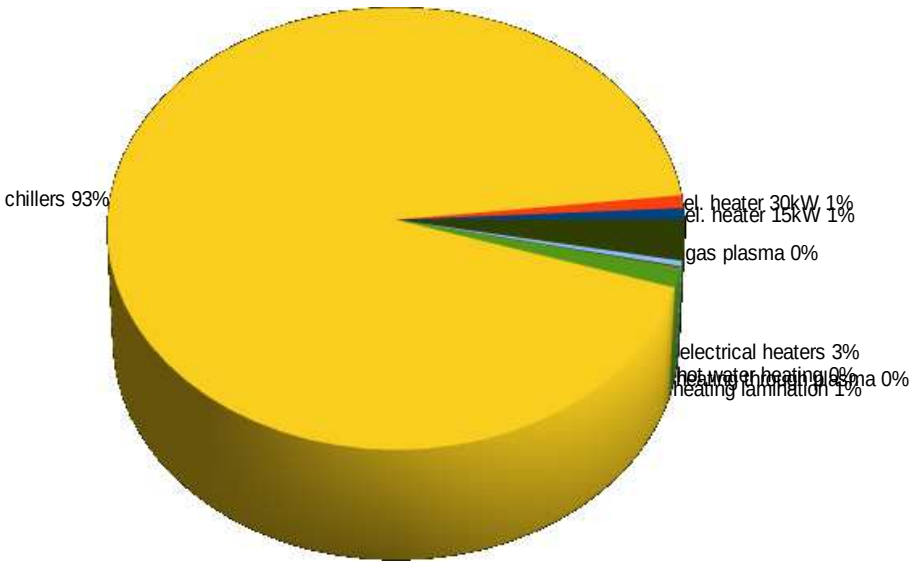

Figure 16: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).

- graphic: heat demand covered by solar thermal system:

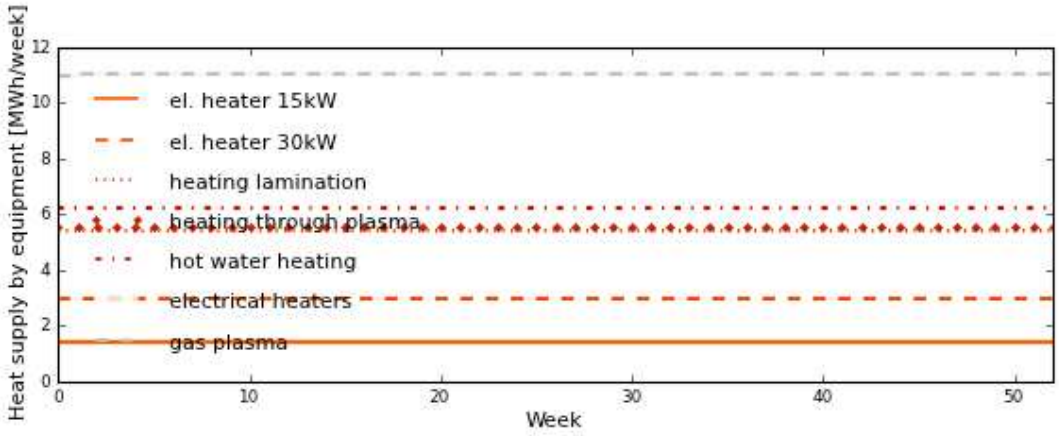

Figure 17: Daily heat supply by equipment

- **CHP:**

Type	CHP engine
Nominal thermal power	93 kW
Nominal electrical power	50 kW
Thermal efficiency	0.52
Electrical efficiency	0.28
Operating hours	7,824 h

Table 13: Heat exchangers and amount of recovered energy

Heat Exchanger	Power [kW]	Heat Source	Heat Sink	Amount of recovered energy [MWh]	[%]
HX_BelowPinch_0	1	cooling production hall total_cooling	cooling production hall total_HW	5	37.16
HX_BelowPinch_1	0	chillers	pre-heating vacuum l	0	0.00
HX_BelowPinch_2	2	cold bath rinsing and laser	hot bath rinsing and laser	8	62.06
HR_recuperation	4	pre-heating vacuum l	heating by electrical heaters_heating	0	0.78
Total	6			**12.9**	**100**

Table 14: 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	o==el. heater 15kW==o o==el. heater 30kW==o o==heating lamination==o o==heating through plasma==o o==hot water==o o==el. heating==o o==plasma==o	93	467	5.43
El. heater 15kW	hot water boiler	o==el. heater 15kW==o	15	19	0.22
El. heater 30kW	hot water boiler	o==el. heater 30kW==o	30	21	0.24
Chillers	compression chiller (water cooled)	o==water cooling==o o==production hall cooling==o o==air AC cooling==o o==cooling rooms and hall==o	1,400	8,022	93.23
Heating lamination	hot water boiler	o==heating lamination==o	29	35	0.40
Heating through plasma	hot water boiler	o==heating through plasma==o	1	2	0.02
Hot water heating	hot water boiler	o==hot water==o	30	9	0.11
Electrical heaters	hot water boiler	o==el. heating==o	50	30	0.34
Gas plasma	hot water boiler	o==plasma==o	200	0	0.00
Total			**1,849**	**8,605**	**100**

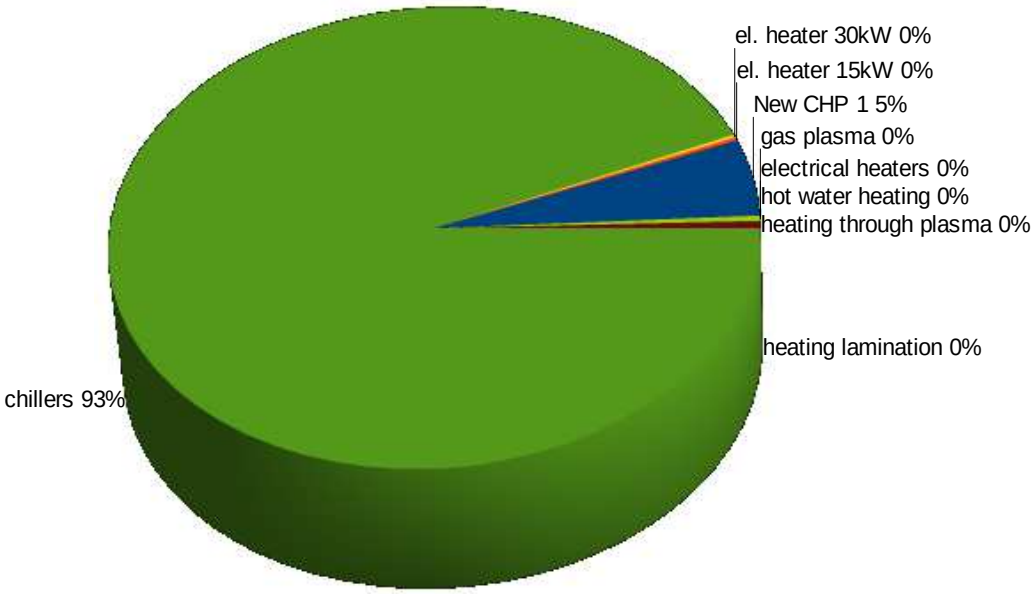

Figure 18: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).

- graphic: heat demand covered by CHP:

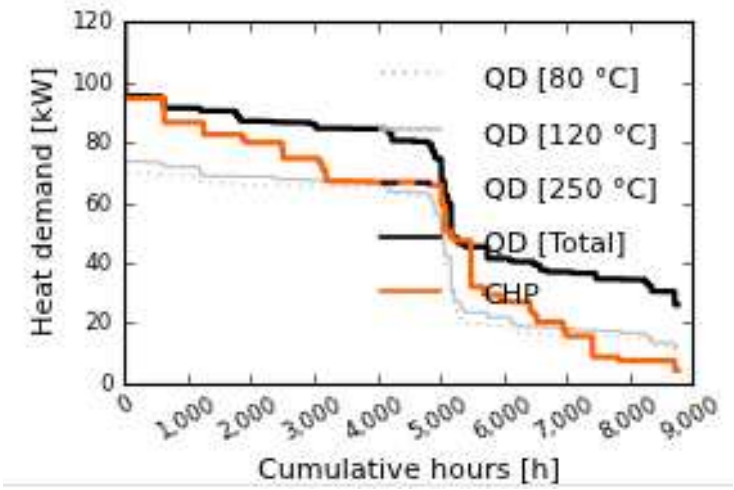

Figure 19: Cumulative heat supply to be covered by CHP

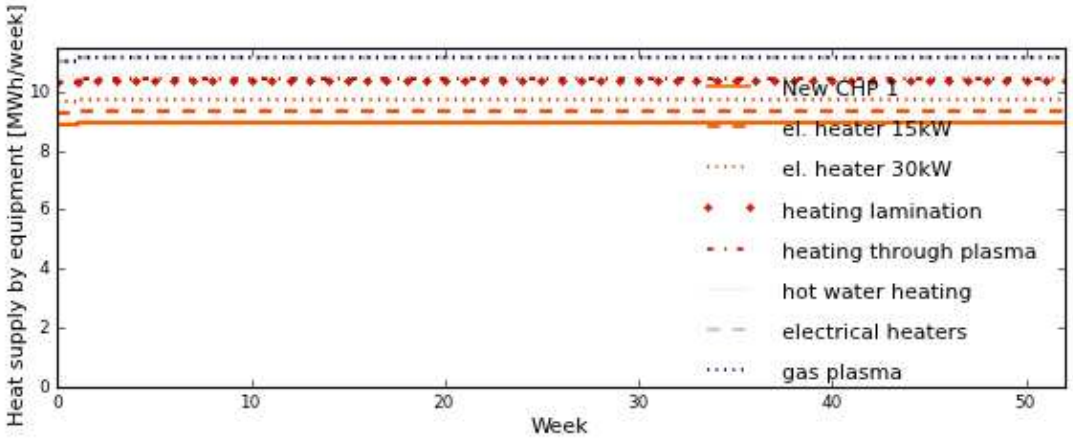

Figure 20: Daily heat supply by equipment

- Primary energy consumption (PEC)

Table 15: primary energy consumption and savings

Alternative	Primary energy consumption	Savings	
	[MWh]	[MWh]	[%]
Present State (checked)	14,522	---	---
SOLAR	14,034	488	3.36
HX	14,252	271	1.86
CHP	13,190	1,332	9.17

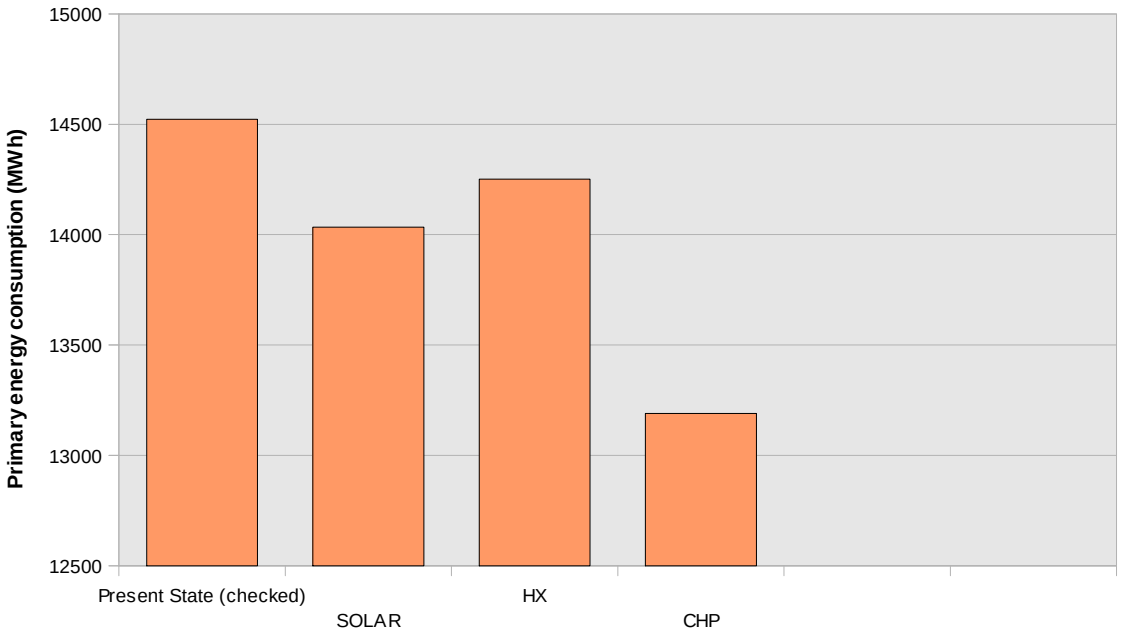

Figure 21: Comparison of alternatives: primary energy consumption

- 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)	571	---	420	---
SOLAR	571	0	589	-169
HX	571	0	578	-157
CHP	571	0	583	-162

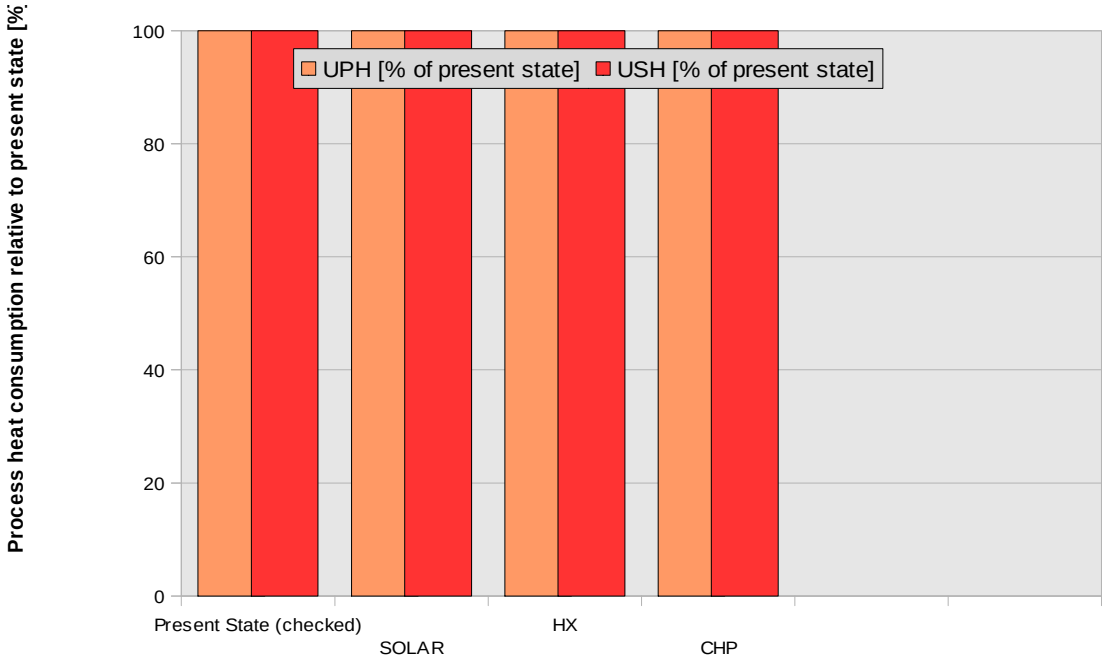

Figure 22: Comparison of alternatives: useful process heat supply

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)	8,046	---	7,936	---
SOLAR	8,046	0	8,035	-99
HX	8,046	0	8,022	-87
CHP	8,046	0	8,022	-87

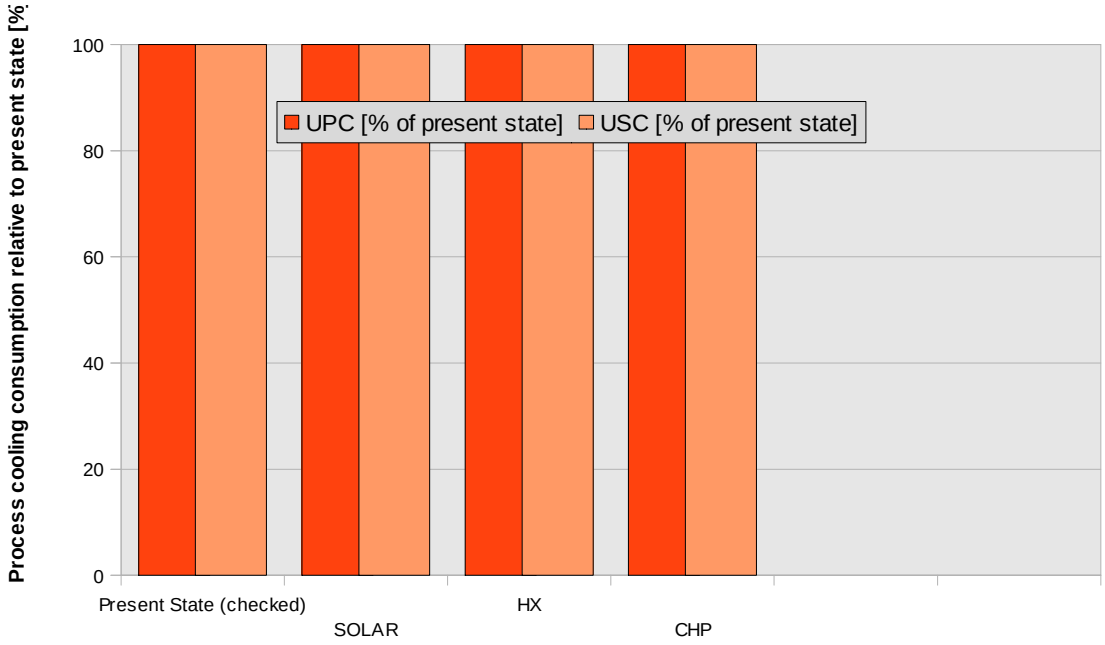

Figure 23: Comparison of alternatives: useful process heat supply

- Environmental impact

Table 18: CO2 production and CO2 savings per year

Alternative	Production of CO2	Water consumption
	[t]	[m3]
Present State (checked)	2503.90	23817.17
SOLAR	2419.68	23555.93
HX	2457.22	23519.18
CHP	2332.42	23519.18

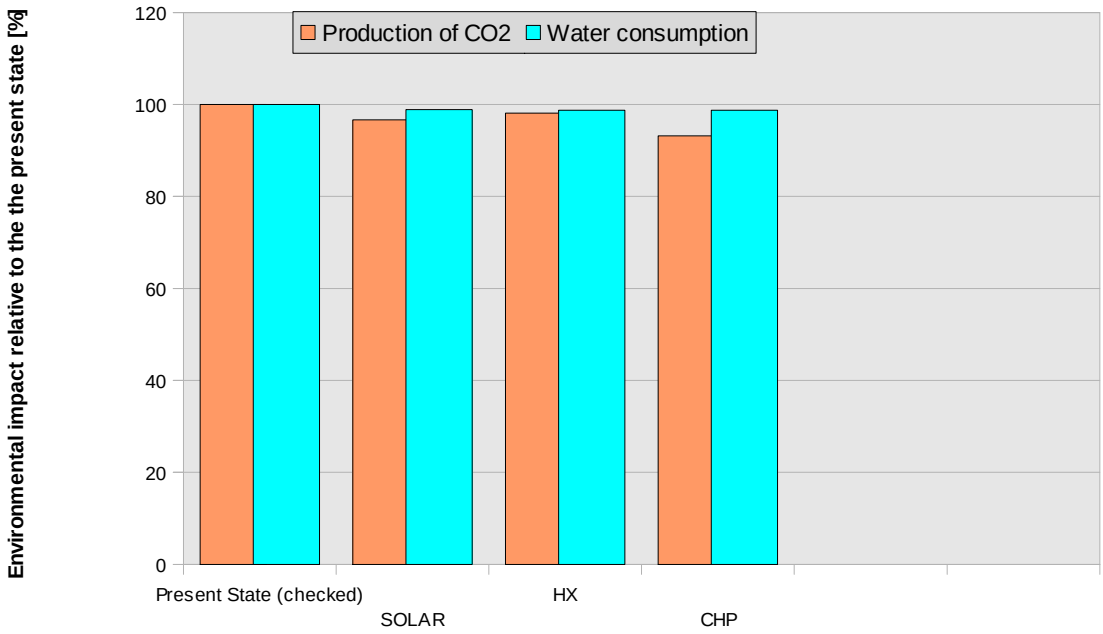

Figure 24: Comparison of alternatives: environmental impact

Table 19: Investment costs and subsidies of the proposals

Alternative	Total investment [€]	Own investment [€]	Subsidies [€]
Present State (checked)	---	---	---
SOLAR	71,000	49,700	21,300
HX	3,000	3,000	0
CHP	100,000	100,000	0

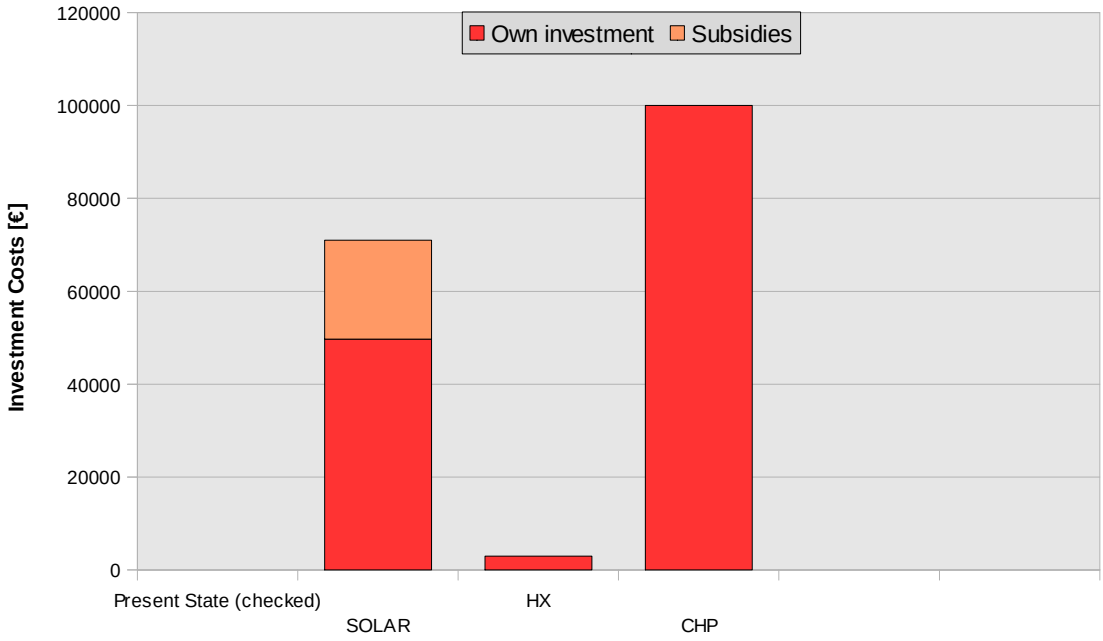

Figure 25: Comparison of alternatives investment cost

5. Selected alternative(s) and conclusions

5.1. Selected alternative

As selected alternative the "solar ETC" 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

Solar (FPC):

Collector type:	FPC (Flat Plate Collectors)
Installed capacity:	100 kW
Installed collector area:	143 m²
Solar buffer storage volume:	32 m³
Solar fraction:	24.6 %
Annual energy yield:	932.5 kWh/kWa

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

Equipment	Type	Heat / cooling supplied to pipe/duct	Nominal capacity	Contribution to total heat / cooling supply	
			[kW]	[MWh]	[%]
Solar thermal system	solar thermal (flat-plate)	o==el. heater 15kW==o o==hot water==o o==el. heating==o	100	93	1.08
El. heater 15kW	hot water boiler	o==el. heater 15kW==o	15	62	0.72
El. heater 30kW	hot water boiler	o==el. heater 30kW==o	30	81	0.94
Chillers	compression chiller (water cooled)	o==water cooling==o o==production hall cooling==o o==air AC cooling==o o==cooling rooms and hall==o	1,400	8,035	93.17
Heating lamination	hot water boiler	o==heating lamination==o	29	129	1.49
Heating through plasma	hot water boiler	o==heating through plasma==o	1	6	0.07
Hot water heating	hot water boiler	o==hot water==o	30	30	0.35
Electrical heaters	hot water boiler	o==el. heating==o	50	187	2.17
Gas plasma	hot water boiler	o==plasma==o	200	1	0.01
Total			**1,856**	**8,624**	**100**

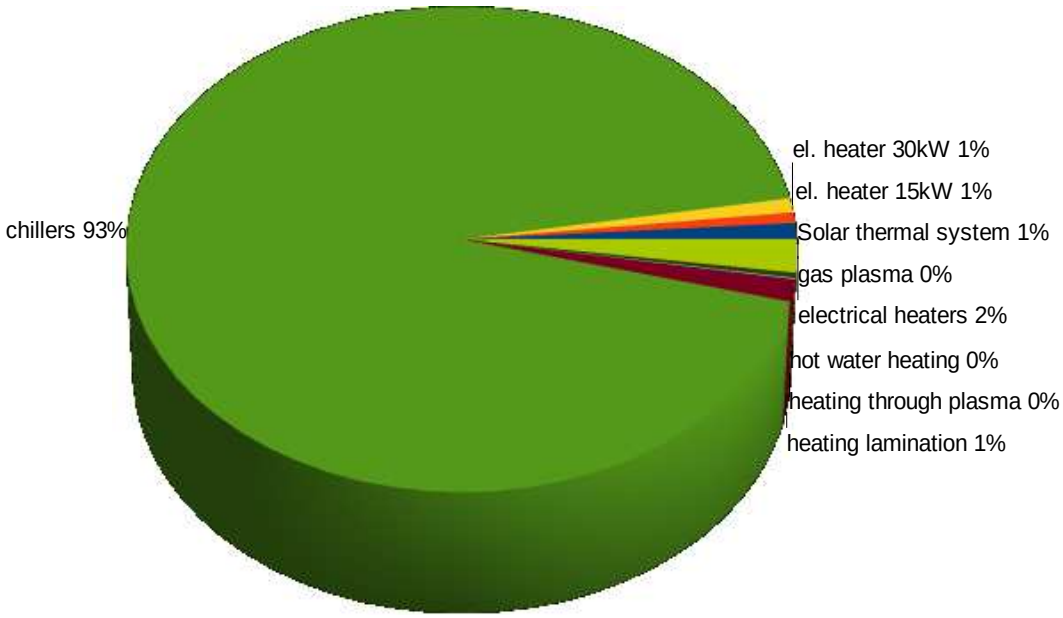

Figure 26: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).

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	1	0.00	1	0.01
Total electricity	14,033	100.00	12,293	99.99
Total (fuels + electricity)	**14,034**	**100.00**	**12,294**	**100.00**

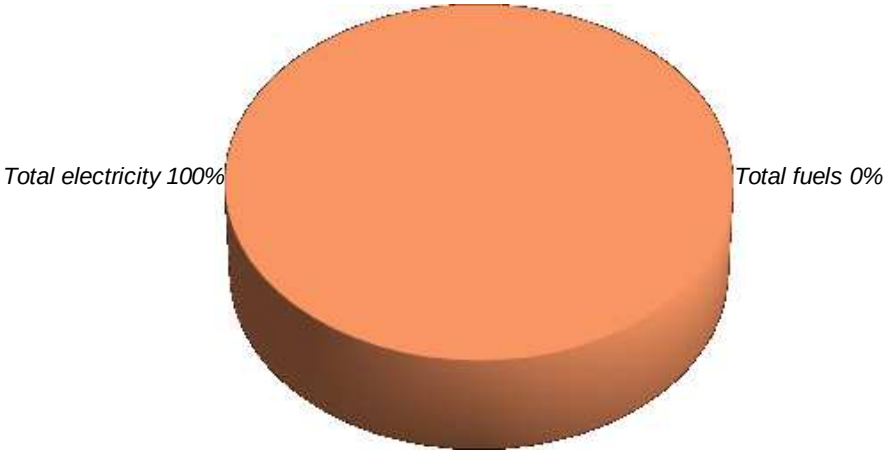

Figure 27: Distribution of PEC by fuel type

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]
Natural gas	1	0.01	1	0.01
Electricity	4,839	99.99	4,239	99.99
Total	4,840	100.00	4,240	100.00

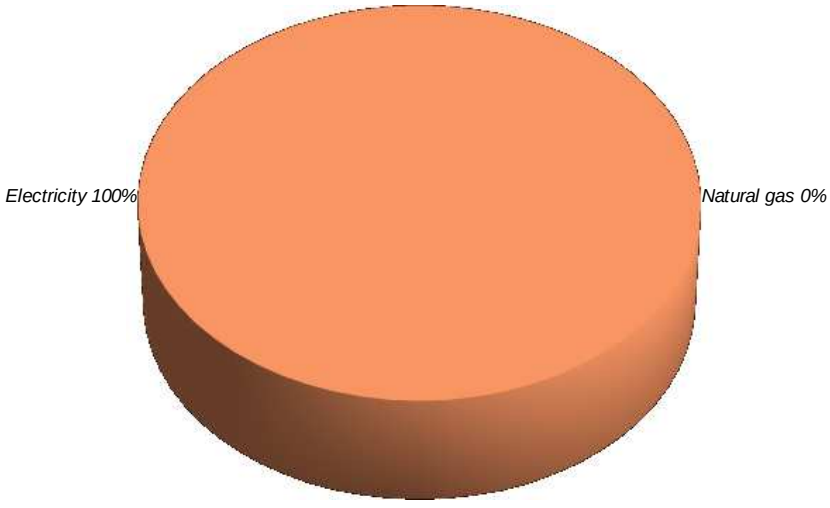

Figure 28: Total final energy consumption (FEC). Proposed final solution.

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

Equipment	Fuel type	FET by equipment	
		[MWh]	[% of Total]
El. heater 15kW	Electricity	62	1.46
El. heater 30kW	Electricity	81	1.91
Chillers	Electricity	3,743	88.28
Heating lamination	Electricity	129	3.04
Heating through plasma	Electricity	6	0.15
Hot water heating	Electricity	30	0.72
Electrical heaters	Electricity	187	4.41
Gas plasma	Natural gas	1	0.01
Solar thermal system	Electricity	1	0.02
Total		**4,240**	**100**

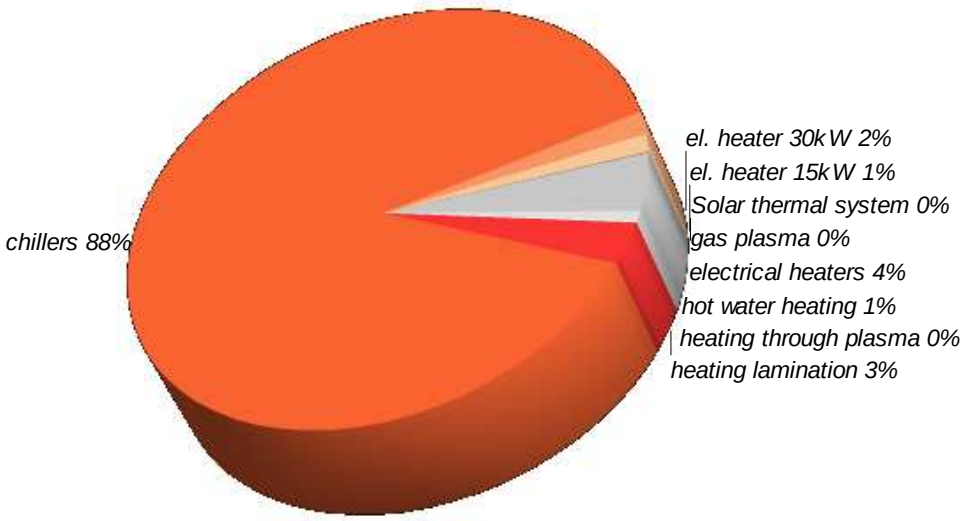

Figure 29: Final energy consumption for thermal use (FET) by equipment

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

Equipment	USH by equipment	
	[MWh]	[% of Total]
El. heater 15kW	62	10.52
El. heater 30kW	81	13.74
Heating lamination	129	21.87
Heating through plasma	6	1.05
Hot water heating	30	5.17
Electrical heaters	187	31.74
Gas plasma	1	0.09
Solar thermal system	93	15.82
Total	**589**	**100**

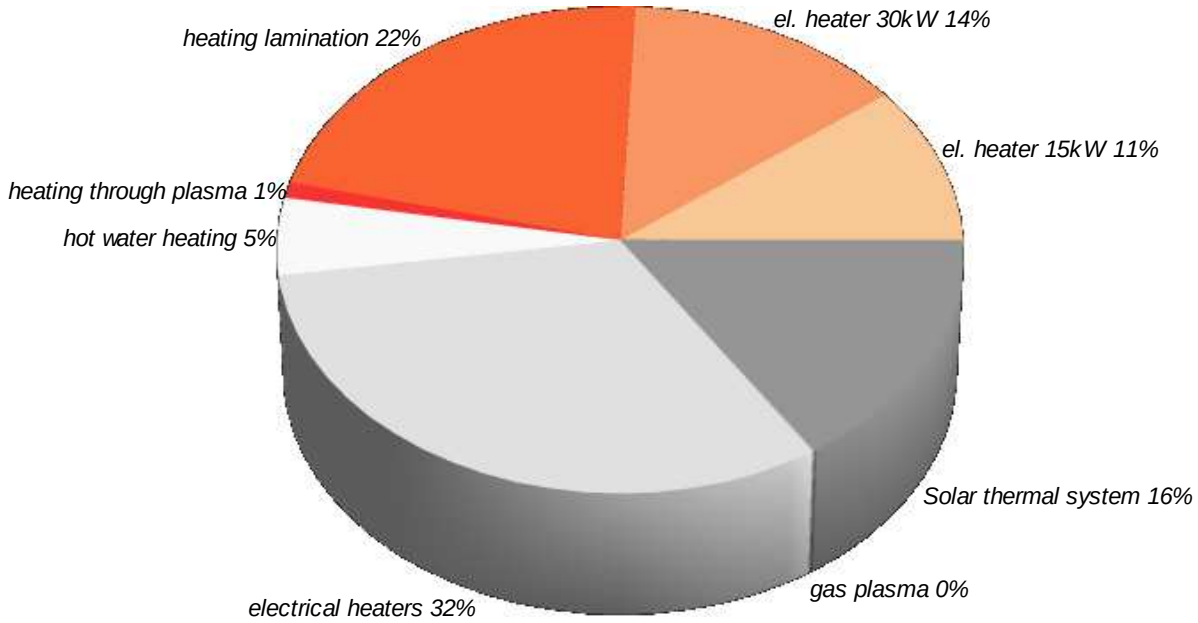

Figure 30: Useful supply heat (USH) by equipment. Proposed final solution

Table 25 : Useful supply cooling (USC) by equipment. Proposed final solution.

Equipment	USC by equipment	
	[MWh]	[% of Total]
Chillers	8,035	100.00
Total	**8,035**	**100**

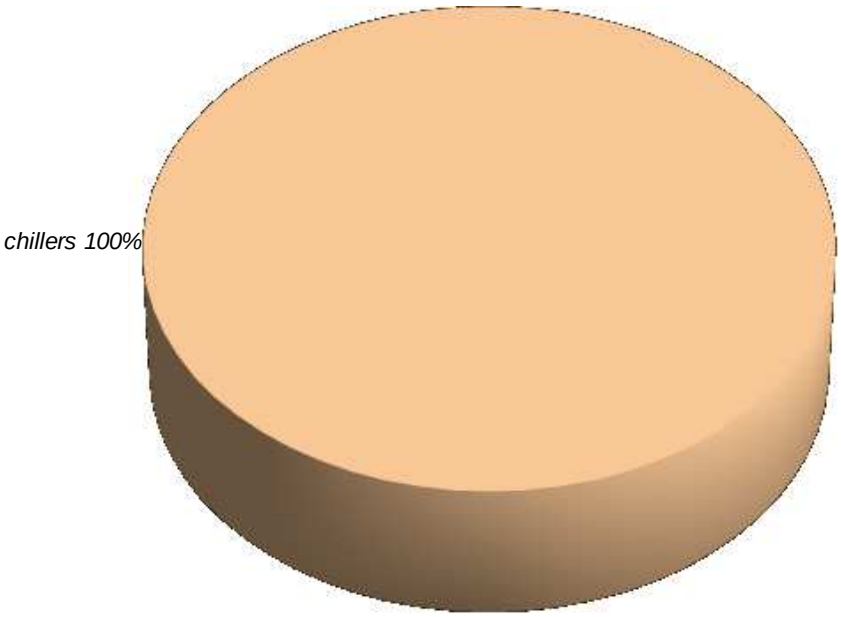

Figure 31: Useful supply cooling (USC) by equipment. Proposed final solution

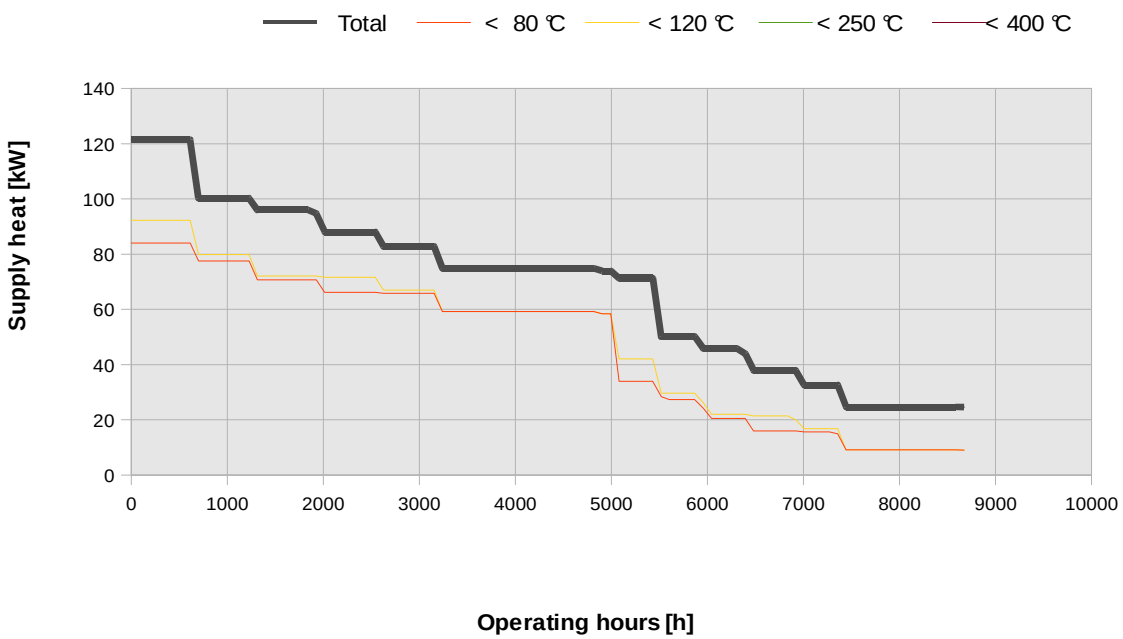

Figure 32: Distribution of supply heat by temperature levels and annual operating hours. Proposed final solution.

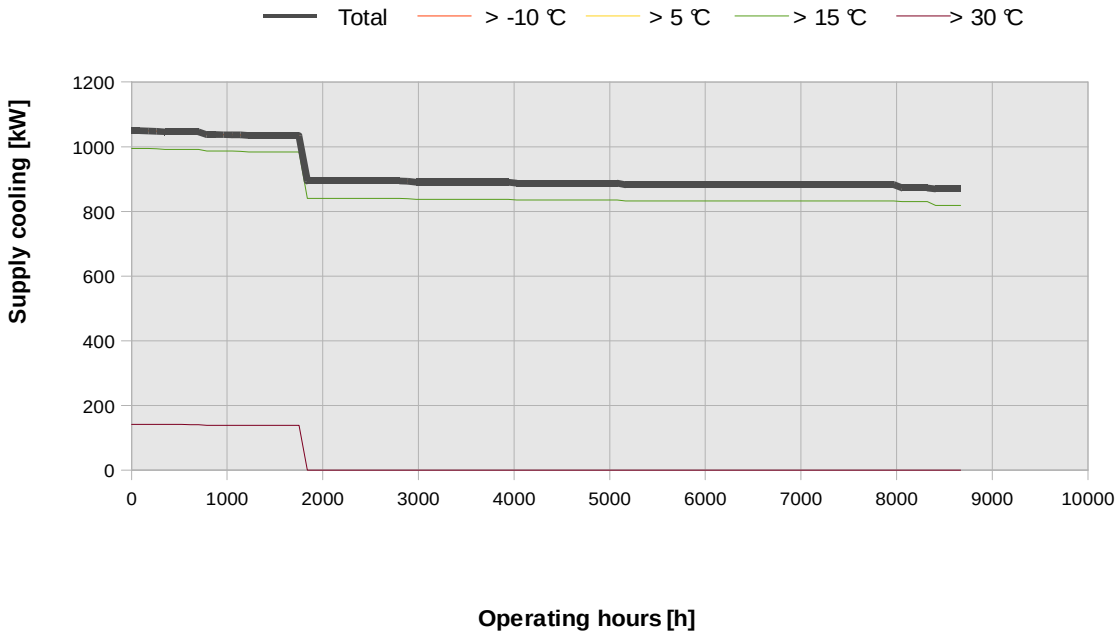

Figure 33: Distribution of supply cooling by temperature levels and annual operating hours. Proposed final solution.

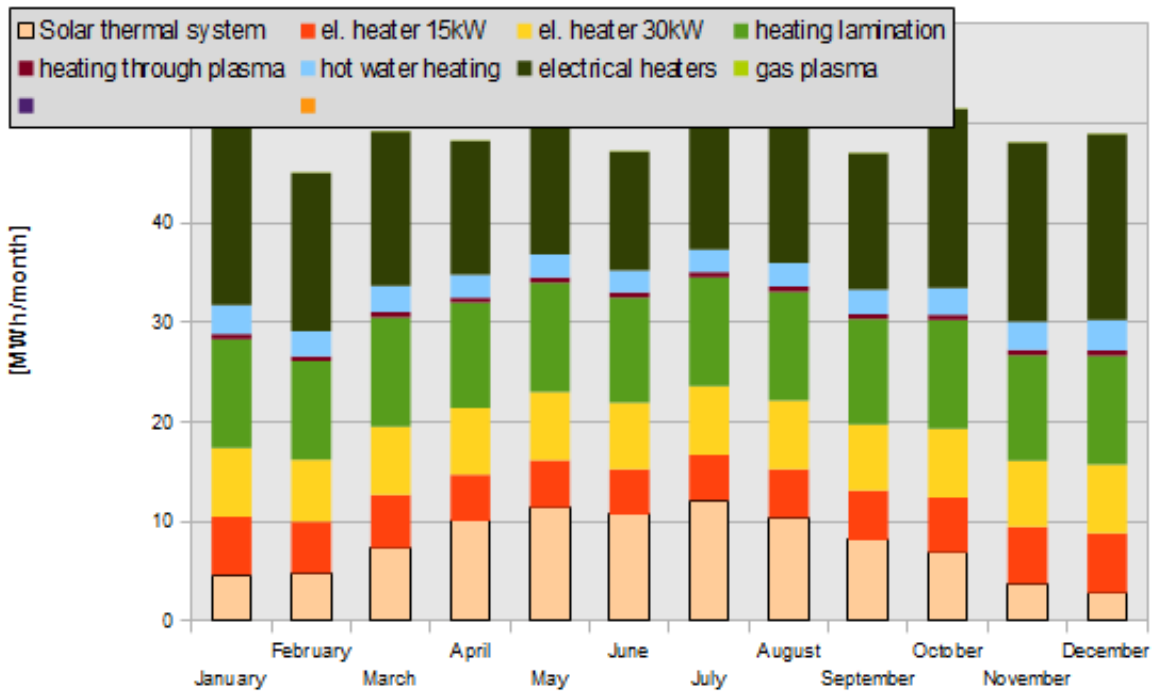

Figure 34: Distribution of the heat supply by months. Proposed final solution.

5.2. Comparative study and conclusions

5.2.1. Energy and environmental analysis

In the proposed alternative around 3 % of the CO_2 pollution can be saved.

5.2.2. Economic analysis

The payback period of about 3.4 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. Investment and installing cost are based on actual cost in Austria and not Bulgaria.

Table 26: Savings of the proposed alternative in comparison to the present state

		Present state	Alternative	Saving	[% savings]
Total primary energy consumption (1)					
- total	[MWh]	14,522	14,034	488	3%
- fuels	[MWh]	1	1	-	0%
- electricity	[MWh]	14,521	14,033	488	3%
Primary energy saving due to renewable energy	[MWh]		488		
CO_2 emissions	[t/a]	2,504	2,420	84	3%
Annual energy system cost (2)	[EUR]	360,078	349,989	10,089	3%
Total investment costs	[EUR]		71,429		
Payback period (3)	[years]		3.4		

(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

- As the calculations of the hot water consumption are based on assumptions and 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 solar thermal installations 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.