



Proposal/Contract no.: FP6-503186

**DEMOHOUSE**

Design and Management Options for improving the energy performance of Housing

SPECIFIC TARGETED RESEARCH OR INNOVATION PROJECT

Thematic Priority 6

**Deliverable 9 Lifecycle optimisation and CO<sub>2</sub> reduction**

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## Executive Summary

The EU - Demohouse project is a specific targeted research and innovation project supported by the EU – 6<sup>th</sup> Framework programme, which started in October 2005 and which is ongoing for 4 years until October 2008. Demohouse is here an acronym for Design and Management Options for Improving the Energy Performance of Housing. ECN from Holland is coordinator and there are realised demonstration projects in 5 countries – Denmark, Austria, Hungary, Spain and Greece with a main focus on housing renovation.

The main goal of WP2: "Generation of solutions and technical designs" which is coordinated by Cenergia from Denmark, is to assist on the development of a new quality and value oriented design process in connection to renovation projects in the housing sector. And to do this in connection to the demonstration projects which are realised in the EU - Demohouse project.

This report covers the effects on CO<sub>2</sub> emission and life cycle costs from the Demohouse building projects.

Each project is analysed with regards to the energy and resource saving potential and the costs for implementing the renovation and operating the buildings after renovation. The energy use for the existing building is compared to a standard renovation in each country, and to the improved Demohouse renovation standard.

The reduction in CO<sub>2</sub> emission is calculated based on the actual CO<sub>2</sub> emission in each country from heat and electricity depending on the use of primary energy for energy production.

Pay-back times for the investments are calculated based on budget costs and, if available, on the actual building costs. Pay-back times for the Demohouse renovation standard is compared to pay-back times for the standard renovation.

For each pilot renovation project, the life cycle costs and CO<sub>2</sub> emissions have been calculated. Compared to the existing building and a standard renovation case, the pay-back times and CO<sub>2</sub> emission reductions are calculated for the projects and the optimal renovation measures are identified.

For the Danish project it is found that CO<sub>2</sub> emission reductions of 68 % are possible at a pay back time of 21 years, but if you only use heat recovery ventilation and airtightness a payback time around 9 years can be obtained. In the first case there is 57 % operation costs reduction compared to existing situation and 45% operation cost reduction compared to standard renovation, and for HRV and airtightness the last mentioned value is 29%. For the Spanish project these figures are 68% and 25 years (63 % operation cost reduction). For Austria the payback is 25 years and reduction in operation costs is 40% and 14%. For Hungary the payback is 35 years, with 60% operation costs reduction compared to existing situation and 46% compared to a standard renovation. For the project in Greece – a 17 year payback is obtained for standard renovation, including heat recovery ventilation, and earth heat exchangers it is 6 years while it is 11 years including building energy management system and an operation costs reduction of 66% compared to existing situation and 52% compared to standard new build.

For Denmark the best economy is for heat recovery ventilation and airtightness while improved insulation and windows are more costly. This is also confirmed in Austria, Spain and Greece.

If cost effective energy savings should be introduced in connection to renovation projects there is a need for a focus on total economy optimisation, and to be able to charge extra payments in f.ex. rent if savings on operation costs are introduced for the users.

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## 1 Introduction

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## 2 Danish demonstration project Gyldenrisparken, Copenhagen

The housing blocks Gyldenrisparken, include 500 apartments divided between several blocks of flats with a total built up area of 43410 m<sup>2</sup>. The heat for the housing blocks is supplied by district heating and the consumption of heat is considerably higher than one would expect in new modern apartments. The housing blocks are built as a concrete panel assembly construction in 1965-69 and just now the buildings are about to be thoroughly renovated.



Fig. 2.1 Illustration of Gyldenrisparken, Demohouse pilotproject in Denmark.

A standard renovation of the housing blocks will be carried out, but for 96 apartments in 3 blocks it is the idea to implement different levels of special energy-saving measures. One block will be renovated using an energy-saving level of 50%, level B, and one area also with 1/3 size at level A with 75% savings and finally the rest of the area with 85% savings at level A + Solar. The savings are related to the present situation.

The three renovation projects with energy-savings will be carried out as stage one, thus the experiences obtained here can be used for the blocks/apartments to follow.

### 2.1 Planned renovation of 3 apartment blocks

In the following we look at 3 housing blocks with 96 apartments in all as an example of how the project can be realised. The chosen blocks in the following are similar as to size and design. Each block holds 32 apartments with a total heated living floor space of 2880 m<sup>2</sup>.

Data for one block:

Windows	432 m <sup>2</sup>
Facades (net area)	1296 m <sup>2</sup>
Gables	240 m <sup>2</sup>
Heated area	2880 m <sup>2</sup>
Building volume	8640 m <sup>3</sup>

## 2.2 Calculations for 4 renovations scenarios

Calculations have been made for several scenarios using the national Danish Be06 calculation tool. The five investigated scenarios are:

1. Existing situation
2. Standard renovation (facades insulated with extra 100 mm mineral wool and new windows with U-value 1,4)
3. Standard renovation incl. airtightness and balanced heat recovery ventilation (infiltration at 0,1 ACH and heat recovery efficiency of 85%).
4. Scenario 3 with improved fans, windows (U-value 1,0) and extra 100 mm mineral wool in roof
5. Scenario 4 with solar DHW. 75 m<sup>2</sup> of solar collectors will supply approx. 60% of the annual DHW consumption, and with PV to match electricity use for operation of fans and pumps.

The calculated energy demands are seen below. Only Scenario 4 and 5 meet the energy demand for Low Energy Class 2, which is an ambitious goal for a renovation project.

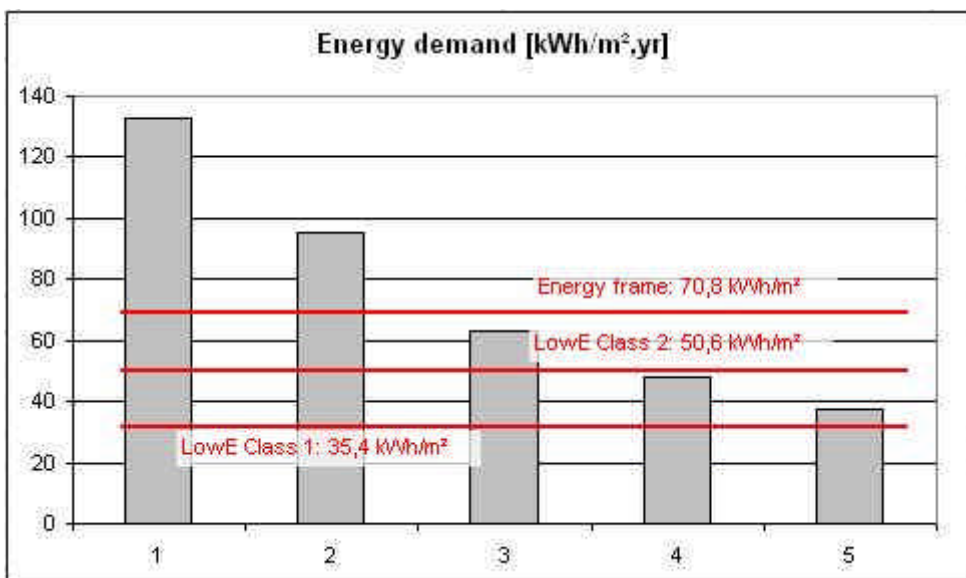


Fig. 2.2.1. Comparison between alternative energy saving scenarios compared to Danish minimum standard for new build and low energy classes 2 and 1. The energy use includes both heating, DHW and electricity use for operation times a factor of 2.5.

It can be seen that standard renovation is less good compared to the minimum demands for new builds, while scenario 3 with heat recovery ventilation and airtightness is somewhere this and low energy class 2. Scenario 4 and 5 is both between low energy class 2 and 1.

	1.	2.	3.	4.	5.	6.	7.
<b>Scenario</b>	<b>Energy demand [kWh/m<sup>2</sup>]</b>	<b>Space heating demand [kWh/m<sup>2</sup>]</b>	<b>Domestic hot water demand [kWh/m<sup>2</sup>]</b>	<b>Heating total demand (2+3) [kWh/m<sup>2</sup>]</b>	<b>Water cons. [m<sup>3</sup>]</b>	<b>Domestic hot water cons. [m<sup>3</sup>]</b>	<b>Electricity demand [kWh/m<sup>2</sup>]</b>
1. Existing situation	132,6	117,3	13,4	130,7	2880	960	2.0
2. Standard renovation	95	67,8	13,4	81,2	2736	912	13.8
3. Std. renov. + airtightness and HRV	63	42,3	13,4	55,7	2160	720	7.5
4. Above + better fans, windows and insulation	48	26,6	13,4	40	2160	720	7.5
5. Above + solar DHW and PV for ventilation	32	26,6	5,4	32	2160	720	0

Table 2.2.1. Calculated yearly consumption of hot water, heating and electricity for pumps and fans for the different energy saving scenarios.

The total yearly energy consumption of heat and domestic hot water is 130,7 kWh/m<sup>2</sup> in the existing situation. By implementing a standard renovation the energy consumption for heat will be reduced to 81,2 kWh/m<sup>2</sup>, but due to introduction of exhaust ventilation the energy demand, including electricity for operation, is here 95 kWh/m<sup>2</sup>, year..

If this is combined with measures for improved airtightness and efficient heat recovery ventilation, the heating demand will be reduced to 55,7 kWh/m<sup>2</sup>. This can be further reduced to 40 kWh/m<sup>2</sup> by using low energy windows combined with roof insulation.

The lowest energy demand is obtained with the above measures combined with a solar DHW system, which reduces the heating demand to only 32 kWh/m<sup>2</sup> which is close to the low energy class 1. This includes use of 0.3 kWp (or 3-4 m<sup>2</sup>) PV-modules.

The environmental improvement can be calculated as a reduction in the yearly CO<sub>2</sub> emission from the heat and electricity consumption. The emission of CO<sub>2</sub> per kWh produced depends on the way the heat and electricity is produced. In Copenhagen, both heat and electricity is produced at CHP plants. The electricity and heating companies calculate the average emission as yearly averages. The current (2007) values are:

Heating: 0,135 kg/kWh  
Electricity: 0,522 kg/kWh

Calculated yearly CO<sub>2</sub> emission per housing block from the heat and electricity consumption is seen in the table below.

Scenario	Energy demand [kWh/m <sup>2</sup> ]	CO <sub>2</sub> emission from heating [ton]	CO <sub>2</sub> emission from electricity [ton]	CO <sub>2</sub> emission total [ton]
1. Existing situation	133	51	18	69
2. Standard renovation	95	32	18	50
3. + airtightness and HRV	63	22	12	34
4. + better windows and insulation	47.5	16	12	28
5. + solar DHW	32	12	10.5	22.5

Table 2.2.2. Calculation of CO<sub>2</sub> emission for different energy saving scenarios.

The economy can be calculated as a pay back time. The costs for heating, electricity and water are seen below. The values are for spring 2007.

Heating: 0,07 Euro/kWh, Electricity: 0,25 Euro/kWh, Water: 3,57 Euro/m<sup>3</sup>

Based on this the costs for operation can be calculated. The total investment costs are calculated as well, based on cost estimates. The calculated pay-back times are seen in the table below. The prices are for one housing block.

Scenario	Costs, operation heating [Euro]	Costs, operation electricity [Euro]	Costs, operation water [Euro]	Costs, operation total [Euro]	Costs, investment [Euro]	Pay-back time [years]
1. Existing situation	26349	8640	10282	45271	0	0
2. Standard renovation	16370	8640	9768	34777	345.942	33
3. + airtightness and HRV	11229	5760	7711	24700	433.142	9
4. + better windows and insulation	8064	5760	7711	21535	628.373	21
5. + solar DHW and PV for ventilation	6451	5040	7711	19202	675.873	21

Table 2.2.3. Costs and payback time for different energy saving scenarios for one housing block with 32 apartments.

Extra costs for scenario 3 compared to scenario 2 are not very high (2.700 Euro per apartment for HRV and airtightness). This is due to the developed low cost Danish HRV unit which was developed in connection to the Demohouse project. This leads to 9 years payback time.

Payback time for scenario 3 with HRV and airtightness is  $87.200 / 10.077 = 9$  years, while for scenario 4 with better insulation and windows it is  $282.431 / 13.242 = 21$  years. For an energy class 1 solution with solar DHW and PV the payback time is  $47.500 / 2333 = 21$  years.

It is seen that the standard renovation has a longer pay-back time than the scenarios with better energy performance. The reason for this is, that the HRV system combined with measures for improving airtightness is a cost-effective way to reduce energy demand, while performing insulation of existing buildings can be costly.

The optimal scenario is scenario 3, as it has a reasonable pay-back time of 9 years while offering the largest reduction in both energy consumption and CO<sub>2</sub> emission. The expected life-time of technical installations is 20-25 years, for windows at least 30 years, and 50-100 years for the extra insulation. In that perspective scenario 4 is a good investment, but it also requires a larger investment. Scenario 5 which includes solar DHW and PV also have a quite long pay back time of 20 years, but if district heating can be stopped in the summer, the economy can be better due to saved distribution losses. This however needs to be done for the whole estate to function well. In Annex 1 is shown similar calculation for individual technologies together with input data for the calculations.

The figures below give an overview of the CO<sub>2</sub> emission reduction and pay-back times for the 4 scenarios compared to the existing building.

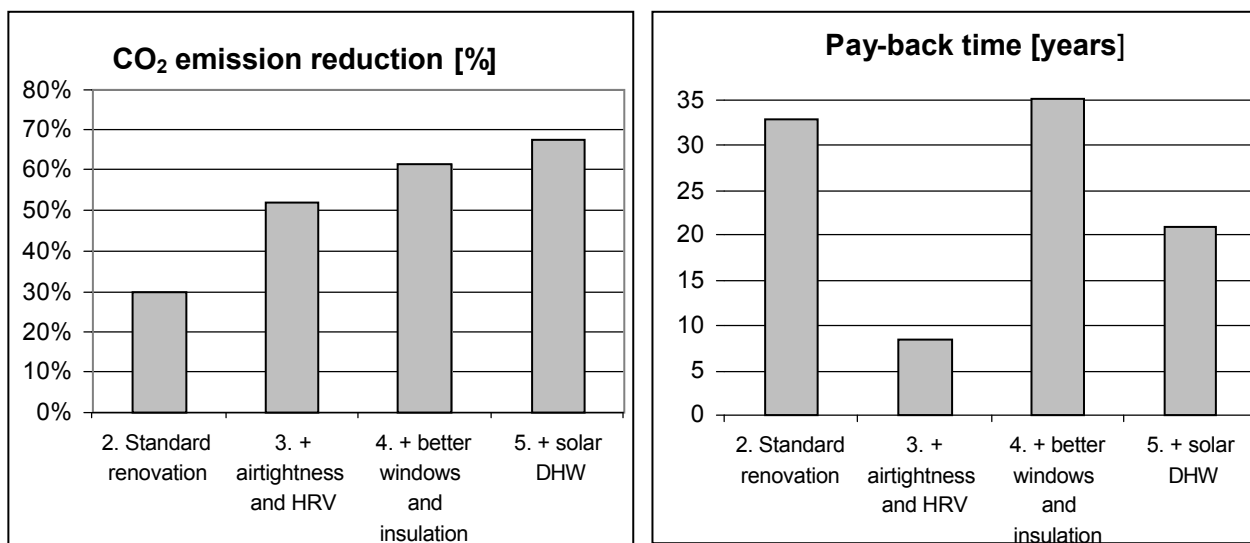


Fig. 2.2.2.. Diagrammes of CO<sub>2</sub> emission reduction and payback time for different energy saving scenarios.

Performing a standard renovation will cause a CO<sub>2</sub> emission reduction of 30% while it is possible to achieve 73% with the best scenario.

### **3 Austrian demonstration project Laudongasse 14/16 and Starhembergasse 13/15, Graz**

#### **3.1 General description**

The Austrian pilot project is two blocks of flats in the city of Graz: Laudongasse 14-16 as well as Starhembergasse 13-15. Both buildings were constructed in 1976 and they consist of 127 flats (between 75 and 110 square meters each). The characteristics of the building are summarised below:

- Constructed in 1975-76, district heating since 1991
- 127 rented dwellings (between 75 and 110 square meters each)
- Total heated living floor space of 9857 m<sup>2</sup>
- Gross floor area 12643 m<sup>2</sup>
- Gross volume (heated) 38910 m<sup>3</sup>
- Area of exterior walls 11082,1 m<sup>2</sup>
- Roof (Area) 1257,3 m<sup>2</sup>
- Area of floor above passage 558,6 m<sup>2</sup>
- Floor area above unheated Basement 698,7 m<sup>2</sup>
- Windows (rough frame opening) 2238,8 m<sup>2</sup>

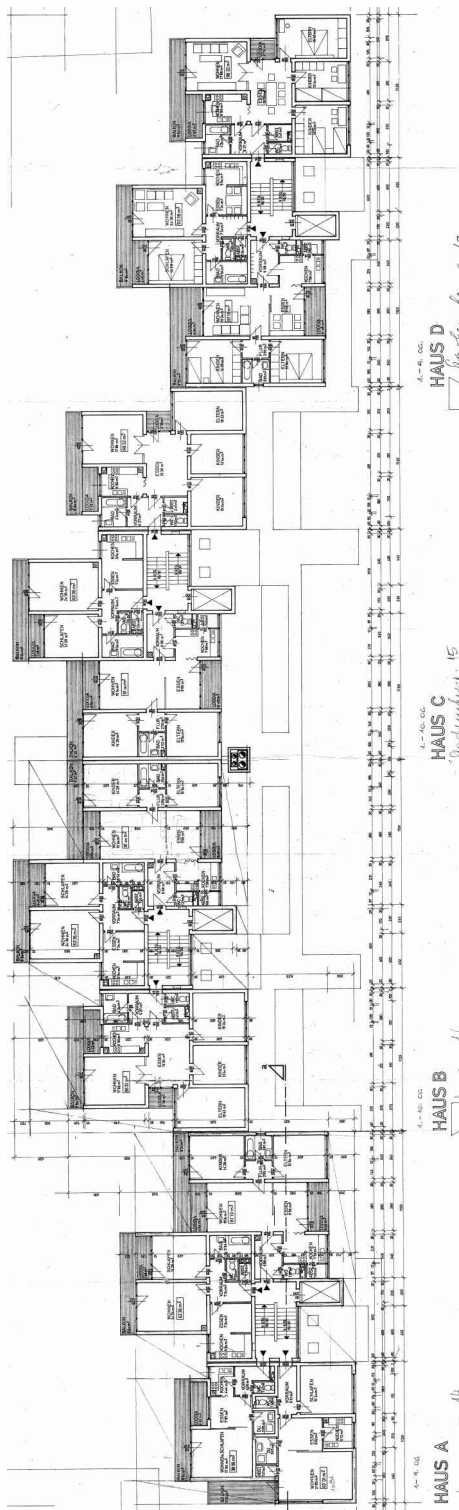


Fig. 3.1.1. Plans and photos of Austrian demonstration project.

### 3.2 Scenarios

Energy calculations have been made for 6 scenarios using Energy-10 (dynamic simulation programme). The calculation of the pay-back time has been done by a dynamic amortisation calculation with an adequate target rate of 3 %. Annual energy costs are based on the energy costs status: 01.01.2006 / Energie Graz (energy agency Graz), all quoted costs are calculated without VAT. The investigated scenarios are:

#### 1. Existing building

The outer walls are wood-fibre coated concrete and isolating plaster with a total thickness of 330 mm and an U-value of 1,42 W/m<sup>2</sup>K. The flat roof has an U-Value of 1,19 W/m<sup>2</sup>K and the existing windows are constructed as wooden windows with compound double glazing with an U-value of 2,30 W/m<sup>2</sup>K. Space heating and hot water supply are provided by the district heating net of the city of Graz. The energy consumption of the existing building for space heating is 137,67 kWh/m<sup>2</sup> gross area/a.

#### 2. Reference building

The reference building is a virtual renovation of the existing building based on the Austrian building standard from the year 2003. The outer walls are insulated with 6 cm of mineral wool, which gives an U-value of 0,45 W/m<sup>2</sup>K, the U-value of the flat roof is upgraded to 0,21 W/m<sup>2</sup>K. Glass of the new windows has an U-value of 1,90 W/m<sup>2</sup>K and the frames have been calculated with an U-value of 2,20 W/m<sup>2</sup>K. The energy consumption of the reference building for space heating is 70,69 kWh/m<sup>2</sup> gross area/a.

#### 3. Reference building + better insulation facade

Scenario 3 is scenario 2 with an improved insulation (10 cm of mineral wool) of the façade, which leads to an U-value of 0,31 W/m<sup>2</sup>K. The energy consumption of scenario 3 for space heating is 63,43 kWh/m<sup>2</sup> gross area/a.

#### 4. Reference building + better windows

Scenario 4 is the reference building with improved windows. Glass of the new windows has an U-value of 1,10 W/m<sup>2</sup>K and the frames have been calculated with an U-value of 1,50 W/m<sup>2</sup>K. The energy consumption of the reference building for space heating is 58,66 kWh/m<sup>2</sup> gross area/a.

#### 5. Reference building + measures 3 and 4

Scenario 5 is the reference building with measures of scenario 3 and 4 (improved insulation façade and improved windows). The energy consumption of the reference building for space heating is 47,96 kWh/m<sup>2</sup> gross area/a.

#### 6. Demonstration building

The demonstration building is scenario 5 with the implementation of a combined heat and power plant (CHP plant). This measure contributes nothing to the minimisation of the energetic and financial performance, but has strong impact on the CO<sub>2</sub> performance of the whole project. Production of heat for hot water and electricity for the local grid will be the output of the planned CHP. Detailed facts of the biomass CHP:

- 37 kW electrical output, 236 MWh green electricity
- 62 kW heat output, 400 MWh heat per year for hot water

### 3.3 Results

#### 3.3.1 Energy

The calculated energy demands for space heating are seen below. Energy savings between scenario 1 (existing building) and scenario 2 (reference building, standard renovation) are almost 50 %. Single measures (better windows, improved insulation) in scenarios 3 and 4 showing lower energy saving potentials. Only the implementation of both measures leads to a decrease of 33% of heating energy demand between scenario 2 (reference building) and scenario 6 (demonstration building) or scenario 5. As already mentioned from scenario 5 to scenario 6 there is no decrease of energy, because the CHP has only influence on the environmental performance.

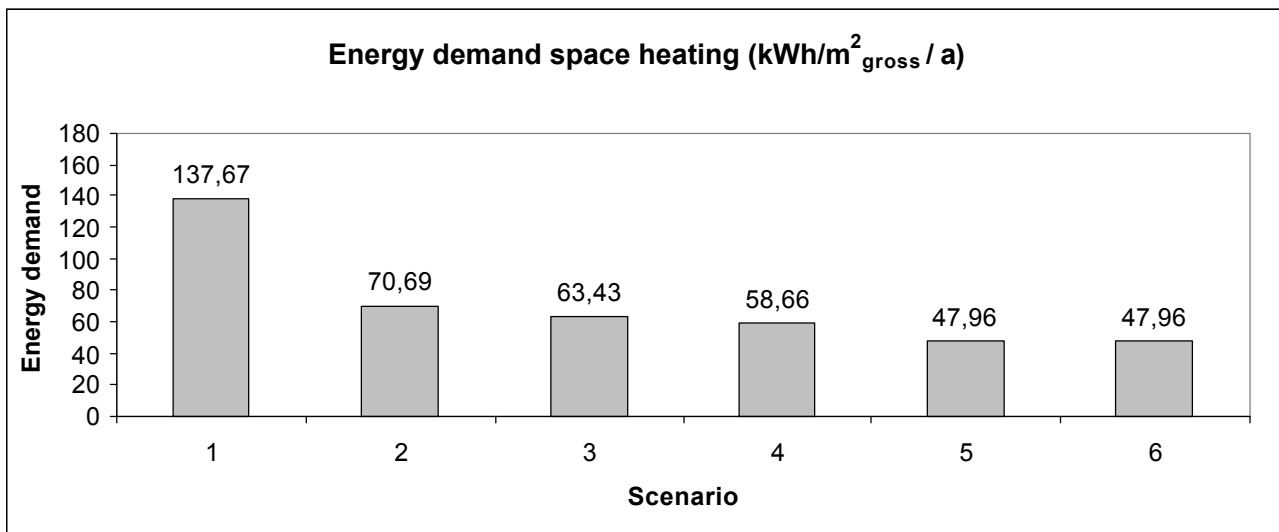


Fig. 3.3.1.1

The table below shows the calculated yearly consumption of water, heat and electricity. As there have been only measures for the decrease of the heating energy consumption in the Austrian demonstration building hot water demand and electricity demand are unaltered.

Scenario	Heating energy demand kWh/m <sup>2</sup> <sub>gross</sub> /a	Hot water services kWh/m <sup>2</sup> <sub>gross</sub> /a	Heating total demand kWh/m <sup>2</sup> <sub>gross</sub> /a	Electricity demand kWh/m <sup>2</sup> <sub>gross</sub> /a	Energy demand total kWh/m <sup>2</sup> <sub>gross</sub> /a
1 Existing building	137,67	31,24	168,91	27,05	195,96
2 Reference building	70,69	31,24	101,93	27,05	128,98
3 Reference + better insulation facade	63,43	31,24	94,67	27,05	121,72
4 Reference + better windows	58,66	31,24	89,90	27,05	116,95
5 Reference + measures 3 and 4	47,96	31,24	79,20	27,05	106,25
6 Demonstration building	47,96	31,24	79,20	27,05	106,25

Table 3.3.1.1

#### 3.3.2 CO<sub>2</sub> Emissions

Reduction of CO<sub>2</sub> emissions will be achieved by two measures:

- Decrease of heating energy demand
- Combined heat and power plant (CHP plant)

Data for CO<sub>2</sub> emissions are based on GEMIS Austria, an official data source, run by the Austrian government. The values are:

- Existing district heating - heating: 0,138 kg/kWh final energy
- Existing district heating – hot water: 0,138 kg/kWh final energy
- Existing electricity from the grid: 0,620 kg/kWh
- CHP heating – hot water: 0,005 kg/ kWh final energy
- CHP electricity: 0,040 kg/kWh

Calculated yearly CO<sub>2</sub> emission of the 6 scenarios from the heat and electricity consumption is seen in the table below.

Scenario	CO2 emission from heating kg / a	CO2 emission from hot water services kg / a	CO2 emission heating total kg / a	CO2 emission electricity kg / a	CO2 emission total kg / a
1 Existing building	240.198	54.510	294.708	212.040	506.748
2 Reference building	123.335	54.510	177.845	212.040	389.885
3 Reference + better insulation facade	110.668	54.510	165.178	212.040	377.218
4 Reference + better windows	102.346	54.510	156.856	212.040	368.896
5 Reference + measures 3 and 4	83.677	54.510	138.187	212.040	350.227
6 Demonstration building	83.677	1.975	85.652	75.130	160.782

Table 3.3.2.1

The table above shows the huge impact on CO<sub>2</sub> emissions of the CHP. From scenario 2 (reference building) to scenario 5 (reference building + improved insulation façade and better windows) there is only a decrease of 11 %, whereas from scenario 2 (reference building) to scenario 6 (demonstration building, with CHP) there is a decrease of 59 %. Energy efficient cogeneration of energy for electricity and for hot water and the use of use vegetable oil (e.g. oil from canola, corn) provide huge reductions of CO<sub>2</sub> emissions.

### 3.3.3 Costs

The calculation of the pay-back has been done by a simple pay-back time model. Annual energy costs are based on the energy costs status: 01.01.2006 / Energie Graz (energy agency Graz), all quoted costs are calculated without VAT.

Based on this the costs for operation have been calculated. The cleared (final) building costs will be available end of 2007, so the total investment costs are based on cost estimates. The calculated pay-back times are seen in the table below.

Table 3.3.3.1.

Scenario	Costs operation heating Euro/a	Costs operation hot water services Euro/a	Costs operation electricity Euro/a	Costs operation total Euro/a	Costs investment Euro/a	simple pay-back time
1 Existing building	112.934	23.909	48.617	185.460	0	
2 Reference building	58.112	23.909	48.617	130.638	1.023.242	19
3 Reference + better insulation facade	52.841	23.909	48.617	125.367	1.139.979	19
4 Reference + better windows	49.378	23.909	48.617	121.904	1.046.412	16
5 Reference + measures 3 and 4	39.796	23.909	48.617	112.322	1.163.149	16
6 Demonstration building	39.796	23.909	48.617	112.322	1.277.149	17

Scenario 2 (reference building, standard renovation) and scenario 3 (reference building + better insulation façade) have longer pay-back times then scenarios 4, 5 and 6. Best pay-back time with 16 years offers scenario 4 + 5, as the demonstration building has 17 years because of the CHP, which provides no reduction of energy consumption (only CO<sub>2</sub> relevant measure). The service life of the relevant components can be calculated as stated below:

- Insulation of the façade (thermal insulation composite system) circa 50 years
- Plastic windows circa 40 years
- CHP circa 25 years

In perspective of above mentioned expected life-time, pay-back times for all scenarios are acceptable, whereas the high potential of CO<sub>2</sub> reduction from the CHP should justify the higher investment costs for scenario 6.

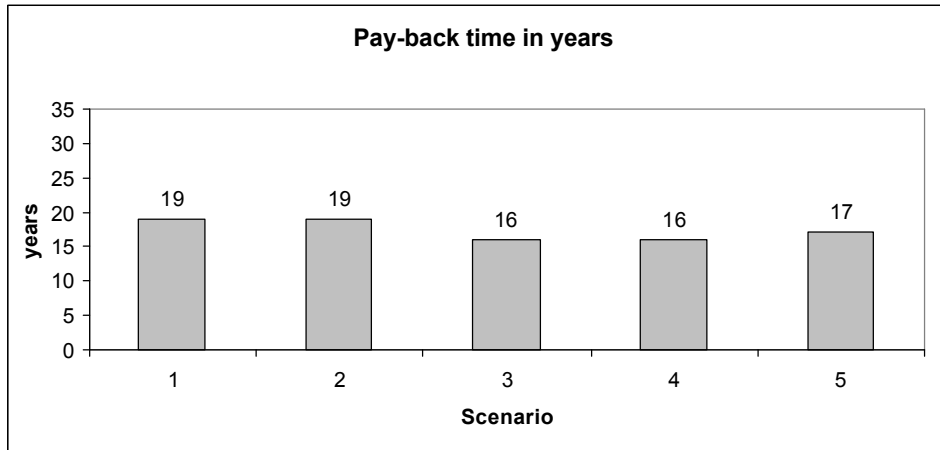


Fig. 3.3.3.1. Payback time for different scenarios.

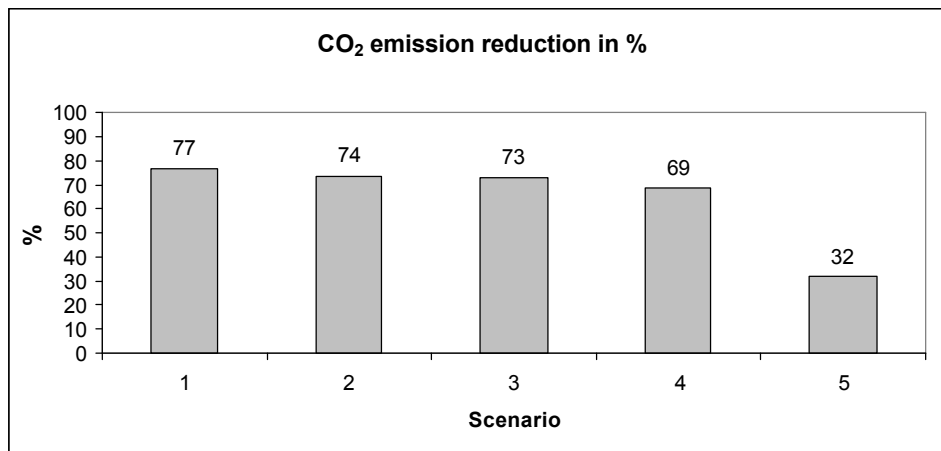


Fig. 3.3.3.2. CO<sub>2</sub> reduction for different scenarios.

#### 4 Greek demonstration project Manetas, Agiostratitis and Rizos

##### Data for building 1 (manetas):

Windows	155 m <sup>2</sup>
Facades (net area)	414 m <sup>2</sup>
Heated area	919 m <sup>2</sup>
Building volume	2575 m <sup>3</sup>

##### Data for building 4 (agiostratitis):

Windows	138.86 m <sup>2</sup>
Facades (net area)	596 m <sup>2</sup>
Heated area	938 m <sup>2</sup>
Building volume	2519m <sup>3</sup>

##### Data for building 2,3 (rizos):

Windows	102 m <sup>2</sup>
Facades (net area)	703 m <sup>2</sup>
Heated area	930 m <sup>2</sup>
Building volume	2511m <sup>3</sup>

In the Greek project, in order to reduce the energy consumption of the dwellings, the proposed techniques deal with the building envelope (extra insulation), the ventilation systems, the use of passive heating and cooling systems and the use of management systems. Therefore, the CO<sub>2</sub> emissions are calculated with regard to the proposed heating and cooling systems.

Scenario – Building 1(manetas)	Energy demand [kWh/m <sup>2</sup> ]	CO2 emission from heating (space heating) [ton]	CO2 emission from electricity (for cooling) [ton]	CO2 emission total [ton]
1. Situation before renovation according to build regulations	129.84	68	15	83
2. Standard renovation (improved thermal insulation, glazing, ceiling fans, night ventilation)	85.7	31	12	43
3. Renovation as standard renovation + heat recovery and heat earth exchangers	40.36	31	2	33

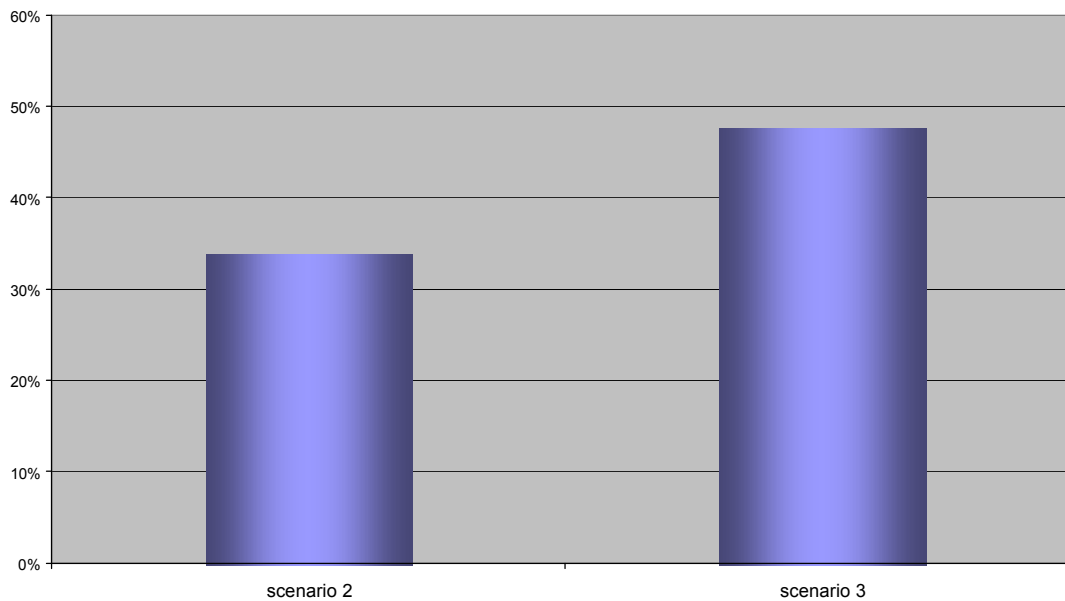
Scenario – Building 2 (Rizos)	Energy demand [kWh/m <sup>2</sup> ]	CO2 emission from heating (space heating) [ton]	CO2 emission from electricity (for cooling) [ton]	CO2 emission total [ton]
1. Situation before renovation according to build regulations	111.25	73	9.8	82.8
2. Standard renovation (improved thermal insulation, glazing, ceiling fans, night ventilation)	84.63	51	8	59
3. Renovation as standard renovation + heat recovery and heat earth exchangers	61.79	48	3.8	51.8

Scenario – Building 4 (Agiostatitis)	Energy demand [kWh/m <sup>2</sup> ]	CO2 emission from heating (space heating) [ton]	CO2 emission from electricity (for cooling) [ton]	CO2 emission total [ton]
1. Situation before renovation according to build regulations	82.32	58	6	64
2. Standard renovation (improved thermal insulation, glazing, ceiling fans, night ventilation)	60.01	40	4.5	44.5
3. Renovation as standard renovation + heat recovery and heat earth exchangers	40.31	23	3.67	26.67

Calculations have been made for three scenarios. The investigated scenarios are:

1. Situation according to the building regulations
2. Standard renovation (facades insulated with extra 40 mm extruded polystyrene, roof extra insulated with 100mm extr polystyrene and new windows with U-value 1,4, ceiling fans and night ventilation)
3. Renovation as case 2 incl. heat recovery ventilation and earth cooling (buried pipes)

**CO<sub>2</sub> reduction (%) for all DEMOHOUSE dwellings**



CO<sub>2</sub> conversion factors

mains electricity: kWh \*0.43= .. kgCO<sub>2</sub> <http://www.nef.org.uk>

(density of CO<sub>2</sub> = 1.965 g/m<sup>3</sup>) [www.depa.gr](http://www.depa.gr)

oil: kWh \*2.31= .. kgCO<sub>2</sub>

\*Heating will be provided by oil-fired boilers

\* Units of air-conditioning will be installed for cooling only after the occupants' request as it is assumed that the proposed techniques of passive cooling will reduce-minimise its use.

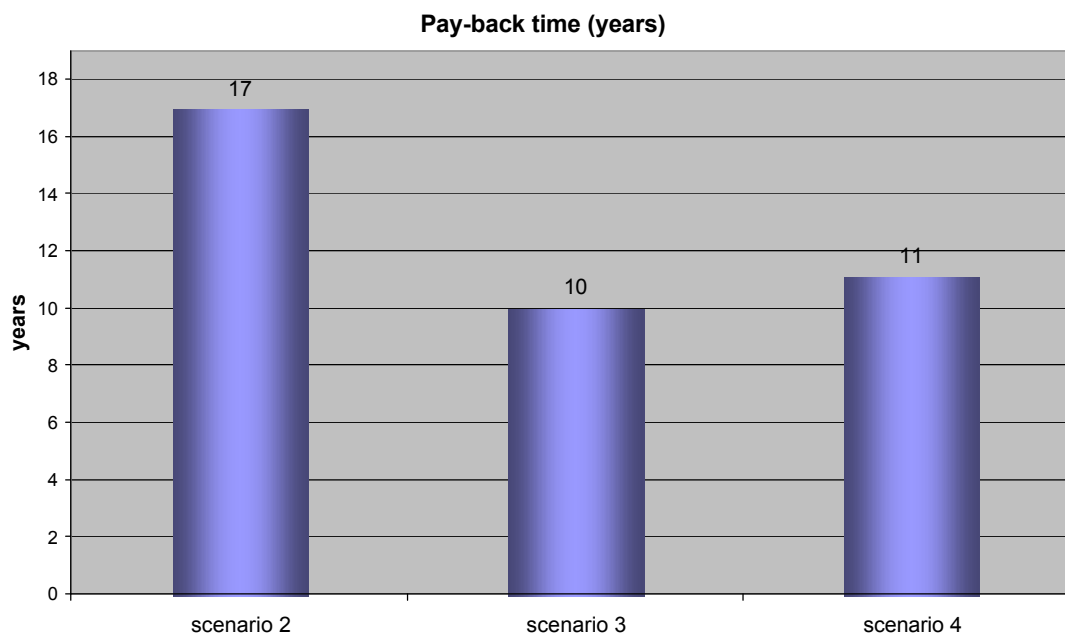
The economy can be calculated as a pay back time. The costs for heating and electricity are seen below. The values are for spring 2007.

Heating (oil): 0,06 Euro/kWh

Electricity for cooling: 0,119 Euro/kWh

Based on this the costs for operation can be calculated. The total investment costs are calculated as well, based on cost estimates. The calculated pay-back times are seen in the table below.

<b>Scenario – ALL BUILDINGS</b>	Costs, operation heating [Euro]	Costs, operation electricity [Euro]	Costs, operation total [Euro]	Costs, investment [Euro]	Pay-back time [years]
1. Situation before renovation according to build regulations	<b>15,258</b>	<b>30,499</b>	<b>45,757</b>	-	-
2. Standard renovation (improved thermal insulation, glazing, ceiling fans, night ventilation)	<b>9,777</b>	<b>16,631</b>	<b>26,408</b>	146,486	17
3. Renovation as standard renovation + heat recovery and heat earth exchangers	<b>5,252</b>	<b>12,522</b>	<b>17,774</b>	210,326	10
4. Renovation as standard renovation + heat recovery and heat earth exchangers+ BMS	<b>7,879</b>	<b>12,379</b>	<b>20,258</b>	426,326	11



## 5 Spanish demonstration project Cortes 34

Up to this moment standard building renovation in Spain involve very low concern related to energy savings and actions are usually focused on structural reinforcement (safety requirements), aesthetical refurbishment of façades, waterproof improvement and recently lift installation. In this framework, there is an important potential for energy efficiency in renovation of buildings, being some of them in very poor conditions.

Concerning the Spanish pilot building (Cortes 34) three scenarios have been considered for energy saving:

- Building before renovation: very poor constructive quality
- Virtual Building: Renovation according to standard practice in building renovation
- Actual Renovation: Renovation according to sustainable measures defined within Demohouse project.

According to energy performance simulations carried out within the project, following energy consumption have been estimated for each one of the scenarios. The following tables includes annual results of energy consumption in terms of KWh/m<sup>2</sup> and energy consumption for each dwelling (average area of 40 m<sup>2</sup>).

<b>ENERGY</b>						
<b>CORTES</b>	<b>BEFORE RENOV.</b>	<b>VIRTUAL</b>	<b>RENOVATED</b>	<b>BEFORE RENOV.</b>	<b>VIRTUAL</b>	<b>RENOVATED</b>
	<b>Gross energy demand (KWh/m<sup>2</sup>year)</b>	<b>Gross energy demand (KWh/m<sup>2</sup>year)</b>	<b>Gross energy demand (KWh/m<sup>2</sup>year)</b>	<b>Gross energy demand (KWh/year)</b>	<b>Gross energy demand (KWh/year)</b>	<b>Gross energy demand (KWh/year)</b>
<b>Q (heating)</b>	245	175	55	9810	7000	2198
<b>Q (hot water)</b>	49	49	25	1980	1980	990
<b>Q (lighting)</b>	19	19	18	743	755	714
<b>Q (equipment)</b>	4	4	4	160	160	160
<b>Q (thermal total)</b>	295	224	55	11790	8980	2198
<b>Q (electric equipment)</b>	23	23	22	903	915	874
<b>TOTAL</b>	<b>317</b>	<b>247</b>	<b>77</b>	<b>12693</b>	<b>9894</b>	<b>3072</b>
<b>REDUCTION</b>		<b>22 %</b>	<b>76 %</b>		<b>22 %</b>	<b>76 %</b>

Table 5.1

It can be clearly seen that the initial situation is very energy wasting with huge energy demands, due to the bad conditions of the buildings before renovation. Standard renovation provides a significant improvement of about 22% energy savings. However, actual renovation will achieve the energy performance around 75 % out of previous situation and 68 % out of standard renovation.

<b>CO2 EMISSIONS</b>						
<b>CORTES</b>	<b>BEFORE RENOV.</b>	<b>VIRTUAL</b>	<b>RENOVATED</b>	<b>BEFORE RENOV.</b>	<b>VIRTUAL</b>	<b>RENOVATED</b>
	<b>Emissions CO2 (Kg/m<sup>2</sup>year)</b>	<b>Emissions CO2 (Kg/m<sup>2</sup>year)</b>	<b>Emissions CO2 (Kg/m<sup>2</sup>year)</b>	<b>Emissions CO2 (Kg/year)</b>	<b>Emissions CO2 (Kg/year)</b>	<b>Emissions CO2 (Kg/year)</b>

<b>Q (heating)</b>	47	34	11	1892	1350	424
<b>Q (hot water)</b>	10	10	5	382	382	191
<b>Q (lighting)</b>	4	4	3	143	146	138
<b>Q (equipment)</b>	1	1	1	31	31	31
<b>Q (thermal total)</b>	57	43	15	2274	1732	615
<b>Q (electric equipment)</b>	4	4	4	174	176	169
<b>TOTAL REDUCTION</b>	<b>61</b>	<b>48</b> <b>22 %</b>	<b>20</b> <b>68 %</b>	<b>2448</b>	<b>1908</b> <b>22 %</b>	<b>783</b> <b>68 %</b>

Table 5.2

These energy consumptions are translated into CO<sub>2</sub> emissions according to emissions associated to natural gas combustion and according to energy mix of the electricity consumed in Basque Country. It is also clear that the CO<sub>2</sub> emission reduction is significant and it is proved that renovation of buildings is a very relevant field where the decrease of greenhouse emissions has a great potential.

Energy savings can be translated not only into environmental benefits but also in economical terms. By means of a simple economical analysis following results can be obtained. Following energy rates have been considered (extracted from the Comisión Nacional de Energía – Spanish National Energy Commission):

Heating: 0,045 €/KWh  
Electricity: 0,100 €/KWh

<b>COSTS</b>						
<b>CORTES</b>	<b>BEFORE RENOV.</b>	<b>VIRTUAL</b>	<b>RENOVATED</b>	<b>BEFORE RENOV.</b>	<b>VIRTUAL</b>	<b>RENOVATED</b>
	<b>Operation costs (euro/m2year)</b>	<b>Operation costs (euro/m2year)</b>	<b>Operation costs (euro/m2year)</b>	<b>Operation costs (euro/year)</b>	<b>Operation costs (euro/year)</b>	<b>Operation costs (euro/year)</b>
<b>Q (heating)</b>	11,23	8,01	2,52	449	321	101
<b>Q (hot water)</b>	2,27	2,27	1,13	91	91	45
<b>Q (lighting)</b>	1,86	1,89	1,78	74	75	71
<b>Q (equipment)</b>	0,40	0,40	0,40	16	16	16
<b>Q (thermal total)</b>	13,50	10,28	4	540	411	146
<b>Q (electric equipment)</b>	2,26	2,29	2	90	91	87
<b>TOTAL REDUCTION</b>	<b>16</b>	<b>13</b> <b>20 %</b>	<b>6</b> <b>63 %</b>	<b>630</b>	<b>503</b> <b>20 %</b>	<b>233</b> <b>63 %</b>

Table 5.3

According to the results very it is clear that relevant economical savings can be achieved

through the improvement of the energy performance of the building, which should be other important incentive to encourage these renovation actions. Money savings estimated for the Demohouse building will be higher than 50% out the standard renovation (virtual building).

These results do not include electricity production generated by photovoltaic modules of the roof, which are estimated around 2500 euros/year (based on current national law on renewable energy production). Considering this figure, a payback time rate of approximately 25 years is estimated (total savings: 5900 euros/year).

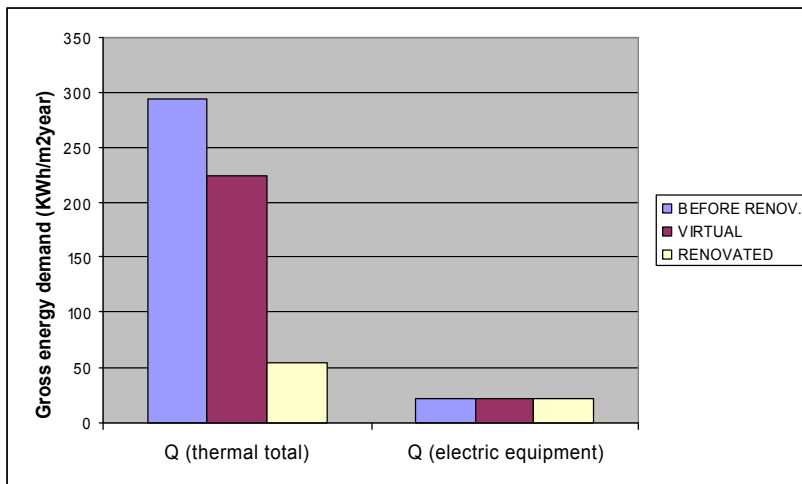


Fig. 5.1

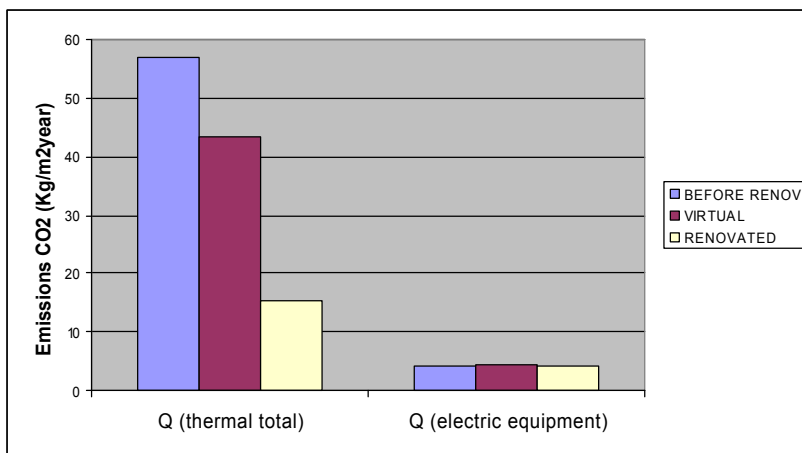


Fig. 5.2

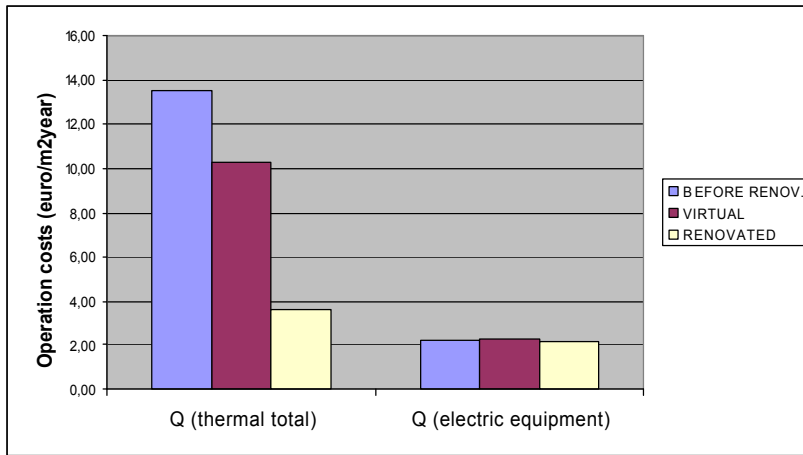


Fig. 5.3

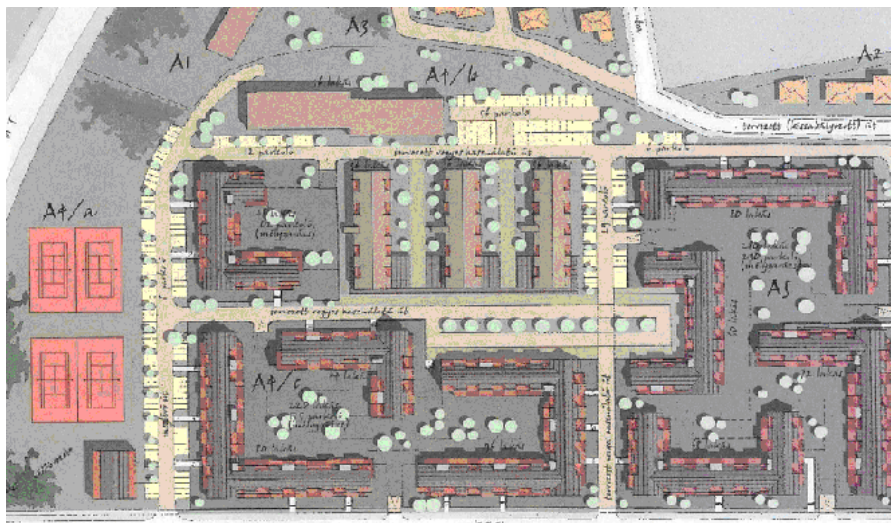
## 6 Hungarian demonstration project in Újpest, Budapest

### Basic data:

- Address: Újpest, Budapest, Hungary
- Typology: Before: military building, After: residential building, social housing
- Year of construction: 1955-1960
- Total original floor area of one block: 2100 m<sup>2</sup>, 3 storeys
- Total floor area of one block after retrofit: 2856 m<sup>2</sup>, 5 storeys (built-in attic)
- Responsible project partner: EMI, Non-profit Company for Quality Control and Innovation in Building

### 6.1 Context

The project site is situated at the northern border of Budapest, in Újpest, close to the planned M0 outer ring motorway, the M2 national highway and the Danube River. It is a former military area, where the buildings were mostly demolished, and a new canalisation-system has been established. The project aims at the retrofit of the remaining three empty buildings by transforming them into social residential buildings. In the neighbourhood area a new housing block was established in 2006, the dwellings were sold and the new tenants/owners now live there.



**Figure: Layout and photo of the project area**

Fig. 6.1.1



**Figure: The project building before and after the retrofit**

..... Fig. 6.1.2

## 6.2 Main energy saving measures

### *Roof-top apartments*

In addition to the renovations, it is also planned to build a new pitch roof and establish roof-top apartments. The roof will be built with high thermal resistance ( $U = 0,2 \text{ Wm}^2/\text{K}$ ). As the main axis of the roof is North and South, for the better orientation of the solar systems a flat roof area is planned between the two West-East oriented pitch roofs. For natural ventilation and natural lighting integrated roof windows are planned.

### *Building envelope*

The internal walls will be demolished and new light-weight partition walls will be erected. The external walls and the size of the openings remain, but ETICS will be mounted on the walls. In the three buildings, thermal insulation of different thickness will be applied (6, 12 and 20 cm). Here lower heat conductance polystyrene will be implemented, achieving better thermal insulation with the same thickness. New low-e windows ( $U = 0,8 \text{ Wm}^2/\text{K}$ ) with external shading will be installed.

### *Ventilation*

After the retrofit, the air-tightness of the building is expected to improve significantly. An effective mechanical ventilation system is planned (with partial heat recovery), which is not a current practice in Hungary. We plan to run the ventilation from a renewable power supply by installing PV modules on the flat part of the roof. In the initial phase the produced electricity

will be sold to the net, as green electricity yields higher prices. Later, when this benefit will be not the case, the electricity will be used to assist the ventilation.

In the first demo phase the PV-tower assisted heat recovery ventilation system will be installed and tested in the reference building in three flats. Here the efficiency, the relative humidity, the acoustic load and the user behaviour will be tested.

### Heating

In one of the buildings, we will use biomass wood chip burner and solar thermal collectors for heating and domestic hot water, which is a new integrated system in Hungary. The two other buildings will be equipped with gas burners, also assisted with thermal collectors. In the initial phase 1 m<sup>2</sup> collector surface/ dwelling is planned, but the system will have the opportunity of a later extension of 2.5 m<sup>2</sup> collector surface/dwelling. The collectors will be installed on the flat roof.

### Water and waste

Reuse of rain water and selective waste management system is also planned.

## 6.3 Energy saving potential

The investigated scenarios are:

- Scenario 1: existing building: masonry walls without insulation, single glazed windows.
- Scenario 2: standard retrofit (reference building): external walls with 8 cm EPS, roof with 16 cm MW, cellar ceiling with 6 cm EPS, double glazed windows ( $U_{\text{window}} = 1,6 \text{ W/m}^2\text{K}$ ), gas-fired boiler central heating.
- Scenario 3: better insulation, better windows and balanced heat recovery ventilation: external walls with 20 cm EPS, roof with 30 cm MW, cellar floor 20 cm EPS,  $U_{\text{window}} = 0,8 \text{ W/m}^2\text{K}$ .
- Scenario 4: + solar collectors supporting DHW and rain water utilisation.

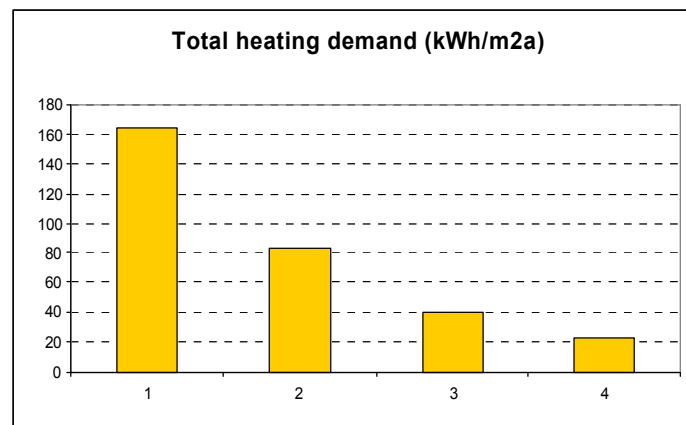
The calculated heating energy demand (space heating and DHW), the electricity demand and the water consumption are shown in the following Table and Figure.

Scenario	Space heating demand [kWh/m <sup>2</sup> ]	Domestic hot water demand [kWh/m <sup>2</sup> ]	Heating total demand [kWh/m <sup>2</sup> ]	Water cons. [m <sup>3</sup> ]	Domestic hot water cons. [m <sup>3</sup> ]	Electricity demand [kWh/m <sup>2</sup> ]
1. Existing situation	125,3	38	163,3	8190	2680	25
2. Standard renovation (reference building)	52,7	30	82,7	7700	2115	25
3. Above + better windows and insulation + heat recovery	10,24	30	40,24	7700	2115	18
4. Above + solar DHW + rain water use	10,24	12	22,24	4900	2115	18

Table 6.3.1

The energy demand for space heating is 125,3 kWh/m<sup>2</sup>a, which can be reduced to less than half (52,7 kWh/m<sup>2</sup>a) by standard retrofit measures complying with the new energy performance regulation (EPBD). If we apply even better insulation, high quality windows and balanced ventilation with heat recovery, we can cut the demand to below 15 kWh/m<sup>2</sup>a. This corresponds to the German passive house standard.

In scenario 4, the solar collectors are able to cover about 60-70 % of the annual hot water demand. The total water consumption is reduced by water saving taps and toilets and the utilisation of rain water. The electricity demand is decreased by applying energy saving light bulbs, etc.



*Fig. 6.3.2*

#### 6.4 Greenhouse gas emissions

Energy saving corresponds to the reduction of greenhouse gas emissions responsible for climate change. The cumulative greenhouse emissions - expressed as CO<sub>2</sub>-equivalent - caused by gas firing and electricity use are taken from the ecoinvent database. This database contains Western European life cycle inventories, but we changed the relevant modules to Hungarian conditions.

The values used in the calculations are:

Heating:

- Before retrofit: 0,332 kg CO<sub>2</sub>-eq/kWh (atmospheric, non-modulating gas boiler)
- after retrofit: 0,311 kg CO<sub>2</sub>-eq/kWh (modulating gas boiler)

Electricity: 0,598 kg CO<sub>2</sub>-eq/kWh

The following Table and Figure show the greenhouse gas emissions from heating and electricity use and the saving potential of the different scenarios. A standard retrofit already cuts down the emissions to 60 %. With better insulation and balanced ventilation the emissions are only 34 % of the original, which can be further reduced if solar collectors are applied (26 %). The values refer to the operation, the emissions caused by the production of the extra insulation, collectors etc. are not taken into account, however, these are usually negligible compared to the savings in the operation.

Scenario	Greenhouse gas emissions from heating [t CO2-eq]	Greenhouse gas emissions from electricity [t CO2-eq]	Greenhouse gas emissions total [t CO2-eq]
1. Existing situation	155	43	198
2. Standard renovation	73	43	116
3. + better insulation and heat recovery	36	31	66
4. + solar DHW	20	31	51

Table 6.4.1

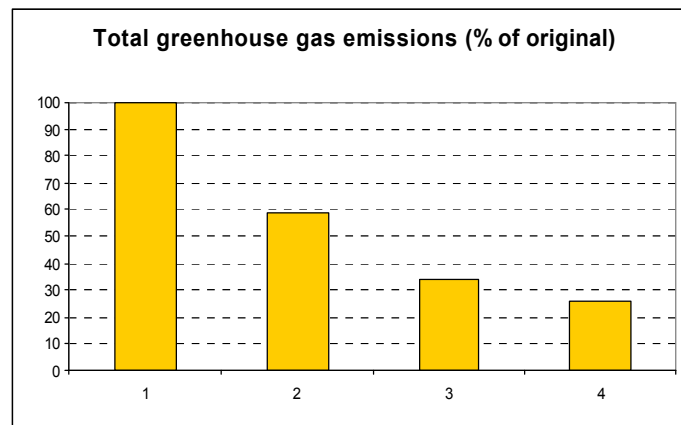


Fig. 6.4.1

### 6.5 Payback time

For the calculation of the simple payback time of the investment, the following operation costs were used (Hungary, 2007, with VAT):

Heating: 0,0391 Euro/kWh ([www.fogaz.hu](http://www.fogaz.hu))  
 Electricity: 0,156 EUR/kWh ([www.elmu.hu](http://www.elmu.hu))  
 Water: 0,732 Euro/m<sup>3</sup> ([www.vizmuvek.hu](http://www.vizmuvek.hu))

The investment cost of the different scenarios was estimated. The payback time of the scenarios is shown in the following Table. The payback time of the standard retrofit is 41 years, which is longer than the payback time of the scenarios with special energy conscious measures.

The payback time is over 35 years in every case, which is rather long. This can be partly explained by the relatively cheap energy prices. In spite of the recent dramatic price hikes, energy prices in Hungary are still well below the European average. However, prices are expected to converge to the European level. The other reason for the long payback time is that the investment costs have already reached the European level.

Scenario	Costs, operation heating [Euro]	Costs, operation electricity [Euro]	Costs, operation water [Euro]	Costs, operation total [Euro]	Costs, investment [Euro]	Payback time [years]
1. Existing situation	18245	11138	5995	35378	0	0
2. Standard renovation	9240	11138	5636,4	26015	380000	41
3. + better insulation and heat recovery	4496	8020	5636,4	18152	680000	39
4. + solar DHW	2485	8020	3586,8	14091	740000	35

Table 6.5.1

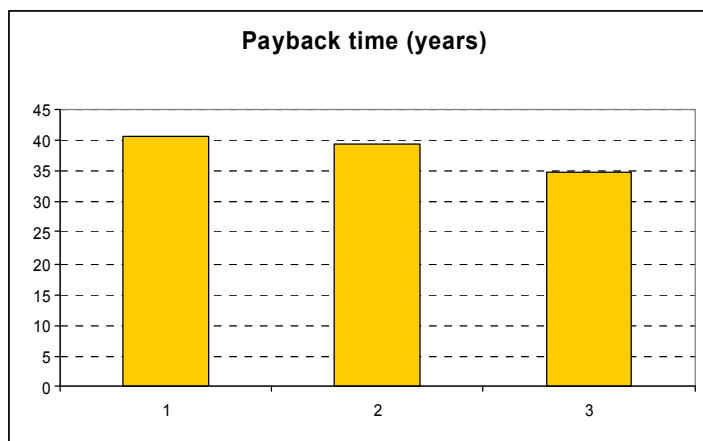


Fig. 6.5.1

## **7 Solving the split incentives problem**

It is important to look at solutions to solve the split incentive problem, where one party is responsible for the energy savings investments (the housing company) and another party will benefit from the resulting energy savings (the tenants). In Denmark this is not a real problem because the housing organisation only are responsible for the administration of the estates that are formally owned by the tenants, who operate based on tenants democracy. Here extra investments can be agreed based on total economy assessment (capital cost of investments compared to value of energy savings). For housing companies who own the estates energy improvements can partly be seen as some kind of maintenance costs to keep the estates up to date. But it could be a solution if the housing company could be allowed to increase the rent with a certain % (f.ex. 50%) of the calculated value of the energy savings. In this way both parties will benefit.

In Spain, splitting incentives is not really a problem, because dwellings are owned by the occupants. Decisions about the renovation are made based on the agreement of all the owners of the building, and investment costs are also assumed by themselves (except small percentage of public subsidies in some cases). Therefore economical investment and benefits from the renovation involve the same stakeholders. In this way, splitting incentives is not really a problem in Spanish housing, where the main barrier is associated to financial schemes for making the sustainable renovation feasible and attractive for the owners.

## 8 Conclusion

For each pilot renovation project, the life cycle costs and CO<sub>2</sub> emissions have been calculated. Compared to the existing building and a standard renovation case, the pay-back times and CO<sub>2</sub> emission reductions are calculated for the projects and the optimal renovation measures are identified.

For the Danish project it is found that CO<sub>2</sub> emission reductions of 68 % are possible at a pay back time of 21 years, but if you only use heat recovery ventilation and airtightness a payback time around 9 years can be obtained. In the first case there is 57 % operation costs reduction compared to existing situation and 45% operation cost reduction compared to standard renovation, and for HRV and airtightness the last mentioned value is 29%. For the Spanish project these figures are 68% and 25 years (63 % operation cost reduction). For Austria the payback is 25 years and reduction in operation costs is 40% and 14%. For Hungary the payback is 35 years, with 60% operation costs reduction compared to existing situation and 46% compared to a standard renovation. For the project in Greece – a 17 year payback is obtained for standard renovation, including heat recovery ventilation, and earth heat exchangers it is 6 years while it is 11 years including building energy management system and an operation costs reduction of 66% is obtained compared to existing situation and 52% compared to standard new build.

For Denmark the best economy is for heat recovery ventilation and airtightness while improved insulation and windows are more costly. This is also confirmed in Austria, Spain and Greece.

If cost effective energy savings should be introduced in connection to renovation projects there is a need for a focus on total economy optimisation, and to be able to charge extra payments in f.ex. rent if savings on operation costs are introduced for the users.



**Conditions**

Amount	
Gross area	2880 m2
Roof	833 m2
Floor slab	833 m2
External wall	1608 m2
Windows/doors	543 m2

**Thickness of insulation - external reinsurance**

	Current	+100 mm	KI 1	PH
Wall	5	100	180	300
Floor	0	0	0	0
Roof	5	100	250	300

Prices from Klaus Boyer / SolarVent				
Thickness	100	180	250	300
Price [euro/m <sup>2</sup> ]	134	188	235	268
			Extrapolation	Extrapolation

**Prices of external reinsurance. Based on prices quoted by Klaus Boyer / SolarVent**

	Current	+100 mm	KI 1	PH	+100 extra costs Euro	KI1-extra costs Euro	PH-Extra costs Euro
Wall	0	134	188	268	301.928	301.928	430.408
Floor	0	0	0	0	0	0	0
Roof	0	134	235	268	111.622	195.755	223.244
Total					413.550	497.683	653.652

**Windows: Prices quoted by SA windows euro/m2 (extrapolation).**

	Price	3	1,7	1,4	1,27	1,07	1	Extra costs incl. a 50% increase for installation	3	1,7	1,4	1,27	1,07	1	
U-value	3	1,7	1,4	1,27	1,07	1		3	1,7	1,4	1,27	1,07	1		
Price/m2	161	201	218	238	289	322		0	60	85,5	115,5	192	241,5		
Infiltration 0.1 h-1 (estimated) EURO/m <sup>2</sup>															2,67
Infiltration 0.05 h-1 (estimated) EURO/m <sup>2</sup>															8,7
Mechanical ventilation with heat recovery and heating surface EUR per flat															2400
Energy price (heating) in euro/kWh excl. VAT (Albertslund 2006)															0,06

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**Table Annex 1.2**

**Annex 2. Cost information – Graz Demohouse project**

<b>Anual energy costs - 1 Existing building</b>			
Energy costs status: 01.01.2006 / Energie Graz (energy agency) - Costs without VAT			
<b>Anual energy costs</b>			<b>€ / year net</b>
Space heating			€ 112.934,20
Hot water services			€ 23.908,93
Mechanical cooling			€ 0,00
Air de/huminidification			€ 0,00
Mechanical ventilation	part of the tenants, no data available		
Artificial lighting	part of the tenants, no data available		
Equipment			
Electricity	127 apartments		€ 48.616,87
<b>All building services</b>			<b>€ 185.460,00</b>
<b>Space heating</b>	<b>costs per unit / net</b>	<b>amount</b>	<b>€ / year net</b>
Annual power price			
VAW 1-1250 kW	per kW	kW	
	13,95	920	€ 12.834,00
Energy price	per kWh	kWh	
	0,046534	2001646,082	€ 93.144,60
Meter charge WZ 40	per month	month per year	
	12,5	12	€ 150,00
Energy tax	per kWh	kWh	
	0,0034	2001646,082	€ 6.805,60
<b>Total</b>			<b>€ 112.934,20</b>
<b>Hot water services</b>	<b>costs per unit / net</b>	<b>amount</b>	<b>€ / year net</b>
Annual power price			
VAW 1-1250 kW	per kW	kW	
	13,95	300	€ 4.185,00
Energy price	per kWh	kWh	
	0,046534	395000	€ 18.380,93
Energy tax	per kWh	kWh	
	0,0034	395000	€ 1.343,00
<b>Total</b>			<b>€ 23.908,93</b>
<b>Electricity</b>	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Home -Small	per month/flat		
Basic charge	3,29	1524	€ 5.013,96
Energy price	per kWh	kWh	
	0,0955	342000	€ 32.661,00
Meter charge per month/flat	2,1	1524	€ 3.200,40
Energy tax	per kWh	kWh	
	0,022636	342000	€ 7.741,51
<b>Total</b>			<b>€ 48.616,87</b>

Table Annex 2.1

<b>Anual energy costs - 2 Reference building</b>			
Energy costs status: 01.01.2006 / Energie Graz (energy agency) - Costs without VAT			
<b>Anual energy costs</b>			<b>€ / year net</b>
Space heating			€ 58.112,05
Hot water services			€ 23.908,93
Mechanical cooling			€ 0,00
Air de/huminidification			€ 0,00
Mechanical ventilation	part of the tenants, no data available		
Artificial lighting	part of the tenants, no data available		
Equipment			
Electricity	127 apartments		€ 48.616,87
<b>All building services</b>			<b>€ 130.637,85</b>
<b>Space heating</b>			
	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Annual power price			
VAW 1-1250 kW	per kW	kW	
	13,95	476	€ 6.640,20
Energy price	per kWh	kWh	
	0,046534	1027793,721	€ 47.827,35
Meter charge WZ 40	per month	month per year	
	12,5	12	€ 150,00
Energy tax	per kWh	kWh	
	0,0034	1027793,721	€ 3.494,50
<b>Total</b>			<b>€ 58.112,05</b>
<b>Hot water services</b>			
	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Annual power price			
VAW 1-1250 kW	per kW	kW	
	13,95	300	€ 4.185,00
Energy price	per kWh		
	0,046534	395000	€ 18.380,93
Energy tax	per kWh		
	0,0034	395000	€ 1.343,00
<b>Total</b>			<b>€ 23.908,93</b>
<b>Electricity</b>			
	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Home -Small	per month/flat		
Basic charge	3,29	1524	€ 5.013,96
Energy price	per kWh	kWh	
	0,0955	342000	€ 32.661,00
Meter charge per month/flat	2,1	1524	€ 3.200,40
Energy tax	per kWh	kWh	
	0,022636	342000	€ 7.741,51
<b>Total</b>			<b>€ 48.616,87</b>

Table Annex 2.2

<b>Anual energy costs - 3 Reference building + better insulation facade</b>			
Energy costs status: 01.01.2006 / Energie Graz (energy agency) - Costs without VAT			
<b>Anual energy costs</b>			<b>€ / year net</b>
Space heating			€ 52.841,20
Hot water services			€ 23.908,93
Mechanical cooling			€ 0,00
Air de/huminidification			€ 0,00
Mechanical ventilation	part of the tenants, no data available		
Artificial lighting	part of the tenants, no data available		
Equipment			
Electricity	127 apartments		€ 48.616,87
<b>All building services</b>			<b>€ 125.367,00</b>
<b>Space heating</b>			
	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Annual power price			
VAW 1-1250 kW	per kW	kW	
	13,95	476	€ 6.640,20
Energy price	per kWh	kWh	
	0,046534	922237,3135	€ 42.915,39
Meter charge WZ 40	per month	month per year	
	12,5	12	€ 150,00
Energy tax	per kWh	kWh	
	0,0034	922237,3135	€ 3.135,61
<b>Total</b>			<b>€ 52.841,20</b>
<b>Hot water services</b>			
	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Annual power price			
VAW 1-1250 kW	per kW	kW	
	13,95	300	€ 4.185,00
Energy price	per kWh		
	0,046534	395000	€ 18.380,93
Energy tax	per kWh		
	0,0034	395000	€ 1.343,00
<b>Total</b>			<b>€ 23.908,93</b>
<b>Electricity</b>			
	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Home -Small	per month/flat		
Basic charge	3,29	1524	€ 5.013,96
Energy price	per kWh	kWh	
	0,0955	342000	€ 32.661,00
Meter charge per month/flat	2,1	1524	€ 3.200,40
Energy tax	per kWh	kWh	
	0,022636	342000	€ 7.741,51
<b>Total</b>			<b>€ 48.616,87</b>

Table Annex 2.3

<b>Anual energy costs - 4 Reference building + better windows</b>			
Energy costs status: 01.01.2006 / Energie Graz (energy agency) - Costs without VAT			
<b>Anual energy costs</b>			<b>€ / year net</b>
Space heating			€ 49.378,12
Hot water services			€ 23.908,93
Mechanical cooling			€ 0,00
Air de/huminidification			€ 0,00
Mechanical ventilation	part of the tenants, no data available		
Artificial lighting	part of the tenants, no data available		
Equipment			
Electricity	127 apartments		€ 48.616,87
<b>All building services</b>			<b>€ 121.903,92</b>
<b>Space heating</b>			
	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Annual power price			
VAW 1-1250 kW	per kW	kW	
	13,95	476	€ 6.640,20
Energy price	per kWh	kWh	
	0,046534	852884,137	€ 39.688,11
Meter charge WZ 40	per month	month per year	
	12,5	12	€ 150,00
Energy tax	per kWh	kWh	
	0,0034	852884,137	€ 2.899,81
<b>Total</b>			<b>€ 49.378,12</b>
<b>Hot water services</b>			
	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Annual power price			
VAW 1-1250 kW	per kW	kW	
	13,95	300	€ 4.185,00
Energy price	per kWh		
	0,046534	395000	€ 18.380,93
Energy tax	per kWh		
	0,0034	395000	€ 1.343,00
<b>Total</b>			<b>€ 23.908,93</b>
<b>Electricity</b>			
	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Home -Small	per month/flat		
Basic charge	3,29	1524	€ 5.013,96
Energy price	per kWh	kWh	
	0,0955	342000	€ 32.661,00
Meter charge per month/flat	2,1	1524	€ 3.200,40
Energy tax	per kWh	kWh	
	0,022636	342000	€ 7.741,51
<b>Total</b>			<b>€ 48.616,87</b>

Table Annex 2.4

<b>Anual energy costs - 5 Reference building + measures 3 and 4</b>			
Energy costs status: 01.01.2006 / Energie Graz (energy agency) - Costs without VAT			
<b>Anual energy costs</b>			<b>€ / year net</b>
Space heating			€ 39.796,28
Hot water services			€ 23.908,93
Mechanical cooling			€ 0,00
Air de/huminidification			€ 0,00
Mechanical ventilation	part of the tenants, no data available		
Artificial lighting	part of the tenants, no data available		
Equipment			
Electricity	127 apartments		€ 48.616,87
<b>All building services</b>			<b>€ 112.322,08</b>
<b>Space heating</b>			
	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Annual power price			
VAW 1-1250 kW	per kW	kW	
	13,95	346	€ 4.826,70
Energy price	per kWh	kWh	
	0,046534	697312,022	€ 32.448,72
Meter charge WZ 40	per month	month per year	
	12,5	12	€ 150,00
Energy tax	per kWh	kWh	
	0,0034	697312,022	€ 2.370,86
<b>Total</b>			<b>€ 39.796,28</b>
<b>Hot water services</b>			
	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Annual power price			
VAW 1-1250 kW	per kW	kW	
	13,95	300	€ 4.185,00
Energy price	per kWh		
	0,046534	395000	€ 18.380,93
Energy tax	per kWh		
	0,0034	395000	€ 1.343,00
<b>Total</b>			<b>€ 23.908,93</b>
<b>Electricity</b>			
	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Home -Small	per month/flat		
Basic charge	3,29	1524	€ 5.013,96
Energy price	per kWh	kWh	
	0,0955	342000	€ 32.661,00
Meter charge per month/flat	2,1	1524	€ 3.200,40
Energy tax	per kWh	kWh	
	0,022636	342000	€ 7.741,51
<b>Total</b>			<b>€ 48.616,87</b>

Table Annex 2.5

<b>Anual energy costs - 6 Demonstration building</b>			
Energy costs status: 01.01.2006 / Energie Graz (energy agency) - Costs without VAT			
<b>Anual energy costs</b>			<b>€ / year net</b>
Space heating			€ 39.796,28
Hot water services			€ 23.908,93
Mechanical cooling			€ 0,00
Air de/huminidification			€ 0,00
Mechanical ventilation	part of the tenants, no data available		
Artificial lighting	part of the tenants, no data available		
Equipment			
Electricity	127 apartments		€ 48.616,87
<b>All building services</b>			<b>€ 112.322,08</b>
<b>Space heating</b>			
	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Annual power price			
VAW 1-1250 kW	per kW	kW	
	13,95	346	€ 4.826,70
Energy price	per kWh	kWh	
	0,046534	697312,022	€ 32.448,72
Meter charge WZ 40	per month	month per year	
	12,5	12	€ 150,00
Energy tax	per kWh	kWh	
	0,0034	697312,022	€ 2.370,86
<b>Total</b>			<b>€ 39.796,28</b>
<b>Hot water services</b>			
	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Annual power price			
VAW 1-1250 kW	per kW	kW	
	13,95	300	€ 4.185,00
Energy price	per kWh		
	0,046534	395000	€ 18.380,93
Energy tax	per kWh		
	0,0034	395000	€ 1.343,00
<b>Total</b>			<b>€ 23.908,93</b>
<b>Electricity</b>			
	<b>costs per unit / net</b>	<b>Amount</b>	<b>€ / year net</b>
Home -Small	per month/flat		
Basic charge	3,29	1524	€ 5.013,96
Energy price	per kWh	kWh	
	0,0955	342000	€ 32.661,00
Meter charge per month/flat	2,1	1524	€ 3.200,40
Energy tax	per kWh	kWh	
	0,022636	342000	€ 7.741,51
<b>Total</b>			<b>€ 48.616,87</b>

Table Annex 2.6