Energy Audit Summary Report

Audit No. 40 - Spain

Office Building

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

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With the collaboration of the Chamber of Commerce and Industry of Madrid.

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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

(Date of the visit on site: 18.03.2011)

2.1. General information of the company

Company, location	-	
Sector	office building	
Activity	office tower occupied by different companies	
Size	28.900 m^2 on 17 floors	
No. of Occupants	1.800	
Current final energy consumption [MWh] (*)	total	for heating and cooling
- gas oil C	807	807
- electricity	1.162	944

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

2.2. Description of the company

a) Activity

The building is an office tower in the city of Madrid, built in 1981 / 1982.

The building consists of 17 floors with a total area of about 28.900 m2 and is occupied by offices belonging to different companies.

The building envelope consists of a fully glazed facade on the North side, and on all other sides from the 4th floor on to the top. About 50 % of the facade is transparent to the interior (windows) and the other part is formed by insulated walls behind the outer glazing.

The offices at the south side require air conditioning during the whole year, while the offices at the north side have to be heated in winter.

The most energy consuming processes in the company are space heating and cooling. In addition, there is a minor demand for domestic hot water and some demand for cooling of equipment (data center; neglected in the present study).

b) Energy supply system

The heat supply system is composed by the following elements:

- a central heat supply for space heating (incl. air handling units) formed by 3 gasoil fired hot water boilers and a hot water distrbution circuit over the whole building
- an outdoor air -to-water heat pump delivering heat into the air handling units
- individual electrical hot water boilers for sanitary hot water preparation in each of the sanitary rooms

(a) (b)

Figure 1. (a) Air handling unit; (b) Hot water distribution piping

Cooling is provided by several electrically driven compression chillers via a central chilled water distribution network.

Cooling and heating to the spaces is provided on the one hand by cooling / heating of air renovation in the air handling units and by fan-coils in the technical roofs of each office.

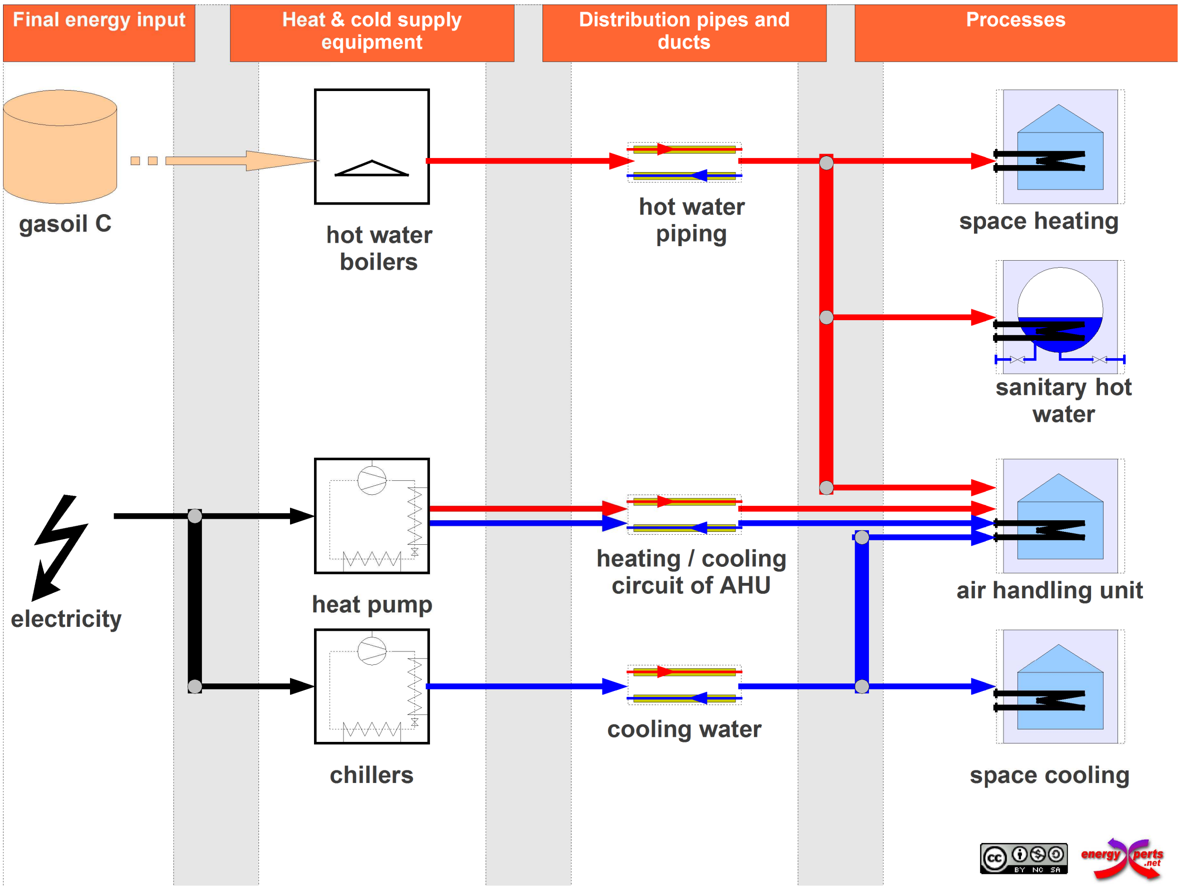

Figure 2. Overview of the heat and cold supply system

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.

The scope of the EINSTEIN audit is focussed on the analysis and optimisation of the supply system of heating and cooling. Building optimisation is not included (although, in alternative "CHP y fachada (= facade)" a rough estimate of the saving potential and investment cost for a renovation of the south facade is included, in order to highlight the order of magnitude of potential additional savings). 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.

The first alternative HR includes heat recovery of warm exhaust air in the air handling units and the reduction of both heating and cooling demands in winter by cross ventilation from south to north zones of the building.

In addition the alternative ACSCentral foresees the elimination of the electrical heaters for sanitary hot water and their substitution by a connection to the central hot water network.

This alternative is ACSCentral is the base on which the other 3 alternatives (CHP, CHP y fachada, SHC) are designed.

The facade modification as included in the alternative "CHP y fachada" suggest a substitution of the glazing in the transparent part of the south facade by a solar control glazing with reduced transparency for infrared radiation.

In addtition to the alternatives listed in Table 1, also the combination of CHP with an ab- or adsorption chiller has been studied, but additional primary energy savings are low, and the economic performance was worse due to the relatively high cost of the gas oil. In case of a fuel substitution from gasoil to natural gas this might change in the future.

Table 1. Overview of the alternative proposals studied

Short Name	Description
HR	heat recovery and cross ventilation in winter from south to north zones
ACSCentral	central generation of sanitary hot water (incl. measures HR)
CHP	cogeneration (gasoil engine, 80 kWe, 115 kWt; incl. measures ACSCentral)
CHP y fachada	like CHP, in addition modification of the south facade
SHC	solar heating and cooling (500 kW / 700 m² of evacuated tube collectors; ab- or adsorption chiller of 70 kWf; incl. all measures ACSCentral).

3.2. Energy performance[1]

Table 2. Comparative study: yearly total primary energy consumption.

Alternative	Primary energy consumption	Savings	
	[MWh]	[MWh]	[%]
Present State (checked)	4.257	---	---
HR	3.645	611	14,36
ACSCentral	3.384	872	20,50
CHP	2.986	1.270	29,84
CHP y fachada	2.409	1.848	43,41
SHC	2.931	1.326	31,15

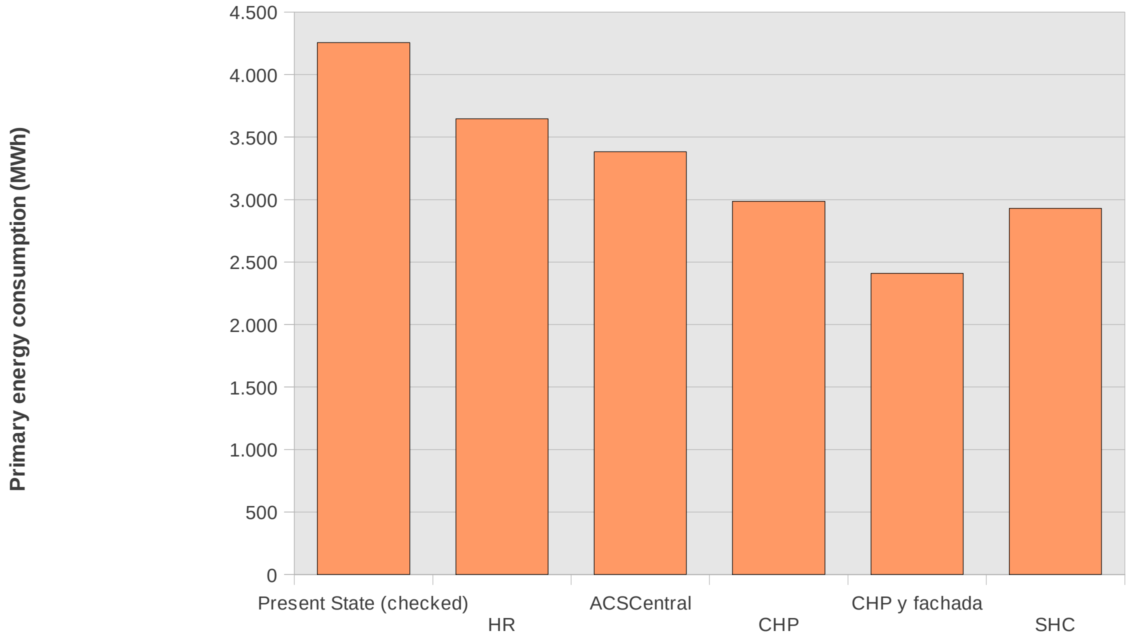

Figure 3. Comparative study: yearly primary energy consumption.

1 The factors for conversion of final energy (for fuels in terms of LCV) to primary energy used in this study are 2,9 for electricity and 1,1 for natural gas.

3.3. Economic performance

Table 3. Comparative study: investment costs. Estimated co-funding: 10 % for investments in heat recovery, CHP and energy efficiency in general, 30 % for solar thermal systems.

Alternative	Total investment [€]	Own investment [€]	Subsidies [€]
Present State (checked)	---	---	---
HR	46.000	41.400	4.600
ACSCentral	110.000	99.000	11.000
CHP	198.000	178.200	19.800
CHP y fachada	398.000	358.200	39.800
SHC	423.853	322.197	101.656

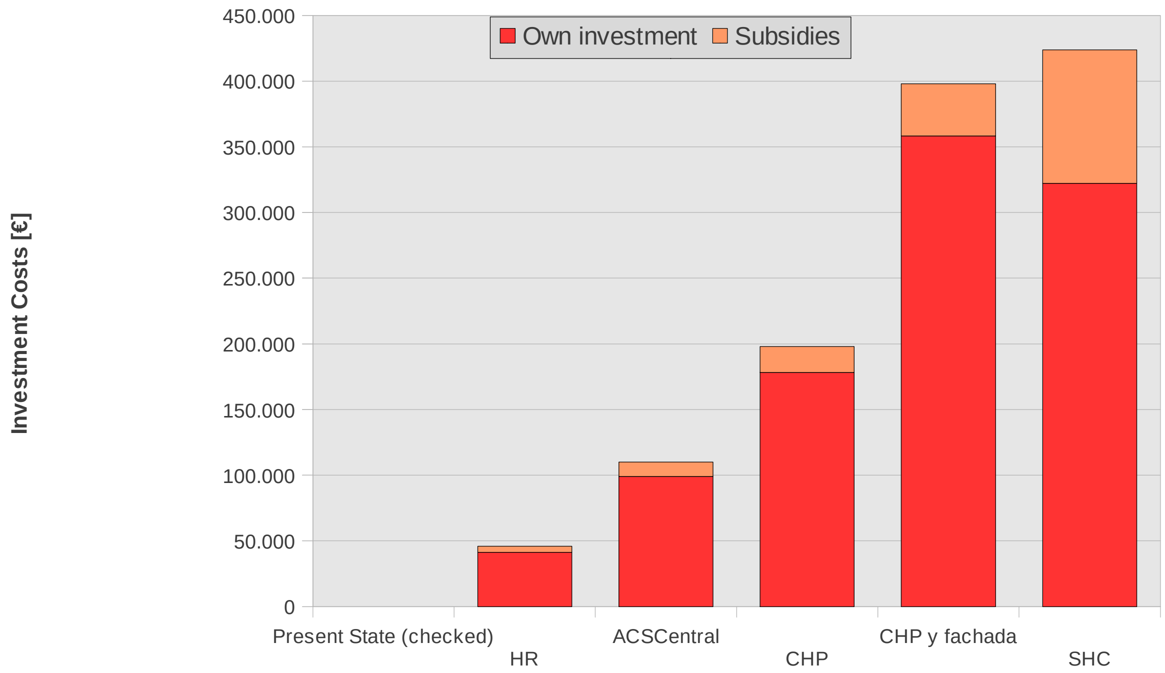

Figure 4. Comparative study: investment costs (see Table 3).

Table 4. 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 [€]
Present State (checked)	---	143.618	0
HR	4.736	114.164	2.400
ACSCentral	11.326	113.917	2.400
CHP	20.387	104.897	5.782
CHP y fachada	40.979	89.688	5.782
SHC	43.641	90.665	5.185

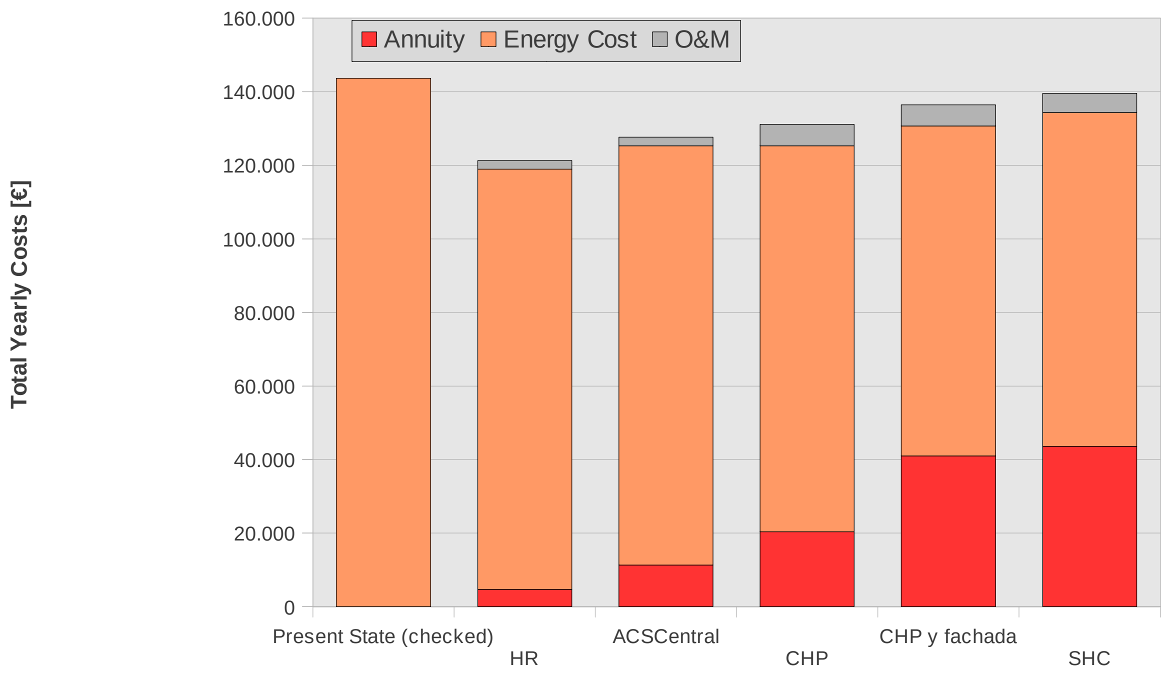

Figure 5. Comparative study: annual costs including annuity of initial investment. The energy cost for CHP includes also the feed-in-tariff revenue for the CHP electricity.

2 Annuity of initial investment: 10,3 % of yearly payments, calculated based on 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" that combines heat recovery, cross ventilation, central hot water preparation and a cogenerative gasoil engine of 80 kW_e /115 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

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

4.1.1. Building optimisation

No building optimisation has been considered in the proposed alternative.

4.1.2. Heat recovery

The proposed heat recovery system consists of 2 measures:

a) cross ventilation from south to north zones in winter by an increase of air renovation flow rate and a decrease of waste air extraction in the south zones, and a corresponding decrease / increase in north zones, so that there is an internal air flow from the south to the north zones. The increase of (cold outdoor) air intake into the south zones reduces the cooling demand in this zone, whereas the substitution of cold outdoor air by warm excess air from the south zones reduces the heating demand in the north zone.

b) heat exchange between the exhaust air and the inlet air in the air handling unit (Table 5).

As can be seen from Table 2, the proposed heat recovery and cross ventilation leads to a saving of more than 14 % of the total current primary energy consumption.

Table 5. List of heat exchangers proposed. UTA-calor: heat exchanger in air-handling unit, winter operation for heating; UTA-frio: heat exchanger in air-handling unit, summer operation for cooling.

Heat Exchanger	Power	Heat Source	Heat Sink	Heat transferred	
	[kW]			[MWh]	[%]
UTA-Calor	37	UTA_heating	UTA_heating	172	86,64
UTA-Frío	16	UTA_cooling	UTA_cooling	27	13,36

4.1.3. Heat and Cold Supply

In the new system proposed a cogeneration plant (gasoil engine) is added to the heat supply system. The CHP plant feeds heat into the existing hot water distribution circuit.

Table 6. Heat and cooling supply equipments . Selected alternative.

Equipment	Type	Heat / cooling supplied to pipe/duct	Nominal capacity	Contribution to total heat / cooling supply	
			[kW]	[MWh]	
New CHP	**CHP engine**	**caliente==o o==distribución ACS==o**	**115**	**516**	
bombas de calor (calor)	hot water boiler	o==UTA calor==o	43	50	
Calderas	hot water boiler	caliente==o o==distribución ACS==o	1.396	146	
enfriadora principal	compression chiller (water cooled)	o==distribución agua fría==o	1.163	1.248	
enfriadora auxiliar	compression chiller (water cooled)	o==distribución agua fría==o	465	0	
enfriadora multistar	compression chiller (water cooled)	o==distribución agua fría==o	465	0	
bombas de calor (frío)	compression chiller (air cooled)	o==dist. bomba calor (frío)==o	374	254	
calderas agua caliente	hot water boiler	o==distribución ACS==o	490	0	

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

Table 7. 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	115,00
Fuel type	-	Gasoil C
Fuel consumption (nominal)	kg/h	20,10
Electrical power generated (CHP)	kW	80,00
Electrical conversion efficiency (CHP)	-	0,32

The total and monthly contribution of the new equipments to the total heait supply is shown respectively in Table 8, Figure 6 and Figure 7.

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

Equipment	USH by equipment	
	[MWh]	[% of Total]
Calderas	146	20,49
bombas de calor (calor)	50	7,03
calderas agua caliente	0	0,00
New CHP 2	516	72,48
Total	**712**	**100**

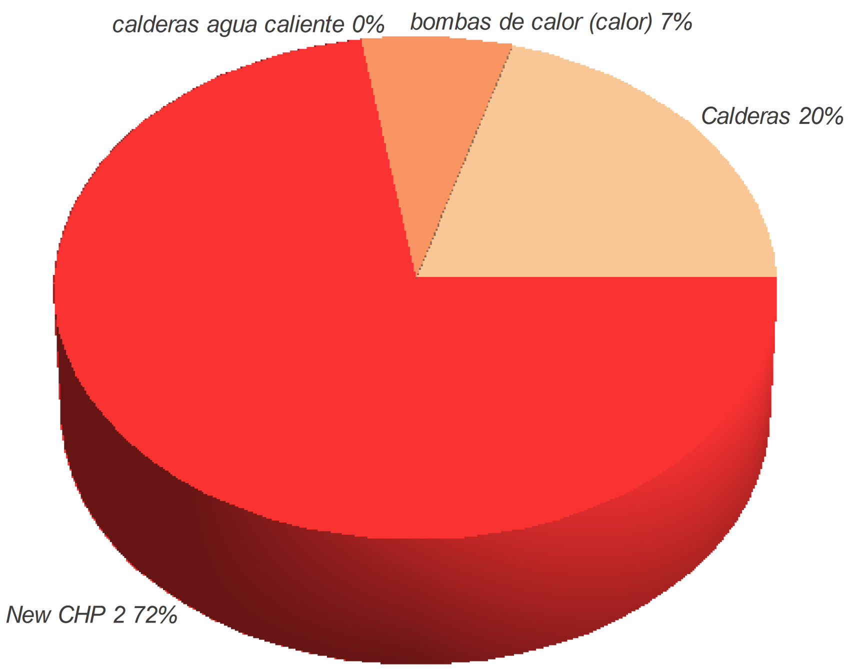

Figure 6. Contribution of the different equipments to the total useful heat supply (USH) in the company.

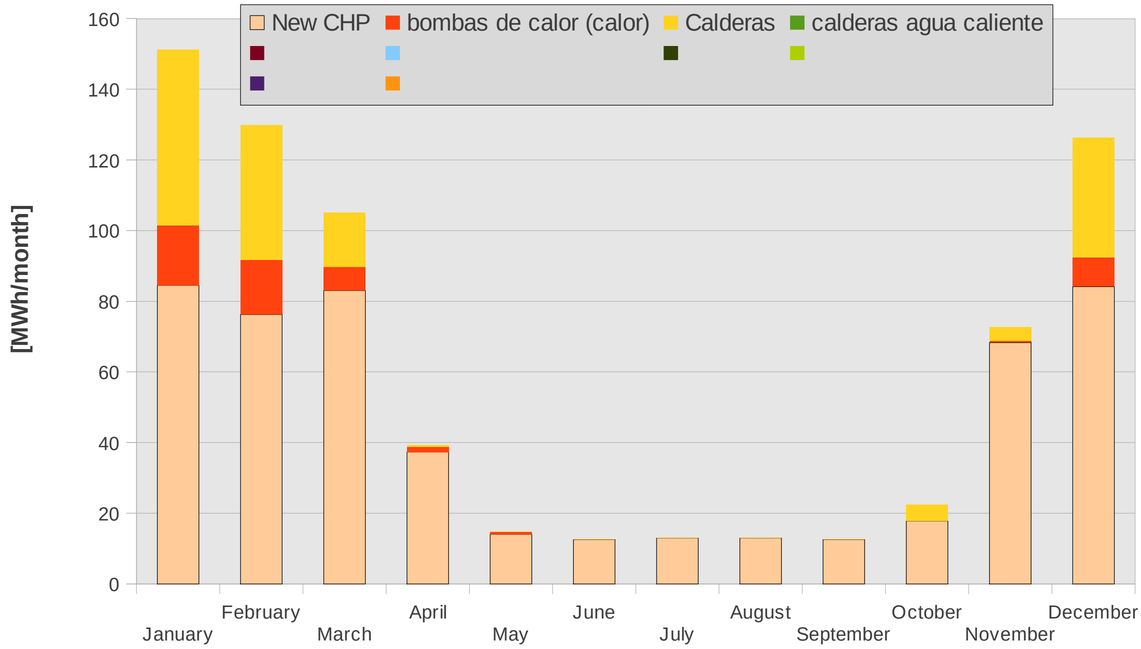

Figure 7. Contribution of the different equipments to the total useful cooling supply (USH) per month.

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

The following measures are proposed:

- heat recovery between exhaust air and fresh incoming air in air handling units
- cross ventilation between south and north zones by an appropriate control of the existing ventilation system
- substitution of electrical water heaters by a connection to the central hot water network
- cogeneration (gas engine) for covering the base load of the heating demand

These measures allow to save 30 % of the current total primary energy consumption and 27 % of current energy cost and leads to a reduction of 9% of the total energy system cost (fuels and electricity, operation and maintenance, amortisation of investment). The total required investment is about 198.000 € and the expected pay-back time is 6,1 years (taking into account possible subsidies; the pay-back period maybe even shorter if the fuel gasoil is substituted by the – cheaper – natural gas).

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*	*4.257*	*2.986*	*29,8%*
- fuels	*MWh*	*887*	*1.461*	*-64,7%*
- electricity	*MWh*	*3.369*	*1.526*	*54,7%*
Primary energy saving due to renewable energy	*MWh*	*0*	*0*	*-*
CO_2 emissions	t/a	*783*	*595*	*24,0%*
Annual energy system cost (2)	*EUR*	*143.618*	*131.065*	*8,7%*
Total investment costs (3)	*EUR*	*-*	*198.000*	*-*
Payback period (4)	*years*	*-*	*6,1*	*-*

(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)*