Energy Audit Summary Report

Audit No. 33

Food Industry

Brewery

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

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1. Contact data of the auditors

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2. Description of the company (status quo)

Reference year of data/information: 2011

2.1. General information of the company

Company, location		
Sector	Food Industry: brewery	
Products	beer	
Yearly producion	280.000 hl	
Turnover	n.a.	
No. of employees	n.a.	
Current final energy consumption [MWh] (*)	total	for heating and cooling
- natural gas	9.373	9.373
- electricity	n/a	538

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

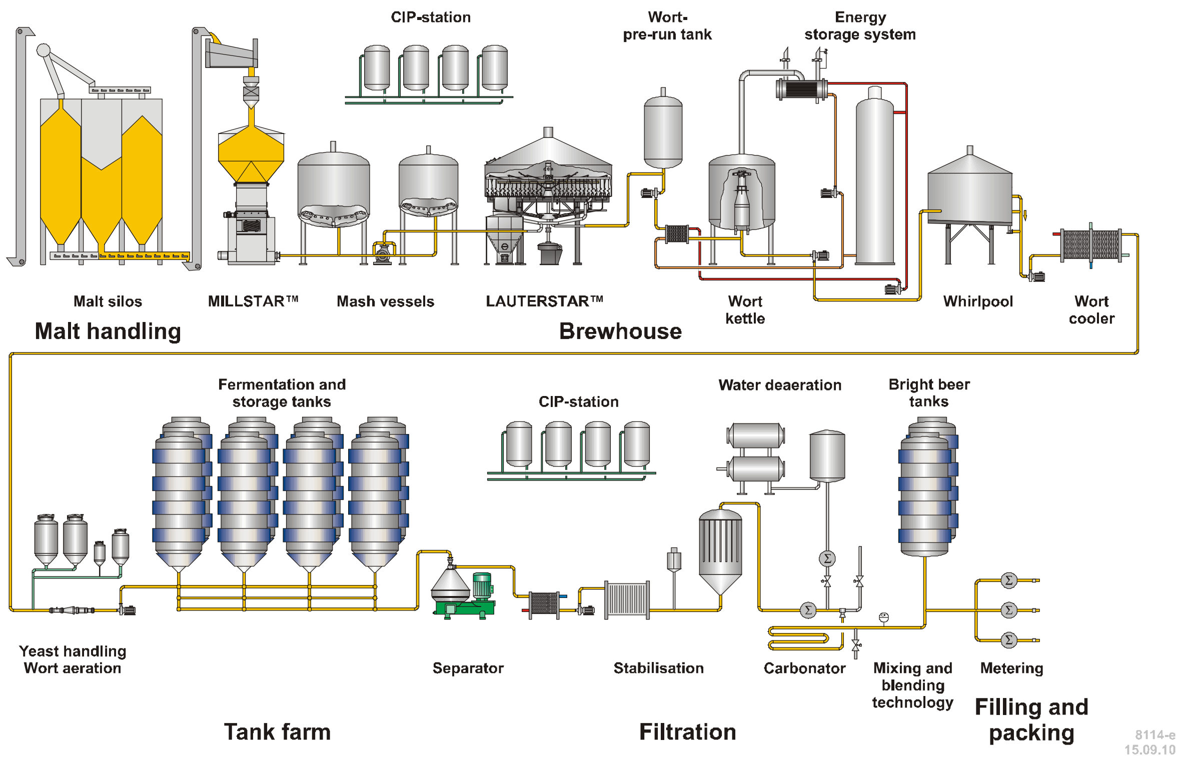

Figure 1. Overview general production process.

2.2. Description of the company

a) Productive process

The company produces beer of different types. The beer brewing process consists of the following main steps:

- mixing of malt and water (mashing), heating up to about 75 °C
- filtering (lautering). In this step hot water is added to elute the malt sugar of the spent grains
- wort boiling (concentration of wort).
- wort cooling
- cold storage for fermentation
- bottling and pasteurisation

In present state within the company there is also a large heat demand for stand-by of boilers and distribution circuits (recirculation).

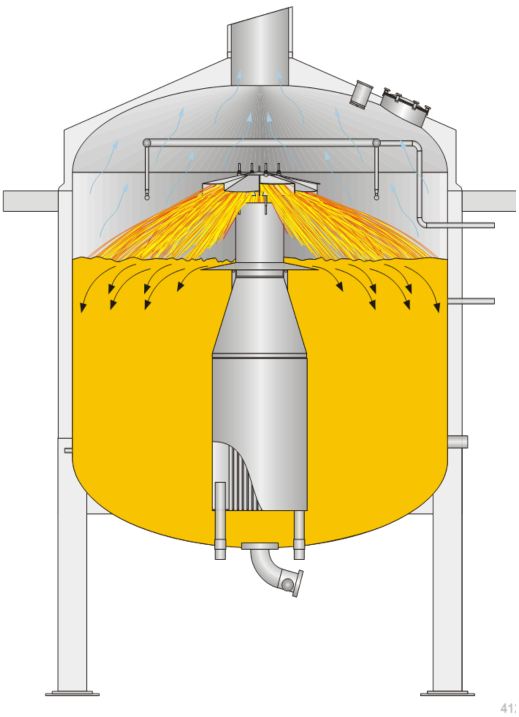

Figure 2. Vessel of GEA Brewery Systems GmbH with JetStar™ for wort boiling

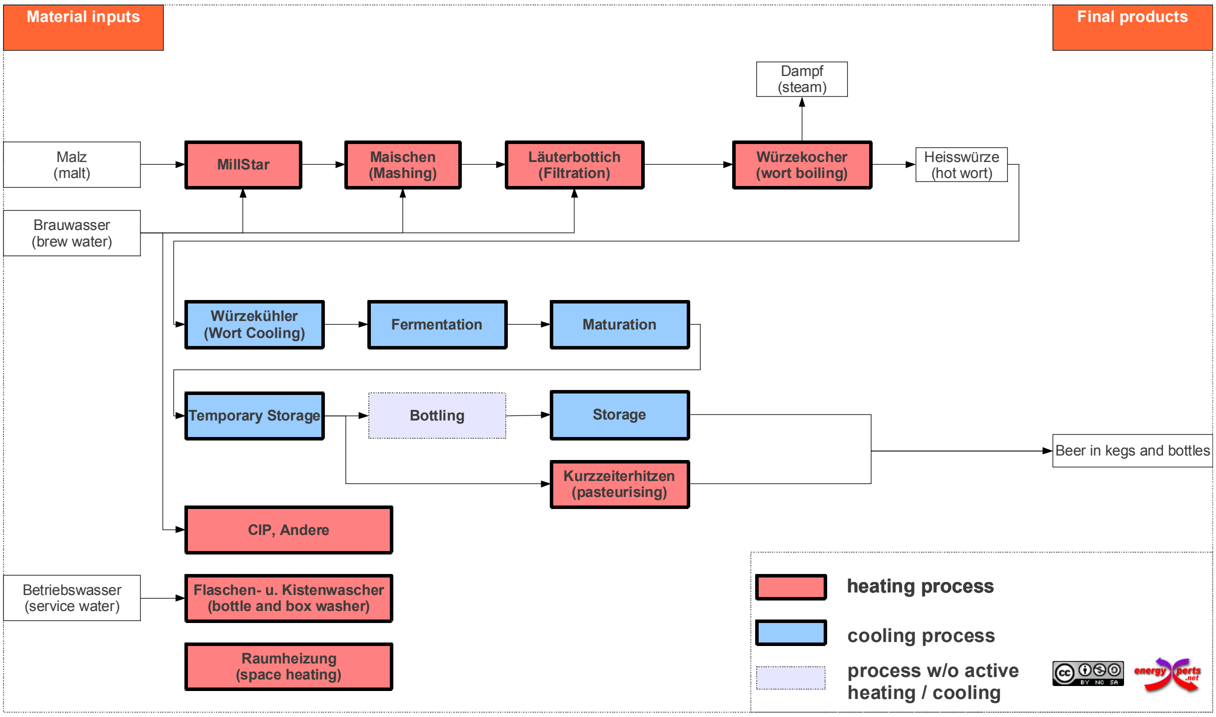

Figure 3. Simplified production flow sheet

The most heat consuming processes in the company are the wort boiling and the different processing steps consuming hot brew water (milling, mashing, lautering).

b) Energy supply system

The heat used in the brewhouse is generated in a gas fired steam boiler. The filling and service water generation is done by a high pressure hot water boiler generating pressurized water.

Cooling at low temperature is provided by several electrically driven chillers.

Wort cooling is provided mainly by heat recovery (heating up of cold water to be used in the production) and partially by fresh water which is currently unused.

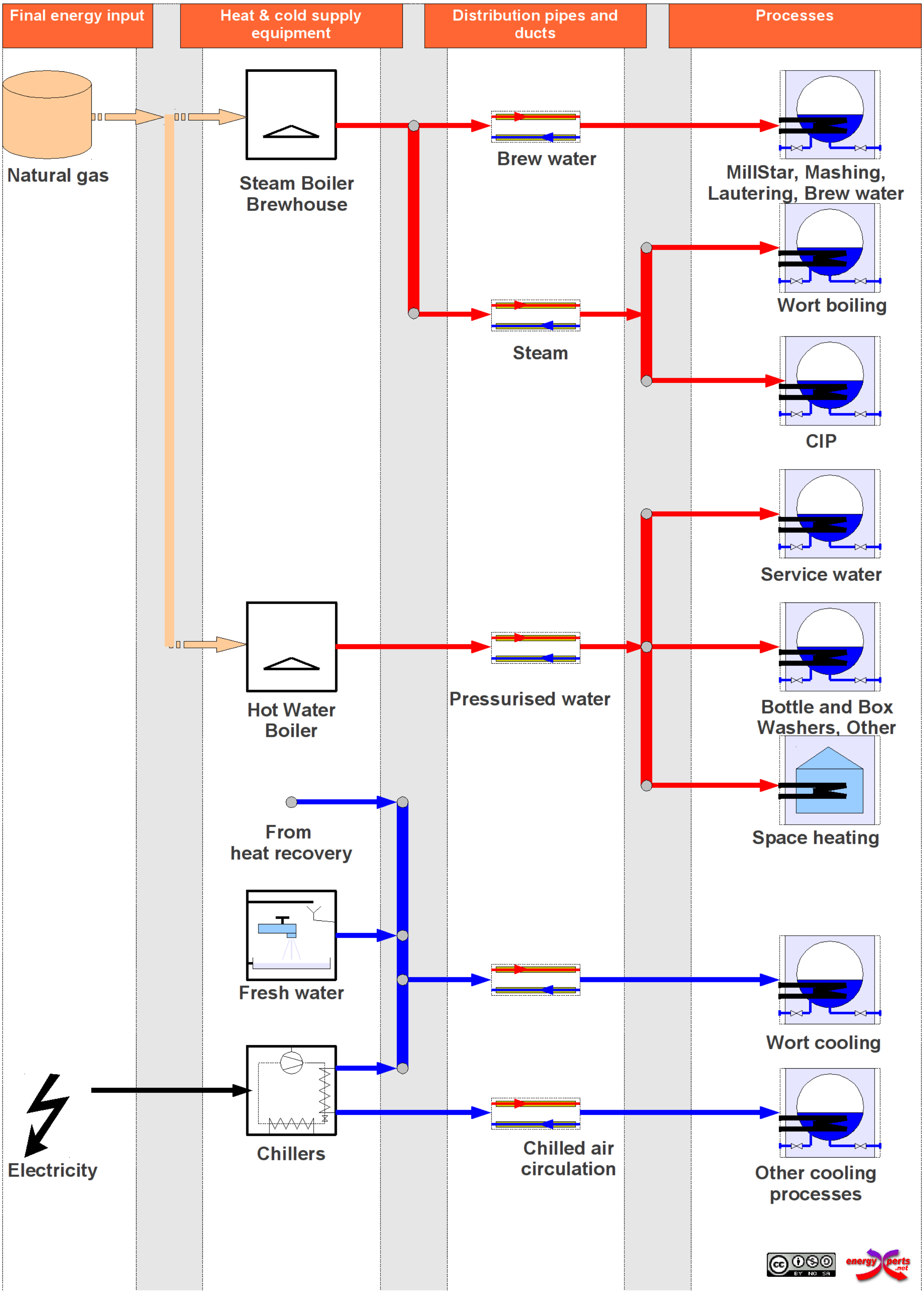

Figure 4. *Overview of the heat and cold supply system*

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 possible technical alternatives that have been studied are listed in Table 1.

All the alternatives include process optimisation as described in section 4.1.1. and all alternatives except PO-1 inlcude the optimised heat exchanger network as described in section 4.1.2.

Table 1. Overview of the alternative proposals studied

Short Name	Description
PO-1	Process optimisation Step 1 (results of a previous study, including process optimisation and heat recovery)
WRG	Optimised heat recovery, including process optimisation bottle washer. Includes all measures from PO-1.
KWK	Combined heat and power: gas turbine 450 kW_e / 844 kW_{th} (includes all measures of alternative WRG)
Solarthermie	Solar thermal system 900 kWth (evacuated tubes; includes all measures of alternative WRG)

3.2. Energy performance[1]

Table 2. Comparative study: yearly primary energy consumption.

Alternative	Primary energy consumption	Savings	
	[MWh]	[MWh]	[%]
Present State (checked)	11.924	---	---
PO-1	8.730	3.194	26,79
WRG	6.596	5.328	44,68
KWK	4.638	7.286	61,11
Solarthermie	6.193	5.731	48,06

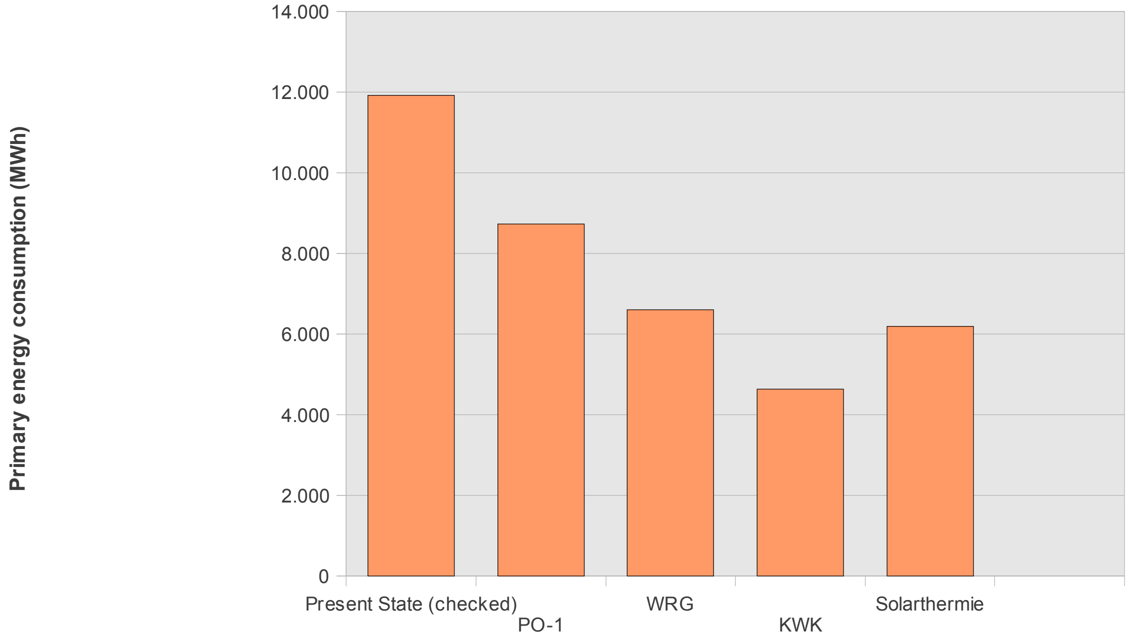

Figure 5. Comparative study: yearly primary energy consumption.

1 The factors for conversion of final energy (for fuels in terms of LCV) to primary energy used in this study are 3 for electricity and 1,1 for natural gas.

3.3. Economic performance

Table 3. Comparative study: investment costs. Estimated co-funding: 10 % for investment in heat recovery and CHP, 30 % for solar thermal systems.

Alternative	Total investment [€]	Own investment [€]	Subsidies [€]
Present State (checked)	---	---	---
PO-1	225.000	202.500	22.500
WRG	279.675	251.708	27.968
KWK	864.675	778.208	86.468
Solarthermie	844.160	646.847	197.313

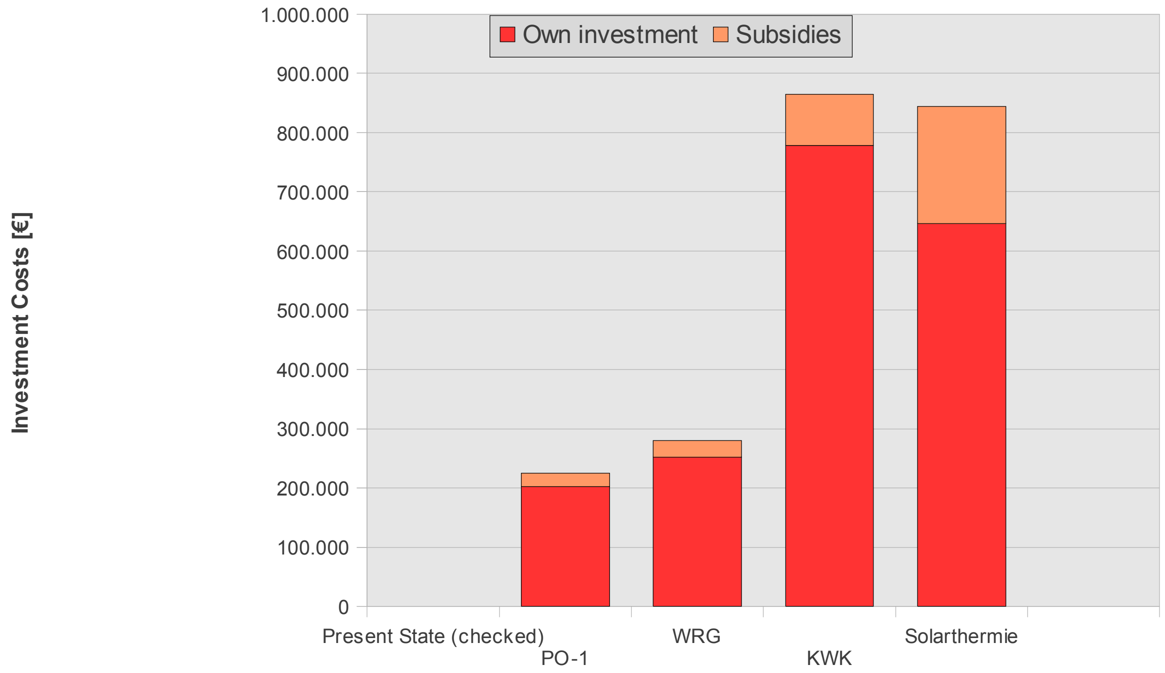

Figure 6. Comparative study: investment costs. Estimated co-funding: 10 % for investment in heat recovery and CHP, 30 % for solar thermal systems.

Table 4. Comparative study: annual costs including annuity of initial investment[2]. The energy cost for CHP includes also the feed-in-tariff revenue for the CHP electricity.

Alternative	Annuity [€]	Energy Cost [€]	O&M [€]
Present State (checked)	---	428.711	0
PO-1	23.167	312.740	11.250
WRG	28.796	234.793	14.175
KWK	89.029	115.394	31.725
Solarthermie	86.917	211.936	18.963

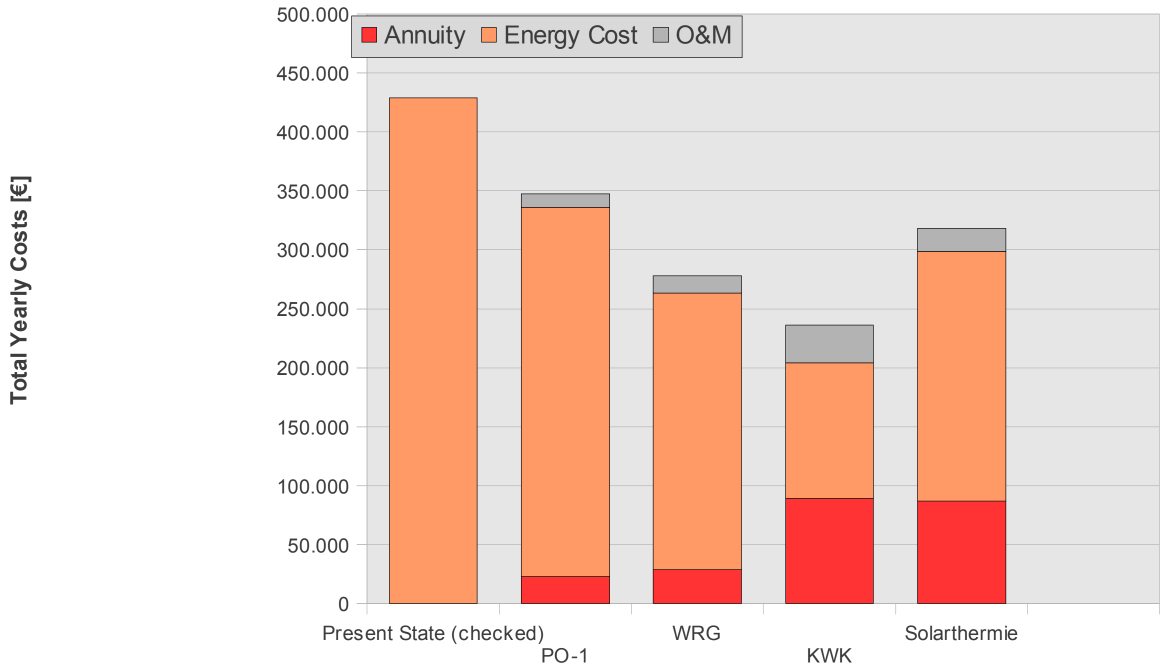

Figure 7. Comparative study: annual costs including annuity of initial investment. The energy cost for CHP includes also the feed-in-tariff revenue for the CHP electricity.

4. Selected alternative and conclusions

4.1. Selected alternative

The alternative proposal “KWK” that combines an optimized heat exchanger network and a cogenerative gas turbine of 450 kW_e / 844 kW_{th} has been considered the best option

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.

among the previously analysed due to both maximum primary energy savings and minimum total energy system costs.

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

4.1.1. Process optimisation

Process optimisation includes a series of measures:

- Reduction of stand-by losses during week-end and nighttime
- Improvement of the boiler efficiency (steam boiler brewhouse) from 85 % to 91 %
- Reduction of process heat demands in several processes in the brewhouse and the filling section
- Reduction of piping losses in pressurized water circuit in the filling section
- Economiser for waste heat recovery from hot water boiler

By process optimization only, the potential of total primary energy savings is 27 %.

4.1.2. Heat recovery

The proposed optimised heat exchanger network improves the already existing heat recovery system. The individual heat exchangers composing the system are listed in Table 5.

The major aspects of the heat recovery system are:

- Heat recovery from the processes in the brewhouse (wort cooling, vapour from wort boiling), feeding heat into a thermally stratified storage system of 75 – 95 °C (level 1), about 55 – 75 °C (level 2) and below 55 °C (level 3). From these intermediate storages almost 100% of the energy requirement of the MillStar, mashing and lautering processes can be supplied, including the sensible heat demand of the wort boiling process (heating up of wort until close below the evaporation temperature).
- Heat recovery from other processes (cleaning water of vessels in brewhouse, hot spent grain from lautering (optional, technical feasibility to be checked) for the preheating of service water
- Economiser in both steam boiler (brewhouse) and hot water boiler of the filling section for heating of the CIP in the brewhouse and of the bottle washer.

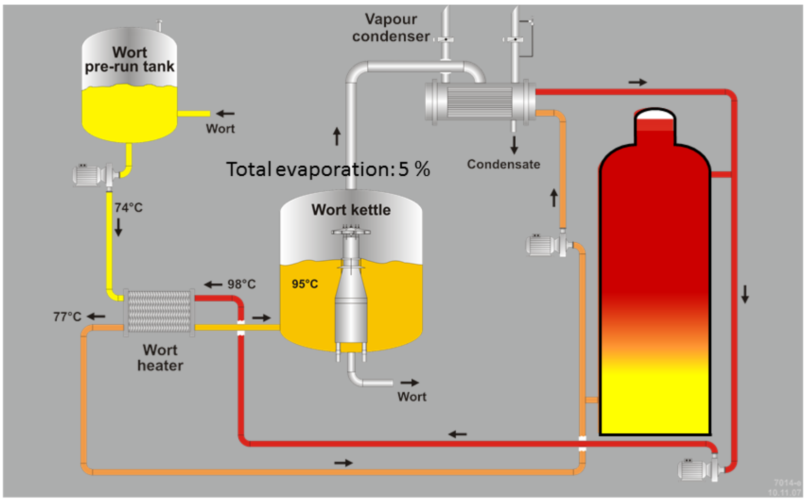

Figure 8. Scheme of low pressure boiling system illustrating energy recovery during wort boiling process with energy storage tank (temperature level 1 of the proposed system).

As can be seen from Table 2, the optimisation of the heat recovery system leads to an additional primary energy saving of 18 %.

Table 5. List of heat exchangers proposed (Legenda: Abfüllung: filling section; Sudhaus: brewhouse

Heat Exchanger	Power	Heat Source	Heat Sink	Heat transferred	
	[kW]			[MWh]	[%]
PfaDuKo	368	Würzekocher (wort boiling)	Würzekocher (wort boiling)	943	21,10
WKühler_MillStar	834	Würzekühler 2 (wort cooling)	MillStar	629	14,07
WKühler_Maischen	1.210	Würzekühler (wort cooling)	Maischen (mashing)	778	17,42
PfaDuKo_BrauWasser	120	Würzekocher (wort boiling)	Brauwasser (Brew water)	296	6,63
Economiser Abfüllung	7	HTHWKessel Abfüllung	CIP Sudhaus	146	3,28
WKühler_MillStar2	141	Würzekühler 2 (wort cooling)	MillStar	76	1,71
WKühler_Läutern1	807	Würzekühler (wort cooling)	Läuterbottich (filtration)	515	11,53
WKühler_Läutern2	731	Würzekühler 2 (wort cooling)	Läuterbottich 2 (filtration)	494	11,05
Treber_BetrWa	391	Läuterbottich (filtration)	Betriebswasser (service water)	253	5,66
AusspülWa_BetrWa	90	Brauwasser (Brew water)	Betriebswasser (service water)	206	4,62
Economiser_Sudhaus	10	Dampferzeuger Sudhaus	FlaWa (bottle washer)	131	2,93
	4.708			**4466,92**	**100**

4.1.3. Heat and Cold Supply

In the new system proposed a cogeneration plant (gas turbine) is added to the heat supply system. The CHP plant can feed heat into the existing steam network via a steam generator using the exhaust gas of the turbine, or alternatively by using the pressurized water circuit substituting steam also in the brewhouse.

Table 6. Heat and cooling supply equipments and contribution to total supply. Selected alternative.

Equipment	Type	Heat / cooling supplied to pipe/duct	Nominal capacity	Contribution to total heat / cooling supply	
			[kW]	[MWh]	[%]
KWK Gasturbine	CHP gas turbine	o==Dampf (steam)==o o==Betriebswasser==o o==HTHW (pressurised	844	2.389	59,57
Dampferzeuger Sudhaus	steam boiler	o==Brauwasser==o o==Dampf (steam)==o	4.500	948	23,63
HTHWKessel Abfüllung	hot water boiler	o==Betriebswasser==o o==HTHW (pressurised water)==o	4.500	673	16,79
Kaltwasser	fresh or ground water	o==Eiswasser (ice water)==o	1.000	168	9,58
Kälteanlagen	compression chiller (air cooled)	o==Eiswasser (ice water)==o	2.700	1.588	90,42
Total			**13.544**	**5.767**	**200**

The technical specifications of the new CHP turbine are given in Table 7.

Table 7. Specifications of the new CHP gas turbine.

Parameter	Units	Technical data
Type of equipment	-	CHP gas turbine
Nominal power (heat or cold output)	kW	843,75
Fuel type	-	Natural gas
Fuel consumption (nominal)	kg/h	113,18
Electrical power generated (CHP)	kW	200,00
Electrical conversion efficiency (CHP)	-	0,30
Contribution to total annual heat supply	MWh	2.389
Relative contribution to total annual heat supply	%	59,57
Heat supplied to pipe/duct	-	o==Brauwasser==o o==Dampf (steam)==o o==Betriebswasser==o o==HTHW (pressurised water)==o
Turn-key price	€	585.000,00
Annual operation and maintenance variable costs dependant on usage	€/MWh	0,04

The contribution of the CHP plant to the total heat supply is shown in Table 8 and Figure 9.

Table 8. Contribution of the different equipments to the total useful heat supply (USH) in the company.

Equipment	USH by equipment	
	[MWh]	[% of Total]
Dampferzeuger Sudhaus	948	23,63
HTHWKessel Abfüllung	673	16,79
KWK Gasturbine	2.389	59,57
Total	**4.011**	**100**

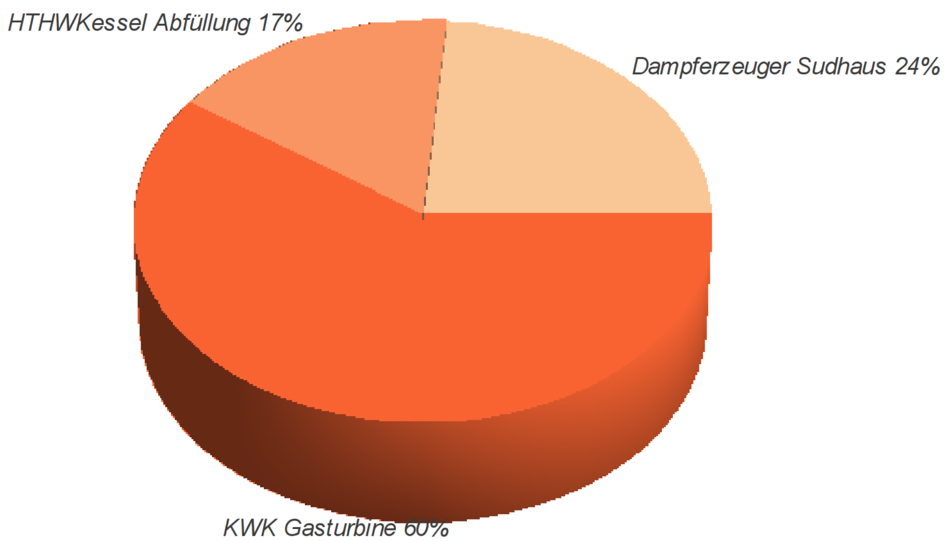

Figure 9. Contribution of the different equipment to the total useful heat supply (USH) in the company.

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

The following measures are proposed:

- process optimisation (including optimisation of piping in the filling section, economiser and improvement of conventional boiler efficiencies
- heat recovery: optimised heat recovery system covering almost 100% of the heat demand in the brewhouse (except latent heat for wort boiling) and part of the filling sections' heat demand
- cogeneration (gas turbine) for covering the base load of the remaining heat demand

These measures allow to save 61 % of the current primary energy consumption and 73 % of current energy cost (about 66% excluding the revenue from the feed-in tariff for the CHP electricity). The required own investment is about 865.000 € with a short pay-back time of 3,0 years.

Table 9. Comparison of the present state and the proposed alternative: saving potential and economic performance.

	U.M.	Present state	Alternative	Saving
Primary energy consumption				
- total	MWh	11.925	4.637	61%
- fuels	MWh	10.312	7.389	28%
- electricity	MWh	1.613	-2.752	271%
Primary energy saving due to renewable energy	MWh	0	0	-
CO_2 emissions	t/a	2.612	1.222	53%
Annual energy system cost (1)	EUR	428.711	236.149	45%
Total investment costs (2)	EUR	-	864.675	-
Payback period (3)	years	-	3,0	-

(1) In the alternative proposal the energy cost includes also the feed-in-tariff revenue for the electricity produced by the CHP plant and sold to the net.

(2) Own investment and subsidies

(3) Supposing 10% of funding of total investment or equivalent other support mechanisms