Energy Audit Summary Report

Audit No. 21

Pharmaceutical Industry

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: 2010

2.1. General information of the company

Sector	Pharmaceutical	
Products	Pharmaceutical	
Yearly production	70 M packages	
Turnover	24 M€	
No. of employees	215	
Current final energy consumption [MWh] (*)	total	for heating and cooling
- natural gas	3.613	3.613
- electricity	3.342	206

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

Figure 1. Tank where products are heated

2.2. Description of the company

a) Productive process

The company receives the pharmaceutical components and processes them to produce the different pharmaceutical products. The products can be divided into different areas: solids (pills, capsules), semisolids (gels, vaselines, moisturiser) and liquids (solutions, suspensions, syrups). The production of the following products requires thermal energy :

1. Production of gels, vaselines and syrups: substances are mixed and heated up in tanks with steam to temperatures between 60 and 90ºC. The mixtures are maintained during some time at the process temperature and are finally cooled down to temperatures oscillating in the range from 25 to 60ºC using cold water.
2. Pills are dried with hot air at 60ºC.
3. In the production of towels, the tanks are previously disinfected with steam at 120ºC.
4. Hot water at 60ºC is daily prepared for: cleaning, kitchen, and other uses.

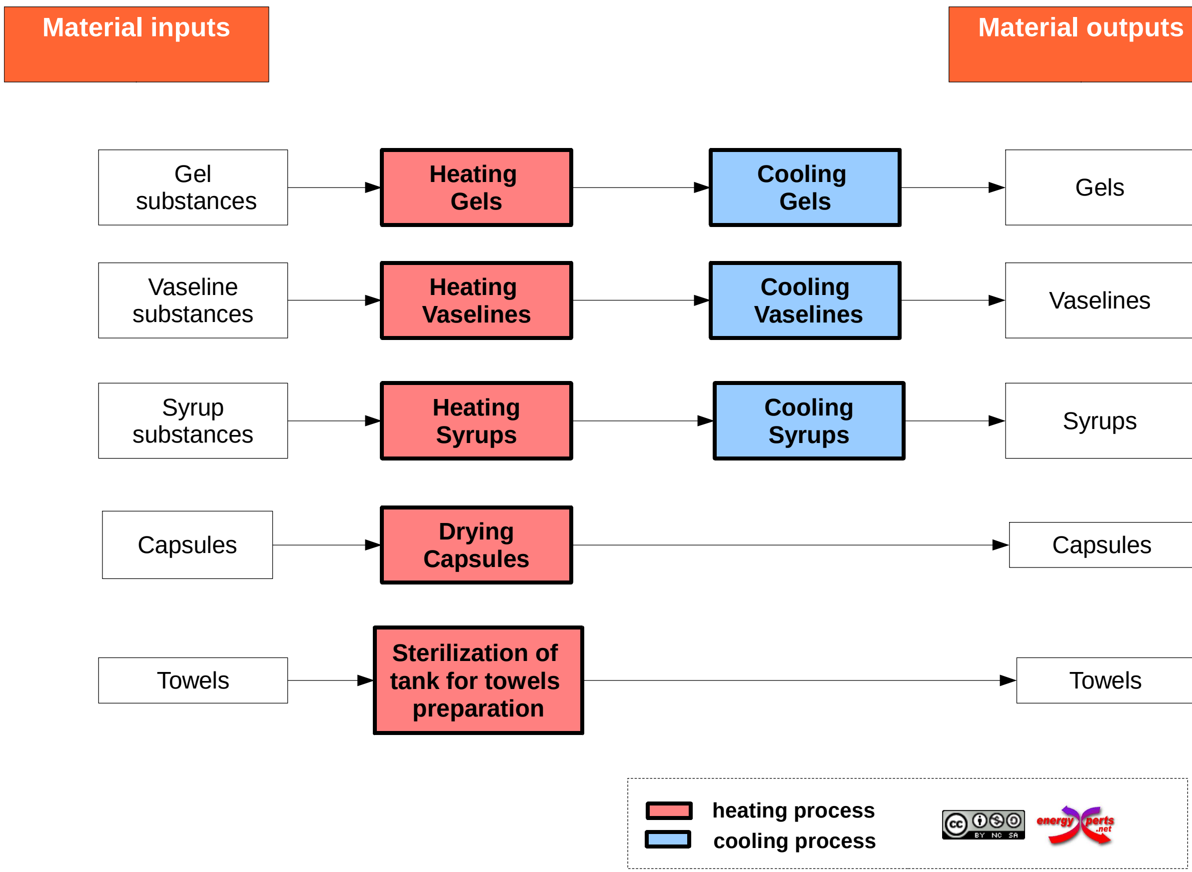

Figure 2. Simplified production flow sheet

(a) (b)

Figure 3. (a) heating products, (b) steam losses in distribution

The most heat consuming processes in the company are the drying process of pills and the heating of syrups. The space heating, in particular the heating of production halls, has also a relevant heat consumption.

Regarding cooling consumption, the cooling of syrups is the most consuming energy process. The sum of the cooling processes corresponds to 30% of the total cooling demand. The main cooling consumers are the refrigeration of buildings, in particular the cooling of the production halls.

b) Energy supply system

The heat used in the company is generated in two natural gas fired steam boilers. Steam at 2 bar and 120ºC is distributed to heat processes and for space heating. Cooling is provided by two electrically drive

n chillers. They generate water at 7ºC, which is used to cool down the processes from around 90ºC to ambient temperature. Cold water is also distributed for space cooling. A cooling tower rejects the heat from the condenser of the electrical chillers and the air compressors. In the next figure, a simplified scheme of the generation and supply system is shown.

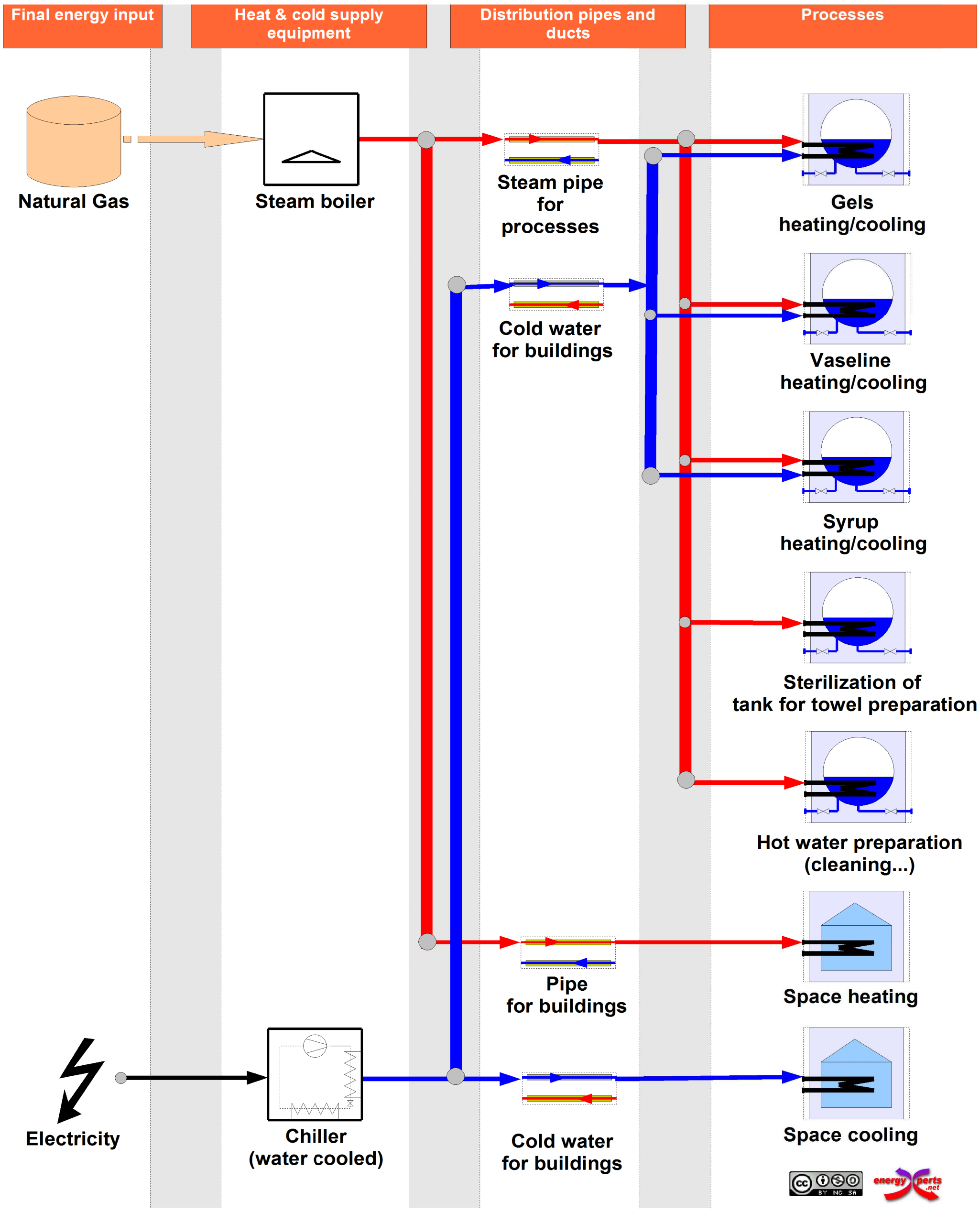

Figure 4. Overview of the heat and cold supply system

2.3. Additional comments

The following additional information is relevant for the analysis:

Further information:

- Waste heat of air compressors is currently not used
- The temperature of air outlet in the pills drying process is 65ºC and is not recirculated

Specific assumptions

Table 1 gives an overview of the most relevant parameters that have been supposed or estimated based on the limited information available.

Table 1. List of assumptions

1	Natural gas demand for space heating	1545 Mwh	Calculated from the historical natural gas consumption. It has been supposed that the difference of gas consumption between winter and summer is due to space heating.
2	Heat demand of buildings	60 kWh/m²year	Limited by supposition 1)
3	Cold demand of buildings	30 kWh/m²year	Limited by the nominal power of the chiller and the processes cold demand.
4	Recirculation rate of condensate	0,30	In the analysis, inefficiencies regarding the steam distribution have been detected.
5	Rendimiento caldera de vapor	0,70	In the analysis, inefficiencies regarding the steam generation have been detected. The company afirms that boilers are obsolete.
6	Water contained in the pills (before drying)	1kg_water/1 kg_pills	Missing data
7	Conditions of outlet air of fryer	45ºC and 20% relative humidity	Missing data
8	Power of waste heat of the air compressors	99 kW	Value calculated assuming that 90% of the generated power, is converted into waste heat. See catalogue at: http://glauber.com/Products/Compressors/Atlas1/
9	Temperature of the waste heat of the air compressors	85ºC	See catalogue: http://glauber.com/Products/Compressors/Atlas1/

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 potential alternatives that have been investigated are listed in Table 2.

Table 2. Overview of the alternative proposals studied

Heat exchanger network	Improvement of recirculation rate of the condensate in the steam pipe + Heat exchanger network of 113 kW
Cogeneration (Gas turbine 375 kWth)	Improvement of recirculation rate of the condensate in the steam pipe + Heat exchanger network of 113 kW + Cogeneration (gas turbine 375 kWth/200 kWel) + Substitution of steam boiler by 2 steam boilers 600 kW
Solar thermal (FPC) 1000 kW	Improvement of recirculation rate of the condensate in the steam pipe + Heat exchanger network of 113 kW + Solar thermal system FPC (flat plate collectors) 1000 kW + Substitution of steam boiler by 2 steam boilers 600 kW
Trigeneration (Gas turbine 563 kWth + Absorption chiller 50 kW)	Improvement of recirculation rate of the condensate in the steam pipe + Heat exchanger network of 113 kW + Cogeneration (gas turbine 563 kWth/300 kWel) + Substitution of steam boiler by 2 steam boilers 600 kW + Absorption chiller (50 kW cooling capacity)
Solar heating and cooling (Solar thermal FPC 1600 kW + Absorption chiller 50 kW)	Improvement of recirculation rate of the condensate in the steam pipe + Heat exchanger network of 113 kW + Solar thermal system FPC (flat plate tube collectors) 1600 kW + Substitution of steam boiler by 2 steam boilers 600 kW + Absorption chiller (50 kW cooling capacity)

3.2. Energy performance[1]

Table 3. Comparative study: yearly primary energy consumption.

Alternative	Primary energy consumption	Savings	
	[MWh]	[MWh]	[%]
Present state	14.000	---	---
Heat exchanger network	13.579	421	3,00
cogeneration	11.146	2.854	20,39
Solar thermal	11.943	2.057	14,69
Trigeneration	10.841	3.159	22,57
Solar heating and cooling	11.606	2.394	17,10

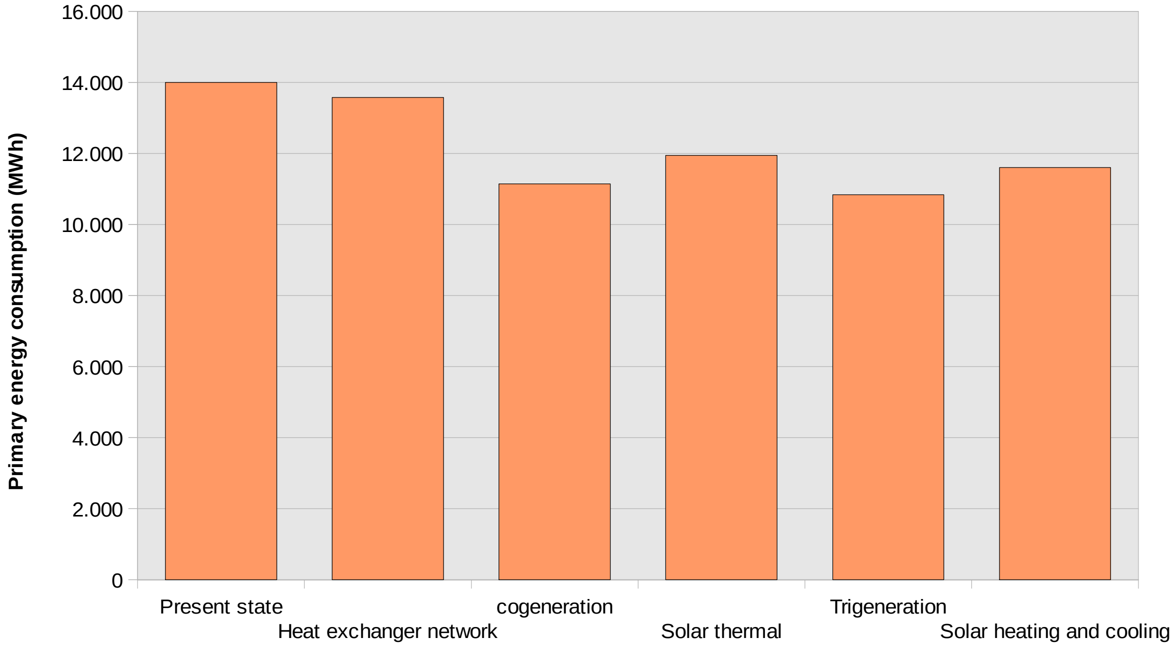

Figure 5. Comparative study: yearly primary energy consumption.

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 4. Comparative study: investment costs.

Alternative	Total investment [€]	Own investment [€]	Subsidies [€]
Estado actual	---	---	---
Heat exchanger network	13.000	11.700	1.300
Cogeneration	327.000	294.300	32.700
Solar thermal	806.063	577.644	228.419
Trigeneration	445.000	400.500	44.500
Solar heating and cooling	1.252.790	893.353	359.437

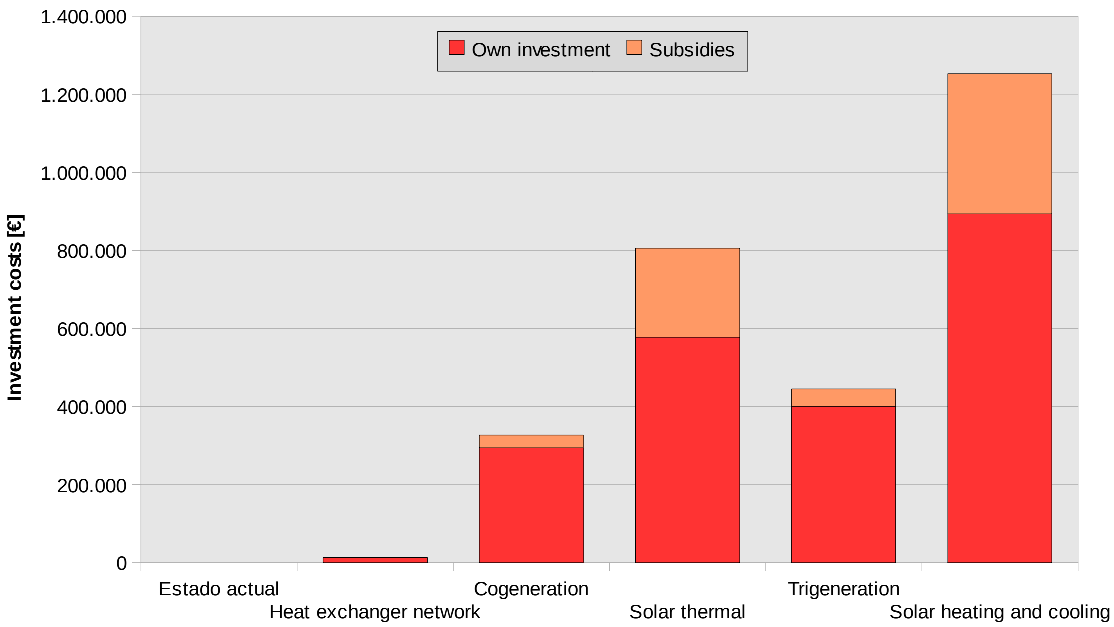

Figure 6. Comparative study: investment costs. Estimated co-funding: 10% for investment in heat recovery, 30% for solar thermal systems, 10% for cogeneration.

Table 5. 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 [€]
Estado actual	---	480.111	0
Heat exchanger network	1.339	466.477	650
Cogeneration	33.669	333.956	14.276
Solar thermal	82.994	411.816	15.850
Trigeneration	45.818	300.255	16.398
Solar heating and cooling	128.991	400.442	23.900

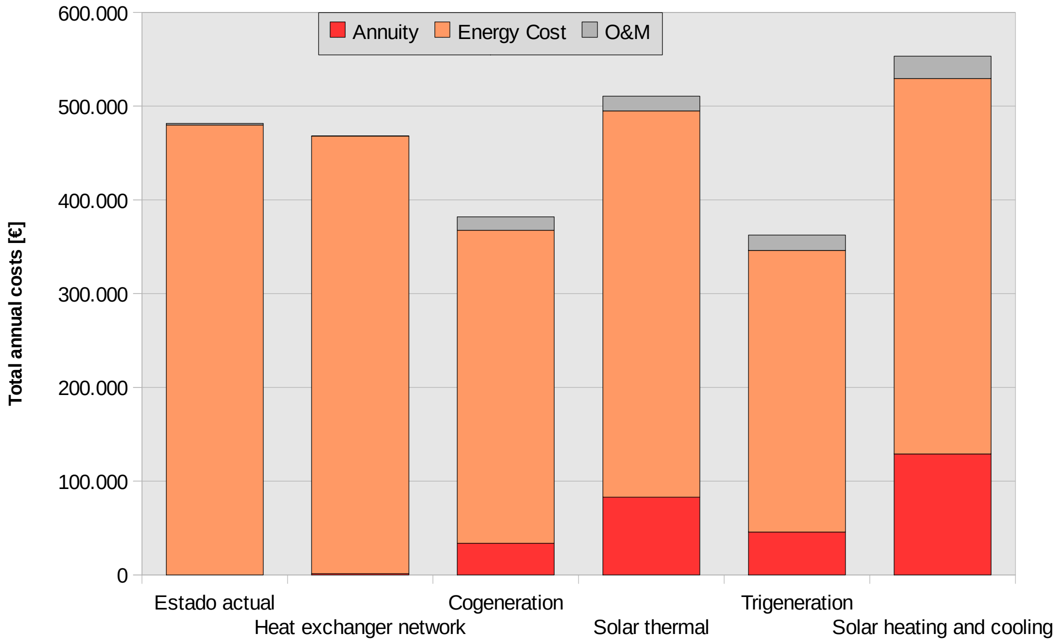

Figure 7. Comparative study: annual costs including annuity of initial investment. The energy cost for CHP includes also the feed-in-tariff revenue for the CHP electricity.

2 Annuity of initial investment: 10,3 % of yearly payments, calculated based on 6 % 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 customized heat exchanger network, a cogenerative gas turbine of 563 kWe / 300 kWth , two new steam boilers of 600 kW and an absorption chiller of 50 kW has been considered the best option among the previously analysed due to a high potential of both primary energy and energy cost savings.

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

4.1.1. Heat recovery

High inefficiencies in the distribution of steam have been detected. The current recirculation rate of the condensate is 30%. It is recommended to improve the condensate recovery by reducing leaks.

On the other side, different waste heat sources are currently not recovered:

1. Outlet air of drying pills process at 45ºC (190 MWh)
2. Residual water of cleaning processes at 45ºC (15 MWh)
3. Condensate of steam used in the disinfection of the towels tank at 70ºC (less than 1MWh)
4. Waste water of the air compressors at 85º (300 MWh)
5. Water used to cool down processes

The possible sinks are the preheating of processes, air for space heating or inlet water of the steam boiler).

In 1) and 4) the next measures are proposed:

- Heat exchanger in the dryer: use the hot and humid air outlet of the drying process to preheat the air inlet. A heat exchanger of 25 kW is proposed. The annual saved useful supply heat is 113 MWh, which corresponds to a saving of 200 MWh of natural gas.
- Heat exchanger in the air compressors: use waste warm water of the air compressors to produce hot water (cleaning, others). A heat exchanger of 88 kW is proposed. The annual saved useful supply heat is 51 MWh, which corresponds to a saving of 90 MWh of natural gas.

Points 2) and 3) have been excluded because of the low potential.

Recovering 80% of the condensate instead of only 30%, and installing the two heat exchangers, the total annual saving of natural gas is 421 MWh, which corresponds to 12% of the actual natural gas consumption.

In addition to the proposed heat exchangers, it can be observed that in the air compressors only 51 MWh of the 300 MWh are recovered. The rest could be used to generate hot water or preheating other processes. Currently, most of the processes (gels, vaselines, syrups) are heated by steam. It is recommended to study the possibility of preheating them with hot water in order to use residual heat to heat them. The low temperature waste heat could furthermore be used to preheat air for space heating.

Concerning point 5): the cooling of gels, vaselines and syrups is currently carried out by using cold water at 7ºC. These processes have a cooling demand of 207 MWh, which corresponds to 30% of the annual total cold demand (70% is space cooling). The company informed that cold water at 7ºC is needed in order to achieve high cooling velocities. Nevertheless, it is recommended to study the possibility of using cold water from the cooling tower (20ºC approx), at least in the beginning of the cooling processes. This measure would decrease the generation of low temperature cold water at 7ºC, which would consequently reduce the electricity consumption of the chillers. Moreover, heat from water (after cooling down processes, water is heated), could be recovered.

Table 6. List of heat exchangers proposed.

Heat Exchanger	Power	Heat Source	Heat Sink	Amount of recovered energy	
	[kW]			[MWh]	[%]
HX_dryer	25	Air outlet of drying capsules	Air inlet of drying capsules	113	69
HX_compressor	88	Waste water of air compressor	Hot water	51	31
	113			**164**	**100**

4.1.2. Heat and Cold Supply

In the new system proposed, the next equipments are installed:

1. Cogeneration (gas turbine) 563 kW thermal / 300 kW electrical

2. Two steam boilers (600 kW)
3. Absorption chiller (50 kW cooling power)

The proposed CHP supplies heat to the processes and space heating. As the heating demand decreases in summer, and in order to optimize the operation of the CHP, in addition an absorption chiller of 50 kW is proposed. The chiller consumes heat to generate cold. The coupling of the CHP system with the thermal cooling system forms the trigeneration system.

The trigeneration system generates 2249 MWh of heat for processes, space heating and refrigeration. It also generates 1669 MWh of electricity, which are sold to the grid, and 187MWh of cold for space cooling.

For covering the heat demand peaks, two boilers are used. Since the current boilers are obsolete, two new boilers of a nominal power of 600 kW and 91% of efficiency are proposed. One supplies 108 MWh and the other one is installed as backup in order to assure security of heat supply.

Regarding the cooling supply systems, the electrical and thermal chillers supply 880 MWh. Due to the cold generated by absorption cooling, the existing electrically driven compression chillers produce now only 693 MWh of cold, less than in the current state. Consequently, the electrical consumption of the chillers is reduced.

Note: As pointed in the heat recovery section, if the heating processes could be carried out with hot water instead of steam, the possibility of installing an electrical engine instead of a gas turbine should be analysed.

Table 7. 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]	[%]
New CHP	CHP gas turbine	Pipe steam processes Pipe space heating Pipe absorption chiller	563	2.449	71,24
Absorption chiller	Thermal chiller	Pipe water space cooling	50	187	5,45
Chillers	Electrical chiller	Pipe water processes Pipe water space cooling	674	693	20,15
New boiler 1	Steam boiler	Pipe steam processes Pipe space heating	600	108	3,15
New boiler 2	Steam boiler	Pipe steam processes Pipe space heating	600	0	0,00
Total			**2.487**	**3.438**	**100**

The contribution of the new equipments to the total heat supply is shown in Table 8 while the contribution to the cooling supply is shown in Table 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]
New CHP	2.449	95,76
New boiler 1	108	4,24
New boiler 2	0	0,00
Total	**2.558**	**100**

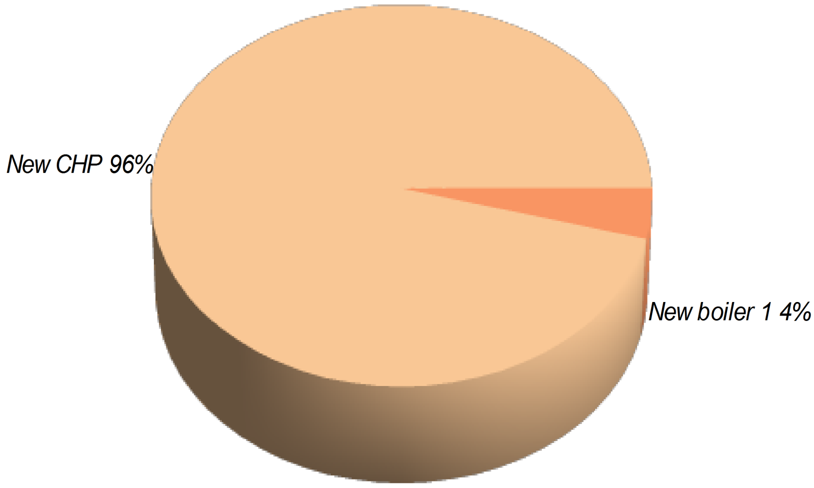

Figure 8. Contribution of the different equipments to the total useful heat supply (USH) in the company.

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

Equipment	USC by equipment	
	[MWh]	[% of Total]
Chillers	693	78,71
Absorption chiller	187	21,29
Total	**880**	**100**

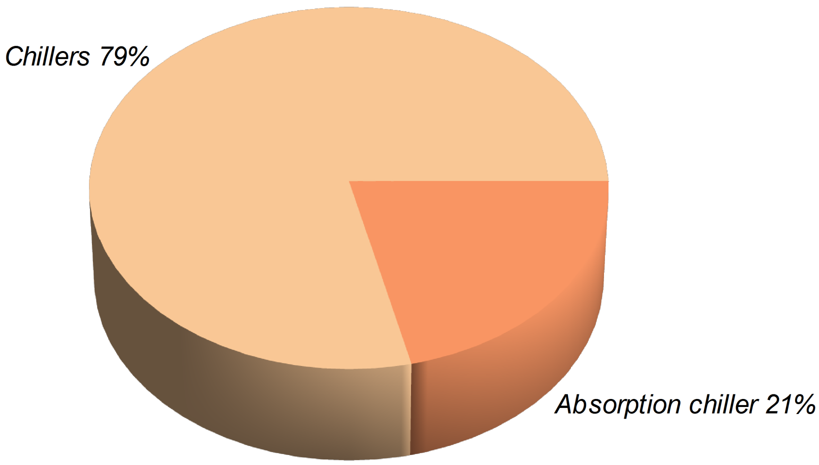

Figure 9. Contribution of the different equipments to the total useful cooling supply (USC) in the company.

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

The following measures are proposed:

- improvement of the steam pipe distribution efficiency
- Fheat recovery: heat exchangers to use waste heat of the dryer to preheat the inlet air of the dyer and the waste heat of air compressors to generate hot water.
- cogeneration (gas turbine) for covering the base load of the remaining heat demand
- substitution of old steam boilers by two smaller new steam boilers (redundancy is needed)
- absorption chiller to cover part of the space cooling demand in summer

These measures allow to save 23 % of the current primary energy consumption and 24,5 % of current energy cost (including fuel and electricity costs, O&M costs and annual amortization). The required investment is about 445.000 € with a very short pay-back time of less than 2,65 years (taking into account the 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*	*14.000*	*10.841*	*22,56%*
- fuels	*MWh*	*3.974*	*5.886*	*-48,11%*
- electricity	*MWh*	*10.026*	*4.955*	*50,58*
Primary energy saving due to renewable energy	*MWh*	*0*	*0*	-
CO_2 emissions	t/a	*2.574*	*2.164*	*15,93%*
Annual energy system cost (2)	*EUR*	*480.111*	*362.471*	*24,50%*
Total investment costs (3)	*EUR*	-	*445.000*	-
Payback period (4)	*years*	-	*2,65*	-

(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) Supposing10% of funding of total investment (subsidies or equivalent other support mechanisms)