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DEMOHOUSE

Design and Management Options for improving the energy performance of Housing

SPECIFIC TARGETED RESEARCH OR INNOVATION PROJECT

Thematic Priority 6

Deliverable 16.1

Report on assessment of environmental, economical and social impacts concerning the pilot project involving the whole life cycle

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Executive Summary

The EU supported project DEMOHOUSE aims at demonstrating the potential of energy saving and environmental improvement in the renovation of residential buildings. In order to achieve this goal different buildings in different European countries (Denmark, Austria, Greece, Spain and Hungary) are being renovating under sustainable criteria.

This document compiles the information and calculations of the demonstration building (*Pilot building*) to be renovated within the project, and assesses the performance of an improved building renovation intervention. The intention of the document is to demonstrate the potential for environmental improvement and economical feasibility of better solutions in the building renovation field.

In general the results of this assessment have demonstrated very successful interventions in all the pilot buildings, since they have been extracted percentages of energy savings compared to pre-retrofitting situation from 50 to 85%. This can be translated into two other aspects:

- Reduction of CO₂ emissions, being greenhouse gases emissions a leading problem in environmental programmes and goals.
- Reduction of operational costs along the use phase of the building (space heating, DHW, ...). From these savings payback periods can be calculated for the evaluation of the feasibility of the projects. In Demohouse payback times ranges from 15 to 35 years, although most common figures are around 25 years.

Additionally all the pilot buildings provide very good sustainable performance, not only in terms of energy savings, but also in many other aspects for the environmental enhancement of the buildings renovations. The overview of the pilot buildings demonstrates that there are many potential actions/measures to be taken when dealing with building retrofitting, addressing and stressing different issues depending on the characteristics of each case. Therefore, further than energy demand reduction, large environmental benefits can be obtained in terms of resources minimization, water savings, waste management, etc.

In general, the results extracted in this stage of the project represents a very promising overview, considering that one of the main objectives of Demohouse should be the transferability of these initiatives to other similar experiences and also to programmes leaded by public bodies. These demonstration cases permits to have real data on potentiality of sustainable renovations further than other theoretical approaches based only in calculations and estimations. And therefore they should be used as examples to push and promote sustainable building renovation in the large European housing stock that will be retrofitted in the next few years.

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1 Introduction

This report is part of the EU supported project DEMOHOUSE (TREN/04/FP6/S07.35744/503186). The project aims at demonstrating the potential of energy saving and environmental improvement in the renovation of residential buildings. In order to achieve this goal different buildings in different European countries (covering diverse climates, socio-economical schemes, etc.) are being renovating under sustainable criteria.

As environmentally optimized renovations by themselves provide only absolute results, a comparison or relation with standard practices in building renovation are required in order to extract conclusions about benefits and feasibility of these interventions. According to this principle, every country involved in the project has defined not only a demonstration (pilot) building for evaluation of improvement but also a reference building corresponding to standard renewal of the country.

This document compiles the information and calculations of the demonstration building (*Pilot building*), and assesses the performance of an improved building renovation intervention. The intention of the document is to demonstrate the potential for environmental improvement and economical feasibility of better solutions in the building renovation field.

In order to achieve a better organization of the information related to the assessment of the pilot building, this document will be divided into two parts:

- Deliverable 16.1: Including the technical, energy, sustainability aspects of the pilot projects, and brief analysis on economical impact of implemented measures on operational costs and payback time.
- Deliverable 16.2: Focused on socio-economical aspects of the pilot projects.

This partition is connected mainly to a time dependency question, since socio-economic assessment will be based on the assessment of the occupants/tenants' perception (through questionnaires designed in WP3) and on the final economic features of the building (market value, rent rates, operational costs, etc.). As in this moment the renovations have not been completed, it is not possible to address these socio-economic aspects in the assessment of the pilot buildings yet.

Therefore the assessment of this part of the document (D16.1) involves a revision on life cycle energy consumption and sustainability/ environmental properties (greenhouse gas emissions, water consumption, wastes management,...) of the pilot building.

The analysis of the pilot building will be adjusted to the contents described in the Common Evaluation Protocol (D22). And in a subsequent phase (Deliverable 19) these results will be contrasted with the performance of the reference buildings (see D14).

2 General description

2.1.1 Denmark

The Danish pilot building is located in Gyldenrisparken, Copenhagen. The housing blocks Gyldenrisparken include 500 apartments divided between several blocks of flats with a total built up area of 43,410 m². The housing blocks were built between 1965-69 of prefabricated concrete panels and they are about to be thoroughly renovated between 2006-2008. In the framework of the DEMOHOUSE project approximately 100 dwellings will be renovated to a higher standard. This is equal to three of the smaller building blocks or one of the bigger blocks. The rest of the blocks will be retrofitted as usual, but to a higher level than that prescribed by the national regulations.

The standard renovation of the Gyldenrisparken includes 100 mm insulation of the external surfaces, new windows with standard specifications and U-value of 1.8 W/m²K, a new heating distribution system and simple water saving measures.

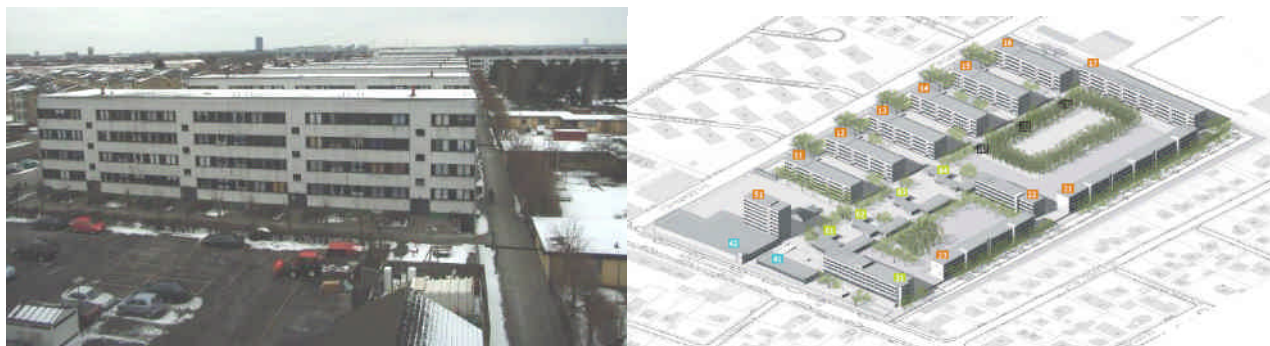


Figure 1. Denmark, the three building blocks used for DEMOHOUSE renovation, 3D-view of Gyldenrisparken.

2.1.2 Austria

In Austria, the building consists of two blocks of flats in the city of Graz: Laudongasse 14 and 16 as well as Starhemberggasse 13 and 15. It was constructed in 1976 and they consist of 127 flats (between 75 and 110 m² each) with around 310 inhabitants.



Figure 2. Austria, East and West view of the pilot building

2.1.3 Greece

Greece participates in the DEMOHOUSE project with a new housing complex. The building is located in an exposed suburb area, north of Athens. The maisonette consists of 3 detached houses of similar design and is intended to house to a 4-6 member family. The maisonette has four levels and a total floor area of approx. 300 m².

Large parts of the building facades are traditional brick cavity construction cladded with stone. Elevations facing south are of concrete finished with plaster. The roofs are partly concrete slabs and partly metallic roofs. The insulation level meets the standards of the Greek Thermal Regulation (1979).



Figure 3. Greece, Artist impression of north-east elevation and ground floor plan of the whole building

2.1.4 Spain

The demonstration project consists of the renovation of an old building located in the centre of Bilbao (North of Spain). The building is about 90 years old and it was built with standard materials in the Spanish cities during the early 20th century, which involves very low energy features. The figure shows two photographs of the pilot demonstration building before the renovation.



Figure 4. *Main façades of the Spanish pilot building.*

2.1.5 Hungary

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 5. *Hungarian demonstration building.*

3 Technical

As Demohouse buildings are located in different European countries and they were erected in different periods, a wide range of technical properties are found and, subsequently, different constrictions and barriers have to be overcome when tackling renovations. Next main technical barriers for buildings renovation are described.

3.1 Architectural background

3.1.1 Denmark

In Denmark external insulation on facades are not possible for the brick masonry buildings and technically difficult on the internal walls. This is not a problem when it is facades of plaster and concrete building.

Renovations project of concrete building from the period 1960 - 1980 where facades are being renewed will normally include external insulation. Renovation of concrete facades is actually a main issues for the building stock of that period, and a lot of external insulation is done in relation to that work. Often it include new windows and glazing of balconies.

For building with plaster on the facade external insulation can be done and only if it is a historical building their may be architectural obstacles from decoration, windows etc.

3.1.2 Austria

Austrian legal barriers or conditions may be obstacles, like for example protection of historic buildings and monuments. For quite a number of renovation projects dealing with a building stock constructed before 1900 it is often impossible to make thermal renovation because of the protected facades. Inside thermal insulation of the outer walls still proves to be a problem of building physics as well as an organisational problem (moving out of occupants), although in Austria there are some pilot projects dealing with this topic. Another barrier in this context is the loss of valuable living space.

Another problem in renovation praxis is the requirement of the zoning plan. In Austria the zoning plan defines different utilisations (living, working, industry...) for special areas. A change of utilisation, for example from working space to living, often means a lot of bureaucratic and legislative problems. Zoning plans also regulate site density, which means a strong barrier for profitable renovations. For landlords from the economical point of view sometimes it is very important to create new extra spaces, which means higher site density. To get the allowance for higher densities often takes longer timetables, in most cases only possible in connection with the revision of the zoning plan (interval 5 years).

3.1.3 Greece

In case of Athens, or other densely occupied Greek areas or areas with traditional architecture i.e. historic centre, where the old housing stock is located in traditional urban context the renovation practice should follow the urban rehabilitation and the surrounding buildings in terms of morphological features. Additionally the renovation of Grade Listed buildings should follow regulations regarding their aesthetics and architecture. This can provide limitations when renovating the façade of the buildings, their window shape, addition of shading or energy measures i.e. installation of PVs.

3.1.4 Spain

The main architectural problems in Spain arising from renovation practice are related to the loading capacity of the frame. In many cases the introduction of some technical solutions (e.g. extra-insulation) involves a reinforcement of the frame.

Changing façades in a renovation of a building is usually very difficult, so they are maintained with the frame. This involves that many elements must also be maintained, such as windows shape, external layer of the walls (internal layers must be added to improve thermal and acoustical insulation), etc. Architectural problems are often closely related to heritage preserving requirements, which reduce importantly the

technical alternatives of renovation.

3.1.5 Hungary

In Hungary the need of changing the buildings use can face further architectural barriers. An example of this can be the problem of blocks with internal courtyards. The apartments of urban housing blocks with internal courtyards are strongly out-dated from a functional viewpoint, and are undergoing a serious process of devaluation. Therefore it is important to provide solutions, which realize the ecological aspects and the use of renewable energy sources, and at the same time expand the living space of the apartments, update its functions, thereby increasing its practical value. Integrating renewable energies by expanding living spaces, however, is possible for several other forms of housing, including all forms of urban multi-storey blocks, panel housing estates, low-rise high density housing or family houses. Utilisation of solar energy is possible by passive indirect solar systems representing transient or permanent additional living space. In urban areas the possible solutions are:

- glazing of existing loggias,
- building glazed loggias, sunspaces to the existing facades,
- transparent covering of courtyards

Without auxiliary heating, thus forming sunspaces, where the temperature is the function of spontaneous heat transfer processes, or with auxiliary heating of the above spaces, when new living spaces are between the new outer elevation of high thermal performance and the original one, or atria are formed. These systems increase the living space, thus the value of the building. The number of habitable hours in correctly designed sunspaces - thus when thermal comfort conditions facilitate the permanent occupation without auxiliary heating - is 4500 - 5300 h/a. The sunspaces act as buffer zones, decreasing the heat loss of the parent houses, the thermal load of the covered part of the elevation becomes less, and ventilation losses of the parent house can be decreased channelling the fresh air through the sunspace where it will be preheated. Application of auxiliary heating system facilitates the permanent occupation. Providing they are added in front of the existing facade with a well-insulated new facade, these spaces represent a new "artificial environment" around the existing building. The new outer facade can be integrated with active energy collecting elements and facilitate the change of the appearance of the building. Atria facilitate to widen or change the intended use of buildings, to decrease the ventilation losses by preheating of fresh air in winter and to avoid the overheating in summer by intensification of natural ventilation. Energy consumption of artificial lighting represent organic component of the energy balance and is influenced by the added spaces. As all of these changes can strongly influence the appearance and aesthetical quality of the building, the architectural aspects should be carefully considered and this can be also a barrier of these solutions.

As regards historical buildings, the eclectic buildings represent a high quantity of the total stock (only in Budapest about 3.500 multi-storey buildings) and in several cases are also part of the built cultural heritage. Using the results of the structural analysis of the facades, the applied materials and structures, general architectural criteria could be determined which are necessary for the rehabilitation. On the basis of the architectural-structural analysis of the facades we have to prove those modern plasters, which are sufficient from the point of the historic authenticity of the restoration. The control of the historic structures is also necessary from the point of the life-quality and insurance of criteria of the 21st century.

3.2 Constructional background

3.2.1 Denmark

In Denmark most large renovation projects of social housing areas involves loans from *Landsbyggefonden*, a national foundation established by social housing cooperation's. They have to approve renovations project if they obtain loans from the foundation and they compile experiences from all the renovation projects they give loans.

The foundation has a practice on what kind of work that can approved and housing cooperation's can obtain

loans for in a renovation project. Energy saving is not a prioritised area in the renovation, but if there is a need for renovation concrete facades for a certain building, extra insulation of facades normally will be a part of the renovation. Similar windows with low U values will be chosen if there is a need for change of them.

Energy reductions measures have to be very cost effective if it is not a part of the approved work otherwise it will not be chosen as a part of the renovation.

For the moment a lot of renovation projects is ongoing in social housing areas from the period 1960-1970. It reflects a period where industrialized building systems of concrete grow very rapidly and dominated the building of social housing areas. These new urban areas fulfil the demand for dwellings for the large after war generations. Now they have an age where there is a need for renovation, and the typical need involves new facades to avoid further damage of the concrete, changes of windows, renewal technical installations etc.

3.2.2 Austria

In Austria every renovation bears some risks for the building owner. On one hand there are risks on the technical level, where necessary measures have to be prepared, the workmanship has to be awarded to experts and their work has to be controlled. Related risks can be reduced if consultants are involved, which also means additional costs for the consultancy. On the other hand the costs are a risk factor: the estimation of costs can be wrong or the assigned workman does not stick to the planned costs. The planning of a renovation is often done on the site, where unpredictable minor details may change the cost calculation. For the most part renovation is manual labour work, not like the construction of new buildings with high industrialized building techniques. This issue and the requirement of highly qualified workers means an increasing of the construction costs in comparison to new building construction.

Economic demands (lacking of rentals, substitutes for dwellings) often leads to renovation with occupants living in the building during the renovation period. This bears a high conflict potential. Avoiding noise, dust, heightened security measures causes complex, time consuming, expensive construction management. Therefore renovation under strong time pressure is state of the art. The builder-owner often concentrates only on the primary reason for renovation (e.g. a specific damage) and wants to get it done as quickly as possible.

3.2.3 Greece

The renovation practice of buildings in Greece during its construction (preparation work, temporary equipment i.e. scaffolding) and the renovation itself i.e. the new equipment for high efficient heating and cooling plant, new systems for shading, improved insulation, results in high costs that may prevent the clients from renovating their property and encourage them for a new construction.

3.2.4 Spain

One of the most important issues to be considered in Spanish renovation activities is related to the selection of the best technique for the demolition or refurbishment. In some cases it can be very aggressive and other parts of the building or adjacent buildings can be damaged because of a bad choice in the renovation practice. It is especially relevant in historical areas where architectonic heritage must be preserved.

In cases of very old buildings, there is quite often a lack of knowledge about the foundations of the buildings, which makes very difficult to make decisions on how to design the renovation and the technical response of the building to these activities. This point increases the costs of the diagnosis and renovation planning.

3.2.5 Hungary

In Hungary in case of certain renovation works additional or extra costs can be high. In case of buildings with danger of stability due to its condition or due to the required changes, an accessory cost of diagnostics should be added. Temporary equipments like scaffolding or hooks can also increase the cost, especially in dense urban environment, where often special solutions are needed in order to avoid disturbance of traffic and in order to ensure safety.

Also retrofit of buildings made with industrialized technology faces constructional barriers. Creating holes

for pipes and ducts can meet difficulties, since the steel reinforcements are often unknown. Plans are lost for many building types and even if it is available it is not guaranteed that the former constructors followed the plans. The discrepancy between plans and reality is very high. Functional changes (for example moving doors or walls) have to face the same difficulties. Another problem can be the limited available space for the new installation systems.

The retrofit of many buildings in one quarter connected to the same district heating network can have significant consequences on the network, since the capacity of the pipes and the heat plant were designed for a larger demand.

3.3 Technical description

Two of the buildings were built in the second half of the 20th century, the Hungarian was part of a military area, the Spanish building is an historic building and the Greek building is new one.

The Danish buildings are made with industrialised technology, the Hungarian and Spanish are masonry constructions and the Greek is a combination of masonry and reinforced concrete.

Regarding the total number of occupants and the net floor area of the housing projects, the largest building is the Austrian the smallest is the Greek. The Austrian and Danish buildings represent the large size, the Hungarian the medium size and the Spanish and Greek the small size category.

The size of the flats also differs in the countries: The largest flats are in Greece followed by Austria. Spain is in the middle, in Hungary the flats are social dwellings, thus they are very small.

Regarding the exposed surface / heated volume ratio and the total length of joints it can be stated that the building with the most complex geometry is the Greek one followed by the Austrian building that has many loggias. The Hungarian building represents a medium level, the other buildings are rather compact.

The highest glazed ratios are for the Greek buildings and the lowest for the Spanish. Therefore shading devices are extremely necessary for the Greek case especially considering the climate.

From the point of view of daylight the Greek building has the highest glazed area per floor area. The Greek house is the only rural building where there are no shading objects in the neighbourhood. Contrarily, the Spanish building is located in a very old urban area surrounded by narrow streets giving some protection in the hot summer.

Table 1. *Main characteristics of the housing projects*

		Austria	Denmark	Greece	Hungary	Spain
Net floor area	m ²	9857	6.701	919	1688	510
Heated volume	m ³	25628	16.753	2481	6524	1200
Number of heated floors	-	11	4	3	4	4
Number of flats	-	127	96	3	50	12
Floor area / flat	m ²	77,6	75	306	33,8	40
Number of dwellers	-	310	250	15	150	30
Dwellers / flats	-	2,44	2,6	5	3	2,5

Table 1. *Main characteristics of the housing projects (cont.)*

		Austria	Denmark	Greece	Hungary	Spain
Exposed surface	m ²	15835	7.752	867	2887	1121
Façade area	m ²	13320	3.912	549	1334	589

Glazed area	m ²	2239	1.958	156	274	85
Exposed surface / heated volume	m ² /m ³	0,61	0,46	0,35	0,44	0,40
Glazed ratio	%	16,8	50	28,5	20,1	14
Glazed area / net floor area	%	22,7	0,29	17	16,2	17

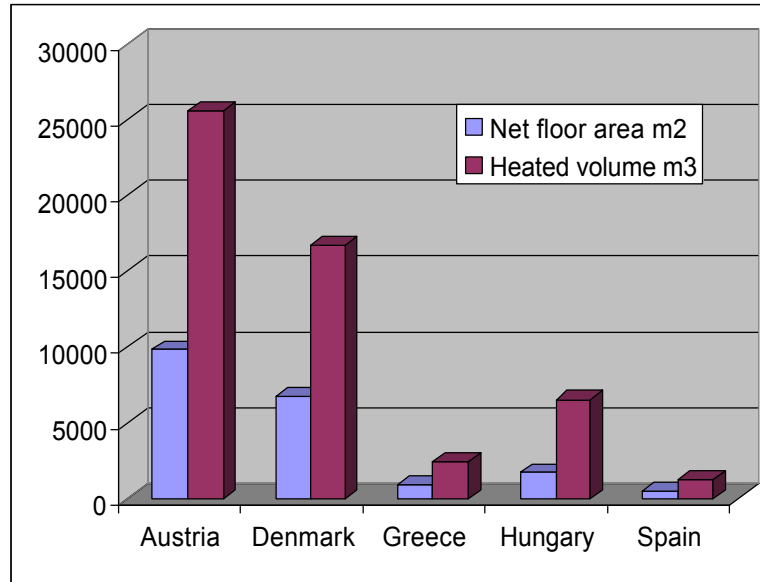


Figure 6. Net floor area (purple) and heated volume (red) of the demonstration buildings..

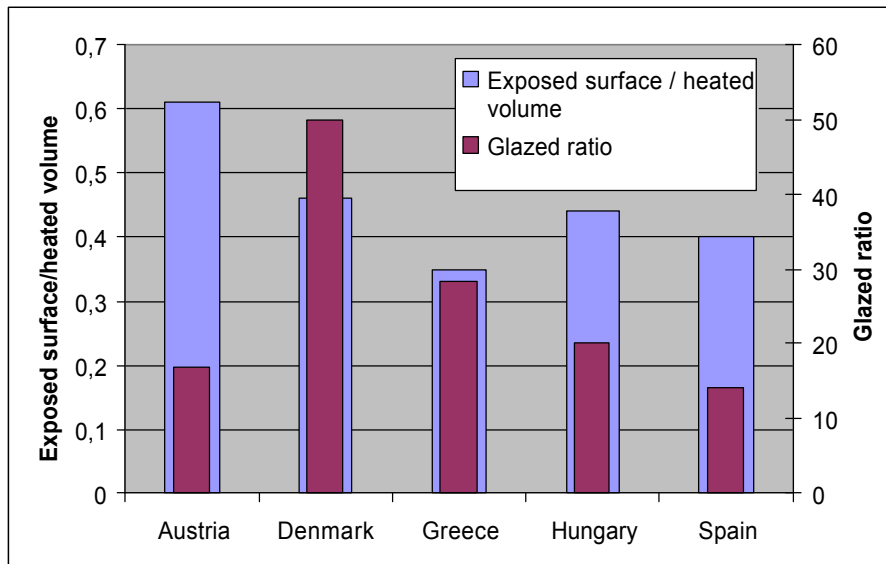


Figure 7. Exposed surface/ heated volume ratio (purple) and glazed ratio (red) of the demonstration buildings.

4 Environmental

The sustainability evaluation of the pilot buildings was made using the Common Evaluation Protocol (D22), based on the Green Build questionnaire. The questionnaire is based on the Danish Green Build Tool, which works as an energy and environmental point system. The tool makes it possible to assess and compare the environmental performance of buildings or complex urban development projects. The questionnaire covers the following fields: A. Water, rainwater and sewage; B. Indoor climate; C. Materials and constructions; D. Waste; E. Energy; F. Building and urban development area. Methods for sustainable development and sustainable urban management. According to the rating system the building can be classified as *poor* (0-20 points), *acceptable* (21-50 points) or *great* (>50 points). In addition, the Austrian partners used the WIN^{BAU} Spinwheel tool and the Spanish partners the Guideline and Rating Code for sustainable building construction of the Basque Country.

4.1 Environmental background

Although Green Build Questionnaire has been applied within the Common evaluation protocol (D22), other regional or national procedures have also been used in some countries for the evaluation. Following, a description of the applied methods is included.

4.1.1 The Green Build questionnaire

The Green Build questionnaire is based on the Danish Green Build Tool, which works as an energy and environmental point system. The tool makes it possible to assess and compare the environmental performance of buildings or complex urban development projects. The questionnaire covers the following fields:

- A. Water, rainwater and sewage
- B. Indoor climate
- C. Materials and constructions
- D. Waste
- E. Energy
- F. Building and urban development area. Methods for sustainable development and sustainable urban management

These categories involve different sustainable measures. According to the rating system the building can be classified as *poor* (0-20 points), *acceptable* (21-50 points) or *great* (>50 points).

[Remark]: The analysis of the sustainability of pilot buildings according to the Green Build Questionnaire has not been finished yet. As soon as the results are available a detailed evaluation of all the aspects compiled in this methodology will be carried out.

4.1.2 WIN^{BAU} Spinwheel tool:

The Austrian partners applied the WIN^{BAU} Spinwheel tool, developed by IFZ for the Styrian government. This tool is based – among other things - on parts of the TQ – Total Quality tool, the OI3 – Index of the Vorarlberg subsidy system and the GEMIS Austria data source. For the DEMOHOUSE project a reduced English version, adapted to the European situation, was developed.

4.1.3 Guía y Código de Valoración de Edificación Sostenible para la Vivienda

The Spanish partners used the Guideline and Rating Code for sustainable building construction of the Basque Country in addition to the Green Build questionnaire. This methodology has been developed in the Basque Country for the evaluation of new residential buildings. The methodology consists of two main parts:

- A Guideline for sustainable building construction, which compiles measurements on 10 different issues (waste, energy, water, etc.) related to the environmental performance of the building.
- A Rating Code, for the assessment of the sustainability of the buildings.

4.2 Water

There are not very high scores for “Water, rainwater and sewage” category in the pilot buildings, ranging from 0 points in Austria to 4 points in Spain and Hungary.

In general there are no measures for rainwater or grey water reuse except in Hungarian building, where rainwater is collected for garden irrigation. Main water saving of the pilot buildings is associated to the installation of water saving taps.

4.3 Indoor climate

Medium to high scores are achieved in the “indoor climate” category for the pilot buildings. Greek building has a very good performance of the indoor quality, with 12 out of a total of 15 points. All of the buildings provide minimum air exchange rates. Each one of the buildings address different aspects connected to indoor environment, such as daylight optimization, air tightness, passive design for avoidance of overheating during summer, noise control, etc.

4.4 Materials and constructions

In general the pilot buildings are free of hazardous materials for health and/or environment, many of them according to normative requirements (e.g. no use of components containing CFC and HCFC). The Greek building employs natural materials for most of the constructions (walls, floors, roofs, ceilings, etc.) and bioclimatic strategies are used in the design of the building thermal performance (thermal mass/solar gains, natural and cross ventilation in summer, etc.). Austrian building incorporates recycled materials in some of its elements, such as insulation materials. Most of the buildings use glasses and windows for better performance of daylighting and reduction of overheating due to solar gains during the summer.

Scores range in a wide interval for the different buildings, from 9 points in Hungary to 23 points in the Greek project.

4.5 Wastes

The “Waste” category is similarly tackled in the different pilot buildings, except in Greece where no measures related to waste management are applied. In Austria and Hungary containers for composting are provided, and fractionated disposal can be found in Hungarian, Danish and Spanish buildings.

Similar results are achieved in the pilot buildings (except for Greece, as mentioned): 2 points in Denmark, 3 points in Austria and 4 points in Hungary and Spain.

4.6 Urban development

Measures related to building and urban development area provide medium to high scores in general (19 points in Spain to 26 points in Greece), depending on the features of the environment of each pilot building. Greek buildings have the highest scoring, related to a new constructive site where more sustainable criteria have taken into account for the whole area. In general the points of this category are more related to buildings performance (use & maintenance, quality assurance and verification process, monitoring, etc.) rather than urban conditions (green common areas, playing ground areas,), where not always are possible in the retrofitting process.

4.7 Energy

The pilot buildings were characterised by the following parameters:

- Geometry (surface to volume ratio, glazed ratio, glazed surface per heated floor area, size of the building)
- Users,
- Applied energy efficiency measures,
- Eventually applied RES,

- Heat demand before and after renovation,
- Yearly heating energy need before and after renovation,
- Yearly cooling energy need if air conditioning applied,
- Yearly energy supply provided by renewables if applied,
- Yearly electric energy need if data available.

4.7.1 Evaluation Method

Energy evaluation was performed according to two different methods:

- a qualitative approach based on the Energy section of the Green Build Questionnaire
- a detailed calculation based on the results of dynamic simulations. According to deliverable 22, the choice of the simulation tool was the free decision of each country, as long as validated tool are being used. The used tools were: EnergyPlus Trnsys, Energy 10, Aiolos, Daylight, Summer Building, E-Audit, Be06, Energy10. Since different tools were used by the countries, a common evaluation chart was filled in by all partners in order to provide comparable data on all relevant questions. The common evaluation chart was based on the guidelines of the “Common Evaluation Protocol” (Deliverable 22). The main energy demands were calculated for the pilot buildings: the heating energy demand, the DHW energy demand, and the electricity demand that can be relevant for the building (lighting and HVAC electricity).

4.7.2 Results of energy evaluations

GREEN BUILD QUESTIONNAIRE. This energy evaluation based on the Green Building Questionnaire is less detailed than the thermodynamic simulation of the buildings, but the conclusions approximately agree.

All the pilot buildings achieve high scores in the “Energy” category, as planned at the beginning of the project where many of the implemented measures addressed an enhancement of the energy performance of the demonstration buildings.

It is particularly remarkable the very low heating consumption of the Hungarian building, where energy demands below 25 KWh/m² are achieved. The buildings in Hungary, Denmark and Spain incorporate solar equipment, while Austrian and also Danish building is coupled to the local district heating. All the buildings include measures oriented to lighting savings, such as low energy bulbs, movement-activated lighting or low-energy lighting in common areas. Common issue for all the buildings is the installation of individual meter displays

4.7.3 Summary of energy savings

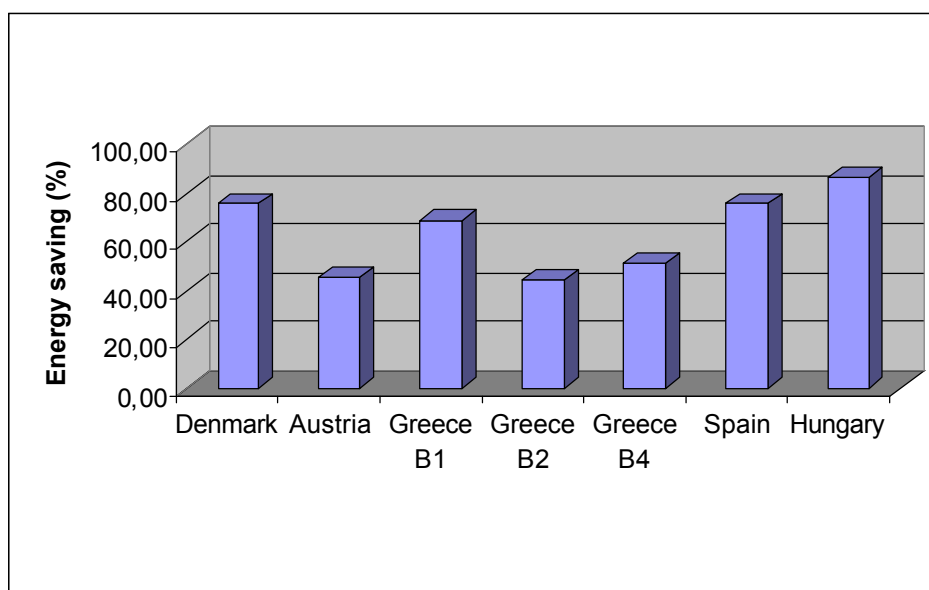
Detailed results of the energy consumption for each country are compiled in Annex 14.I, analyzing savings between original condition before renovation of the buildings, and energy performance achieved due to sustainable measures implemented in the pilot buildings.

As the following table compiles, energy savings from the original situation of the building to the pilot renovation differs in the different countries, but always achieving very relevant savings ranging from approx. 45% (in Austria) to 86% (in Hungary). These percentages reveal the high potential of energy savings associated to building renovation.

Table 2. *Energy results of pilot buildings (KWh/m²): existing situation (prior to renovation), demonstration project with sustainable measures (pilot building) and savings between both situations.*

Scenario	Denmark	Austria	Greece B1	Greece B2	Greece B4	Spain	Hungary
Existing situation	133	196	130	11	82	317	188
Demonstration building	32	106	40	62	40	77	22
Energy saving (%)	76	46	69	44	51	76	88

The energy consumption in the different buildings varies from 22 KWh/m² in Hungary to 106 KWh/m² in Austria. This is related to the energy demand distribution (space heating, DHW, electricity,... see Annex 16.I) and the measures implemented for the energy savings, e.g. the Austrian building achieve large energy savings in space heating but it does not represent a high percentage of the total energy consumption. It must be remarked also the starting situation for each case differs significantly, with a very low energy demand for the Greek buildings (approx. 100 KWh/m²), medium values for Denmark, Austria and Hungary and huge energy for the Spanish one (as it was a very old and abandoned building in very poor conditions). As a consequence of that variety in the conditions of the original situation of the buildings prior to renovation, many different percentage of energy savings can be seen, but very significant for all them (from a minimum savings of 46% in Austria to 88% in Hungary).

**Figure 8.** *Energy savings calculations for pilot buildings according to pre-renovation situation..*

4.8 Greenhouse gases emissions

According to the results of energy consumption shown above, following greenhouse gases emissions have been calculated.

4.8.1 Denmark

Table 3. *CO₂ emissions for the Danish pilot building.*

Scenario	CO2 emission heating [ton]	CO2 emission electricity [ton]	CO2 emission total [ton]
Existing situation	51	18	69
Demo. building	12	6	18

4.8.2 Austria

Table 4. CO₂ emissions for the Austrian pilot building.

Scenario	CO2 emission heating [ton]	CO2 emission electricity [ton]	CO2 emission total [ton]
Existing situation	294	212	507
Demo. building	85	75	161

4.8.3 Greece

Table 5. CO₂ emissions for the Greek pilot building.

Scenario	CO2 emission heating [ton]	CO2 emission electricity [ton]	CO2 emission total [ton]
Building 1 (manetas)			
Situation before renovation according to build regulations	68	15	83
Demo. building	31	2	33
Building 2 (Rizos)			
Situation before renovation according to build regulations	73	9,8	82,8
Demo. building	48	3.8	51.8
Building 4 (Agiostatitis)			
Situation before renovation according to build regulations	58	6	64
Demo. Building	23	3.67	26.67

4.8.4 Spain

Table 6. *CO₂ emissions for the Spanish pilot building.*

Scenario	CO ₂ emission heating [ton]	CO ₂ emission electricity [ton]	CO ₂ emission total [ton]
Existing situation	57	4	61
Demo. Building	15	4	20

4.8.5 Hungary

Table 7. *CO₂ emissions for the Hungarian pilot building.*

Scenario	CO ₂ emission heating [ton]	CO ₂ emission electricity [ton]	CO ₂ emission total [ton]
Existing situation	155	43	198
Demo. Building	20	31	51

As described for the energy consumption, the potential savings of the pilot buildings in terms of greenhouse gases emissions are very large and promising for future similar activities (with the aim of extending these practices). These results show exceptionally high environmental benefits. Again the savings differs according to the initial situation of each building.

4.9 Sustainability

As it can be seen in the figure all the pilot buildings achieve very high scores and they exceed largely the threshold of 51 points for the “great” category (up to 88 points for Hungarian and Spanish buildings). Each building show slightly different profiles from the others responding to the measures implementation design, barriers of the renovation and local particularities (e.g. district heating systems, solar-based design, heat recovery units,...). In general, measures related to energy savings are very relevant, especially for Denmark, Spain and Hungary. The Greek building provides very good performance in terms of indoor climate. “Building and urban development” category is also particularly significant for the Greek project, but for the Austrian, Danish and Hungarian as well.

In general following conclusions can be extracted from the sustainability assessment of the pilot buildings of the project:

- Water saving is related to water saving taps.
- Different solutions in indoor climate are addressed (passive solar design for overheating avoidance, ventilation with heat recovery, daylight optimization) depending on particular problems of each building/location.
- Natural and recycled materials are employed in some of the pilot buildings, and healthy/environmentally hazardous substances are avoided (PVC, CFC and creosote). In addition high quality glasses are included in the installed window of the buildings (low emissive and low U-values).

- Waste management in the pilot buildings are focused on the composting possibility and fractionated disposal.
- Different strategies can be found for the energy saving and improvement of energy performance of the demonstration buildings: incorporation of renewable systems, improved systems for lighting saving, optimized building design (low emissive windows, solar-based design), equipment coupled to district heating, etc. Results of energy savings and greenhouse gases emissions reduction of the pilot projects show a very high potential in buildings renovation all over Europe.
- Good quality assurance procedures during design, construction and maintenance of the demonstration retrofittings can be found.

As mentioned, all the pilot buildings provide very good sustainable performance, not only in terms of energy savings, but also in many other aspects for the environmental enhancement of the buildings. This overview demonstrates that there are many potential actions/measures to be taken when dealing with building retrofitting addressing and stressing different issues depending on the characteristics of each case.

Table 8. Final results of Green Build Questionnaire

	Denmark	Austria	Greece	Spain	Hungary
Water, rainwater and sewage	2	0	2	4	4
Indoor air climate	9	5	12	6	6
Materials and constructions	6	11	23	19	9
Waste	2	3	0	4	4
Energy	33	22	16	36	40
Building and urban development area	23	23	26	19	25
TOTAL	75	64	79	88	88

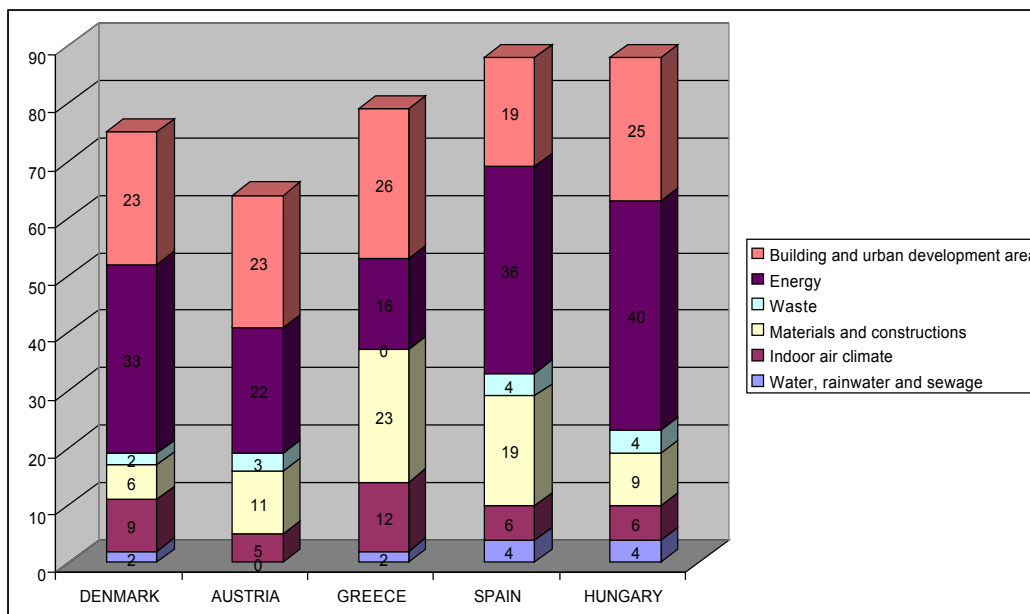


Figure 9. Final results of Green Build Questionnaire

5 Economical

This chapter includes a brief analysis of the economical impact associated to the operational costs of the building after the renovation, calculating the savings and the payback time according to the total investment costs required for the energy efficient retrofitting. Nevertheless the assessment will be completed in a more comprehensive approach in the second part of this document (Deliverable 16.2, see introduction), addressing issues more oriented to socio-economic influence on the tenants/occupants: market value of the dwellings, increase of the rent rates, new organizational scheme for building management (including equipment, renewable systems, etc.), social perception of the sustainable renovation, etc.

5.1 Summary of economical impact of measures

Detailed description of the operational costs (by energy concepts) can be found for each of the countries in Annex 16.II. Following table compiles the most relevant economical indicators for the assessment of the pilot building: investment cost and payback time for sustainable renovation.

Table 9. *Summary of economical impact of implementation of the sustainable measures in the pilot buildings.*

Scenario	Costs, investment [Euro]	Payback time [years]
Denmark	658373	23
Austria	1277149	25
Greece	426326	10-17
Spain	148000	25
Hungary	740000	35

As explained, it is not the intention of this table to make extensive conclusions on economical criteria, since otherwise it should have been included normalized values to euro/flat or euro/m², but the intention is to have some overall figures. From these it can be extracted that many different renovation have been carried out within the project in terms of investments, from 148000 euros in Spain to more than 1277149 euros in Austria, which agrees with the number of flats and size of the buildings. Nevertheless, it can be noticed that despite the different volumes and areas of the renovations they presents very similar payback times. Particularly pilot buildings in Denmark, Austria and Spain have values around 25 years, although Danish and Austrian cases corresponds to the biggest buildings of the project, while the latter is much smaller. Payback time to Hungarian building is a bit higher and the Greek case has shorter payback period, even not achieving the highest energy saving percentages.

6 Conclusions

After the assessment of the demonstration buildings, it can be concluded some preliminary points (pending on a more extensive analysis to be carried out in following deliverables, *D19 Report on sustainability concerning comparison of reference project with pilot project and comparison with reference and pilot projects from other countries*):

- There are a large potential for energy savings in building renovation along Europe, not only considering existing situations but also considering the standard or normative practice as a reference point. This represents a very promising overview, considering that one of the main objectives of Demohouse should be the transferability of these initiatives to other similar experiences and also to programmes led by public bodies. These demonstration cases permits to have real data on potentiality of sustainable renovations further than other theoretical approaches based only in calculations and estimations. Anyway these data should be contrasted with the monitoring phase of the project.
- Connected to energy demand minimization, the environmental performance during the use phase of the buildings will be much more adequate in terms of greenhouse gases emissions. Considering that these aspects is one of the main goals addressed by many international organisms in environmental policy and considering also the number of European housing buildings that will be renovated in the next few years, the sustainable approach in this field seems to be essential in the construction sector.
- Related to sustainability assessment the overview presented in this document demonstrates that there are many potential actions/measures to be taken when dealing with building retrofitting, addressing and stressing different issues depending on the characteristics of each case. Although energy savings seem to be the most relevant aspect to be achieved, there are many other measures (sometimes easy to be implemented) that can provide many environmental benefits in terms of water savings, wastes recycling, improvement of indoor conditions, minimization of resources consumption, etc.
- Investment costs represent extra resources for the renovations which can be recovered as operational costs savings in acceptable periods of time (although this point is further discussed in WP3).
- Although a holistic approach for building renovation is required for an optimum design, it has been demonstrated that the level of success of the experiences does not depend on their technical features: size, year of construction, materials, constructive systems, etc. It is true that every renovation project will face different barriers, but different solutions can be proposed in each case.

Recommendations / Lessons learned

Although the original situation for the pilot buildings were very different in the countries involved in Demohouse project (location, climate, age, size, constructive systems, etc.), it has been demonstrated that all of them can improve its energy and environmental performance.

Main points to be considered in the technical filed (socio-economic aspects will be tackled in D16.2) should be oriented towards:

- Compile as much as possible information about the building for a better knowledge. In this way more balanced and adjusted decisions will be made when proposing measures to be implemented; and thus unexpected problems will be avoided.
- Good identification of the weak points of the building to be renovated (e.g. cold bridges problems, condensations, low performance heating/cooling equipment, etc.)
- Analyse other similar (total or partial) renovations experiences, both in the same region/countries or other countries.
- Use of predictive tools (e.g. energy performance programs) for testing, improving and selection of most suitable alternatives.
- Try to incorporate “green” technologies, such as renewable systems, cogeneration equipment, ...

Annex 16.I – Energy savings

Denmark

Table 10. Detailed energy demand in Danish pilot building.

Scenario	Energy demand [kWh/m ²]	Space heating demand [kWh/m ²]	Domestic hot water demand [kWh/m ²]	Heating total Demand [kWh/m ²]	Electricity Demand [kWh/m ²]
Existing situation	132,6	117,3	13,4	130,7	12
Demo. Building	32	26,6	5,4	32	4

Austria

Table 11. Detailed energy demand in Austrian pilot building.

Scenario	Energy demand [kWh/m ²]	Space heating demand [kWh/m ²]	Domestic hot water demand [kWh/m ²]	Heating total Demand [kWh/m ²]	Electricity Demand [kWh/m ²]
Existing situation	195,9	137,67	31,2	168,91	27,0
Demo. Building	106,25	47,96	31,2	79,20	27,0

Greece

Table 12. Detailed energy demand in Greek pilot building.

Scenario	Energy demand [kWh/m ²]
Building 1 (manetas)	
Situation before renovation according to build regulations	129.84
Demo. building	40.36
Building 2 (Rizos)	
Situation before renovation according to build regulations	111.25
Demo. building	61.79
Building 4 (Agiostatitis)	
Situation before renovation according to build regulations	82.32
Demo. building	40.31

Spain

Table 13. *Detailed energy demand in Spanish pilot building.*

Scenario	Energy demand [kWh/m²]	Space heating demand [kWh/m²]	DHW demand [kWh/m²]	Heating total Demand [kWh/m²]	Electricity Demand [kWh/m²]
Existing situation	317	245	49	295	23
Demo. building	77	55	25	80	22

Hungary

Table 14. *Detailed energy demand in Hungarian pilot building.*

Scenario	Space heating demand [kWh/m²]	DHW demand [kWh/m²]	Heating total demand [kWh/m²]	Electricity demand [kWh/m²]
Existing situation	125,3	38	163,3	25
Demo. building	10,24	12	22,24	18

Annex 16.II – Economical impact of measures implementation

Denmark

Table 15. *Economical impact of measures and payback time in the Danish building.*

Scenario	Costs, operation heating [Euro]	Costs, operation electricity [Euro]	Costs, operation total [Euro]	Costs, investment [Euro]	Pay-back time [years]
Existing situation	26349	8640	45271	0	0
Standard renovation	16370	8640	34777	345.942	33
Demonstration project	6451	2880	17042	658.373	23

Austria

Table 16. *Economical impact of measures and payback time in the Austrian building.*

Scenario	Costs, operation heating [Euro]	Costs, operation hot water [Euro]	Costs, operation electricity [Euro]	Costs, operation total [Euro]	Costs, investment [Euro]	Pay-back time [years]
Existing situation	112934	23909	48617	185460	0	0
Standard renovation	58112	23909	48617	130638	1023242	28
Demonstration project	39796	23909	48617	112322	1277149	25

Greece

Table 17. *Economical impact of measures and payback time in the Greek building.*

Scenario – ALL BUILDINGS	Costs, operation heating [Euro]	Costs, operation electricity [Euro]	Costs, operation total [Euro]	Costs, investment [Euro]	Pay-back time [years]
Situation before renovation according to build regulations	12888	8704	21592	0	0
Standard renovation (improved thermal insulation, glazing, ceiling fans, night ventilation)	8254	6992	15246	146,486	2.9
Demonstration project	4433	2893	7326	426,326	5.9

Spain

Table 18. *Economical impact of measures and payback time in the Spanish building.*

Scenario	Costs operation energy demand [Euros/a]	Costs, operation space heating [Euro]	Costs operation DHW demand [Euros/a]	Costs operation heating total demand [Euros/a]	Costs operation electric. Demand [Euros/a]	Costs, investment [Euro]	Payback time [years]
Existing situation	630	449	91	540	90	0	0
Demonstration project	233	101	45	146	87	148000	25

Hungary

Table 19. *Economical impact of measures and payback time in the Hungarian building.*

Scenario	Costs, operation heating [Euro]	Costs, operation electricity [Euro]	Costs, operation water [Euro]	Costs, operation total [Euro]	Costs, investment [Euro]	Payback time [years]
Existing situation	18245	11138	5995	35378	0	0
Standard renovation	9240	11138	5636,4	26015	380000	41
Demonstration project	2485	8020	3586,8	14091	740000	35