Energy Audit Summary Report

Audit No. 51 - GER05

Recreational, cultural and sporting activities

Thermal Bath (Spa)

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: 2011

(Date of the visit on site: 09-01-2012)

2.1. General information of the company

Company, location	-	
Sector	Thermal bath (spa)	
Current final energy consumption [MWh] (*)	total	for heating and cooling
- natural gas	6.851	6.851
- electricity	185	-1885

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

2.2. Description of the company

a) Activity

The spa facilities are used for swimming and recreation activities. Part of the water is mixed with sole, which is extracted from a 1000m deep borehole at 20ºC. The main energy demanding processes are:

- Hot water for the pools 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. Only one area is dehumidified by a chiller.

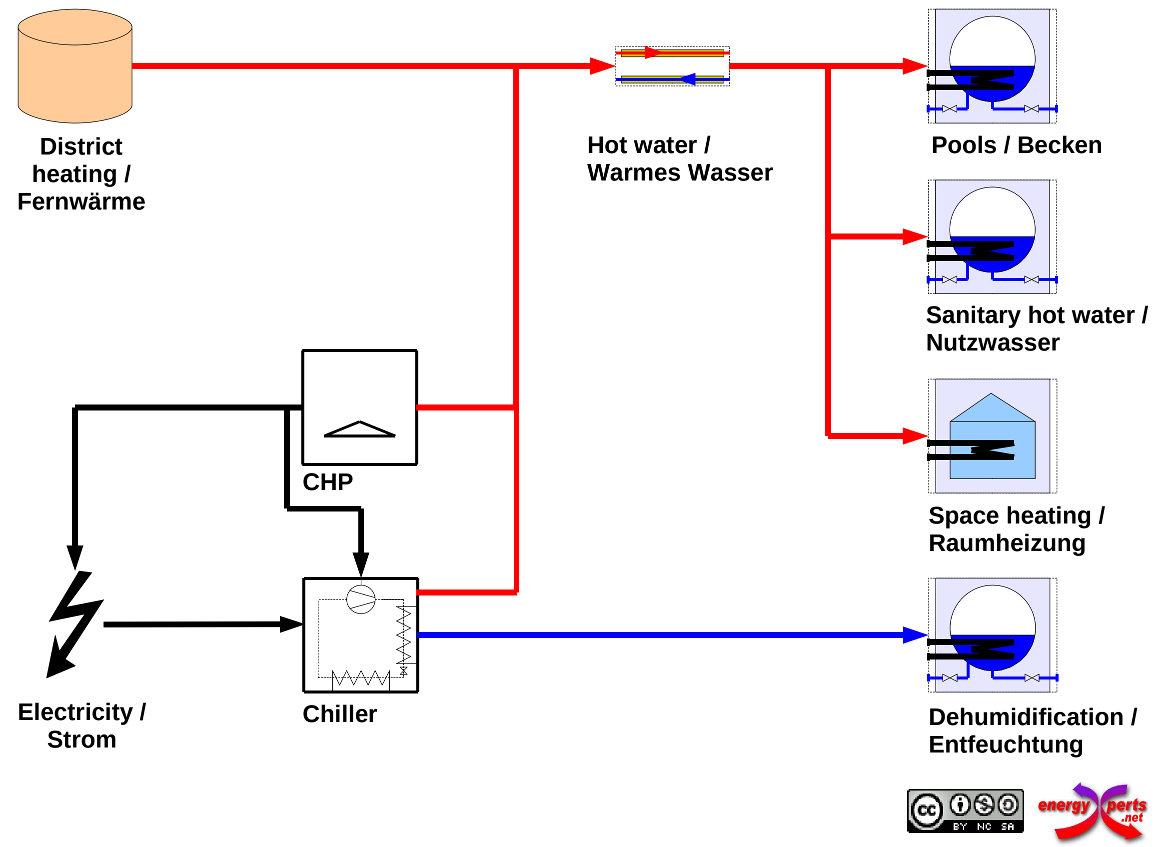

Figure 1. Overview of heating and cooling demands.

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. Two cogenerative engines (CHP) and two hot water boilers generate hot water at 75ºC, 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.

The boundaries of the present study include the CHP plant operated by the city council . See Figure 2.

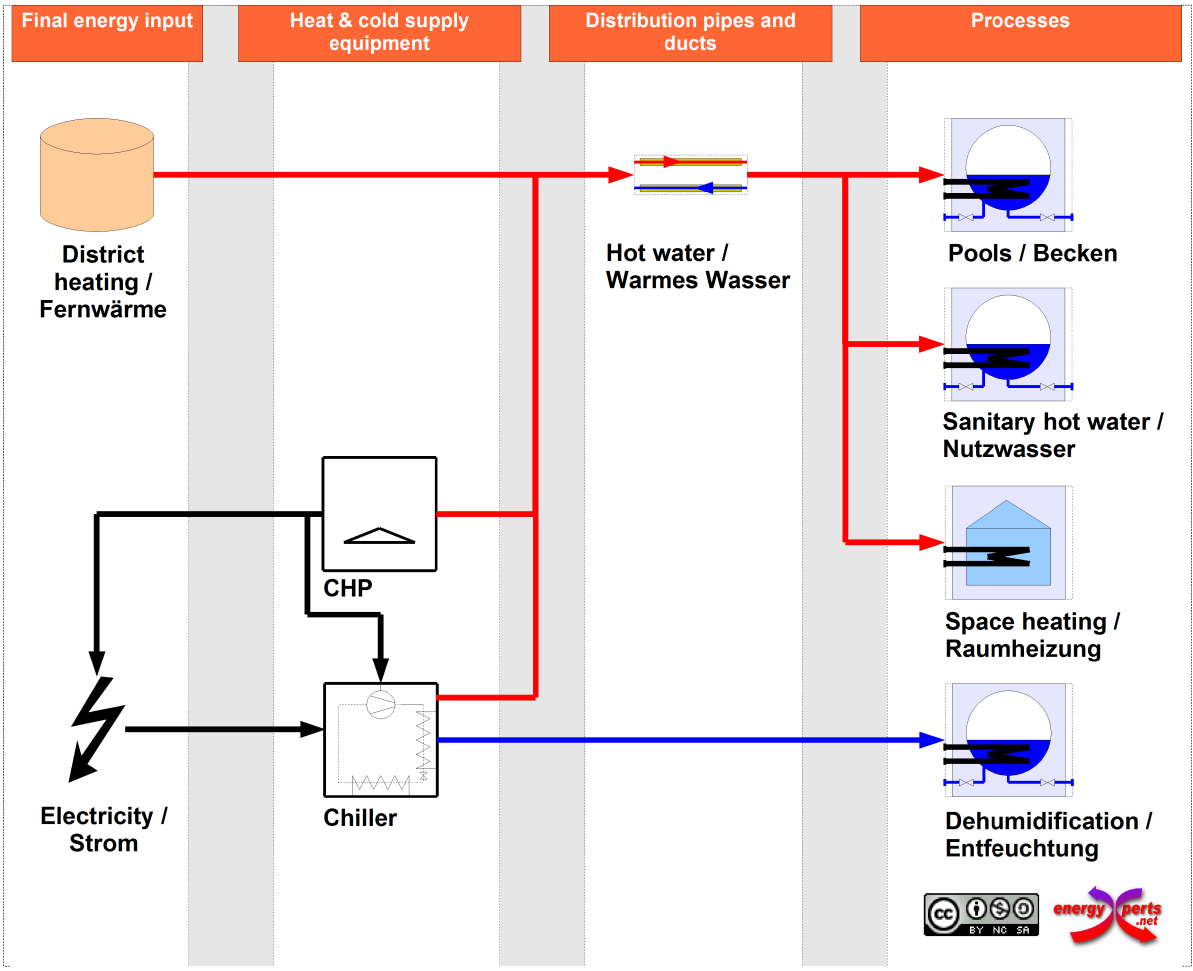

Figure 2. Overview of the heat and cold supply system

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.

For buildings: 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 1.

Table 1. Overview of the alternative proposals studied

Short name	Description
HR	**Heat Recovery** 1) Heat recovery: Installation of a **heat exchanger** to use waste water of pools to preheat inlet water of the same pools.
HP	**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** (200 kW) to preheat water for processes and space heating - Reduction of rate of renovation
AC	**Absorption chiller** 1) Idem to heat recovery 2) Optimisation of ventilation: - Active dehumidification: cooling air with an **absorption chiller** (45kW) and a **compression chiller** (30kW). The waste heat of the chillers is used in a **heat exchanger** to preheat water for processes and space heating - Reduction of rate of renovation Note: instead of using the compression chiller, dehumidification could be carry out by increasing again the renovation rate.
AC2	**Absorption chiller** 1) Idem to AC, but only one CHP is operating (236 kW)
ST	**Solar thermal** 1-2) Idem to alternative “Absorption chiller” 3) **Solar thermal system ETC** (Evacuated tube collectors) 900 kW

3.2. Energy performance[1]

Table 2. Comparative study: yearly primary energy consumption.

Alternative	Primary energy consumption	Savings	
	[MWh]	[MWh]	[%]
Present state	8.035	---	---
HR	7.783	252	3,13
WP	7.384	650	8,10
AC	7.066	968	12,05
AC2	7.267	767	9,55
ST	6.713	1.321	16,44

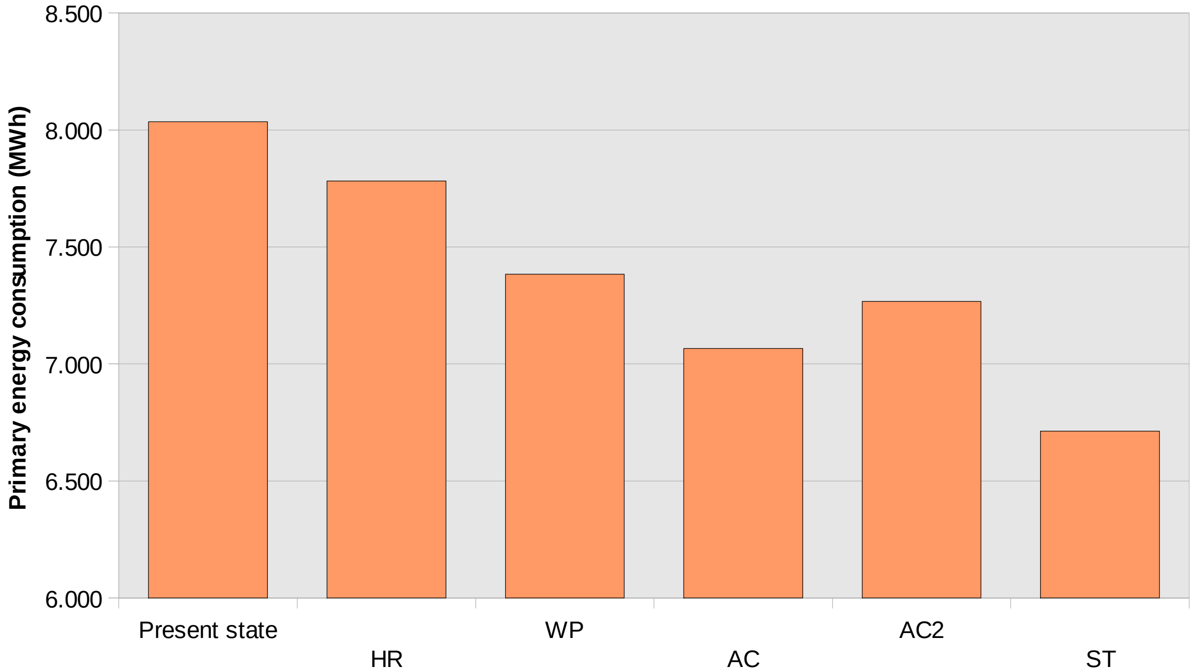

Figure 3. Comparative study: yearly primary energy consumption.

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 3. 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	---	---	---
HR	40.000	36.000	4.000
WP	140.000	126.000	14.000
AC	106.000	95.400	10.600
AC2	26.000	23.400	2.600
ST	773.715	562.801	210.915

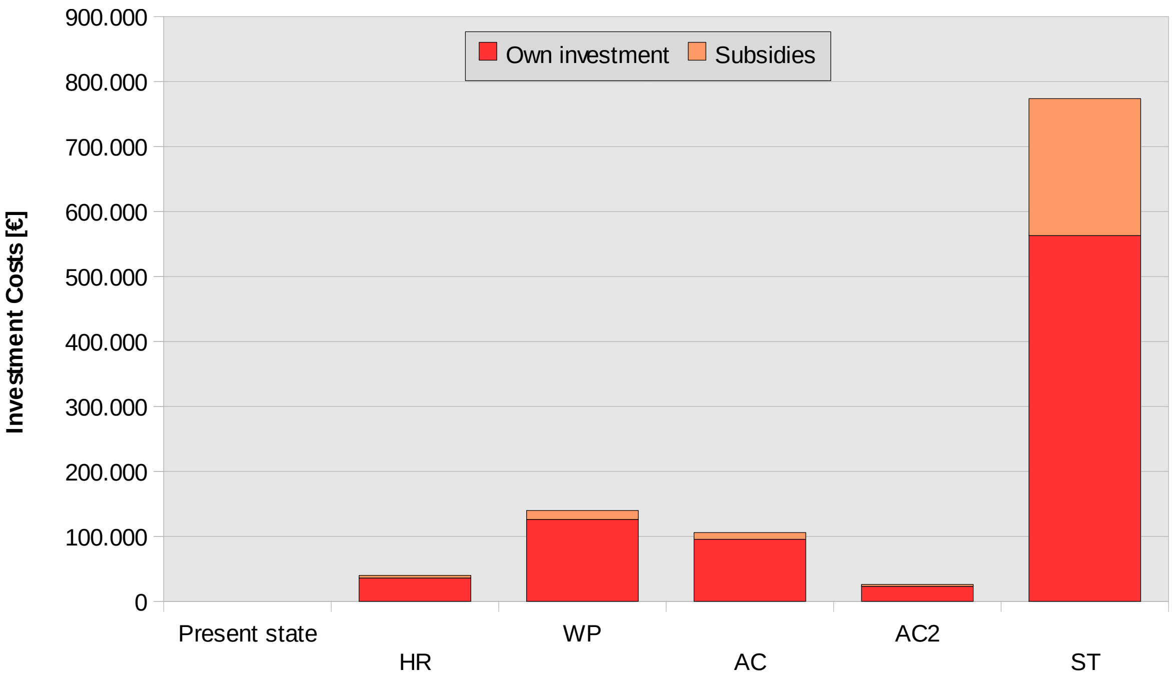

Figure 4. Comparative study: investment costs. Estimated co-funding: 30% for solar thermal and 10% for the rest of technologies.

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

Alternative	Annuity	Energy Cost	O&M	Total
	[€]	[€]	[€]	[€]
Present state	---	300.583	10.228	310.811
HR	4.119	290.430	13.563	308.112
WP	14.415	305.778	12.987	333.180
AC	10.914	290.187	12.690	313.791
AC2	2.677	296.373	11.159	310.208
ST	79.664	288.566	23.607	391.837

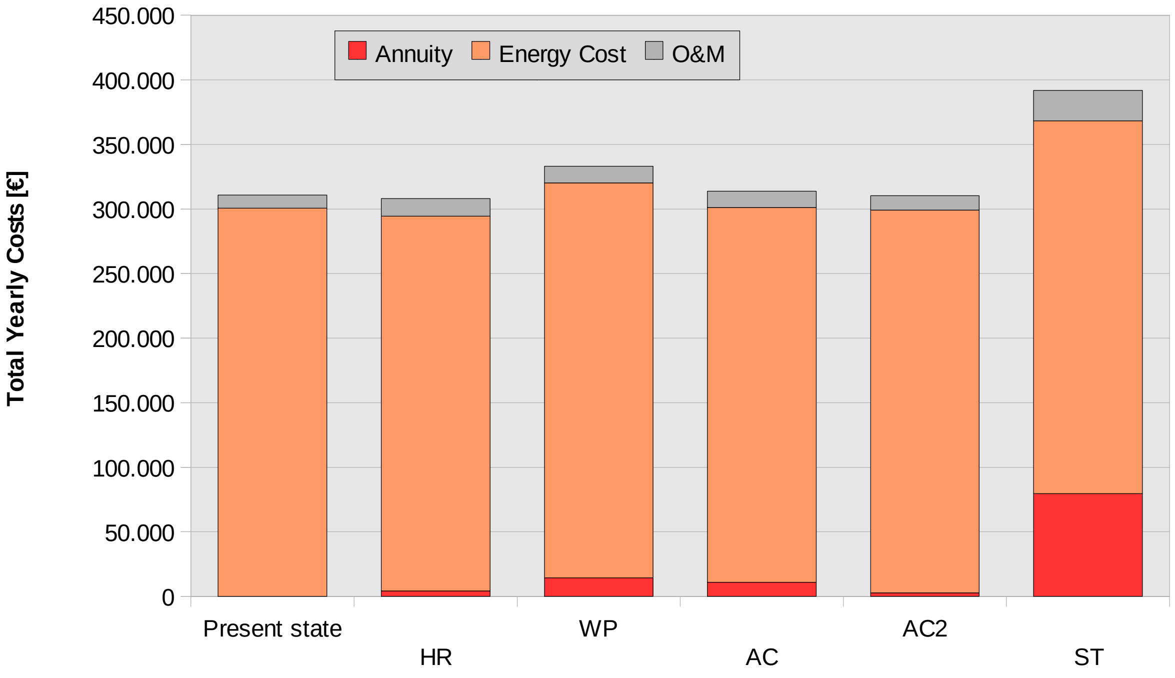

Figure 5. Comparative study: annual costs including annuity of initial investment.

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: 45 €/MWh for natural gas, 176 €/MWh a for electricity if low consumption, 130 €/MWh a for bought electricity if high consumption , 21€/MWh of feed-in tariff.

4. Selected alternative and conclusions

4.1. Selected alternative

The alternative proposal "Absorption chiller" that combines:

- A customized heat exchanger network
- Optimisation of ventilation system:
  - active dehumidification with an absorption chiller and a compression chiller
  - reduction of rate of air renovation
  - use of waste heat of chillers to pre-heat water

has been considered the best option among the previously analysed due to the following reasons:

- high potential of primary energy savings
- the alternative of absorption chiller 2 (one of the CHP is sold) has been discarded due to the fact that boilers have to work more than the CHP and, therefore, more primary energy is consumed
- the alternative of solar system (flat plate collector) has been discarded due to the longer pay-back period

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

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.

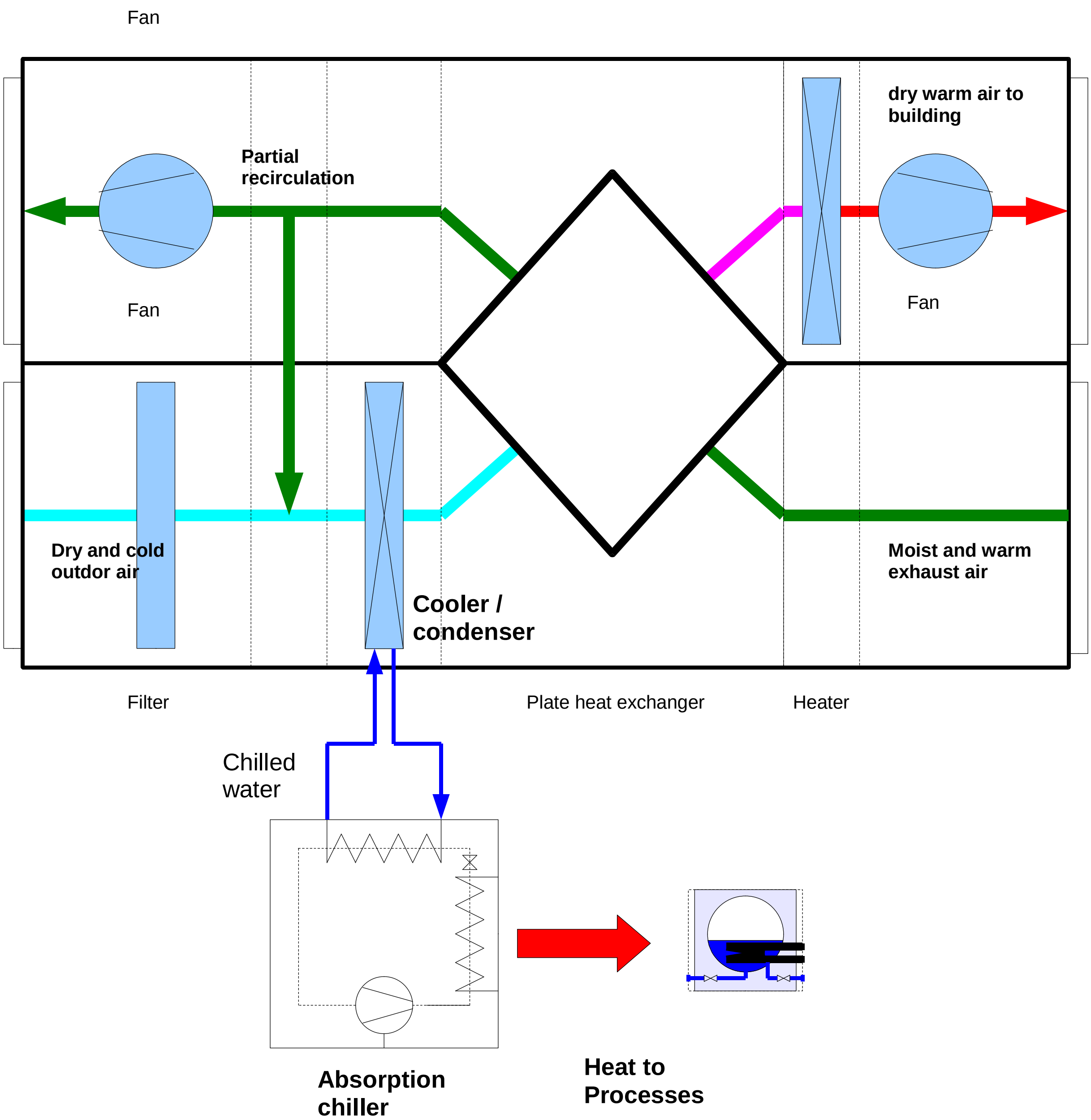

Figure 6. Scheme of the active dehumidification system proposed

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.
The cooling down of air is carried out in an absorption and a compression chiller. The waste heat of both equipments is used to preheat water for processes (hot water for pools, sanitary uses or space heating). See Figure 6 .

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 compression) to preheat water for processes (hot water, space heating)

Table 5. 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 absorption chiller and a compression chiller are added to the system for air dehumidification.

The technical specifications of the absorption chiller and the compression chiller are given in Table 6 and Table 7 respectively.

Table 6. Technical specifications and economics of the new absorption chiller

Parameter	Units	Technical data
Type of equipment	-	**Absorption chiller**
Nominal power (heat or cold output)	kW	45,00
COP	-	0,70
Turn-key price	€	22.000
Annual operational and maintenance fixed costs	€	900

Table 7. Technical specifications and economics of the new compression chiller

Parameter	Units	Technical data
Type of equipment	-	**Compression chiller**
Nominal power (heat or cold output)	kW	30,00
COP	-	3,00
Turn-key price	€	14.000
Annual operational and maintenance fixed costs	€	600

The total and monthly contribution of the new equipments to the total heat supply (1.851 MWh) is shown respectively in Table 8, Figure 7 and Figure 8 while the contribution to the cooling supply (712 MWh) is shown in Table 9, Figure 9 and Figure 10.

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

Equipment	USH by equipment	
	[MWh]	[% of Total]
CHP	1.348	72,79
Boilers	504	27,21
Total	**1.851**	**100**

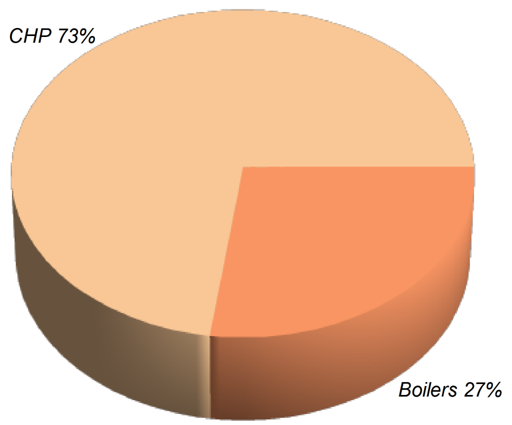

Figure 7. Contribution of the different equipments to the total useful heat supply (USH) in the company.

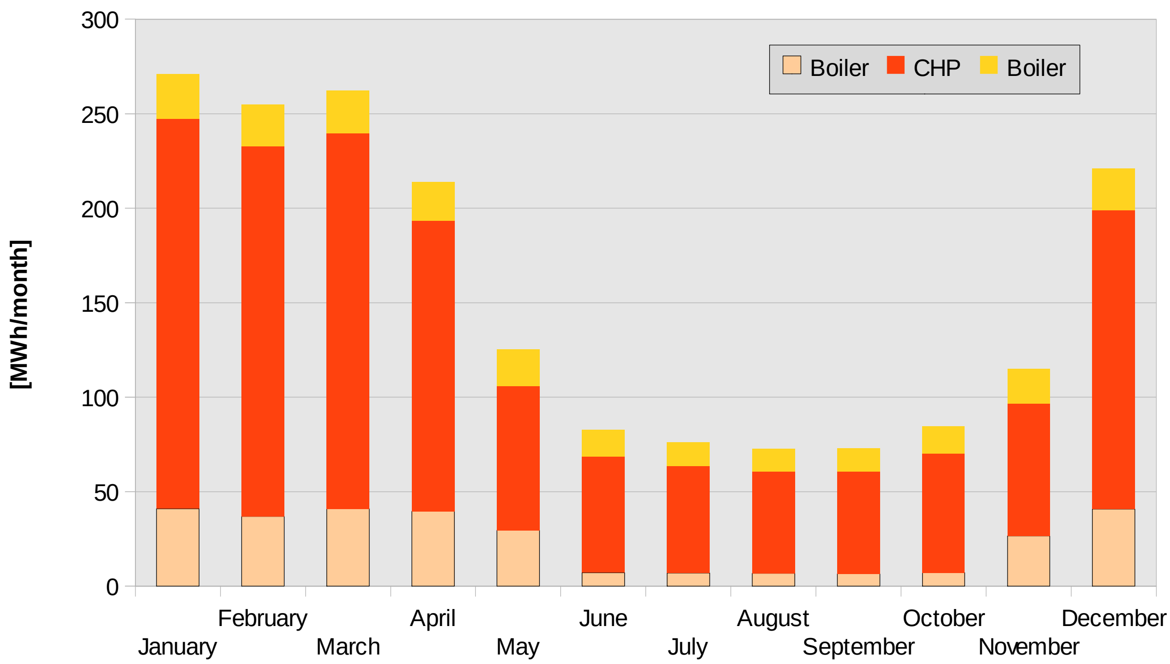

Figure 8. Contribution of the different equipments to the total useful heat supply (USH) per month.

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

Equipment	USC by equipment	
	[MWh]	[% of Total]
Old compression chiller	138	19,41
New absorption chiller	400	56,26
New compression chiller	173	24,33
Total	**711**	**100**

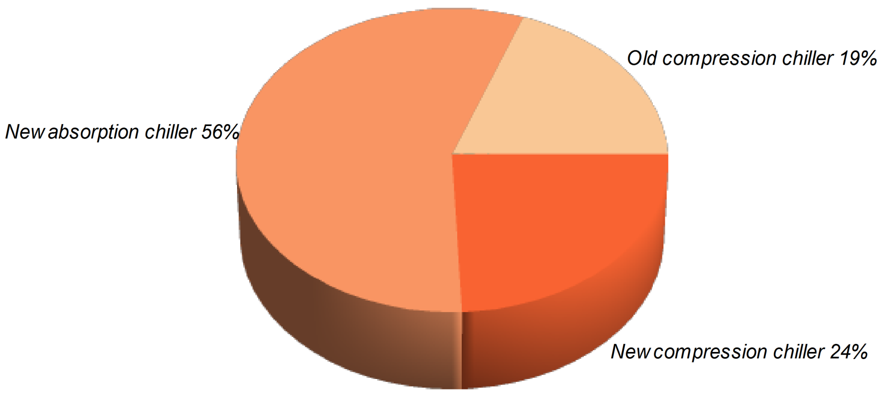

Figure 9. Contribution of the different equipments to the total useful cooling supply (USC)in the company.

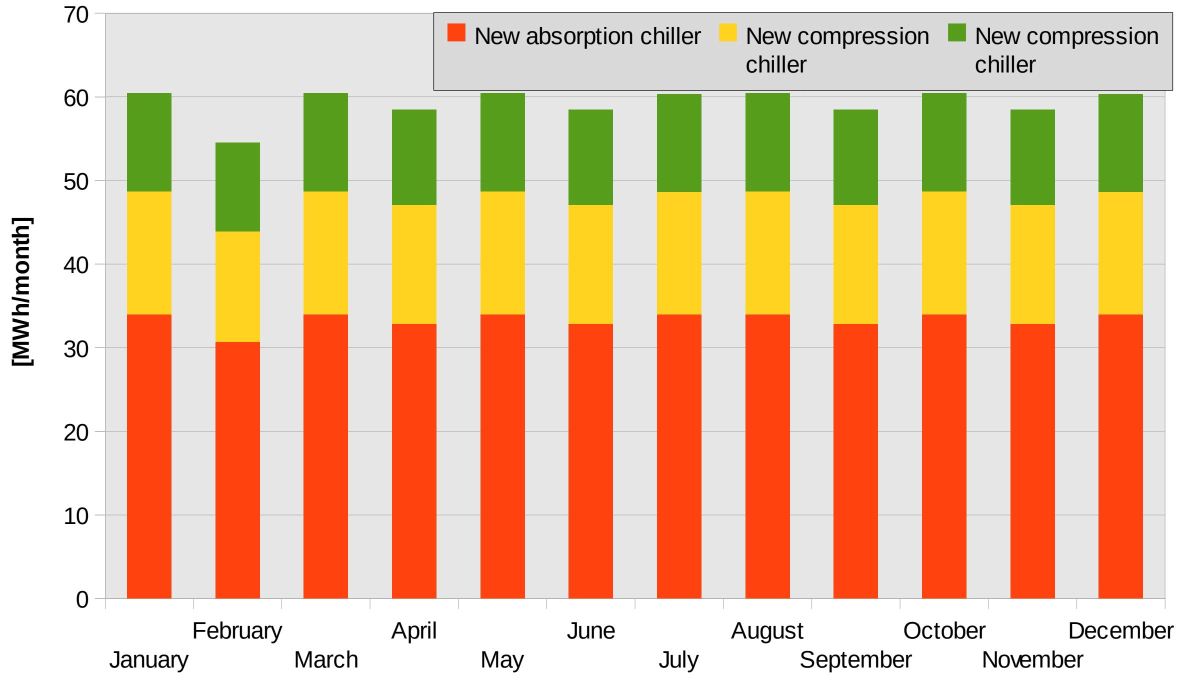

Figure 10. Contribution of the different equipments to the total useful cooling supply (USC) per month.

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

The following measures are proposed:

- A customized heat exchanger network
- Optimisation of ventilation system:
  - active dehumidification
  - reduction of rate of air renovation
  - use of an absorption chiller and a compression chiller for dehumidification
  - use of a customized heat exchanger to use waste heat of the chillers to preheat water

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 46%). Their application also saves 3,46% of energy cost (cost of fuel and electricity, including auto-generated electricity) under the supposed scenario of energy tariffs.
The reduction of energy cost with respect to the actual current energy cost are 255.520 €. Nevertheless, these potential savings are mostly due to supposed changes in tariffs (purchase of natural gas instead of purchase of heat and self-generated electricity). An analysis of the economic savings due to the proposed technical change depends strongly on the tariffs supposed, and specially on the relation of electricity and natural gas tariffs.

The total required investment is about 207.400 € and the expected pay-back time for the technical change in the system is 14,4 years (taking into account the subsidies). This very high pay-back time nevertheless may be substantially lower in the case that a lower electricity tariff than the supposed value of 130 €/MWh can be negotiated.

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

		Present state	**Proposed alternative**	**Savings**
Total primary energy consumption (1)				
Total	MWh	8.035	7.066	12,05%
- Total fuels	MWh	7.536	3.955	47,52%
- Electricity	MWh	498	3.111	-524,29%
Primary energy saving due to renewable energy	MWh	-	-	-
CO_2 emissions	t/a	1.805	1.475	18,28%
Total annual energy system cost (2)	€	310.811	0	-0,96%
Total investment cost(3)	€	-	0	-
Pay-back period (4)	a	-	14,4	-

(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.*

(3) *total investment excluding subsidies.*

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