Energy Audit Summary Report

Audit No. 53

Fruit Juices

Somewhere

Food Industry

Production of fruit juices, puree and concentrate

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: forecast 2011

(Date of the visit on site: 26-07-2011)

2.1. General information of the company

Company, location	Fruit Juices	
Sector	Food Industry	
Products	Fruit and vegetable juices, juice concentrate and purees	
Yearly production	10.000 t (raw products)	
Turnover	n.a.	
No. of employees	n.a.	
Current final energy consumption [MWh] (*)	total	for heating and cooling
- gas oil	5.083	5.083
- propane	94	94
- electricity	1.183	570

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

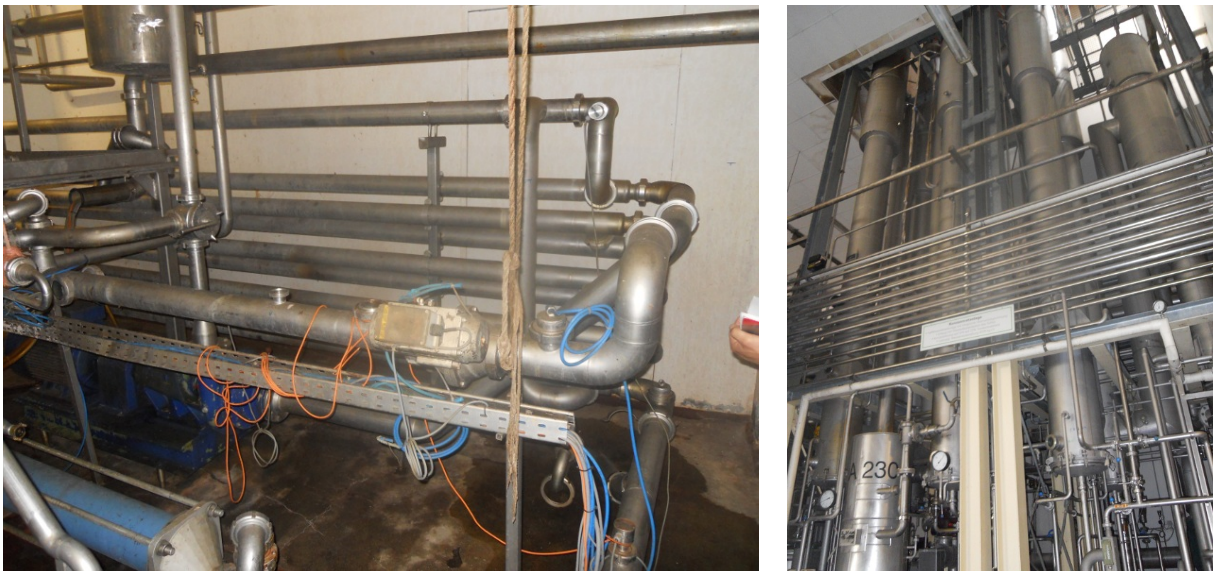
2.2. Description of the company

a) Productive process

The company receives both fresh and – in some cases - frozen raw materials.

Fruits are milled, and then heated up and maintained at temperature (55 – 75 °C) for encymation. In further steps, depending on the final product, the juices and purees are either sterilised or concentrated to juice concentrate.

The juices and other final products are delivered to other companies. No filling into bottles is taking place in the plant.



(a) *(b)*

Figure 1. (a) Heat exchanger for mash heating; (b) multi-stage falling film evaporator

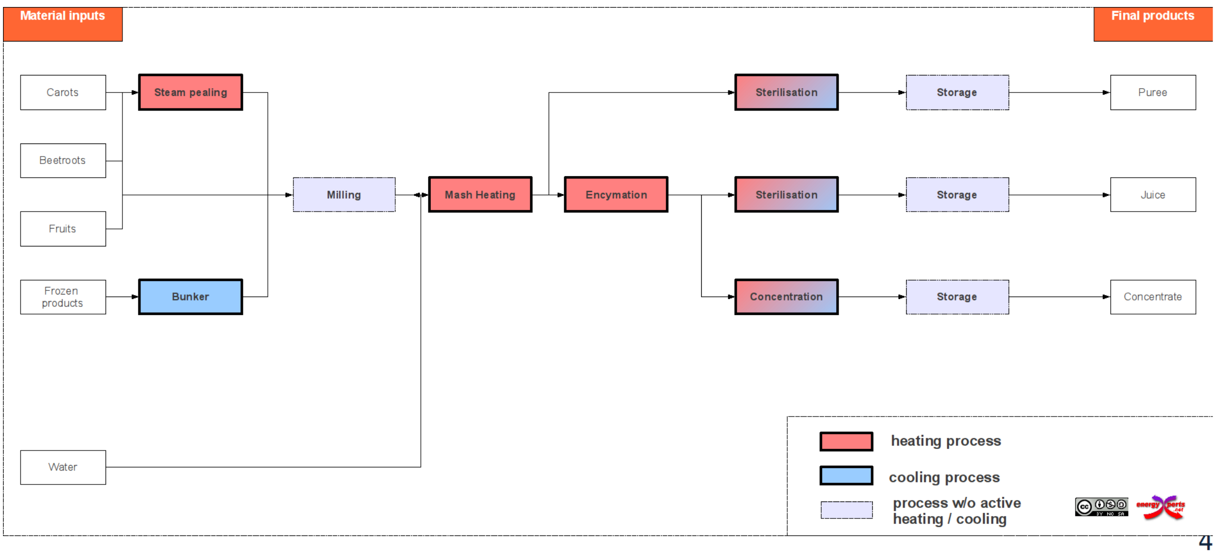


Figure 2. Simplified production flow sheet.

The most energy consuming processes in the company are the heating up of the mash and the sterilisation (both heating and cooling).

b) Energy supply system

The major part of the heat used in the company is generated in a gas-oil fired thermal oil boiler. From the thermal oil circuit then steam and hot water are generated. Only space heating is provided by a propane gas fired hot water boiler.

Cooling at low temperature is provided via an ice-water circuit supplied by two electrically driven water-cooled chillers. Cooling and freezing chambers are supplied by own independent electrically driven chillers.

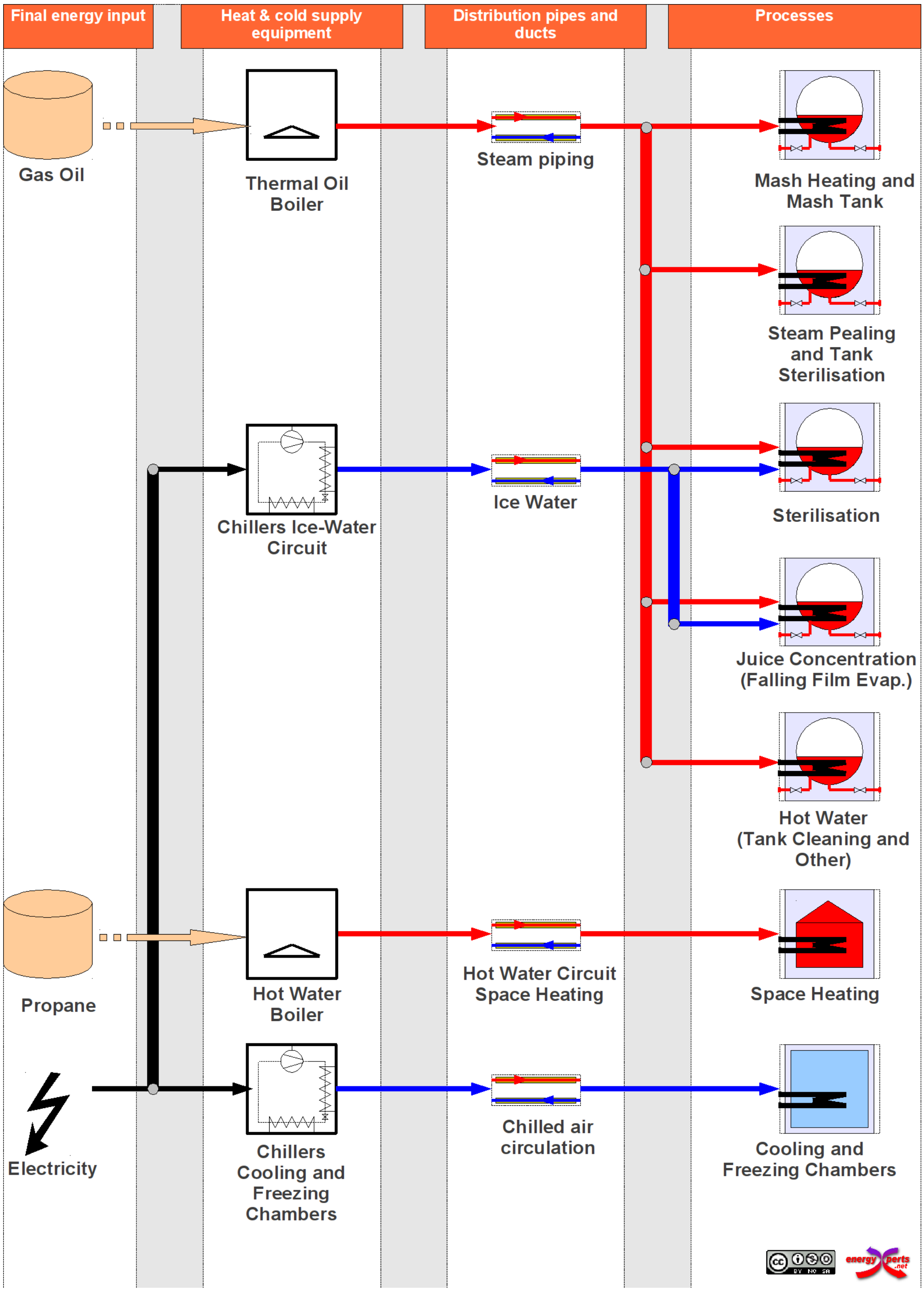


Figure 3. Overview of the heat and cold supply system

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

Table 1. Overview of the alternative proposals studied

Short Name	Description
PO - Sterilisation	Process optimisation sterilisation process
WRG	Heat recovery from sterilisation for mash preheating (includes measures of PO-sterilisation)
E+V	Optimisation of heat & cold generation and distribution - new steam boiler 1500 kW - reduction of piping losses in heat distribution (includes measures of PO-sterilisation and WRG)
KWK	CHP (combined heat and power): gas engine 200 kWe/ 333 kWth for steam and hot water generation (includes measures of PO-sterilisation, WRG and E+V)
WP	Heat pump (150 kWth) for hot water generation (includes measures of PO-sterilisation, WRG and E+V)

3.2. Energy performance[1]

Table 2. Comparative study: yearly primary energy consumption.

Alternative	Primary energy consumption	Savings	
	[MWh]	[MWh]	[%]
Present State (checked)	8.889	---	---
PO - Sterilisation	8.404	485	5,46
WRG	5.883	3.005	33,81
E+V	4.857	4.032	45,36
KWK	4.326	4.562	51,33
WP	4.668	4.221	47,48

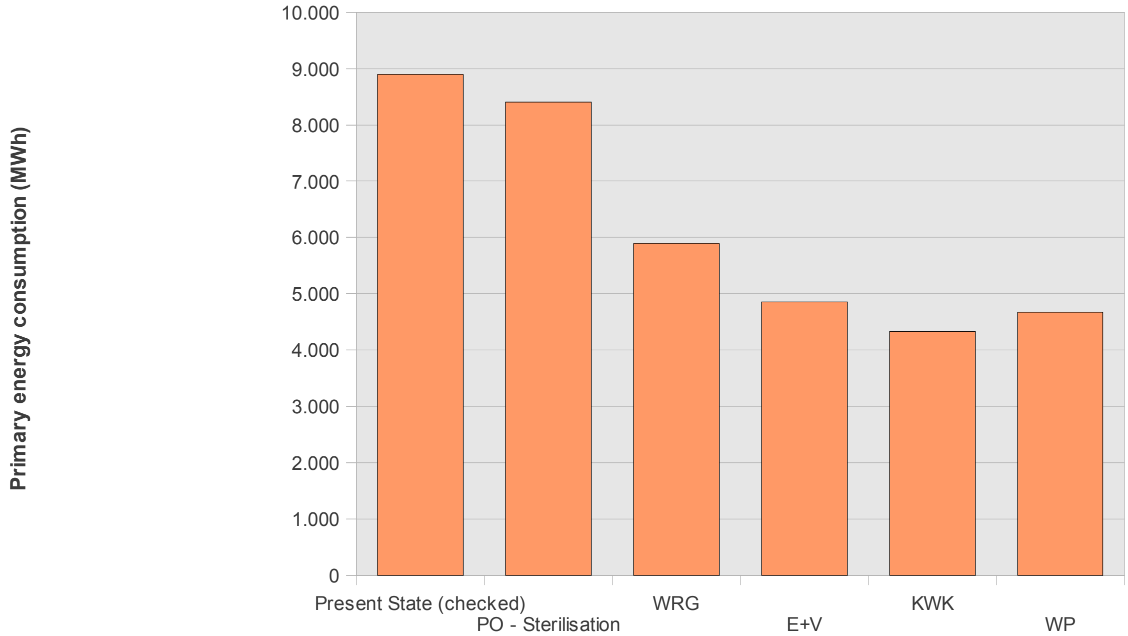


Figure 4. Comparative study: yearly primary energy consumption.

1 The factors for conversion of final energy (for fuels in terms of LCV) to primary energy used in this study are 2,7 for electricity and 1,1 for fuels.

3.3. Economic performance

Table 3. Comparative study: investment costs. Estimated co-funding: 10 % for investment in energy efficiency.

Alternative	Total investment [€]	Own investment [€]	Subsidies [€]
Present State (checked)	---	---	---
PO - Sterilisation	50.000	45.000	5.000
WRG	110.000	99.000	11.000
E+V	325.000	315.000	10.000
KWK	495.000	468.000	27.000
WP	370.000	355.500	14.500

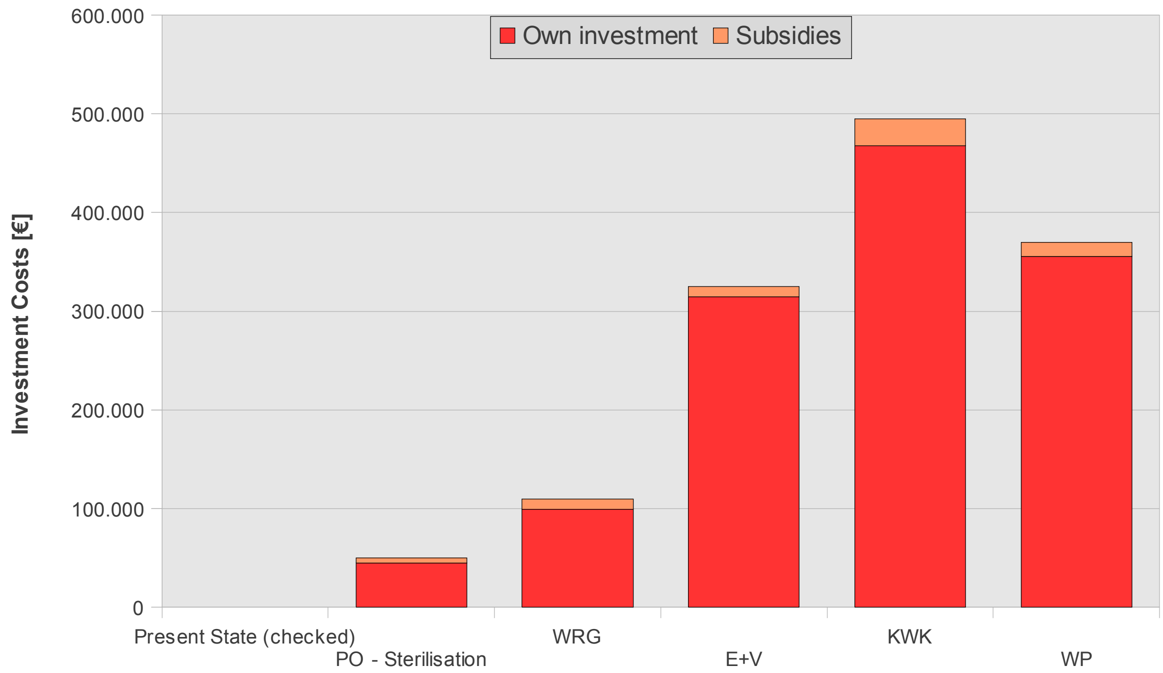


Figure 5. Comparative study: investment costs. Estimated co-funding: 10 % for investment in energy efficiency.

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

Alternative	Annuity [€]	Energy Cost [€]	O&M [€]	Total [€]
Present State (checked)	---	483.430	0	483.430
PO - Sterilisation	5.148	459.384	0	464.532
WRG	11.326	327.674	4.800	343.800
E+V	33.463	275.842	4.800	314.105
KWK	50.967	218.866	10.674	280.507
WP	38.096	268.957	5.550	312.603

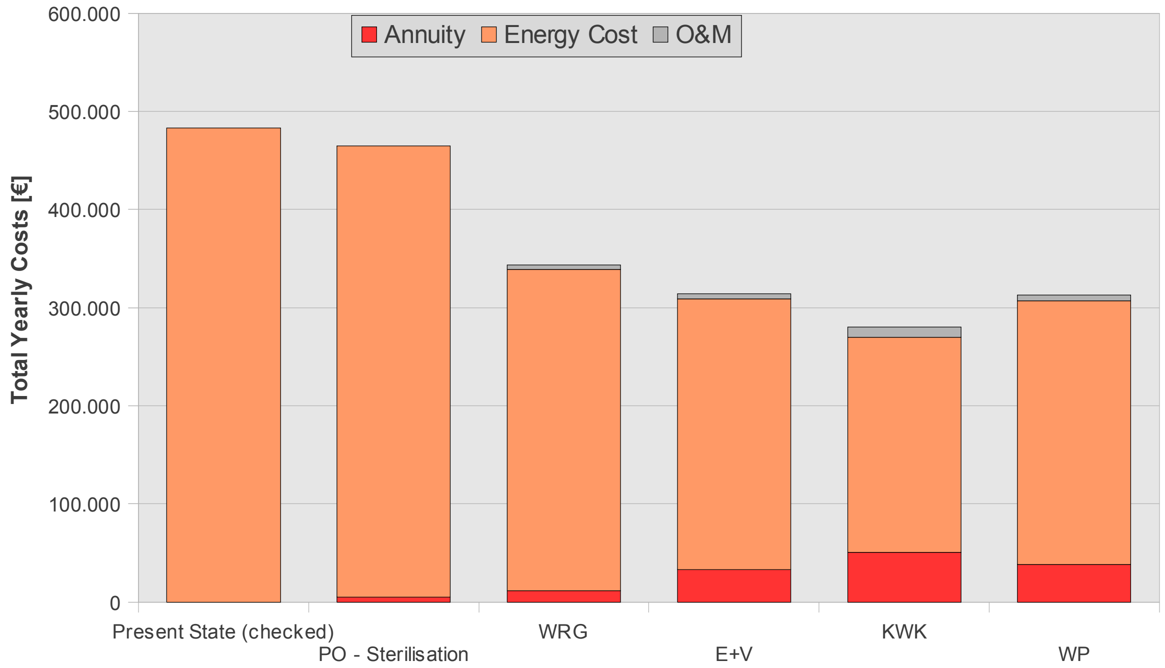


Figure 6. Comparative study: annual costs including annuity of initial investment.

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. Tariffs: 54,5 €/MWh for gas oil, 45,1 for propane, 171 €/MWh a for purchased electricity, 21 €/MWh prime for self-generated electricity.

4. Selected alternative and conclusions

4.1. Selected alternative

The alternative proposal “KWK” that combines process optimisation, heat recovery, optimisation of the conventional supply and a cogenerative engine of 200 kW_e /333 kW_{th} has been considered the best option among the previously analysed due to the highest potential of both primary energy and energy cost savings

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

4.1.1. Process optimisation

Currently heat recovery in the sterilisation process seems to be not optimum. By a reduction of thermal losses of the juices before entering the sterilisation process the inlet temperature can be risen from 40 to 50 °C and within the sterilisation process, so that the temperature after heat recovery can be increased from 95 to 105 °C.

By process optimization, the total primary energy demand can be reduced by more than 5%.

Figure 7. Heat exchanger for sterilisation

4.1.2. Heat recovery

The proposed heat exchanger network uses mainly waste heat from the sterilisation process for preheating of mash. By this, also the external cooling demand for sterilisation is reduced.

Smaller heat exchangers are also proposed for heat recovery from warm waste water from tank cleaning and from the cooling circuit of the falling film evaporator for fresh water preheating (Table 5). As can be seen from Table 2, heat recovery leads to an additional saving of 28 % of the primary energy consumption after process optimisation.

Table 5. List of heat exchangers proposed.

Heat Exchanger	Power	Heat Source	Heat Sink	Heat transferred	
	[kW]			[MWh]	[%]
WT Maische (Karotten)	193	Sterilisation (sterilisation)	Maischeerhitzen Karotten (Mash heating carots	486	47,38
WT Maische (Andere)	243	Sterilisation (sterilisation)	Maischeerhitzen Andere (Mash heating other	456	44,43
WT Tankreinigung	16	Tankreinigung (tank cleaning)	Tankreinigung (tank cleaning)	42	4,07
WT Warmwasser	28	Fallstromverdampfer (falling film evaporator)	Warmwasser (hot water)	42	4,12
	481			**1025,33**	**100**

4.1.3. Heat and Cold Supply

In the new system three measures are proposed:

- reduction of piping losses and increase of condensate recovery, so that the distribution efficiency in the steam distribution is increased from about 86 % (estimated value for present state) to 95 %.
- substitution of the thermal oil boiler by an efficient steam boiler of 1500 kW.
- cogeneration plant (gasoil driven engine) of 200 kWe / 333 kWth for covering the base load of the heating demand. The CHP plant feeds heat into the hot water network, and in the existing steam network via a steam generator using the exhaust gas of the engine.

Table 6. Heat and cooling supply equipments . Selected alternative.

Equipment	Type	Heat / cooling supplied to pipe/duct	Nominal capacity	Contribution to total heat / cooling supply	
			[kW]	[MWh]	[%]
New CHP 1	**CHP engine**	**o==Dampfverteilung (steam distribution)==o o==Heizung (space heating)==o**	**333**	**808**	**26,62**
Dampfkessel NEU	**steam boiler**	**o==Dampfverteilung (steam distribution)==o**	**1.500**	**862**	**28,39**
Thermoölkessel (thermal oil boiler)	steam boiler	o==Dampfverteilung (steam distribution)==o	4.000	0	0,00
Heizungskessel	hot water boiler	o==Heizung (space heating)==o	60	62	2,05
Kälteanlagen (chillers)	compression chiller (water cooled)	o==Eiswasser==o	932	178	5,86
Kälteaggregat Kühllager (chiller cold store)	compression chiller (air cooled)	o==Kühllager==o	146	257	8,45
Kälteaggregat Tiefkühllager (chiller freezing	compression chiller (air cooled)	o==Tiefkühllager==o	269	472	15,54
Kälteanlagen (chillers) +10	compression chiller (water cooled)	o==Kaltwasser==o	932	398	13,09
Total			**8.173**	**3.037**	**100**

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

Table 7. Technical specifications and economics of the new CHP plant.

Parameter	Units	Technical data
Type of equipment	-	CHP engine
Nominal power (heat or cold output)	kW	333,00
Fuel type	-	Gas oil
Fuel consumption (nominal)	kg/h	53,60
Electrical power generated (CHP)	kW	200,00
Electrical conversion efficiency (CHP)	-	0,30
Contribution to total annual heat supply	MWh	808
Relative contribution to total annual heat supply	%	26,62
Heat supplied to pipe/duct	-	o==Dampfverteilung (steam distribution)==o o==Heizung (space heating)==o
Turn-key price	€	170.000
Annual operational and maintenance fixed costs	€	1.800
Annual operation and maintenance variable costs dependant on usage	€/MWh	5

The total and monthly contribution of the new equipment to the total heat supply is shown respectively in Table 8, Figure 8 and Figure 9 while the contribution to the cooling supply is shown in Table 9, Figure 10 and Figure 11.

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

Equipment	USH by equipment	
	[MWh]	[% of Total]
Thermoölkessel (thermal oil boiler)	0	0,00
Heizungskessel	62	3,60
Dampfkessel NEU	**862**	**49,75**
New CHP 1	**808**	**46,64**
Total	**1.733**	**100**

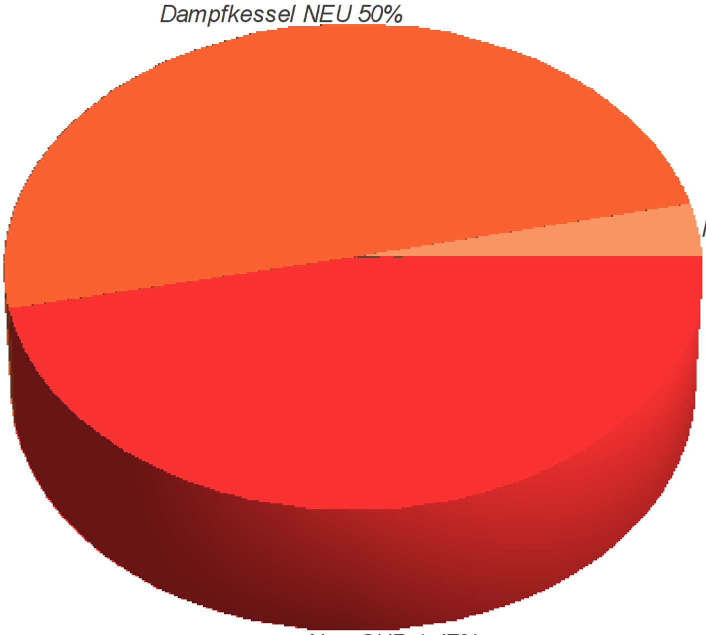


Figure 8. Contribution of the different equipments to the total useful heat supply (USH) in the company.

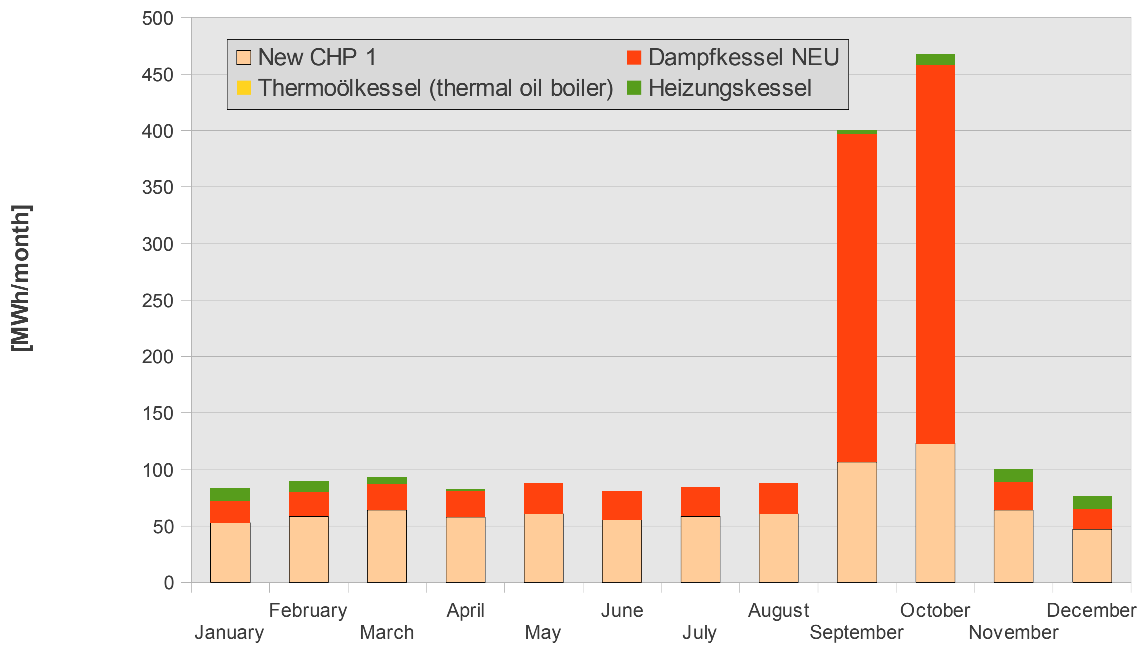


Figure 9. Contribution of the different equipments to the total useful heat supply (USH) per month.

Table 9. Contribution of the different equipments to the total useful cooling supply (USC) in the company.

Equipment	**USC by equipment**	
	[MWh]	[% of Total]
Kälteanlagen (chillers)	178	13,64
Kälteaggregat Kühllager (chiller cold store)	257	19,67
Kälteaggregat Tiefkühllager (chiller freezing	472	36,20
Kälteanlagen (chillers) +10	398	30,49
Total	**1.304**	**100**

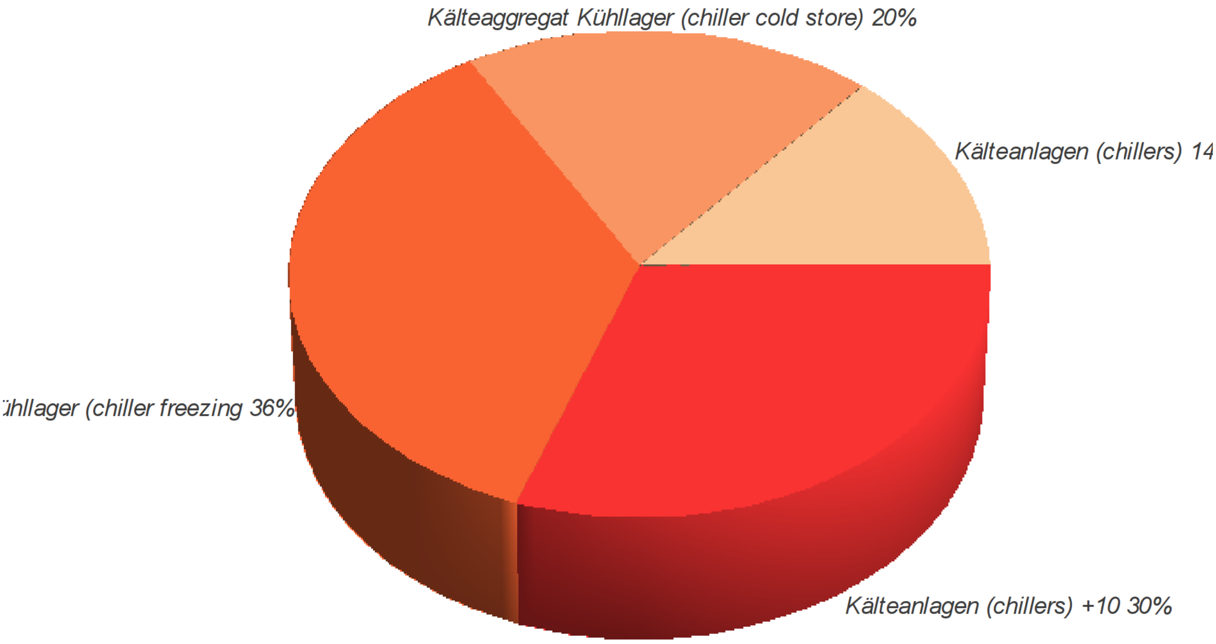


Figure 10. Contribution of the different equipments to the total useful cooling supply (USC)in the company.

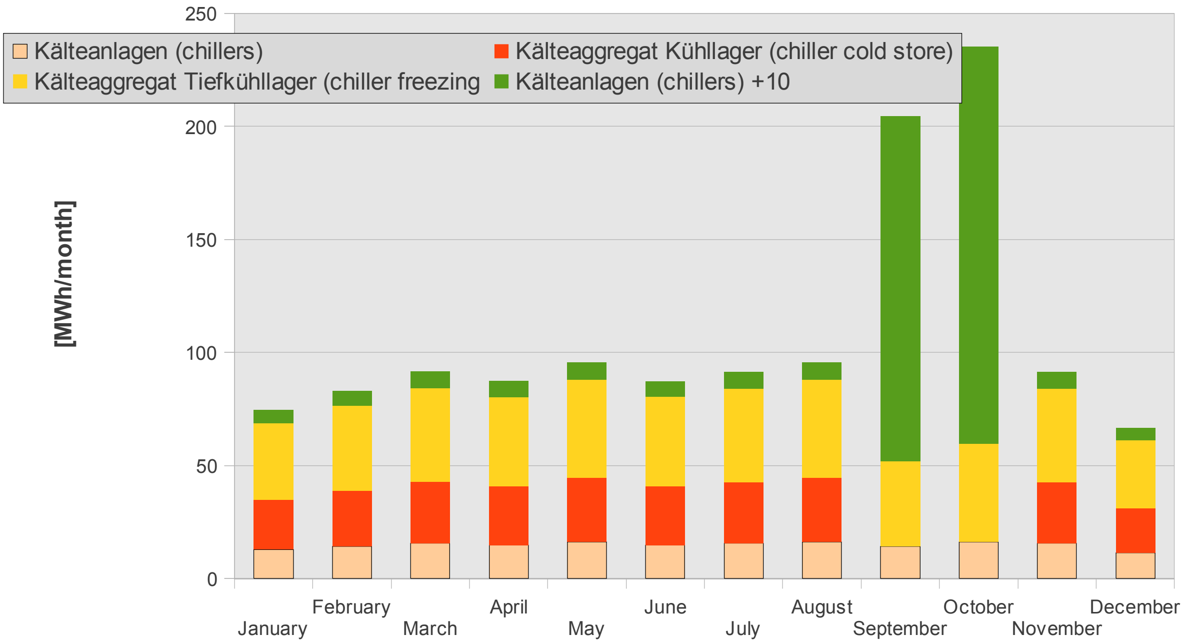


Figure 11. Contribution of the different equipments to the total useful cooling supply (USC) per month.

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

The following measures are proposed:

- optimisation of the sterilisation process: increase of inlet temperature and heat recovery
- heat recovery: waste heat recovery from sterilisation for mash preheating and recovery of heat from waste water and falling film evaporation for water preheating
- substitution of the thermal oil boiler by an efficient steam boiler of 1500 kW.
- cogeneration (gas engine) of 200 kWe/ 333 kWth for covering the base load of the remaining heat demand

These measures allow to save 51 % of the current primary energy consumption and 55 % of current energy cost. The total required investment is about 495.000 € and the expected pay-back time is 1,9 years (taking into account possible subsidies).

Table 10. Comparison of the present state and the proposed alternative: saving potential and economic performance.

	U.M.	Present state	Alternative	Saving
Total primary energy consumption (1)				
- total	*MWh*	*8.889*	*4.326*	*51,33%*
- fuels	*MWh*	*5.694*	*3.138*	*44,89%*
- electricity	*MWh*	*3.194*	*1.188*	*62,81%*
Primary energy saving due to renewable energy	*MWh*	*0*	*0*	*-*
CO_2 emissions	t/a	*1.886*	*993*	*50,51%*
Annual energy system cost (2)	*EUR*	*483.430*	*280.507*	*41,98%*
Total investment costs (3)	*EUR*	*-*	*495.000*	*-*
Payback period (4)	*years*	*-*	*1,9*	*-*

(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) *total investment excluding subsidies.*

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