Energy Audit Summary Report

Audit No. 47 - GER03

Thermal Bath (Spa)

Germany

Recreational, cultural and sporting activities

Thermal Bath (Spa)

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

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1. Contact data of the auditors

Cristina Ricart, Hans Schweiger

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

(Date of the visit on site: 10-11-2011)

2.1. General information of the company

Company, location	Thermal bath (spa) Germany	
Sector	Thermal bath (spa)	
Current final energy consumption [MWh] (*)	total	for heating and cooling
- local district heating network	3.168	3.168
- electricity	1.245	202

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

Figure 1. Big hall with port pool

2.2. Description of the company

a) Activity

The facilities of the thermal bath are used for swimming, sport and sauna activities. The main energy demanding processes are:

- Hot water for the pools (sport pool, amusing pool, etc.) and pool heating
- Hot water for sanitary uses (showers, etc.)
- Space heating of different areas (in the modelling, areas with pool and without are differentiated).Dehumidification of air in halls with pools: dehumidification is currently

done by (increased) ventilation with dry outdoor air, so that dehumidification energy demand is included in space heating demand.

- Saunas (steam generation)

Figure 2. Sauna in the garden

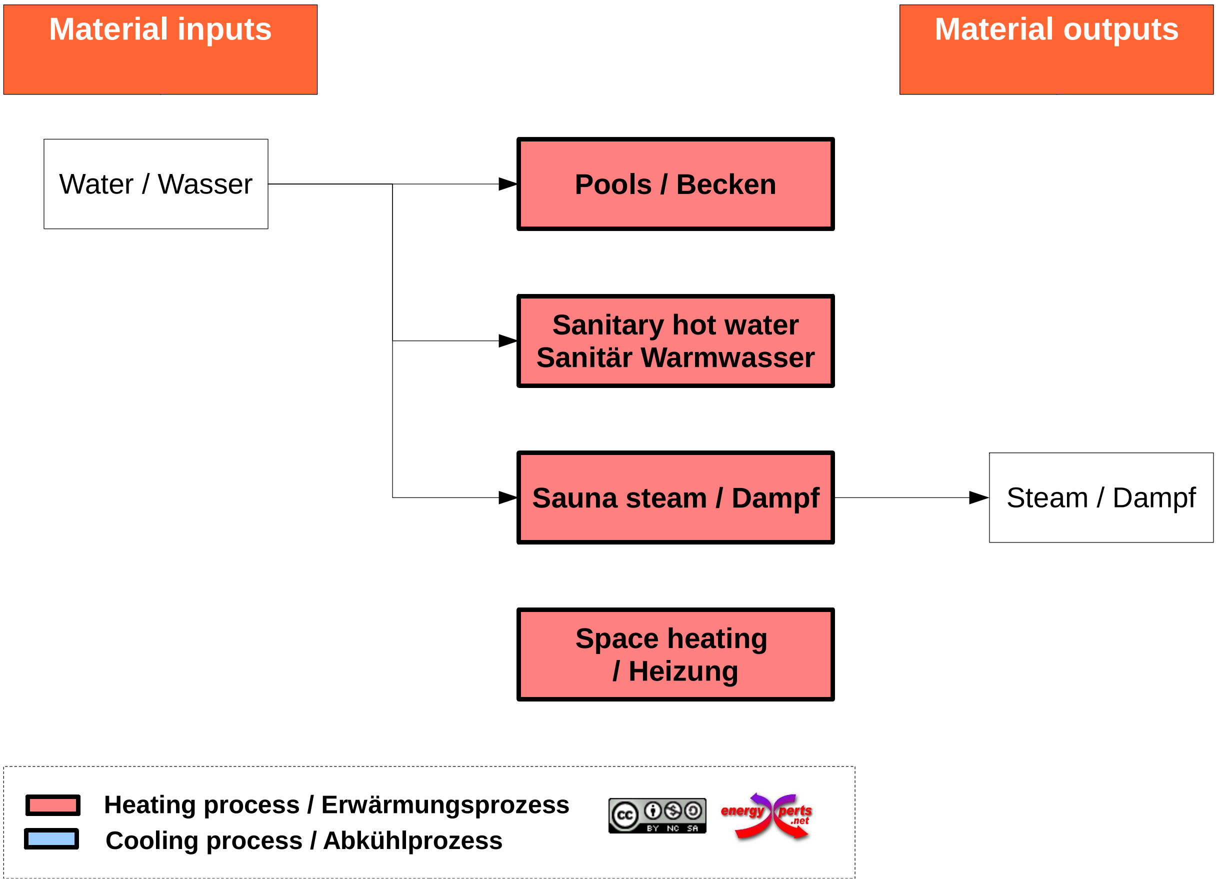

Figure 3. Overview of heating and cooling demands.

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 increased ventilation for dehumidification.

b) Energy supply system

The heat used in the company is generated in a centralised heating plant located in the same building complex, but owned and operated by the city council. Three hot water boilers generate hot water at 78ºC, which is distributed to the different users. The 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.

Furthermore, electrical steam generators are used in the saunas.

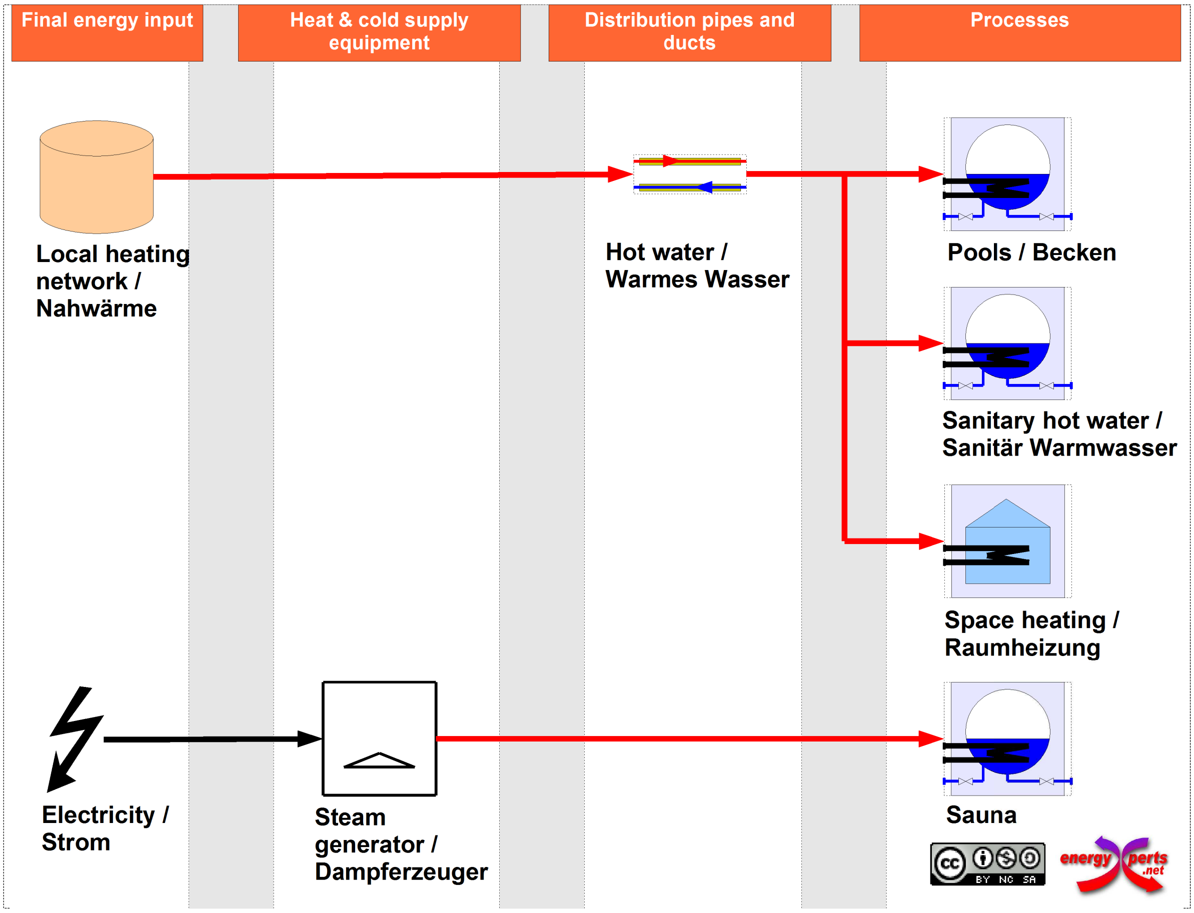

Figure 4. Overview of the heat and cold supply system

2.3. Additional comments

Specific assumptions

The hypothesis listed in Table 1 have been assumed by the auditor:

Table 1. Assumptions made by the auditor

	Description	Value	Justification
1	Average outside ambient temperature	8,8ºC	Weather data of Potsdam data file
2	Average relative humidity inside the building	60,00%	Estimated
3	Efficiency of boilers of the district heating	0,90	Estimated
4	Fuel of district heating	Natural gas	Estimated
5	Waste water pool massflow	80% of inlet	It has been supposed that massflow waste water of pool (renovation, filtratio can be recovered corresponds to the 8 the inlet massflow, since some p evaporated or lost.
6	Waste water pool temperature	27ºC	Estimated

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

Heat recovery	1) Heat recovery: Installation of e **heat exchanger** to use waste water of pools to preheat inlet water of the same pools.
Heat pump	1) Idem to heat recovery 2) Optimisation of ventilation: - Active dehumidification: cooling air with a **heat exchanger**. The transferred heat is used in an electrically driven **heat pump** (100 kW) to preheat water for processes and space heating - Reduction of rate of renovation
Solar thermal FPC	1-2) Idem to alternative “Heat pump” 3) **Solar thermal system** (FPC = Flat Plate Collector) 600 kW
CHP – engine	1-2) Idem to alternative “Heat pump” 3) **Cogeneration system** (Engine 333 kWth / 200 kWel)

3.2. Energy performance[1]

Table 3. Comparative study: yearly total primary energy consumption.

Alternative	Primary energy consumption	Savings	
	[MWh]	[MWh]	[%]
Present state	7.853	---	---
Heat recovery	7.641	212	2,70
Heatp pump	6.616	1.238	15,76
Solar thermal FPC	6.154	1.699	21,63
CHP – engine	5.092	2.761	35,16

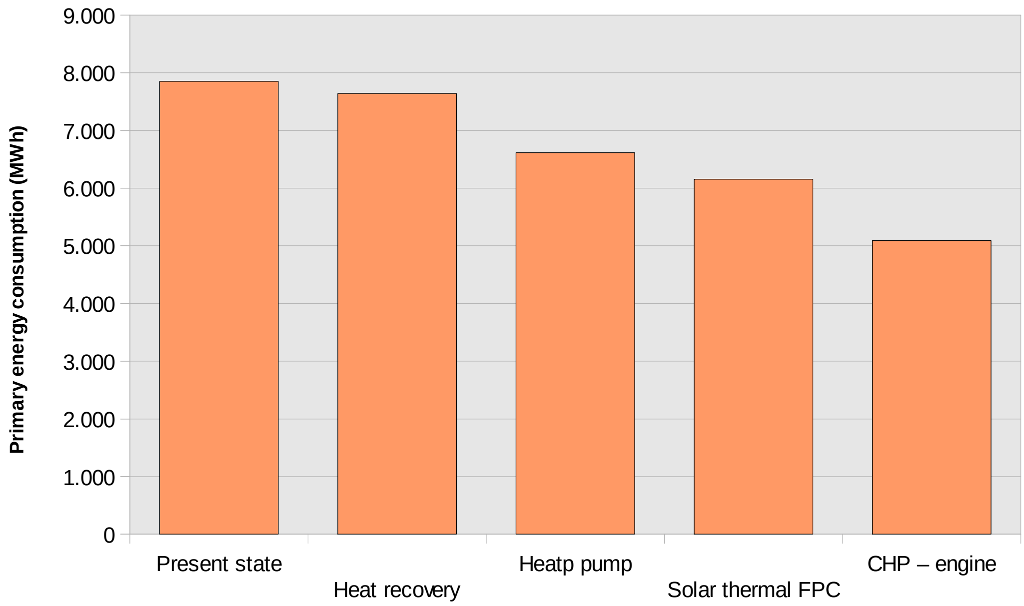

Figure 5. Comparative study: yearly primary energy consumption.

3.3. Economic performance

The following tables show the economic performance of the different alternatives studied. The rather high savings in energy cost and the corresponding short periods of return are partially due to the fact that current energy tariffs (both heat and electricity) are rather high compared to tariffs of other consumers with similar demands. Energy costs in the

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, 1,1 for natural gas and 1,3 for district heating.

alternatives have been calculated based on an estimated tariff for the purchase of natural gas of 40 €/MWh.

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

Alternative	Total investment [€]	Own investment [€]	Subsidies [€]
Present state	---	---	---
Heat recovery	2.400	2.160	240
Heatp pump	37.400	33.660	3.740
Solar thermal FPC	392.125	281.968	110.158
CHP – engine	207.400	186.660	20.740

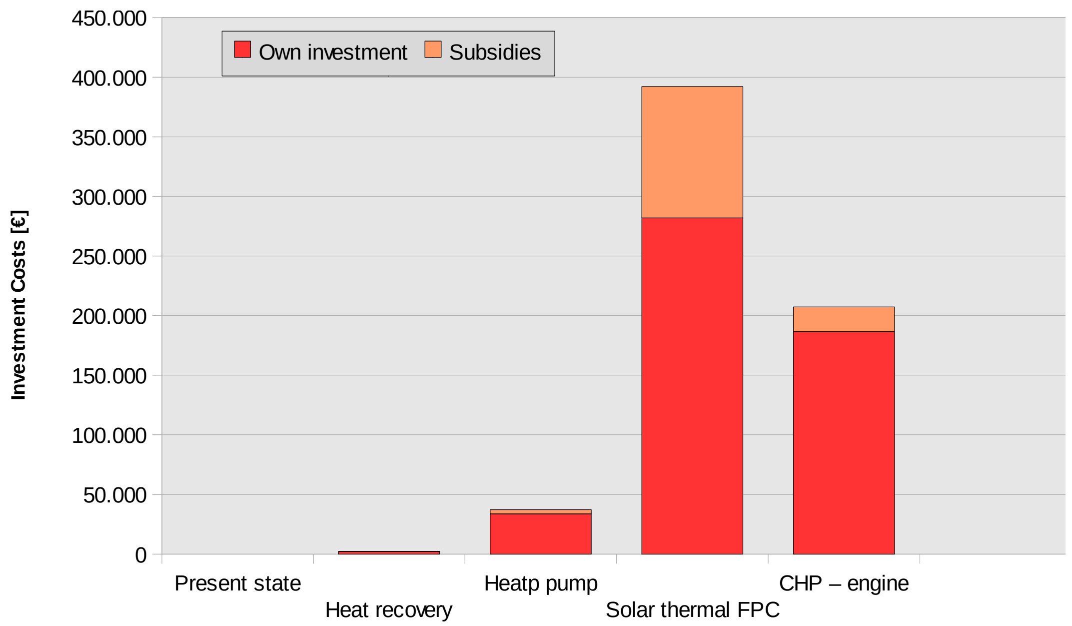

Figure 6. Comparative study: investment costs. Estimated co-funding: 30% for solar thermal and 10% for the rest of technologies.

Table 5. Comparative study: annual costs including annuity of initial investment[2].

Alternative	Annuity [€]	Energy Cost [€]	O&M [€]	Total [€]
Present state	---	463.934	0	463.934
Heat recovery	247	451.133	200	451.580
Heatp pump	3.851	387.798	1.250	392.898
Solar thermal FPC	40.374	359.924	8.750	409.048
CHP – engine	21.354	180.344	11.845	213.544

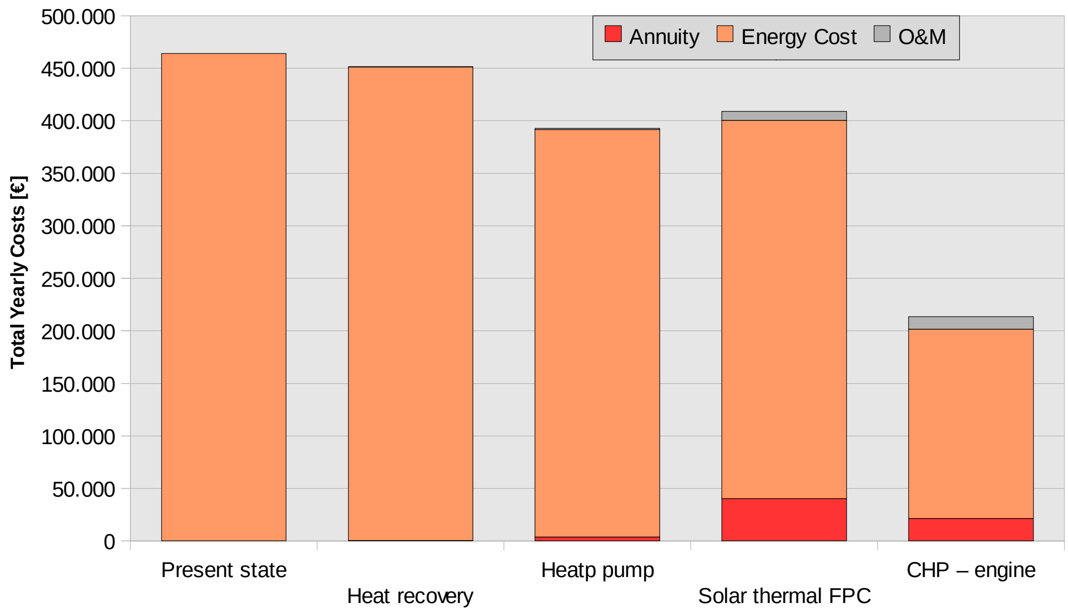

Figure 7. Comparative study: annual costs including annuity of initial investment.

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: 40 €/MWh for natural gas, 78,5 for district heating, 170 €/MWh a for bought electricity, 21 €/MWh of feed-in tariff.

4. Selected alternative and conclusions

4.1. Selected alternative

The alternative proposal "CHP-engine" that combines:

- A customized heat exchanger network
- Optimisation of ventilation system:
  - active dehumidification
  - reduction of rate of air renovation
  - use of heat pump to use latent heat of air to pre-heat water
- Cogenerative engine 200kW_e /333 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 alternative of solar system (flat plate collector) has been discarded due to the longer pay-back period and lower primary energy savings.

Nevertheless, the solar system is an interesting second option that can be taken into account, as an alternative itself or in combination with the cogeneration system.

Figure 8. Pools

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

4.1.1. Building optimisation

Currently the rate of air renovation is higher than would be required for maintaining indoor air quality, due to the high humidity that reaches the atmosphere of the pool areas. This fact supposes a high additional energy demand to heat the inlet air.

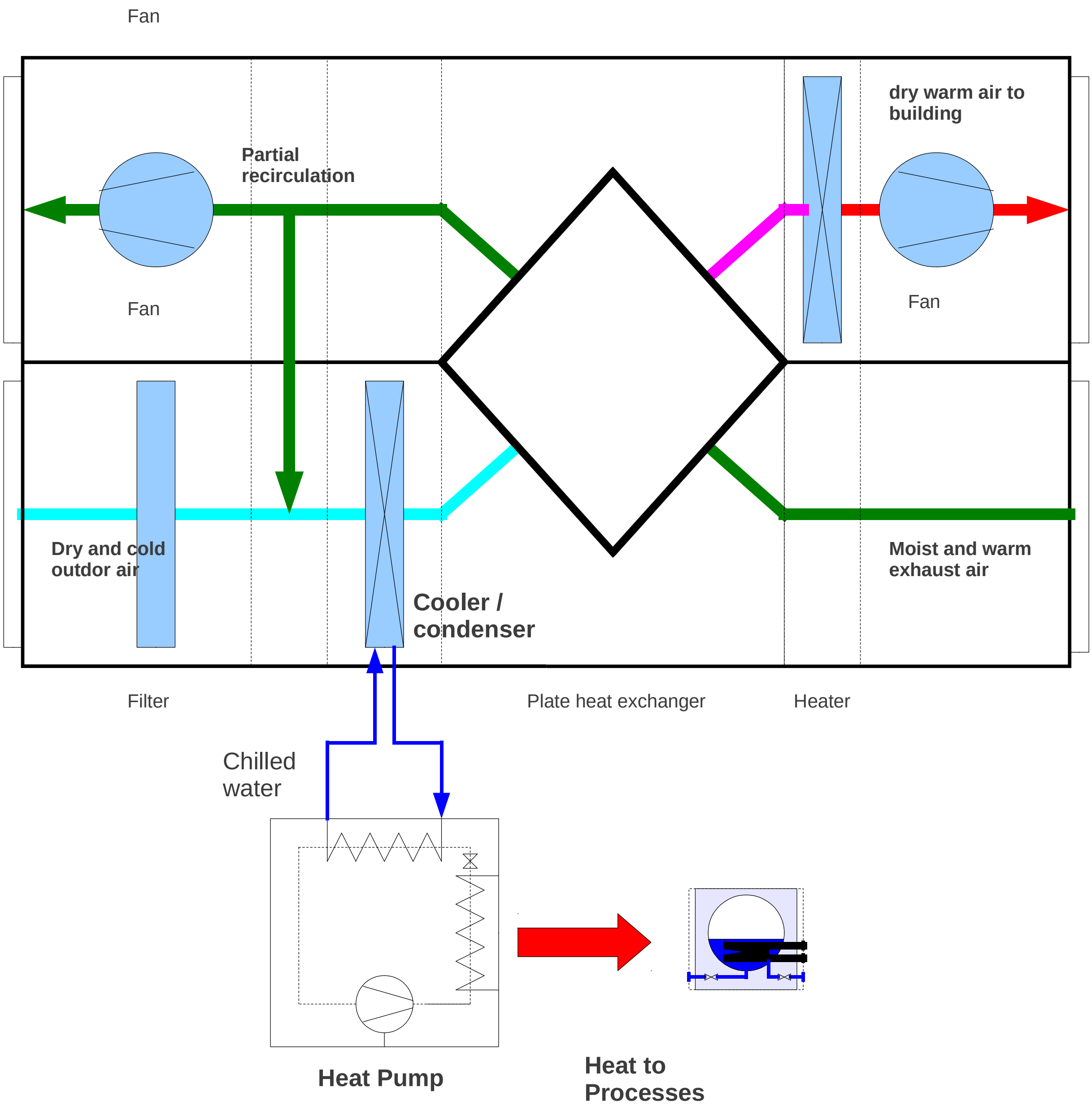

Figure 9. Scheme of the active dehumidification system proposed

In order to avoid this, it is proposed to perform an active dehumidification of air. This process consists in cooling the air down in order to condensate the content of water (dehumidification). After dehumidification, the outlet air is post-heated by heat exchange with the air flow before dehumidification and is then recirculated into the building. Therefore, the intake of cold outdoor air is lower and so is the corresponding energy demand.

Moreover, the latent heat extracted for the condensation of air humidity is used as low temperature heat source for an electrically driven heat pump, that supplies heat to the different processes (hot water for pools, sanitary uses or space heating). See Figure 9 .

4.1.2. Heat recovery

There is currently a heat exchanger:

- HX_Ozone: uses waste heat of the ozone preparation equipment to preheat water for the pools.

Two new heat exchangers are proposed:

- HX_pools: uses heat from the waste water of the pools to preheat the inlet water.
- HX_chiller: uses waste heat of the chillers (absorption and conpression) to preheat water for processes (hot water, space heating)

Table 6. List of heat exchangers proposed.

Heat Exchanger	Power	Heat Source	Heat Sink	Amount of recovered energy	
	[kW]			[MWh]	[%]
HX_Ozone	15	Ozone preparation	Pool inflow	21	1,23
HX_Pools	301	Pool outflow	Pool inflow	220	12,56
HX_Chiller	172	Waste heat chillers	Hot water processes	1.509	86,21
Total	**488**			**1750**	**100**

4.1.3. Heat and Cold Supply

In the new system proposed an electrically driven heat pump and a cogenerative engine are added to the heat supply system. Both systems feed heat into the existing hot water network. The heat pump simultaneously produces cooling (for air dehumidification) and heating.

No changes regarding the steam generation (for the sauna) have been carried out.

Table 7. Contribution of the different equipments to the total useful heat supply (USH) in the company. Selected alternative.

Equipment	Type	Heat / cooling supplied to pipe/duct	Nominal capacity	Contribution to total heat / cooling supply	
			[kW]	[MWh]	[%]
Sauna boilers	Electrical steam generator	-	116	200	7,35
New heat pump	**Electrically driven**	Hot water	200	715	26,27
New CHP	**Engine**	Hot water	333	1.759	64,62
District heating	District heating	Hot water	2.250	44	1,63
Total			**3.199**	**2.722**	**100**

The technical specifications of the new CHP engine are given in Table 8 and for the heat pump in Table 9.

Table 8. Technical specifications and economics of the new CHP engine.

Parameter	Units	Technical data
Type of equipment	-	CHP engine
Nominal power (heat or cold output)	kW	333
Fuel type	-	Natural gas
Fuel consumption (nominal)	kg/h	52,60
Electrical power generated (CHP)	kW	100
Electrical conversion efficiency (CHP)	-	0,30

Table 9. Technical specifications and economics of the heat pump. COP and nominal power refer to heating.

Parameter	Units	Technical data
Type of equipment	-	Heat pump
Nominal power (heat or cold output)	kW	100
COP	-	3,10

The total and monthly contribution of the new equipments to the total heat supply (2722 MWh) is shown in Figure 10.

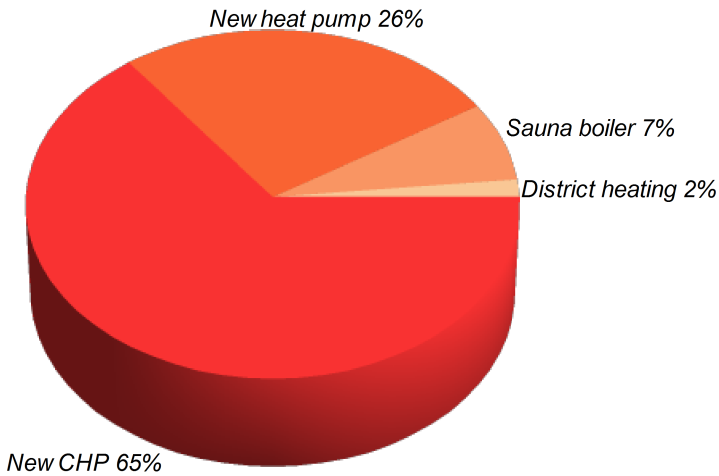

Figure 10. Contribution of the different equipments to the total useful heat supply (USH) in the company.

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

The following measures are proposed:

- A customized heat exchanger network
- Optimisation of ventilation system:
  - active dehumidification
  - reduction of rate of air renovation
  - use of heat pump to use latent heat of air to pre-heat water
- Cogenerative engine 200kW$_e$ /333 kW$_{th}$

These measures allow to save 35% of the current primary energy consumption (including primary energy for non-thermal purposes. For thermal purposes only, the savings are 58%). Their application also saves 61% of current energy cost (cost of fuel and electricity, including auto-generated electricity) and leads to a reduction of 54% of the total energy system cost (fuel and electricity, operation and maintenance, amortisation). The total required investment is about 207.400 € and the expected pay-back time is 0,7 years (taking into account the subsidies). This very short pay-back time is partially due to the fact that current energy tariffs are very high.

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*	*7853*	*5092*	*35,16%*
- fuels	*MWh*	*4118*	*4255*	*-3,32%*
- electricity	*MWh*	*3735*	*837*	*77,58%*
Primary energy saving due to renewable energy	*MWh*	*0*	*0*	*-*
CO_2 emissions	t/a	*1.541*	*1.259*	*18,32%*
Annual energy system cost (2)	*EUR*	*463.934*	*213.544*	*53,97%*
Total investment costs (3)	*EUR*	*-*	*207.400*	-
Payback period (4)	*years*	*-*	*0,7*	-

(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.

(3) total investment excluding subsidies.

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