EINSTEIN thermal energy industry audit

Energy Audit Summary Report

Audit No. 55 - ESP08

Beverages Industry

Production of beer in bottles and kegs

energyXperts.NET
Berlin (Germany) / Barcelona (Spain)

May 2012

With the collaboration of the Chamber of Commerce and Industry of Madrid.

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) 39)

1. Contact data of the auditors

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2. Description of the company (status quo)

Reference year of data/information: 2010

(Date of the visit on site: 06-06-2011)

2.1. General information of the company

Company, location	-	
Sector	Beverages (Beer)	
Current final energy consumption [MWh] (*)	total	for heating and cooling
- natural gas	65.236	65.236
- biogas	3.433	3.433
- electricity	22.932	7.722

(*) fuel consumption in terms of MWh lower calorific value (LCV)

2.2. Description of the company

a) Productive process

The productive process is the typical process of beer brewing. Malt is milled, mixed with warm water, and then gradually heated up during the mashing process. In a subsequent step additional hot water is added and the sweet juice is filtered, separating the wort from the malt. Part of the wort (weak wort) is used in the mashing process as a partial replacement of hot water.

Then the wort is boiled for sterilisation and aromatisation (hop is added to provide flavours). After the boiling, the water is passed through a so-called whirlpool for filtering, and then immediately cooled down and stored for some time in the fermentation tanks. Fermentation is an exothermic reaction so that the fermentation tanks need to be cooled down continuously.

After the fermentation, the beer has to be maintained at about 1ºC during some weeks for maturation. Finally beer is pasteurised, poured in bottles and kegs and stored.

Auxiliary processes are washing bottles and kegs, cleaning of vessels, pipes and other equipment.

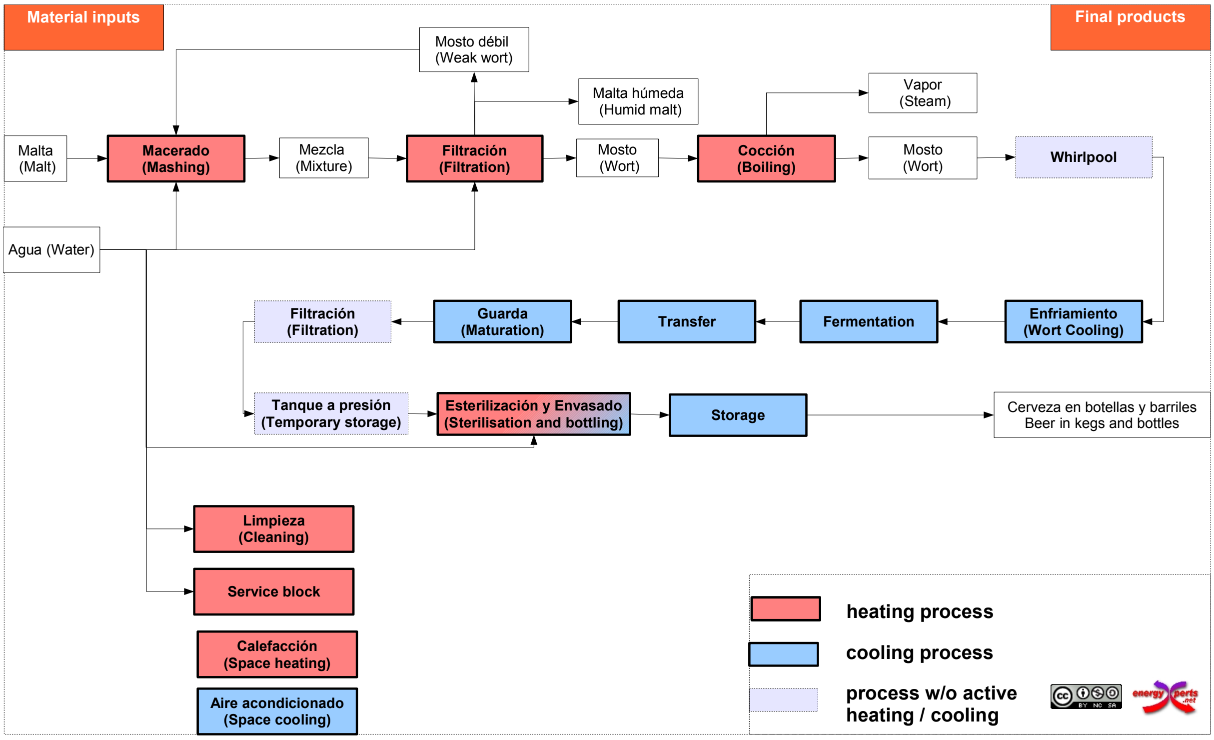

Figure 1. Simplified production flow sheet

The most heat consuming processes in the company are sterilisation and bottling, water for filtration and the boiling process. Regarding the cooling demand, the wort cooling process and sterilisation are the most consuming processes.

b) Energy supply system

The heat used in the company is generated in four gas fired steam boilers. About 5 % of the gas consumption is covered by biogas.

During the boiling process, part of the steam is recovered and used to heat-up water, which is then stored in a tank. Furthermore, fresh water is used for cooling down the wort and, by exchanging heat with the vapour, is heated up. This water is also stored in the tank. This hot water tank is maintained at around 85ºC and it is used to provide hot water to the mashing and filtration processes. Since the temperature of these processes is lower than 85ºC, the hot water is mixed with net water to achieve the desired temperature. The fresh water generated for this purpose is produced in a water-cooled compression-chiller.

The cooling demand of the rest of the processes is supplied via a water-glycol circuit, generated in a water-cooled compression-chiller.

In Figure 2, a simplified schema of the generation and distribution systems of the industry is shown.

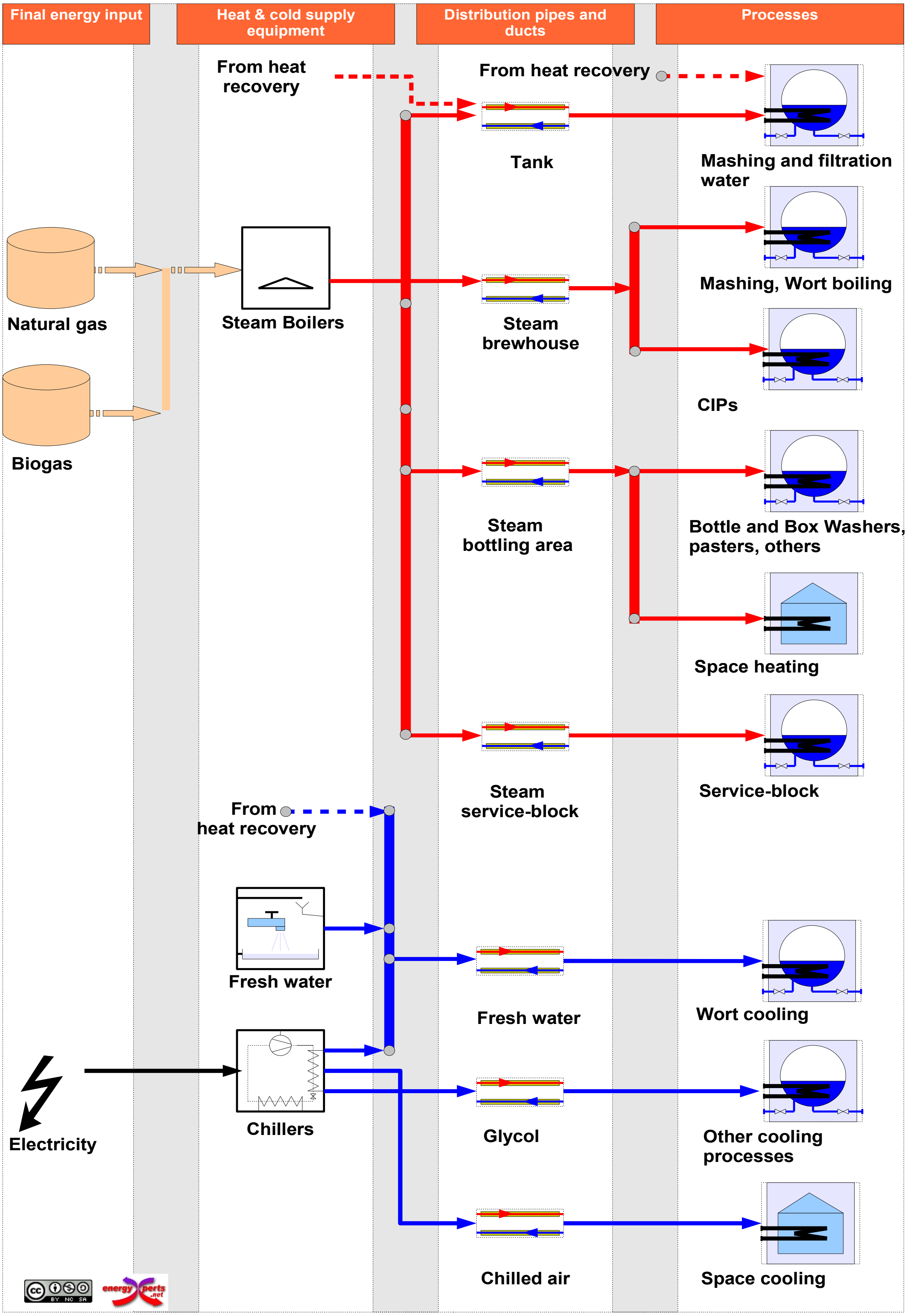

Figure 2. Overview of the heat and cold supply system

2.3. Additional comments

Specific assumptions

The results of this study are based on specific assumptions:

- Heat generated during the fermentation process calculated based on the following parameters:
  - enthalpy of fermentation: 569 kJ/kg glucose
  - diminution of 1º Plato per day during fermentation
- Processes of bottling, pasteurisation, washing and rinsing are treated as black-box processes. It is supposed that in those processes already internal heat recovery is used, covering the part of heat demand at low temperature and the part of cooling demand at high temperature. It has been supposed furthermore, that this internal heat recovery is already close to optimum and no further improvement has been considered.
- The cooling demand has been calculated from the electricity consumption of the chillers assuming an average EER of 3,5.

3. Comparative study of alternative proposals

A comparative study of several technically feasible alternative proposals for energy saving has been carried out. In the following sections the alternatives are first shortly described and then the results of the comparative study are presented.

3.1. Proposed alternatives

The technical potential alternatives that have been analysed are listed in Table 1.

Table 1. Overview of the alternative proposals studied

HR improved	**Improved heat recovery** Improvement of the current heat recovery system: full use of waste heat in the brewhouse for covering low temperature demands also in the bottling and service section.
Solar thermal	**Improved heat recovery and solar thermal system** - Includes all measures from alternative "HR improved" - Installation of a FPF solar system (FPC = flat plate collector) of 6.000 kW
Cogeneration	**Improved heat recovery and cogenerative engine** - Includes all measures from alternative "HR improved" - Installation of a cogenerative engine (8.000 kW thermal / 6.560 kW electric)
Solar + Cogeneration	**Improved heat recovery, solar thermal system and cogenerative engine** - Includes all measures from alternative "Cogeneration" - Installation of a FPC solar system (FPC = flat plate collector) of 3.000 kW
Trigeneration	**Improved heat recovery, cogenerative engine and absorption chiller** - Includes all measures from alternative "HR improved" - Installation of a cogenerative engine (13.000 kW thermal / 10.460 kW electric) - Installation of an absorption chiller (3.500 kW)

3.2. Energy performance[1]

Table 2. Comparative study: yearly primary energy consumption.

Alternative	Primary energy consumption	Savings	
	[MWh]	[MWh]	[%]
Present State	142.038	---	---
HR improved	132.265	9.774	6,88
Solar thermal	124.279	17.760	12,50
Cogeneration	74.143	67.896	47,80
Solar + Cogeneration	72.478	69.560	48,97
Trigeneration	53.689	88.350	62,20

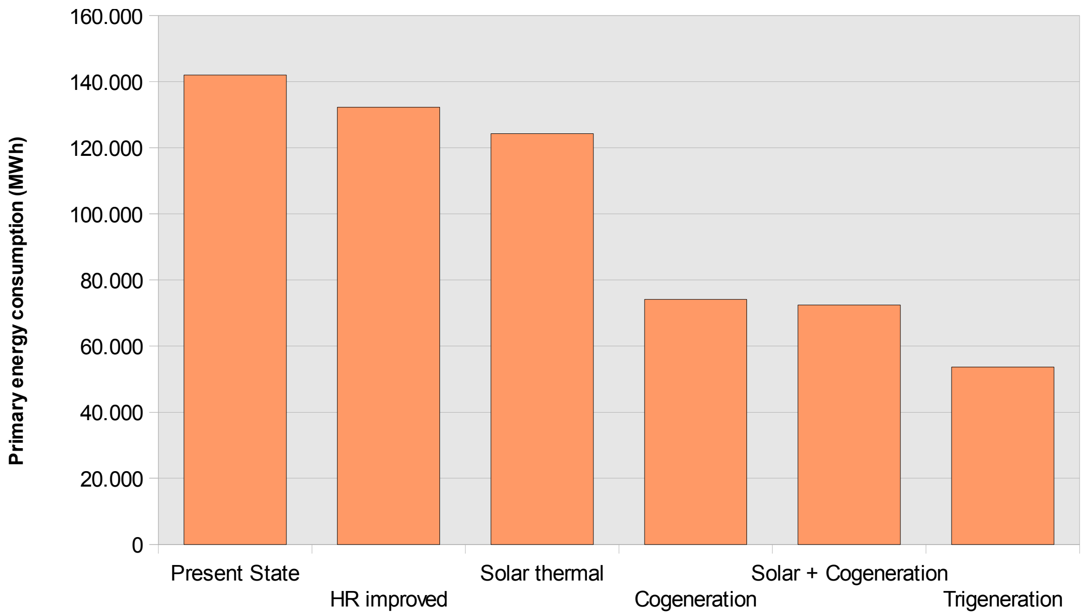

Figure 3. Comparative study: yearly primary energy consumption.

1 The factors for conversion of final energy (for fuels in terms of LCV) to primary energy used in this study are 2,9 for electricity and 1,1 for natural gas.

3.3. Economic performance

Table 3. Comparative study: investment costs. Estimated co-funding: 30 % for solar thermal systems and 10% for the rest of technologies.

Alternative	Total investment [€]	Own investment [€]	Subsidies [€]
Present State	---	---	---
HR improved	275.000	275.000	0
Solar thermal	3.694.810	2.668.867	1.025.943
Cogeneration	4.342.200	3.935.480	406.720
Solar + Cogeneration	6.052.200	5.132.480	919.720
Trigeneration	8.171.900	7.382.210	789.690

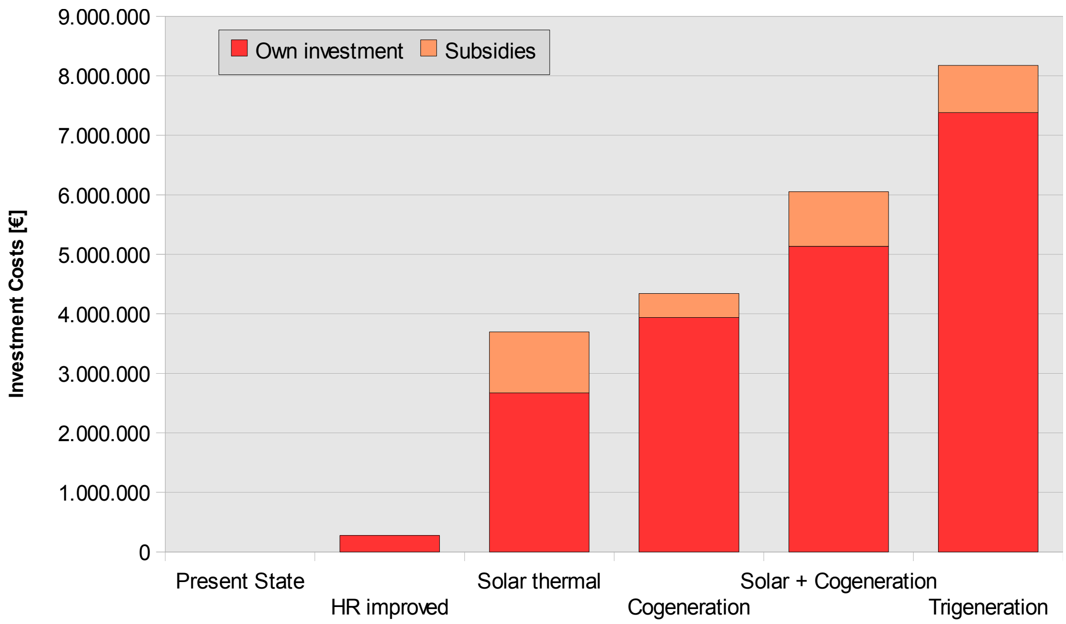

Figure 4. Comparative study: investment costs. 30 % for solar thermal systems and 10% for the rest of technologies.

Table 4. Comparative study: annual costs including annuity of initial investment[2].

Alternative	Annuity [€]	Energy Cost [€]	O&M [€]	Total [€]
Present State	---	4.022.560	0	4.022.560
HR improved	28.315	3.725.671	22.000	3.775.986
Solar thermal	380.428	3.479.236	97.000	3.956.664
Cogeneration	447.085	1.730.105	146.191	2.323.381
Solar + Cogeneration	623.151	1.683.741	179.428	2.486.320
Trigeneration	841.401	1.022.166	285.495	2.149.062

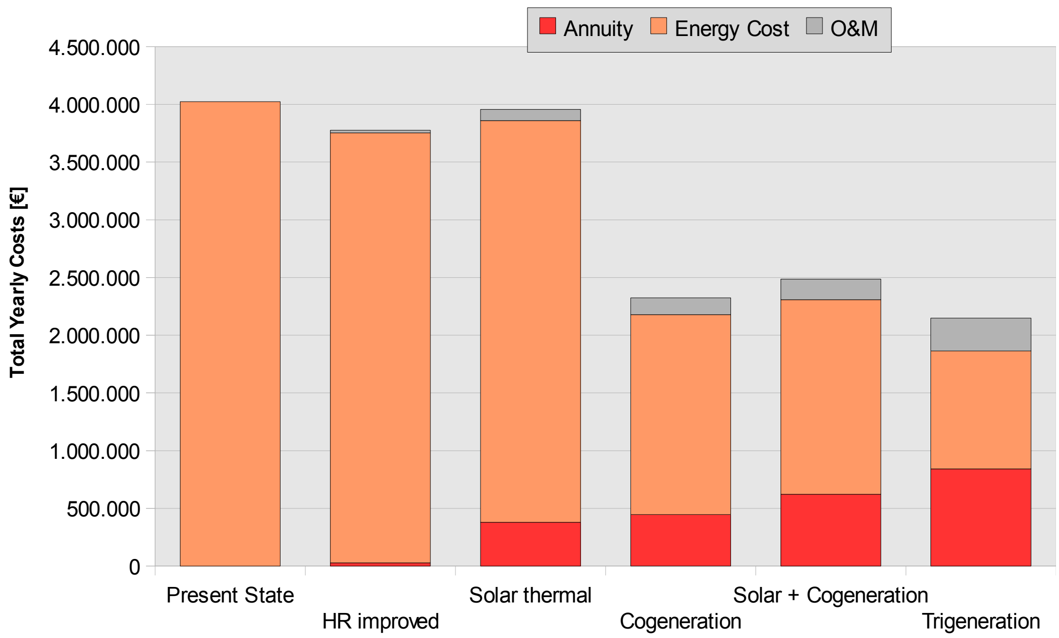

Figure 5. Comparative study: annual costs including annuity of initial investment.

2 Annuity of initial investment: 10,3 % of yearly payments, calculated based on 8 % nominal interest for external financing, 2 % general inflation rate and 15 years of economic depreciation period.

4. Selected alternative and conclusions

4.1. Selected alternative

The alternative proposal "Trigeneration" that combines a cogenerative gas engine system of 10.460 kWe / 13.000 kWth and an absorption chiller of 3.500 kW has been considered the best option among the previously analysed due to the high potential of both primary energy and energy cost savings. However, a solar system is an interesting complementary option that could be taken into account in combination with the trigeneration system.

In the following sections, the selected alternative is described in detail.

4.1.1. Process optimisation

No process optimisation has been considered.

4.1.2. Heat recovery

In the present study, an improvement of the current heat exchanger network is proposed. Wort cooling and steam from the boiling process are used to generate hot water for mashing and filtering. However, not all the available potential is currently exploited: part of the steam is not used, as the amount of low temperature process heat demand in the brewhouse alone is not enough. For this reason, the following changes in the heat recovery system are proposed:

1) Use mainly the water from wort cooling to provide heat for the processes of the brew zone

2) Use the whole amount of vapour from the cooking process to generate hot water also for other processes in the bottling area

The heat exchanger network is shown in Table 5. A comparison between the recovered energy in the present state and in the proposed alternative is shown in Table 6. As it can be seen from Table 2, the improvement of heat recovery leads to a saving of almost 7 % of the primary energy consumption.

Table 5. List of heat exchangers proposed.

Heat Exchanger	Power	Heat Source	Heat Sink	Heat transferred	
	[kW]			[MWh]	[%]
HX_cooling	9.370	Cooling wort	Tank for water for brewhouse processes	21.018	69,40
HX_boiling	2.424	Boiling steam	Tank for water for bottling processes	7.457	24,62
HX_filtration	723	Weak wort	Water for filtration /mashing	1.812	5,98
	12.518			**30.288**	**100**

Table 6. Comparison between present state and proposed alternative.

Heat exchanger	Heat source	Potencial	Heat transferred in the present state	Heat transferred in the proposed alternative
HX_cooling	Cooling wort	16.959	19.364	20.826
HX_boiling	Boiling steam	10.060	2.177	7.457
HX_filtration	Weak wort	1.923	1.812	1.812
TOTAL		**28.942**	**23.354**	**30.095**

4.1.3. Heat and Cold Supply

In the new system a trigeneration plant is proposed. It consists on the combination of a cogenerative system and a thermal chiller. Heat, electricity and cooling are provided simultaneously. The CHP can feed heat into the existing steam network for processes and also to drive the thermal chiller. The thermal chiller provides cooling to the cooling processes.

Table 7. Heating and cooling supply equipments . Selected alternative.

Equipment	Type	Nominal capacity	Contribution to total heat and cooling supply	
		[kW]	[MWh]	[%]
Absorption chiller	**Thermal chiller (air cooled)**	3.500	16.824	15,27
New CHP 2	**CHP engine**	8.000	50.214	45,58
New CHP 1	**CHP engine**	5.000	19.982	18,14
Boilers biogas	Steam boiler	490	2.047	1,86
Boilers natural gas	Steam boiler	40.265	8.108	7,36
Chiller_water	Compression (water cooled)	4.500	4.246	3,85
Chiller_glycol	Compression (water cooled)	5.500	6.849	6,22
Chiller_air	Compression (water cooled)	1.300	1.907	1,73
Total		**68.555**	**110.179**	**100**

The technical specifications of the new CHP engine and the absorption chiller are shown in Table 8 and Table 9.

Table 8. Technical specifications and economics of the new CHP engine

Parameter	Units	Technical data
Type of equipment	-	New CHP 1
Nominal power (heat or cold output)	kW	8000,00
Fuel type	-	Natural gas
Fuel consumption (nominal)	kg/h	1287,70
Electrical power generated (CHP)	kW	6560,00
Electrical conversion efficiency (CHP)	-	0,40

Parameter	Units	Technical data
Type of equipment	-	New CHP 2
Nominal power (heat or cold output)	kW	5000,00
Fuel type	-	Natural gas
Fuel consumption (nominal)	kg/h	804,80
Electrical power generated (CHP)	kW	3900,00
Electrical conversion efficiency (CHP)	-	0,40

Table 9. Technical specifications and economics of the new absorption chiller

Parameter	Units	Technical data
Type of equipment	-	Enfriadora térmica
Nominal power (heat or cold output)	kW	3500,00
COP	-	0,70

The total and monthly contribution of the new equipments to the total heat supply (80.352 MWh) is shown respectively in Table 10 and Figure 6 while the contribution to the cooling supply (29.827 MWh) is shown in Table 11, Figure 7 and Figure 8.

Table 10. Contribution of the different equipments to the total useful heat supply (USH) in the company.

Equipment	USH by equipment	
	[MWh]	[% of Total]
Boilers biogas	2.047	2,55
Boilers natural gas	8.108	10,09
New CHP 1	19.982	24,87
New CHP 2	50.214	62,49
Total	**80.352**	**100**

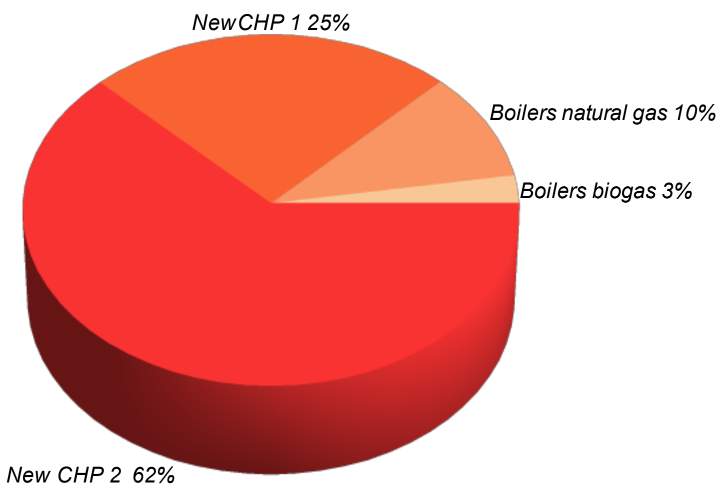

Figure 6. Contribution of the different equipments to the total useful heat supply (USH) in the company.

Table 11. Contribution of the different equipments to the total useful cooling supply (USC) in the company.

Equipment	USC by equipment	
	[MWh]	[% of Total]
Chiller_water	4.246	14,24
Chiller_glycol	6.849	16,19
Chiller_air	1.907	6,39
Absorption chiller	16.824	63,18
Total	**29.827**	**100**

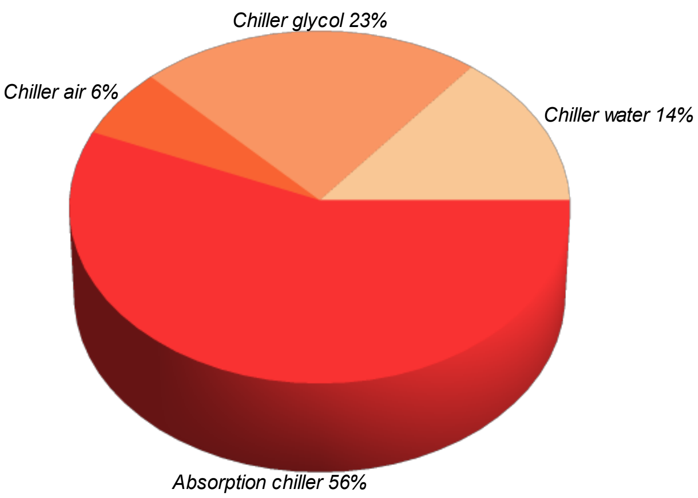

Figure 7. Contribution of the different equipments to the total useful cooling supply (USC)in the company.

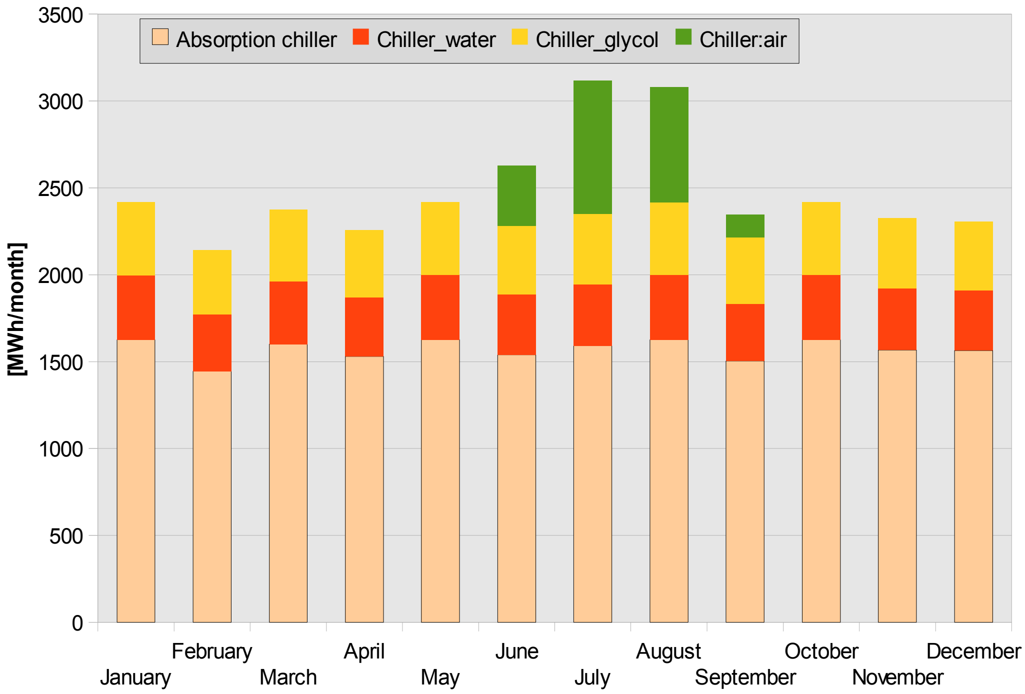

Figure 8. Contribution of the different equipments to the total useful cooling supply (USC) per month.

4.2. Summary: saving potential with respect to present state and economic performance

The following measures are proposed:

- optimisation of the current heat recovery network: full use of waste heat in the brewhouse for covering low temperature demands also in the bottling and service section
- addition of a trigeneration system:
  - absorption chiller (3.500 kW cooling) to provide cooling to the process
  - cogeneration (engine) 10.460 kWe/ 13.000 kWth for covering the base load of the remaining heat demand and for driving the absorption chiller

These measures allow to save 62,2 % of the current primary energy consumption (including primary energy for non-thermal purposes).They also save 75 % of current energy cost (cost of fuel and electricity, including auto-generated electricity) and lead to a reduction of 47% of the total energy system cost (fuel and electricity, operation and maintenance, amortisation). The total required investment is about 8.171.900 € and the expected pay-back time is 3 years (taking into account the subsidies).

Table 12. Comparison of the present state and the proposed alternative: saving potential and economic performance.

		Present state	**Proposed alternative**	**Savings**
Primary energy consumption (1)				
Total	MWh	142.038	53.689	62,20%
- Total fuels	MWh	75.536	186.788	-147,28%
- Total electricity	MWh	66.503	-133.100	300,14%
Primary energy saving due to renewable energy	MWh	-	-	-
CO_2 Emissions	t/a	28.633	19.504	31,88%
Total annual energy system cost (2)	€	4.022.560	2.149.062	46,57%
Total investment cost(3)	€	-	8.171.900	-
Pay-back period (4)	a	-	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. It also includes the feed-in-tariff revenue for the electricity produced by the CHP plant and sold to the net.

(3) total investment excluding subsidies

(4) supposing 10% of funding of total investment (subsidies or equivalent other support mechanisms)