Energy Audit Summary Report

Audit No. 19 – ESP02

Plastic Industry

Production of expanded polystyrene

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

September 2011

In collaboration with the Chamber of Commerce and Industry of Madrid

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)

1. Contact data of the auditors

Cristina Ricart, Hans Schweiger, Claudia Vannoni

energyXperts.NET, Barcelona (Spain) - Berlin (Germany)

www.energyxperts.net

info@energyxperts.net

2. Description of the company (status quo)

Reference year of data/information: 2010

2.1. General information of the company

Sector	Manufacture of plastics	
Products	Expanded polystyrene (EPS)	
Yearly production	310.5 tones	
No. of employees	14	
Current final energy consumption [MWh] (*)	Total (FEC)	For heating and cooling (FET)
- natural gas	2321	2321
- electricity	207	11

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

(a) *(b)*

Figure 1. (a) EPS blocks (b) Cutting and shaping of the EPS blocks

2.2. Energy consumption

The final energy consumed in this industry are natural gas and electricity. The primary energy consumption (FEC) needed to generate the final energy is plotted in the next graph. It is seen that almost all thermal energy (heat and cold) is generated from natural gas, while electricity is just for other purposes such as lighting, machines, etc.

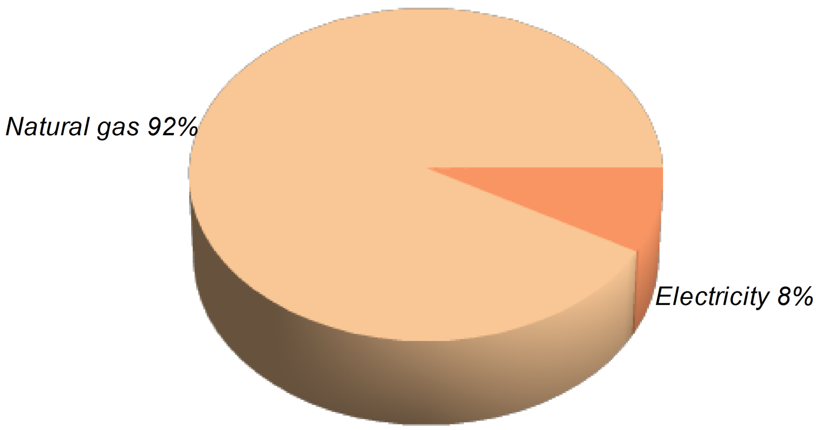

Figure 2. Total primary energy consumption of the plant (FEC)

2.3. Description of the process and supply system

a) Productive process

The manufacturing of the EPS consists of the following stages:

- Pre-expansion of the polystyrene (PS) beads
- Stabilisation (storage)
- Expansion (bloc or moulds) and cooling
- Cutting and shape molding

The company receives expandable polystyrene beads, already prepared for the expansion. The raw material has a density of about 650 kg/m^3 and has to be expanded to densities between 12-40 kg/m^3. In the first stage, the beads are fed into an agitation tank and are expanded to the desired density through the addition of steam. The control of the density depends on some parameters such us the temperature and time of exposition. Beads expand to medium densities. To achieve low densities, a second pre-expansion is needed. After the pre-expansion, the EPS beads are immediately stored for several hours in open air for stabilization (thermal and mechanical).

The next step is again an expansion, which can be done in blocks or mouldes. In the first case, the beads are introduced in a closed block chamber where steam is injected again. The chamber has been previously preheated by steam. Since there is no room for expansion, the pearls fuse and form a solid block. Afterwards, the EPS block has to be cooled down before leaving the block chamber. The cooling is achieved by vacuum. Once the blocks have been cooled down, they are stored and cut into several shapes for final use.

Regarding the mould expansion, beads are introduced in moulds which already have the final shape. Steam is injected for preheating of the molds and expansion of the beads. Finally, moulds are cooled down with water. Water for cooling comes from the same expansion. The condensed steam is recovered and stored in a warm pool.

In the present study, pre-heating, expansion and cooling have been treated separately in order to analyse separately the energy consumption of each step.

On the other hand, liquid rings of the forming machines have to be cooled down. The cooling is achieved by the use of fresh water stored in the fresh pool. Water from the warm pool that has not been used is cooled down in a wet cooling tower and stored in the fresh pool.

Figure 3. (a) Expansion of EPS in the molds

In the next diagram a simplified process flow-sheet is shown:

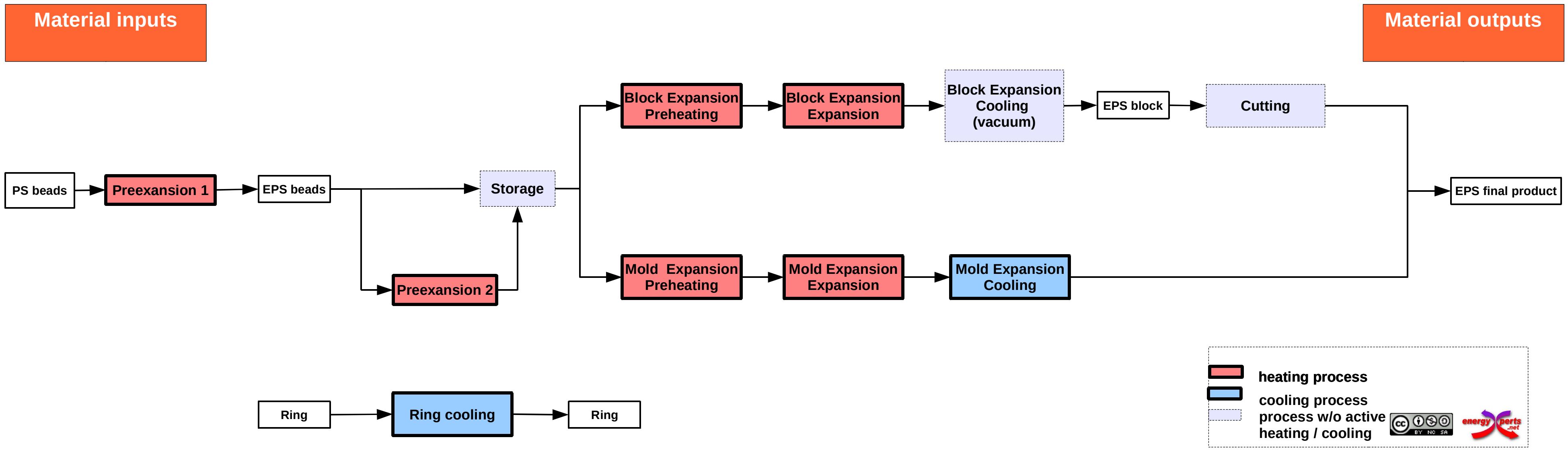

Figure 4. Simplified production flow sheet

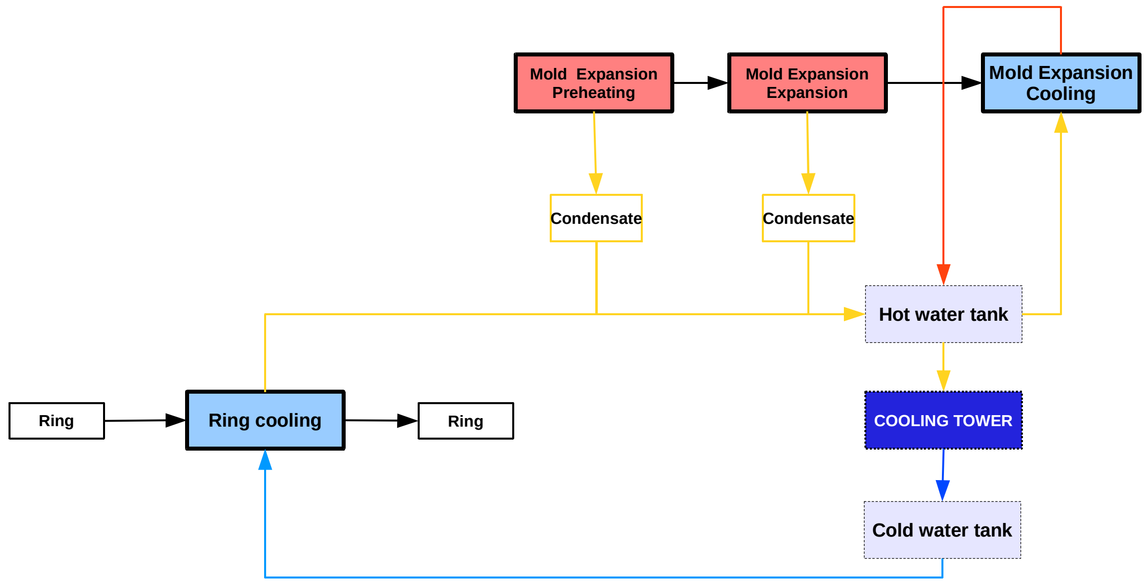

Figure 5. Current heat recovery

The most energy consuming processes in the company are the mold expansion and the block expansion. Regarding the cooling demand, the liquid ring cooling is the most energy consuming process.

b) Energy supply system

The heat used in the company is generated in a natural gas fired steam boiler. The steam is distributed to the different processes. In the two expansions the steam is injected together with the process material, so the condensate is not returned to the boiler. Most of the condensate is not recovered, except for the mold expansion. The condensate at 70ºC is stored in a warm pool and it is used for the mold cooling. The rest is cooled down in a cooling tower down to 25ºC and used to cool the liquid ring down.

In the next figure simplified flow-sheet of the generation and supply system is shown:

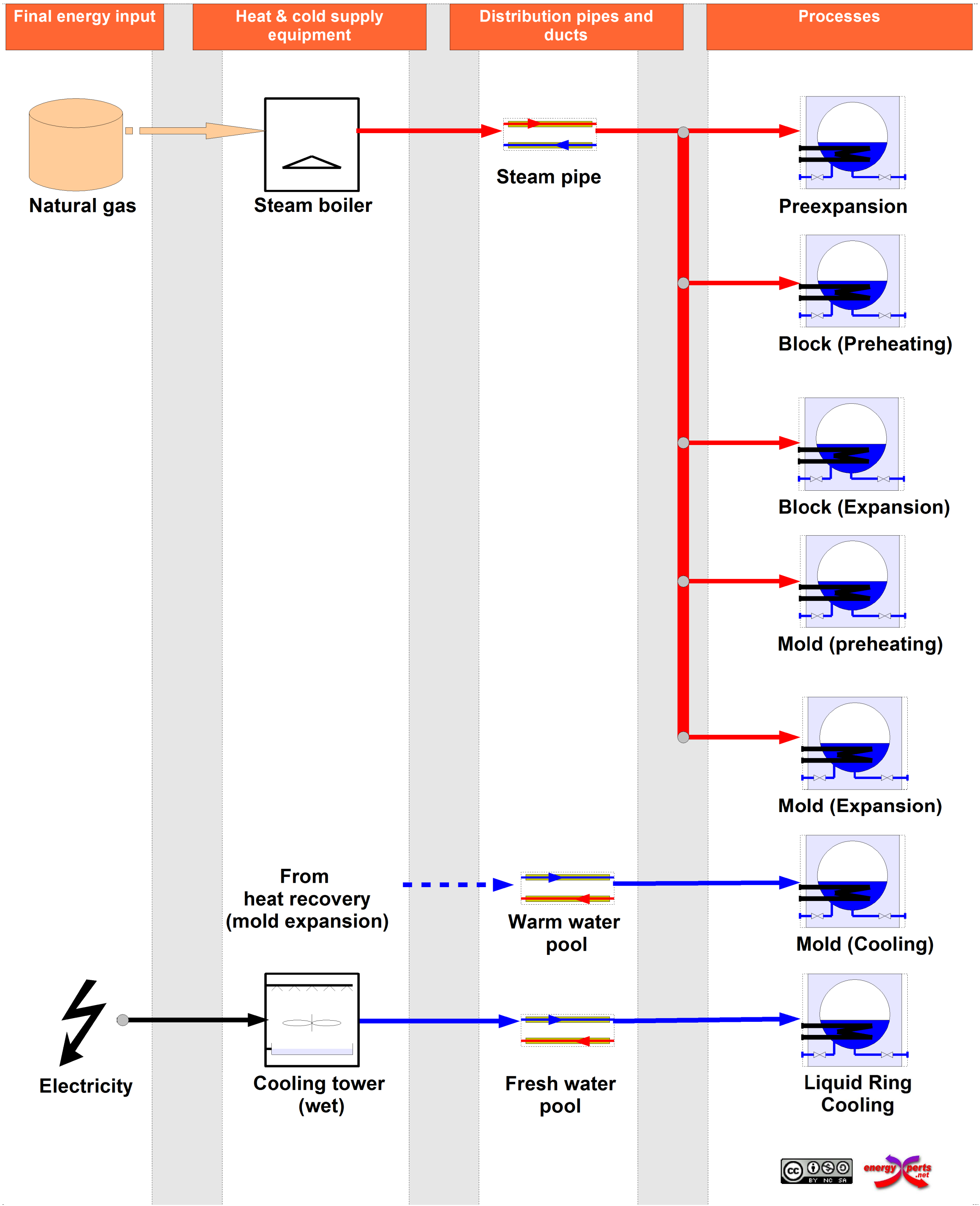

Figure 6. Overview of the heat and cold supply system

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 alternatives include heat recovery improvement as described below in section 4.1.1. The other alternatives consist in solar thermal and cogeneration systems of different sizes.

Table 1.Overview of the alternative proposals studied.

Short Name	Description
Improved Heat Recovery	Economizer in the steam boiler
Solar Thermal FPC 200 kW	Economizer + Solar Thermal System of Flat Plate Collectors (200 kW)
Solar Thermal ETC 300 kW	Economizer + Solar Thermal System of Evacuated Tube Collectors (300 kW)
Cogeneration Turbine 375 kW	Economizer + Cogeneration of heat and power (CHP) - Turbine - 375 kW thermal / 200 kW electrical
Cogeneration Turbine 563 kW	Economizer + Cogeneration of Heat and Power - Turbine - 563 kW thermal / 300 kW electrical

3.2. Energy performance[1]

Table 2. Comparative study: yearly primary energy consumption.

Alternative	Primary energy consumption [MWh]	Savings [MWh]	Savings [%]
Present State	3.175,20	---	---
Improved Heat Recovery	3.006,82	168,38	5,30
Solar Thermal FPC 200 kW	2.859,57	315,63	9,94
Solar Thermal ETC 300 kW	2.697,64	477,56	15,04
Cogeneration Turbine 375 kW	2.225,79	949,41	29,90
Cogeneration Turbine 563 kW	2.025,36	1.149,84	36,21

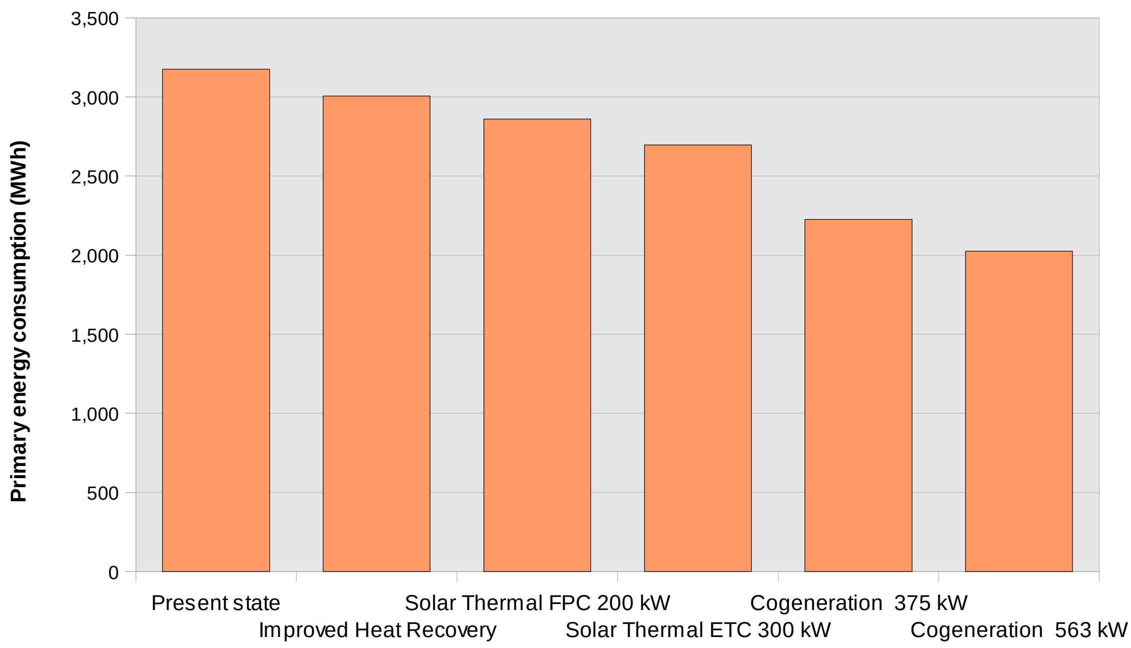

Figure 7. Comparative study: yearly primary energy consumption.

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, 30% for solar thermal systems.

Alternative	Total investment [€]	Own investment [€]	Subsidies [€]
Present State (checked)	---	---	---
Improved Heat Recovery	5.660	5.094	566
Solar Thermal FPC 200 kW	132.256	93.711	38.545
Solar Thermal ETC 300 kW	242.947	171.195	71.752
Cogeneration Turbine 375 kW	265.660	239.094	26.566
Cogeneration Turbine 563 kW	368.660	331.794	36.866

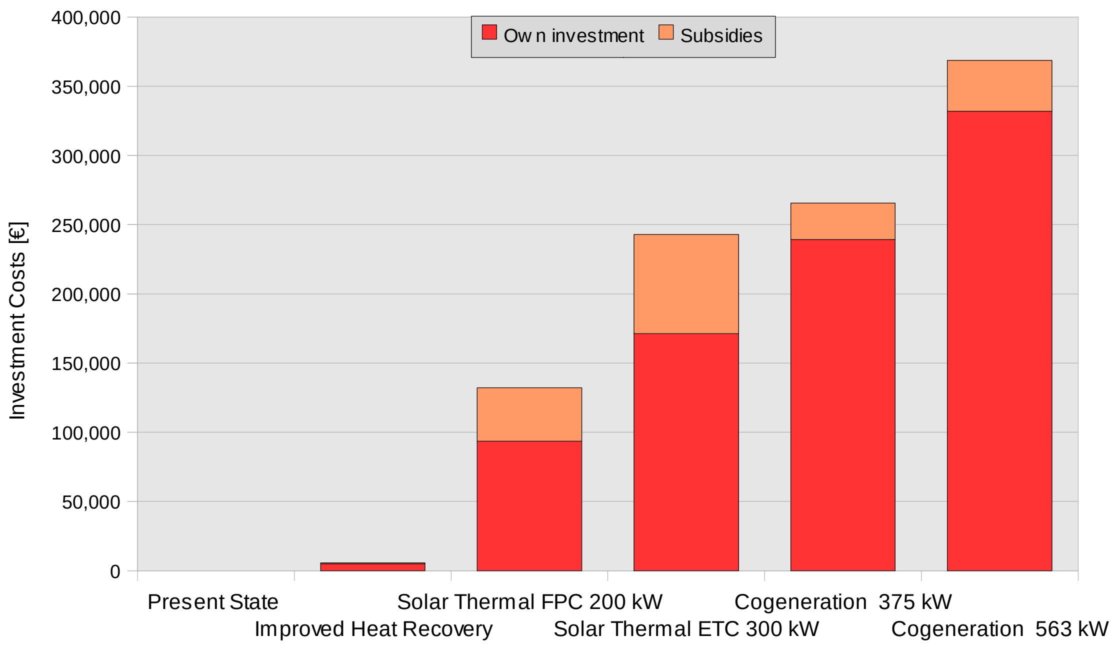

Figure 8. Comparative study: investment costs. Estimated co-funding: 10 % for investment in heat recovery, 30% for solar thermal systems.

Table 4. Comparative study: annual costs[2] including annuity of initial investment[3]. The energy cost for CHP includes also the feed-in-tariff revenue for the CHP electricity.

Alternative	Annuity [€]	Energy Cost [€]	O&M [€]
Present State	---	124,240	0
Improved Heat Recovery	583	118,614	457
Solar Thermal FPC 200 kW	13,617	113,726	2,957
Solar Thermal ETC 300 kW	25,014	108,351	4,620
Cogeneration Turbine 375 kW	27,353	64,220	6,217
Cogeneration Turbine 563 kW	37,958	49,587	7,225

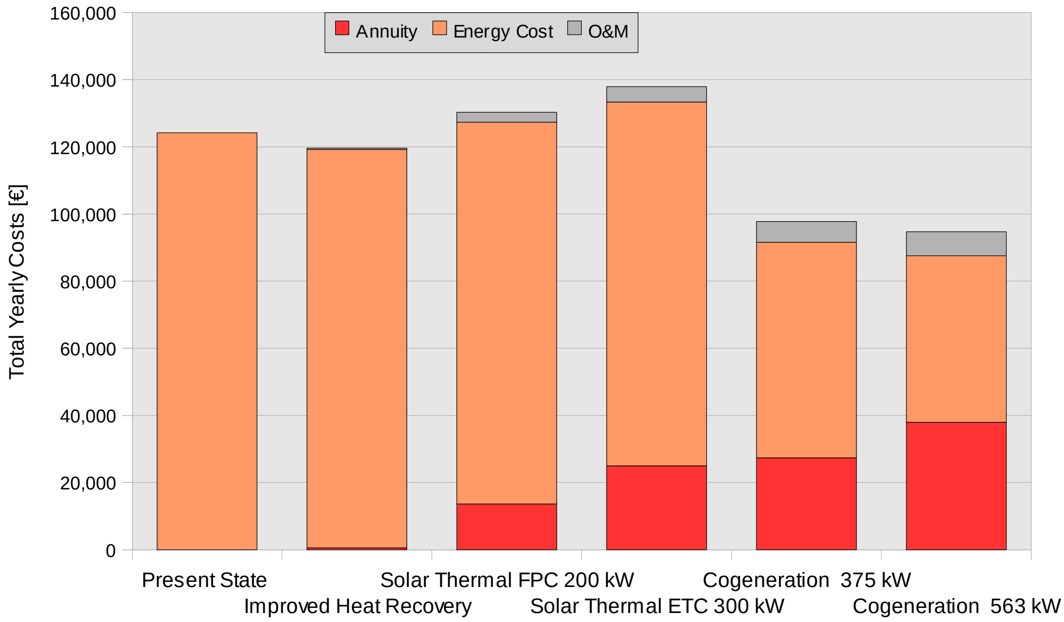

Figure 9. Comparative study: annual costs including annuity of initial investment. The energy cost for CHP includes also the feed-in-tariff revenue for the CHP electricity.

2 The tariffs used are 37 €/MWh (based on lower calorific value – LCV) for natural gas, 185 €/MWh for electricity consumed and 145 €/MWh for electricity exported to the grid.
3 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 “CHP gas turbine 375 kW” that combines an economizer and a cogenerative gas turbine of 200 kWe / 375 kWth has been considered the best option among the previously analysed due to the high potential of both primary energy and energy cost savings.

A larger CHP plant would be possible and lead to both higher primary energy savings and less energy system costs at a medium term. Nevertheless, due to the higher investment requirements the return on investment in this larger CHP option is worse, so that the smaller option has been chosen as a compromise between (short term) economic profitability and primary energy saving potential.

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

4.1.1. Heat recovery

Currently, the condensate generated during the mold expansion is used to cool the mold chambers (HX1).

The exhaust gas of combustion in the boiler is currently lost to the ambient at a high temperature. Installing a heat exchanger (HX2) that uses the energy content of the exhaust gas to heat up the boiler feed water (economizer), 93 MWh would be recovered in one year, which corresponds to the 5.3% of the total consumption of the plant.

Table 5. List of heat exchangers proposed.

Heat Exchanger	Power	Source	Sink	Contribution to the total heat	
	[kW]			[MWh]	[%]
HX1 (Existing)	5,07	Mold cooling	Condensate	10,52	10,16%
HX2 (New)	180,00	Exhaust gas from boiler	Feed-in water to the boiler	93,00	89,84%
	185,07			103,52	100,00%

4.1.2. 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.

Table 6. Heat and cooling supply equipments and supply system. Selected alternative. The new equipment is marked in bold.

Equipment	Type	Heat / cooling supplied to pipe/duct	Nominal capacity	Contribution to total heat / cooling supply	
			[kW]	[MWh]	[%]
New CHP	**CHP gas turbine**	**Steam pipe**	**375,00**	**791,70**	**32,74**
Steam_boiler	steam boiler	Steam pipe	2.275,00	1.158,32	47,91
Cooling tower	cooling tower (wet)	Fresh water pipe	300,00	467,49	19,34

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

Table 7. Technical specification of the new CHP gas turbine.

Parameter	Units	Technical data
Type of equipment	-	CHP gas turbine
Nominal power (heat or cold output)	kW	375,00
Fuel type	-	Natural gas
Fuel consumption (nominal)	kg/h	50,30
Electricity power input	kW	0,00
Electrical power generated (CHP)	kW	200,00
Electrical conversion efficiency (CHP)	-	0,32

The contribution of the CHP plant to the total heat and cold supply is shown in Table 8 and Figure 10.

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

Equipment	Type	Heat / cooling supplied to pipe/duct	Nominal capacity	Contribution to total heat / cooling supply	
			[kW]	[MWh]	[%]
New CHP	CHP gas turbine	Steam pipe	375	792	40,60
Steam boiler	steam boiler	Steam pipe	2.275	1.158	59,40
Total			**3.050**	**1.950**	**100**

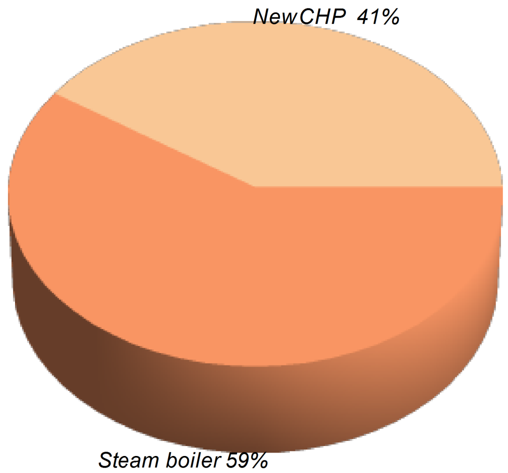

Figure 10. Contribution of the different equipments to the total useful heat supply (USH) in the company.

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

The following measures are proposed:

– heat recovery: use of exhaust gas of the boiler for preheating of the boiler feed water

– cogeneration (gas turbine) for covering the base load of the remaining heat demand

These measures allow to save 29 % of the current primary energy consumption. It also saves 48,31% of current energy cost (cost of fuel and electricity, including auto-generated electricity) and leads to a reduction of 21,29% of the total energy system cost (fuel and electricity, operation and maintenance, amortisation). The required investment is about 265.660 € with a pay-back time of 4,95 years (taking into account the subsidies).

Table 9. 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*	*3.175*	*2.226*	*29,9%*
- fuels	*MWh*	*2.553*	*2.950*	*-15,55%*
- electricity	*MWh*	*622*	*-724*	*216,40%*
Primary energy saving due to renewable energy	*MWh*	*-*	*0*	*-*
CO_2 emissions	t/a	*684*	*550*	*19,62%*
Annual energy system cost (2)	EUR	*124.240*	*97.790*	*21,29%*
Total investment costs (3)	*EUR*	*-*	*265.660*	-
Payback period (4)	*years*	*-*	*4,95*	-

(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)