industry audit

Energy Audit Summary Report

Audit No. 62 - GER09

Saarow Therme

Bad Saarow, Germany

Thermal bath (spa)

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

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2. Description of the company (status quo)

Reference year of data/information: 2011

(Date of the visit on site: 03-05-2012)

2.1. General information of the company

Company, location	Saarow Therme	
Sector	Thermal bath (Spa)	
No. of visitors	210.000	
Current final energy consumption [MWh] (1)	total	for heating and cooling
- natural gas	9.181	9.181
- electricity	41	-1.599 (2)

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

(2) the electricity generated in the CHP system is considered as negative

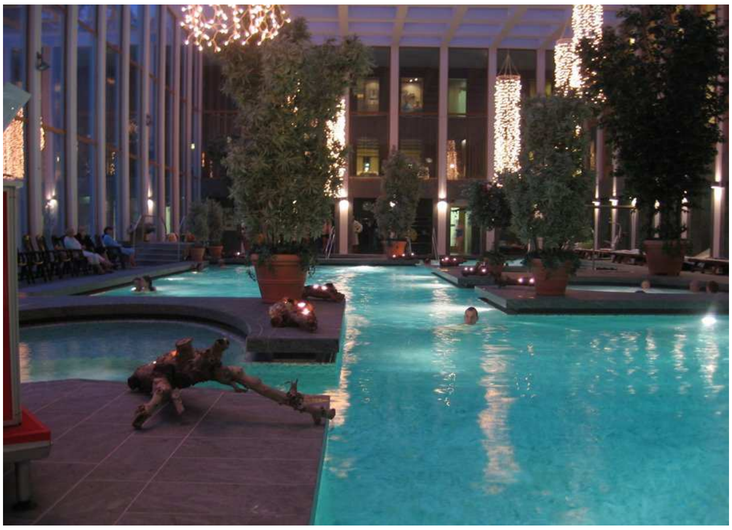

Figure 1. Indoor pool

2.2. Description of the company

a) Activity

The facilities of the company are used for swimming activities. Part of the water is mixed with sole, which is extracted from a borehole. The heat generation equipments supply heat for the therm and also district heat for neighbouring buildings. The main energy demanding processes of the therm are:

- Hot water for sanitary uses (showers, etc.)
- Hot water for indoor pools
- Space heating of different areas (in the modelling, the heat losses of water to the ambient are included here. Therefore, areas with pool and without are differentiated).
- Energy losses of outdoor pools
- Dehumidification of air in halls with pools

The district heat has been modelled as a process demand. The energy demand of the saunas has been ignored since the generation of steam is electrical and there is no possibility of process optimisation.

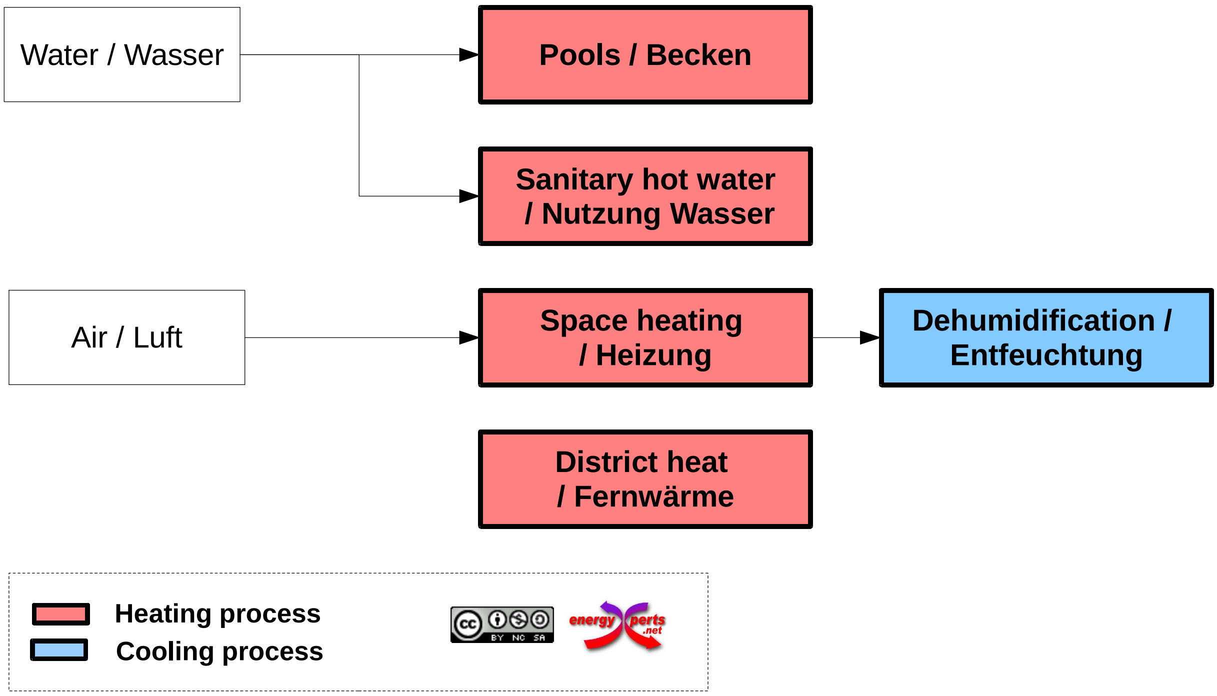

Figure 2. Overview of heating and cooling demands.

The most energy consuming process is the space heating of the areas with pools, which includes the pool heating and the heat demand due to heat losses of water to the ambient.

The distribution of the process heating demands in the company is shown in Figure 3.

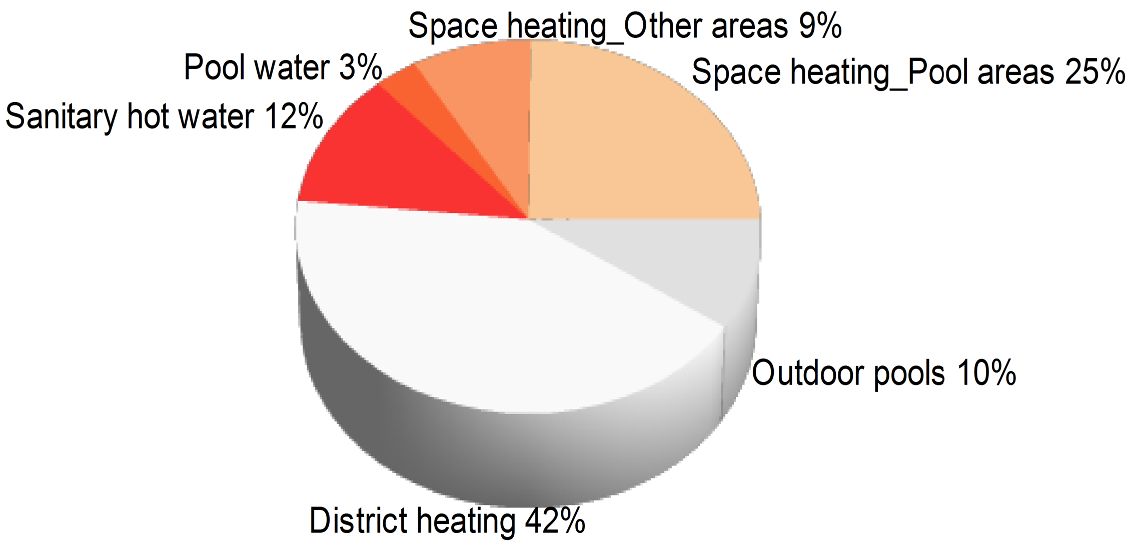

Figure 3. Distribution of process heat demand by processes

b) Energy supply system

Three cogenerative engines and two boilers generate hot water which is distributed between the therm and the district heating. In the therm, hot water is used in heat exchangers to generate hot water for the pools, hot water for sanitary uses and heating of air for space heating.

The cogenerative engines generate electricity. Some part is auto-consumed and the rest is sold to the grid. Electricity is also purchased to cover peaks, mismatch between demand and supply, etc.

For dehumidification of the air of the pool areas, a small chiller is installed.

See Figure 4.

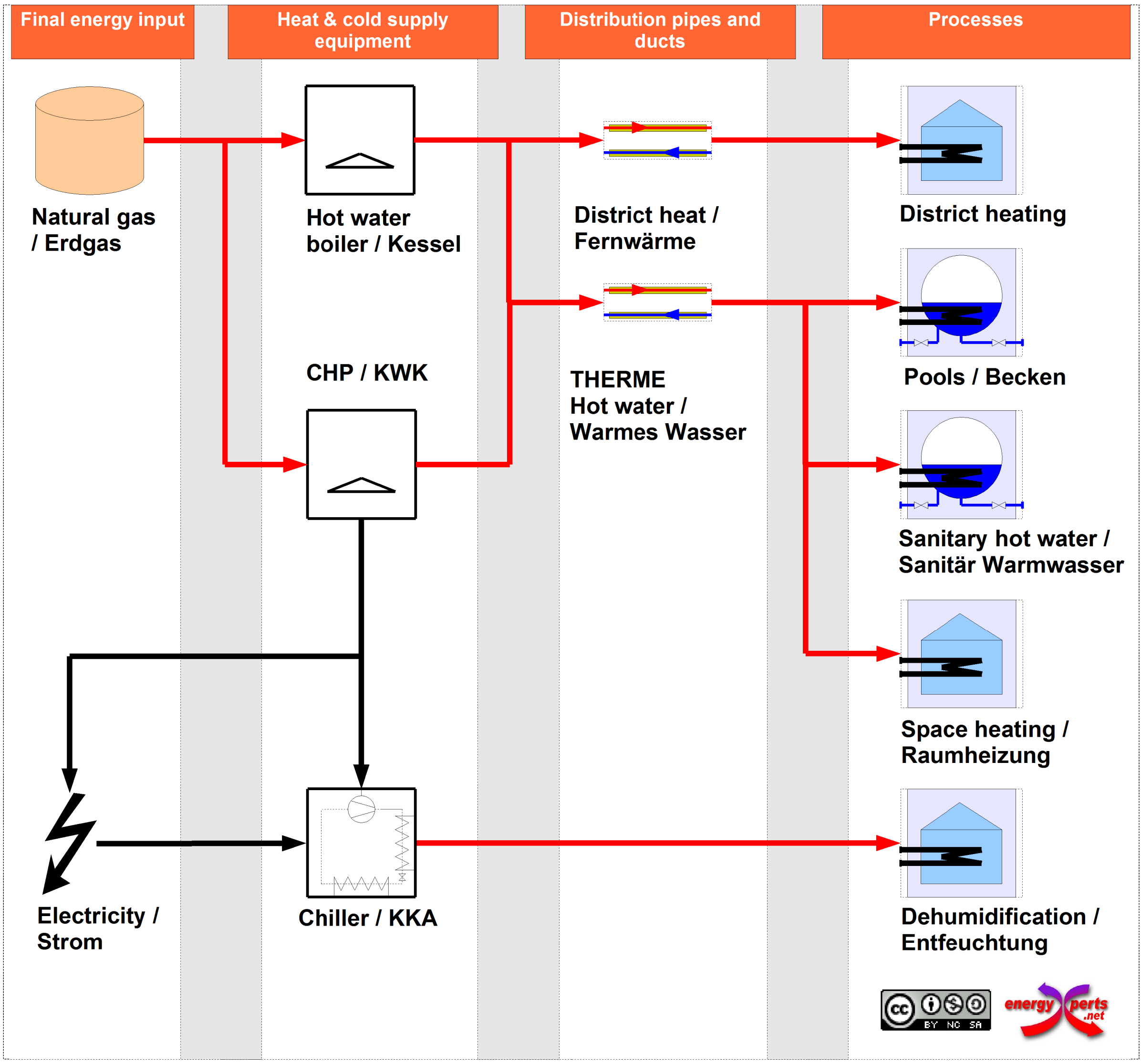

Figure 4. Overview of the heat and cold supply system

2.3. Additional comments

Specific assumptions

The results of this study are based on specific assumptions which should be further assessed in the framework of the follow-up actions for the implementation of the proposed measures. See Table 1.

Table 1. List of assumption

Paramet	Beschreibung	Wert	Begründung
1	Annual water renovation pools	6.300 m^3	Assumption: 30 liters/person
2	Annual sanitary hot water demand	10.500 m^3	Assumption: 50 liters per person/day
3	Variation of hot water demand	-	Constant along the year
5	Average ambient temperature	8,8ºC	Assumption: similar to Potsdam conditions, taken from a weather file.
6	Average inflow in the AHUs (air handling units)	50% of the nominal value	Estimated
7	Waste water of pools	85% of inlet	It has been supposed that the difference is due to evaporation,splashing, etc).
8	Annual cooling demand for dehumidification	250 Mwh	Electrical power of chiller: 17,5 kW COP = 3,5 (estimated) Partload: 50% (estimated)
9	Water temperature	Pools: 32ºC Sanitary: 60ºC	Estimated
10	Space heating temperature	Pool areas: 32ºC Other areas: 24ºC	-
11	Temperature of air inflow after heat recovery	22ºC in pool areas 18ºC in other areas	Estimated

Figure 5. Outdoor swimming pools

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.

The scope of the EINSTEIN audit is focussed exclusively on the analysis and optimisation of the supply system of heating and cooling. Building optimisation is not included. It is strongly recommended to carry out a study on potential demand reductions in the building itself (building envelope, lighting, reduction of internal gains) and – in case of modifications – adapt the measures proposed in this study to the then reduced heating and cooling demands.

3.1. Proposed alternatives

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

Table 2. Overview of the alternative proposals studied

CHP opt	**Optimisation of current CHP** - Improvement of the regulation of the CHP equipments performance (increasing operating time).
Heat recovery	**Heat recovery** - Installation of a heat exchanger of 23 kW to recover waste heat of waste water of the pools to preheat the inlet water. - Measures taken in alternative "CHP optimisation" are included.
Solar ETC	**Solar thermal ETC** - Solar thermal system (evacuated tube collectors) 800 kW - Measures taken in alternative "Heat recovery" and "CHP optimisation" are included.
CHP 2	**Cogeneration** - Amplification of the CHP-system (addition of a gas engine 193 kWth / 110 kWel) - Measures taken in alternative "Heat recovery" and "CHP optimisation" are included.
CHP 2 + HP	**Cogeneration + Heat pump** Same measures as alternative “CHP 2” with the addition of: - Heat pump (150 kW) to preheat air inflow of the AHUs (air handling units)

The combination of a CHP plant or a solar plant with an absorption chiller (trigeneration, solar cooling) have been discarded due to lower energy savings. Under the current conditions, a compression chiller is more efficient.

3.2. Energy performance[1]

Table 3. Comparative study: yearly primary energy consumption.

Alternative	Primary energy consumption	Savings	
	[Mwh]	[MWh]	[%]
Present state	10.212	---	---
CHP opt	9.465	746	7,3
Heat recovery	9.368	843	8,3
Solar ETC	8.869	1.343	13,1
CHP 2	8.669	1.542	15,1
CHP 2 + HP	8.583	1.628	15,9

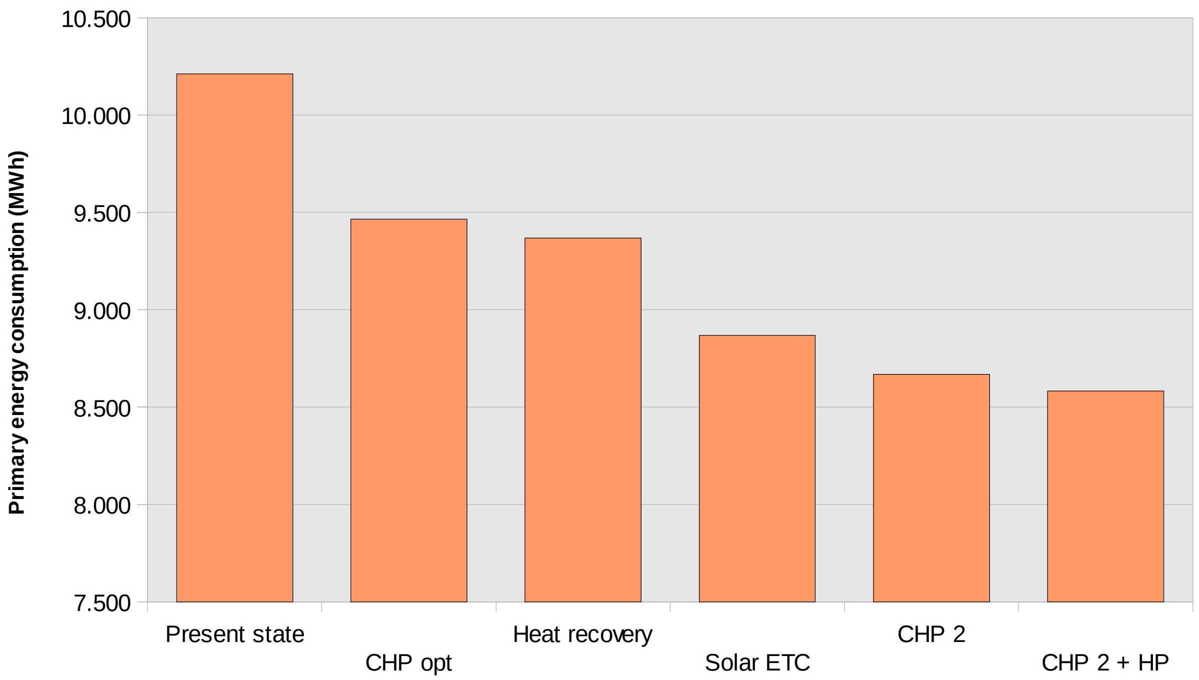

Figure 6. Comparative study: yearly primary energy consumption.

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 natural gas.

3.3. Economic performance

Table 4. Comparative study: investment costs. Estimated co-funding: 30% for solar equipments and 10% for the rest of technologies.

Alternative	Total investment [€]	Own investment [€]	Subsidies [€]
Present state	---	---	---
CHP opt	15.000	15.000	0
Heat recovery	17.400	17.160	240
Solar ETC	613.908	434.716	179.192
CHP 2	125.200	114.180	11.020
CHP 2 + HP	174.800	158.820	15.980

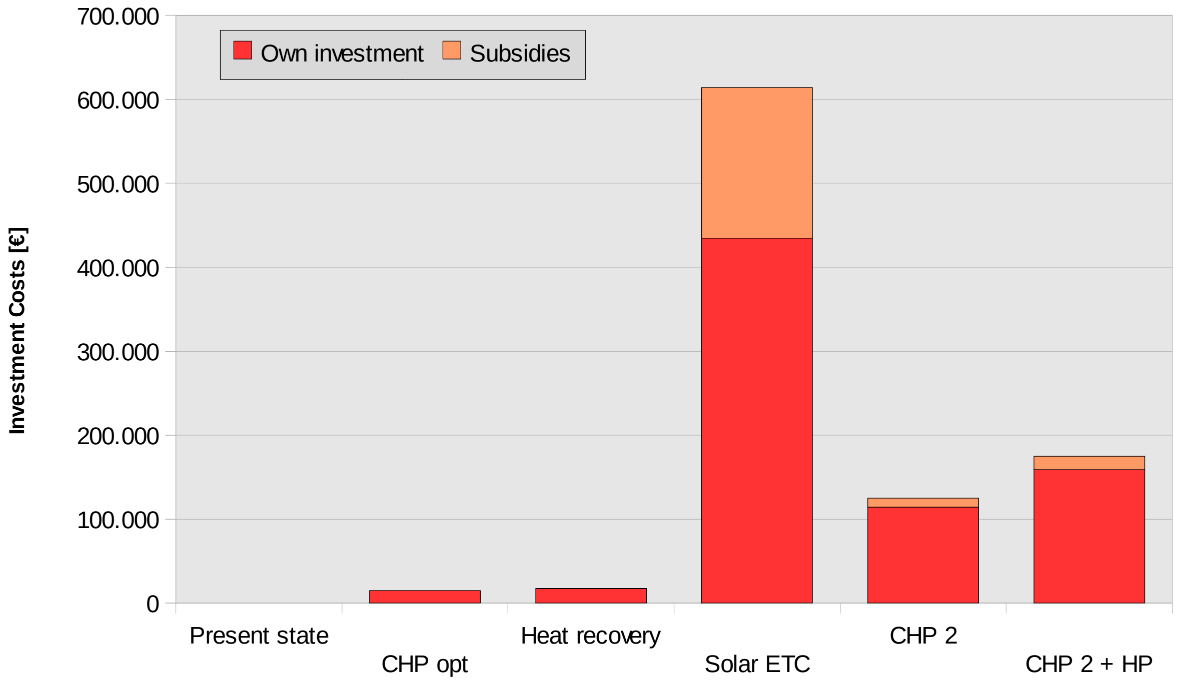

Figure 7. Comparative study: investment costs. Estimated co-funding: 30% for solar equipments and 10% for the rest of technologies.

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. Gains due to sold district heat have not been taken into account. These gains are constant and do not depend on the technical option chosen for the supply system.

Alternative	Annuity [€]	Energy Cost [€]	O&M [€]	Total [€]
Present state	---	314.775	0	314.775
CHP opt	1.544	296.036	0	297.581
Heat recovery	1.792	292.948	200	294.940
Solar ETC	63.210	275.049	10.200	348.458
CHP 2	12.891	275.410	5.760	294.061
CHP 2 + HP	17.998	280.451	6.260	304.709

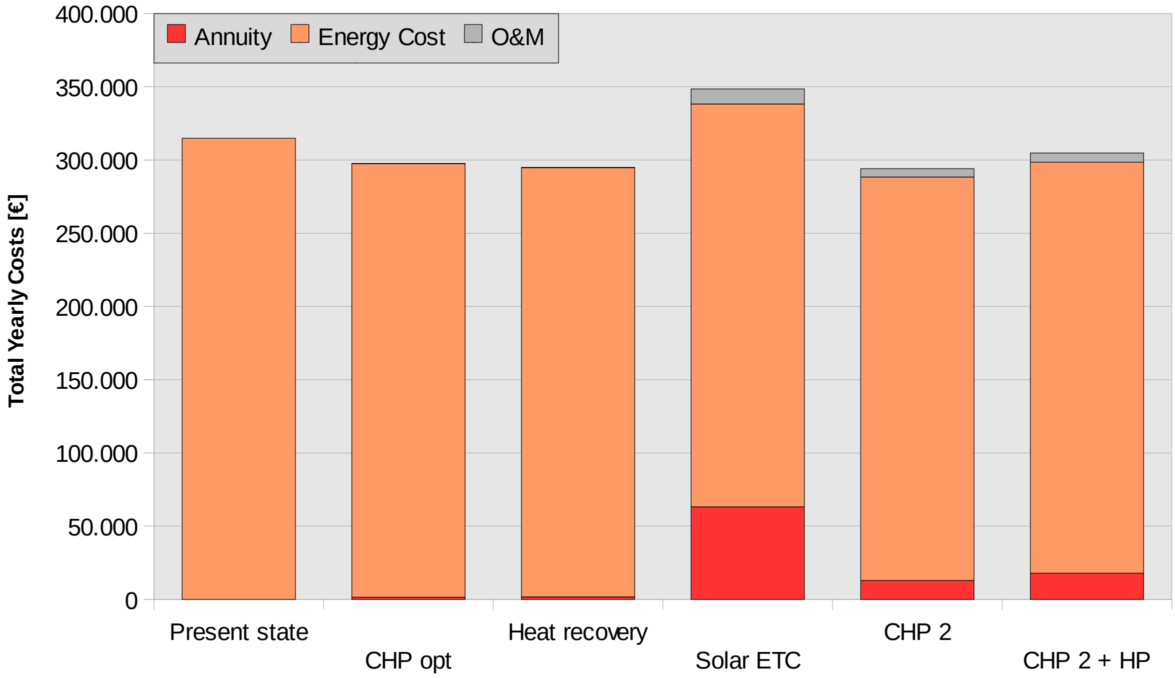

Figure 8. Comparative study: annual costs including annuity of initial investment. Data from Table 5.

4. Selected alternative and conclusions

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: 33,85 €/MWh for natural gas, 157,80 €/MWh a for bought electricity, 54,73 €/MWh for sold electricity and 21 €/MWh for feed-in tariff.

4.1. Selected alternative

The alternative proposal "CHP 2" that combines the optimisation of the performance of the current CHP-system, a customized heat exchanger network and an addition of a cogenerative gas engine of 110 kW_e / 193 kW_{th} has been considered the best option among the previously analysed due to the following reasons:

- high potential of both primary energy and energy cost savings
- the energy savings achieved by the implementation of a heat pump are very low
- the addition of a solar system in combination with the proposed alternative is an interesting second option that can be taken into account

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

4.1.1. Building optimisation

No building optimisation has been carried out. EINSTEIN audit is focussed exclusively on the analysis and optimisation of the supply system of heating and cooling. Nevertheless, it is recommended that the company revises the potential of increasing active dehumidification. In that case, a heat pump could be used to dehumidify the air of the pool areas. Thus, the renovation of air will be decreased and the heat pump could provide heat to preheat air or water.

Figure 9. Therm at night

4.1.2. Heat recovery

The proposed heat exchanger network uses heat from the waste water of the pools to preheat the inlet water (Table 6).

Table 6. List of heat exchangers proposed.

Heat Exchang	Power	Heat Source	Heat Sink	Heat transferred	
	[kW]			[MWh]	[%]
HX-Pools	23	Pools water outflow	Pools water inflow	99	100
	23			**99**	**100**

4.1.3. Heat and Cooling Supply

The current CHP has to be optimised by increasing the number of operating hours. Currently, some technical problems (regulation, hydraulic) limit the operation of the CHP. By solving these problems and operating the CHP during the maximal hours possible, 7% of primary energy is saved (see Figure 6). Moreover, a cogeneration plant (gas engine) is added to the heat supply system. The CHP plant feeds heat into the existing hot water network and generates electricity for auto-consumption. Part is also fed into the grid.

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

Table 7. Technical specifications and economics of the new CHP gas engine:

Parameter	Units	Technical data
Type of equipment	-	**New CHP**
Nominal power (heat or cold output)	kW	193
Fuel type	-	Natural gas
Fuel consumption (nominal)	kg/h	27
Electricity power input	kW	0
Electrical power generated (CHP)	kW	110
Electrical conversion efficiency (CHP)	-	33,20%
Relative contribution to total annual heat supply	-	13,99%
Heat supplied to pipe/duct	-	- district heat - therme
Turn-key price	€	107.800
Annual operational and maintenance fixed costs	€	1.100

The total and monthly contribution of the new equipment to the total heat supply (6.131 MWh) is shown respectively in Table 8, 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]
Boilers	1.050	17
CHP-System	4.189	68
New CHP	892	15
Total	**6.131**	**100**

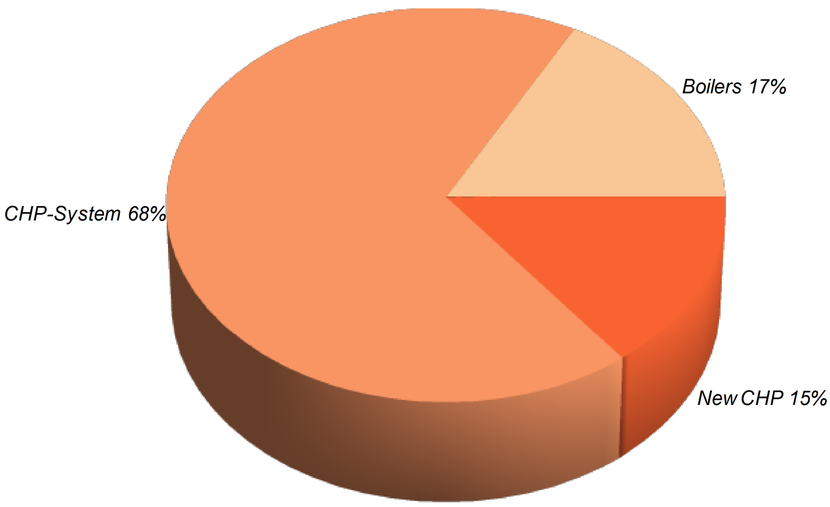

Figure 10. Contribution of the different equipments to the total useful heat supply (USH) in the company.

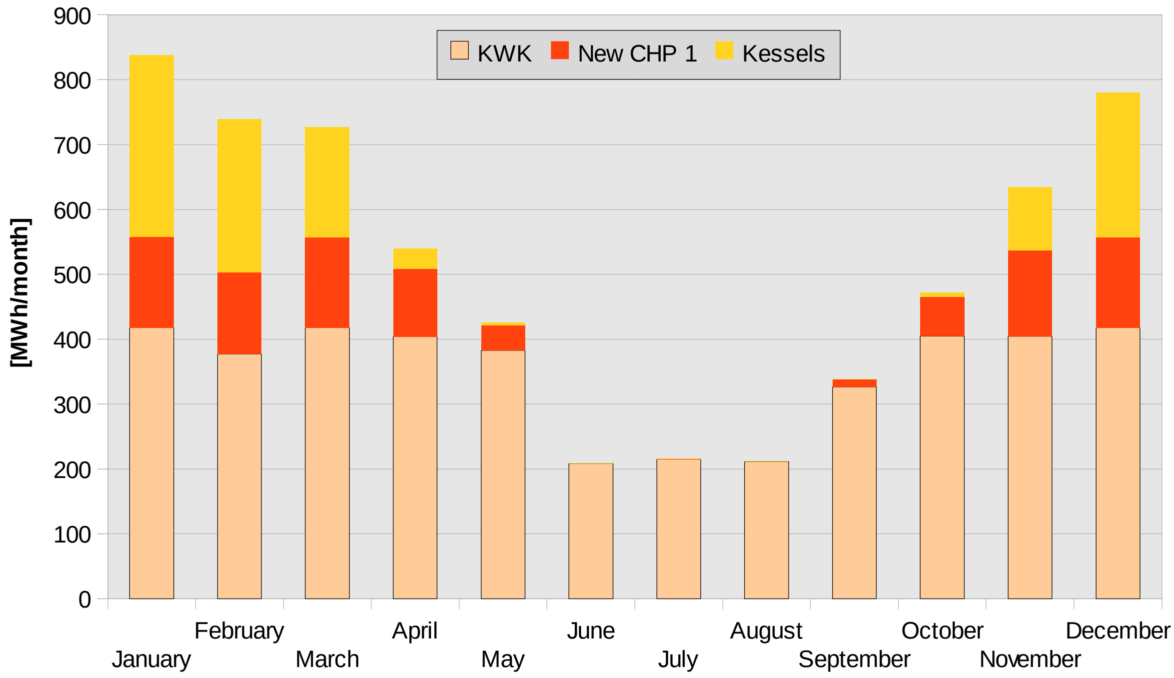

Figure 11. Contribution of the different equipments to the total useful heat supply (USH) per month.

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

The following measures are proposed:

- optimisation of the regulation of the current CHP-system
- heat recovery: use of water outflow of the pools to preheat water inflow
- addition of a cogeneration (gas engine) for covering the base load of the remaining heat demand

These measures allow to save 15% of the current primary energy consumption (including primary energy for non-thermal purposes. For thermal purposes only, the savings are 27%). It also saves 12,5 % of current energy cost (cost of fuel and electricity, including auto-generated electricity) and leads to a reduction of 6,5% of the total energy system cost (fuel and electricity, operation and maintenance, amortisation). The total required investment is about 125.200 € and the expected pay-back time is 2,5 years (taking into account the subsidies).

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

		Present state	**Proposed alternative**	**Savings**
Total primary energy consumption				
Total	MWh	10.212	8.669	15,0%
- Natural gas	MWh	10.100	11.554	-14,4%
- Electricity	MWh	112	-2.885	2676,7%
Primary energy saving due to renewable energy	MWh	0	0	-
CO2 emissions	t/a	2.316	2.092	9,7%
Total annual energy system cost (2)	€	314.775	294.064	6,5%
Total investment cost(3)	€	-	125.200	-
Pay-back period (4)	a	-	2,5	-

(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. Sold heat has not been taken into account

(3) total investment excluding subsidies.

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