Proposal/Contract no.: FP6-503186 16 May 2008

DEMOHOUSE

Design and Management Options for improving the energy performance of Housing

SPECIFIC TARGETED RESEARCH OR INNOVATION PROJECT

Thematic Priority 6

Deliverable 8: Implementation and monitoring
First part: D8.1 Monitoring programme

Due date of deliverable: October, 2006
Actual submission date: October 2007

Start date of project: October 18th, 2005 Duration: 4 years

Cenergia Energy Consultants
Peder Vejsig Pedersen

Executive Summary

The EU- Demohouse project is a specific targeted research and innovation project supported by the EU – 6th Framework programme. It started in October 2004 and 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 main focus on housing renovation.

The main goal of WP2 is: "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 gives a presentation of the foreseen monitoring programmes for pilot projects in the EU Demohouse project.

The monitoring programmes of the EU-Demohouse building projects have a key role when the effect and quality of the renovation projects are evaluated.

The consumption of heat, electricity and water is here monitored, analysed, and compared to design calculations and reference buildings. The building projects that include production of renewable energy have special programmes for monitoring of the energy production besides monitoring of the actual energy consumption

Special tools such as BEMS systems and the Energy Signature will be used to further analyse the energy consumption, and determine if the building functions well.

In the EU-Demohouse project a common evaluation protocol D22 was developed by the partners. This is used as the input to all national monitoring programmes.
Also information from the deliverables D4 on the Green Build Quality Building Process and D5 on airtightness of constructions has been used as input to the development of the national monitoring programmes.

Contents

1 Introduction

This report covers the monitoring programmes for the EU-Demohouse building projects. This report is part I of Deliverable 8: Monitoring Programme. Part II will cover the actual implementation and monitoring, and will be submitted after implementation of the projects.

The relevant resources used in the Demohouse buildings are monitored as well as resources produced and the indoor environment achieved.

The consumption of water, heating (district heating, gas or other) and electricity is monitored. For some resources this is done at apartment-level, while others are monitored on building-level.

The building integrated production of renewable energy is monitored, and include solar thermal systems and PV systems.

Special tools may be used to analyse the consumption of resources, such as Energy Signature or BEMS systems.

Monitoring of the indoor environment after renovation is also used to analyse the quality of the renovation projects.

2 Danish demonstration project Gyldenrisparken

The housing blocks Gyldenrisparken include 500 apartments divided between several blocks of flats with a total built up area of 43410 m². 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 were built as a concrete panel assembly construction in 1965-69. From the year 2007 to the year 2009 all the buildings are going through a renovation process in several phases, where the first phase covering three housing blocks with 96 apartments is realised as part of the EU - Demohouse project.

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

Here it is the idea to implement different levels of special energy-saving measures, which can be used to determine the best and most economic energy quality measures to be implemented in the following phases. One housing block will be renovated using an energy-saving level of 50% - level B, and one at level A with 75% savings and finally the third housing block with 85% savings using level A + Solar energy features like solar DHW and PV panels. The savings are related to the present situation.

In the following, the monitoring programme for Gyldenrisparken is described.

2.1 Blower door test and thermography

As described in the report D5 on Airtightness, it is important to use a blower door test as early as possible to identify possible leakages that need repair. For reference, blowerdoor tests will be made before start of the renovation. The apartments will be chosen among the first to be renovated. When the first apartment have been renovated with new windows, insulation and airtightness measures, another blowerdoor test will be performed in order to check if the airtightness meet the target value. Based on this, leakages will be identified and repaired, and a new test will be made. Finally at least 3 apartments will be checked by blowerdoor tests covering both mid- and gable at centre and top floors. The experiences gained from the selected apartments will be used in the renovation of the rest of the apartments.

In connection to the blowerdoor test a good way of identifying possible leaks is by help of smoke detectors where you can see smoke being sucked into a construction part which is leaking.

The same apartments will also be analysed using thermographic equipment. An analysis will be made before renovation to identify cold bridges and leakages in the existing building. This knowledge will be used to further focus the renovation work. When the selected apartments have been renovated with new windows, insulation and measures for airtightness, another thermographic analysis will be made to quantify the effect of the renovation in relation to cold bridges and leakages. The results will be used in the renovation of the remaining apartments, and if necessary changes in the focus of insulation will be made.

2.2 District heating consumption

In each block a meter for monitoring district heating consumption is already installed in the existing situation. This will not be changed as part of the renovation, and the meter will be used for reading the district heating consumption after the renovation. The readings will be done on a monthly basis, and compared to the calculated values.

There is not installed district heating meters in the apartments. Instead, simple meters based on evaporation are installed in the existing building. The evaporation meters are used to determine the heating bill for each apartment, based on the total measured energy consumption for heating. To monitor the consumption in each apartment, the tenants of the 96 apartments will be invited to participate in a metering-programme. They will be asked to read their meters once a month. The results will be analysed and compared to the calculated values. The results will also be given to the tenants with information on their consumption compared to the average consumption.

2.3 Energy signature

The readings af district heating consumption will be analysed using the Energy Signature method, described in report D4, Green Build Quality Process. This is used to state if the energy consumption is higher than the calculated consumption. This is done by comparing the monitored consumption with a calculated consumption.

By analysis of the monitored consumption a heat characteristic is recorded where the heat consumption is expressed as W/m^2 versus outside temperature. The expected consumption has already been calculated and the result of the calculations is recorded as heat characteristic as well.

If the calculated heat characteristic is identical with the monitored, the consumption is reasonable and there is no need for further analysis. However if the monitored consumption exceeds the calculated consumption, further analyses are made to find the reason for difference. By adjusting the application parameters (inside temperature, air change, idling loss / circulation pipe loss, etc.) the changes are made until the two characteristics are identical.

The energy characteristic is thus a powerful tool when used to evaluate if the renovation has met the energy reduction target.

2.4 Electricity consumption

In each block a meter for monitoring electricity consumption is already installed in the existing situation. This will not be changed as part of the renovation, and the meter will be used for reading the electricity consumption after the renovation. The readings will be done on a monthly basis, and compared to the calculated values. The meter measures both the electricity used in the apartments and the electricity used in the common areas.

In each apartment a separate meter for monitoring electricity consumption is installed in the existing situation. It is not possible to read these automatically from a central location; they must be read manually by entering each apartment.

2.5 Water consumption

In each block a meter for monitoring the consumption of tap water is already installed in the existing situation. This will not be changed as part of the renovation, and the meter will be used for reading the water consumption after the renovation. The readings will be done on a monthly basis, and compared to the calculated values.

The domestic hot water consumption will also be monitored directly.

In each apartment a separate meter for monitoring both water and DHW consumption is installed in the existing situation. It is not possible to read these automatically from a central location; they must be read manually by entering each apartment.

To monitor the consumption in each apartment, the tenants of the 96 apartments will be invited to participate in a metering-programme. They will be asked to read their meters once a month. The results will be analysed and compared to the calculated values. The results will also be given to the tenants with information on their consumption compared to the average consumption.

2.6 Solar thermal system energy production

The heat supplied to the DHW tank is monitored using a meter for manual reading. The meter will be read monthly, and the readings will be compared with calculated values, and the system efficiency will be calculated.

The water temperature before and after the solar collectors will be monitored by thermometers, as well as the temperature in the DHW tank. After installation, these values will be read regularly and analysed so that optimal system performance is obtained. Besides supplementing energy use and the efficiency of this in the same sense is monitored as well.

2.7 PV system electricity production

The PV system will be grid-connected, and thus the electricity produced by the PV system will be supplied to the grid. The amount of electricity produced will be monitored by a meter. The meter must be read manually, and this will be done monthly. The readings will be compared with calculated values, and the system efficiency will be calculated.

In a period of 2-3 month after installation of the PV system, data logging equipment will be used to analyse the efficiency of the PV system.

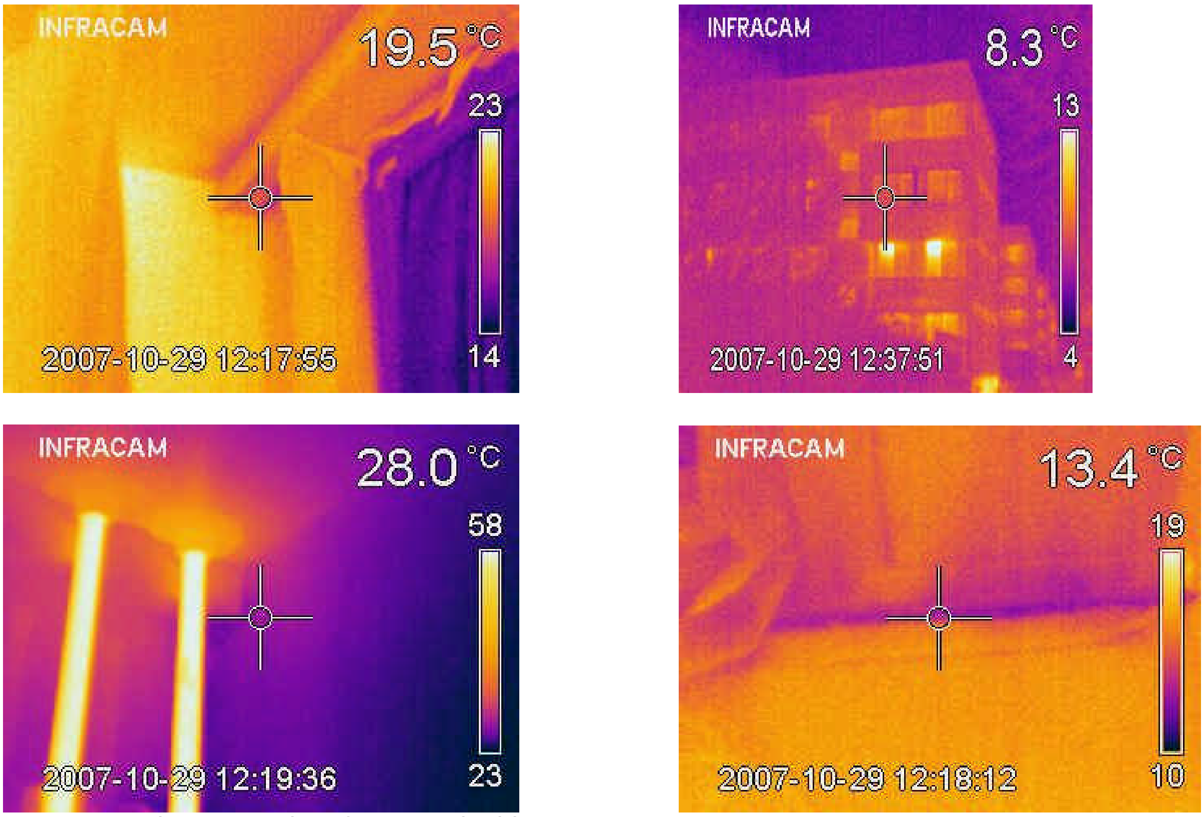
2.8 Indoor environment

The indoor environment will be monitored in selected apartments using small autonomous dataloggers of temperature and humidity (ThermoTags/TinyTags). The dataloggers will be used to analyse the indoor environment both in the winter and the summer situation.

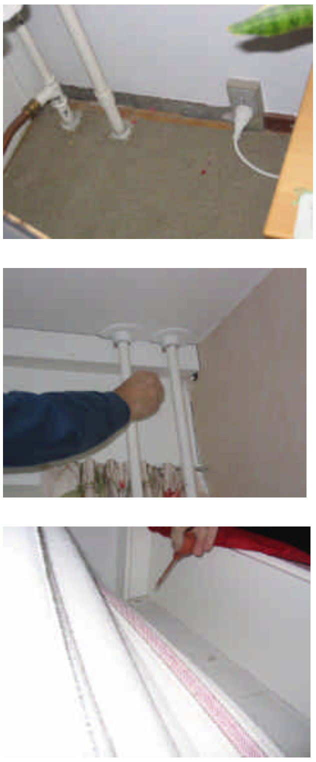
Overview of measurements – Danish project

Measurement	Duration	Regularity	No. of flats	Comments
Global measurements				
Total energy	1 year	Monthly	Estate	The energy use in
Electricity consumption	1 year	Monthly	Estate	each housing block
Water consumption	1 year	Monthly	Estate	Will be identified
Heat consumption	1 year	Monthly	Estate	
Climatological data	1 year	Monthly	Estate	
More detailed measurements				
Thermal comfort	4-7 days	Hourly	4 flats	Temperature/humidity
Air quality	4-7 days	Once	4 flats	
Specific measures				
Air tightness		After finalisation of flats, after improvements, and finally as check	3-4	ISO 9972
ACH (airchange per hour)		Once (day + night)	2	ISO 12569
DHW flow rate		Monthly meter reading	Overall estate	
IR-Thermography		Once during heating season	Whole building	ISO 6781
Specific components				
PV	1 year	Monthly production	Estate	
Solar collectors	1 year	Monthly production	Estate	

Table 2.8.1.



Figur 2.8.1 Thermography of existing building



Figur 2.8.2. Blowerdoor test in Gyldenrisparken

3 Austrian demonstration project

The Austrian pilot project is two blocks of flats in the city of Graz: Laudongasse 14-16 as well as Starhemberggasse 13-15. Both buildings were constructed in 1976 and they consist of 127 flats (between 75 and 110 square meters each). All flats are rented flats. Renovation activities will be finished in October 2007 and the following monitoring activities will be done (respectively already have been done).

3.1 Thermography

Thermographic analyses will be carried out in different phases of the construction to detect any malfunctions.

1st phase:
Thermographic analysis of the existing building have shown the main malfunctions and was a base for renovation measures.

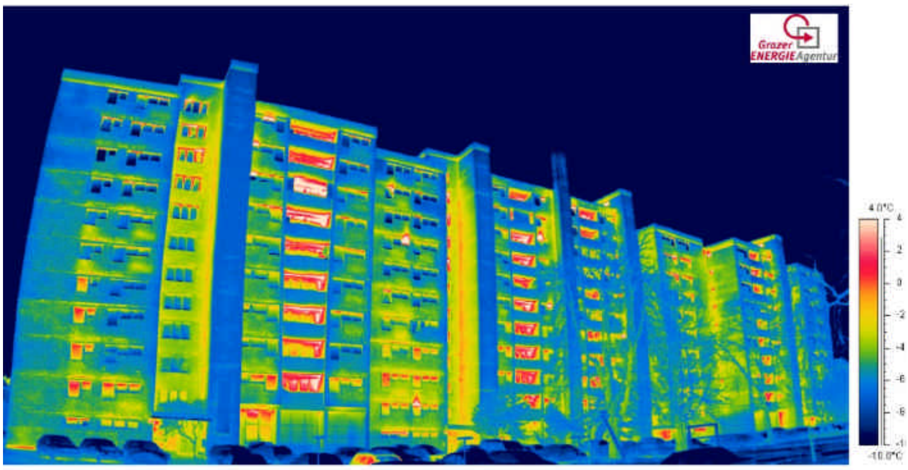
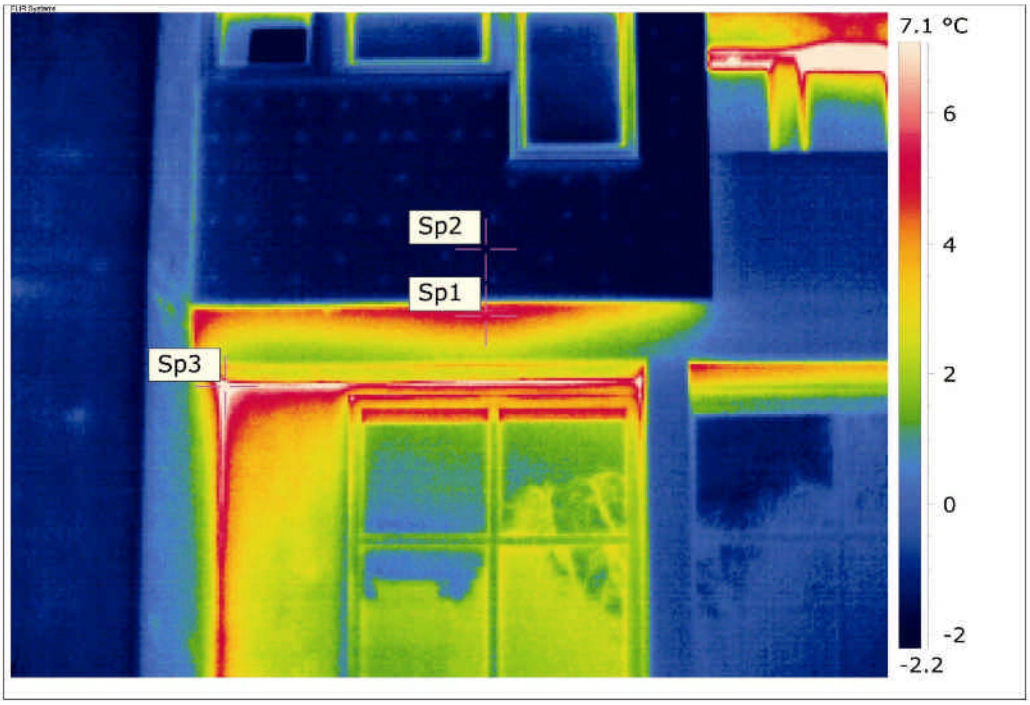
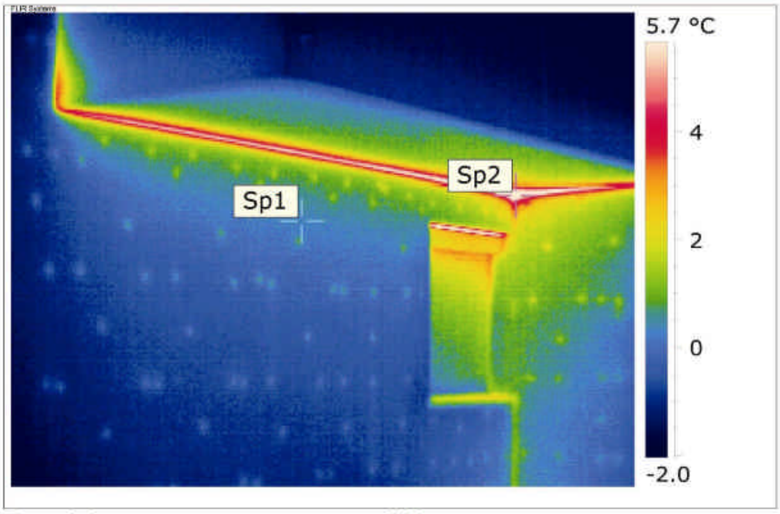


Figure 3.1.1. Thermography – Existing

2nd phase:
Thermographic analysis will be carried out during the construction phase (after completion of insulation and exchange of window in the first building unit). This evaluation gives chance to avoid failures in the next 3 units and gives support in finding improved solutions. The next two pages show thermographic pictures of the already renovated part of the building, detecting missing insulation on the overhanging ceilings above the main entrances of the building.



Objektparameter	Wert
Emissionsgrad	0.91
Objektabstand	10.0 m
Reflektierte Temperatur	-1.0 °C
Atmosphärentemperatur	-1.0 °C
Atmosphärische Transmission	0.99
Bezeichnung	**Wert**
Sp1	5.2 °C
Sp2	-1.8 °C
Sp3	9.1 °C



Bezeichnung	Wert
Sp1	0.4 °C
Sp2	8.1 °C

Figure 3.1.2: Missing insulation

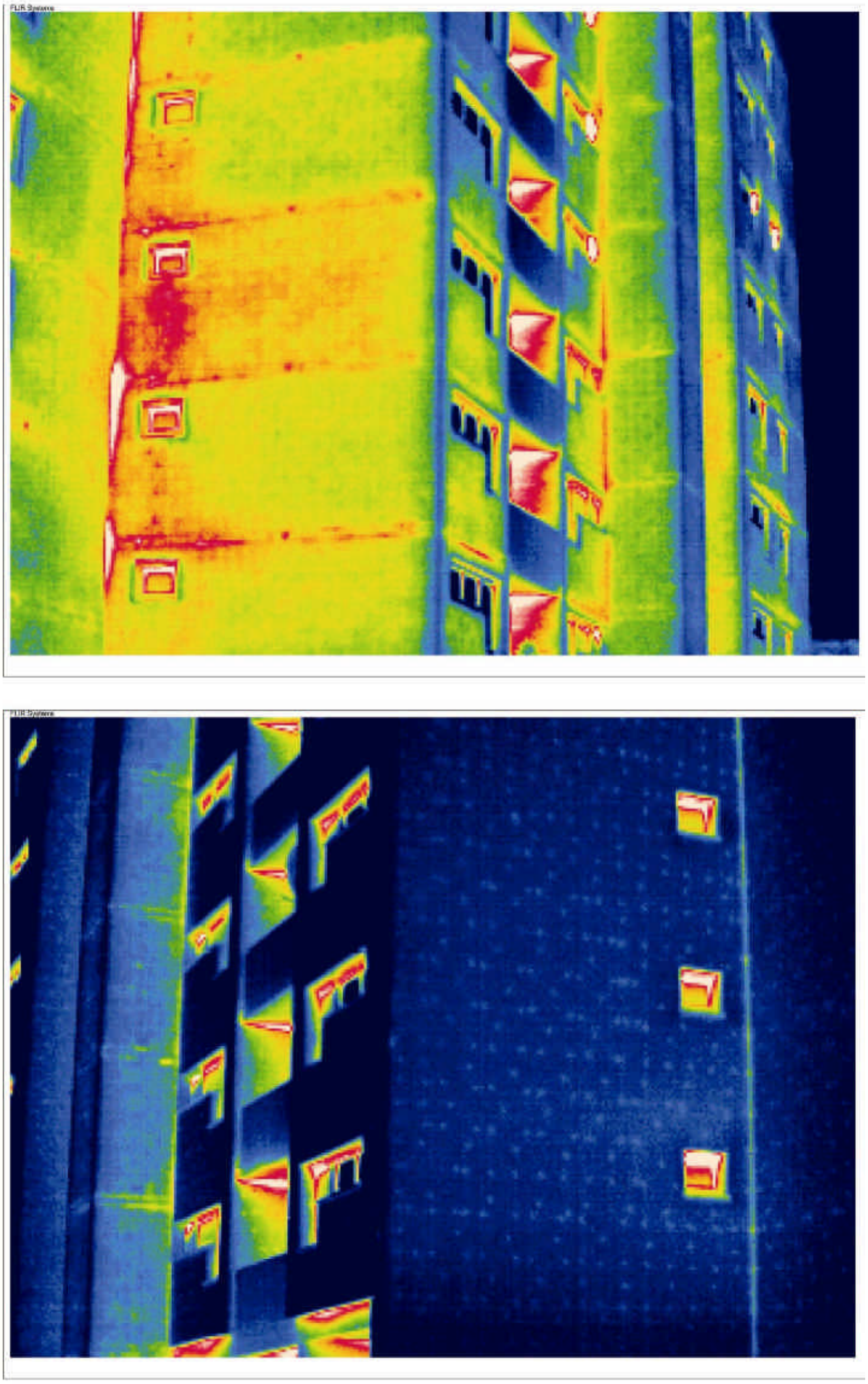


Figure 3.1.3: Thermographic analysis of the building before and after the renovation showing a large improvement of the thermal insulation.

3rd phase:
Thermographic analyses will be carried out after the building envelope is completed by 100% to detect any thermal losses.

3.2 Energy consumption

A meter for monitoring district heating consumption will be installed in the building. The meter will be used for reading the district heating consumption after the renovation. The readings will be done on a monthly basis, and compared to the calculated values.
Another meter will be installed to measure heating energy for hot water and electricity generated by the CHP (combined heat and power plant).

3.3 Indoor environment

As the change of windows and their airtight fitting is the main aspect for the indoor environment in the Austrian demonstration project, the focus on the measurements will be on the CO_2 concentration of the flats. Besides CO_2 there will be detection of substances like VOC`s and formaldehyde. Checks for mould will also be carried out. Measurements will be done in three flats by an accredited company.

3.4 Blower door test

After the completion of the construction works, the buildings' air tightness will be assessed using the blower door test based on EN 13829, a methodology that can measure the tightness of a building and at the same time finding any leaks. Three flats will be tested, following the schema below:
To measure the air tightness of the windows all ventilation ducts in bathrooms and WCs are sealed air tight and the ventilator for Blower Door testing is placed in the entrance door of the dwelling. In a second step Blower Door testing is done without sealing ducts of bathrooms and WCs. In a third step the ventilator for Blower Door testing is placed in a window, ducts of bathrooms and WCs are air tight sealed. This constellation will show the influence of the entrance door (although there was no change of entrance doors in the demonstration building) on the air tightness of the dwelling. Above mentioned approach gives chance to identify the air tightness of different building components and their influence on the total performance of the air tightness.
Measurements will be done by an independent, accredited contractor, relevant construction firms (windows, thermal insulation composite system) are invited to attend the Blower Door procedure, discussing malfunctions (if detected) of their work. Blower Door testing must be repeated until the appropriate standard is achieved.
In connection to the blowerdoor test a good way of identifying possible leaks is by help of smoke detectors where you can see smoke being sucked into a construction part which is leaking.

3.5 Climatological data

Meteorological information for the Austrian demonstration building will be monitored based on hourly generated data by Meteonorm.:

- Ambient temperature (°C)
- Relative humidity (%)
- Solar radiation (W/m²)

4 Greek demonstration project

The Greek project is a new to build housing complex. Four buildings (each one consisting of three detached houses) are constructed within the DEMOHOUSE project with a total area of approx 3000m^2 of heated space. All buildings are under construction.

During the construction works, monitoring of the energy and environmental performance of various components will control the quality and standards of the project.
The performance verification procedure (PVP) to be followed includes:

- Detection of thermal losses using thermo photography equipment
- Monitoring of air tightness and cold bridges with blower door test

4.1 **Monitoring of building 4** (Agiostratitis, dwellings I2, I3)

Monitoring was carried out in building 4 – dwellings I2 and I3 (Agiostratitis) to assess the quality of the building envelope. The following measurements were performed:

-Thermography and blower door test (according to Deliverable 4-performance verification procedures)
-Tracer gas
-Internal and external temperatures
-Lighting levels

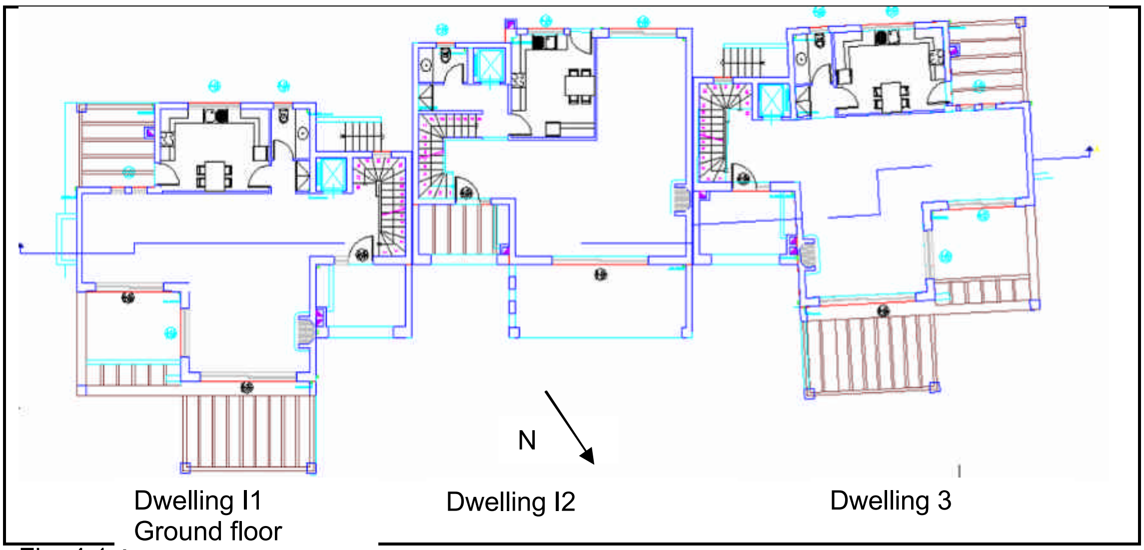
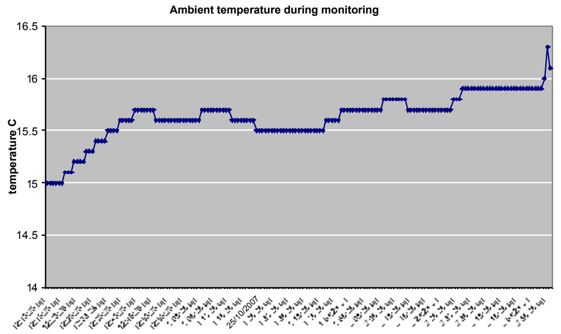


Fig. 4.1.1.

4.2 IR-photography

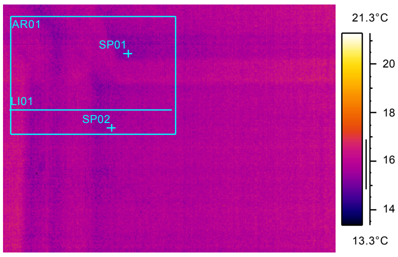
The thermography is a special way of infrared photography where different colours in a picture show the temperature of each object. In this way hot and cold parts of a building can be visualised. (Deliverable 4)
The pictures show the heat radiation and can detect any malfunctions in the installation of the thermal insulation and the presence of thermal bridges.
The monitoring was carried out along one day in October. In the following graph, the external temperatures of the day are visualised. The temperatures are rather high for the period, and show that the heating season has not started yet in Greece.
The monitoring was carried out using the thermographic camera 'Thermovision 570' and focused on the following areas:

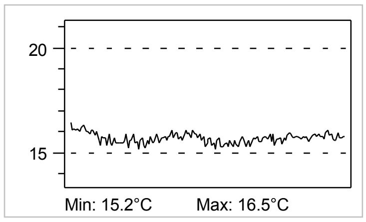
- Connection between the building components
- Around the doors and windows.

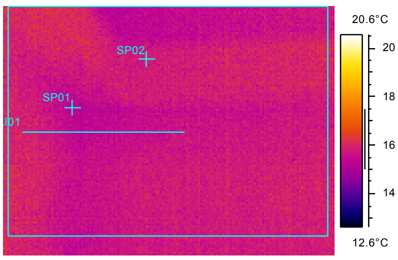


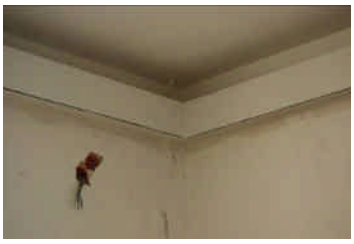
Graph 1: External temperatures during monitoring

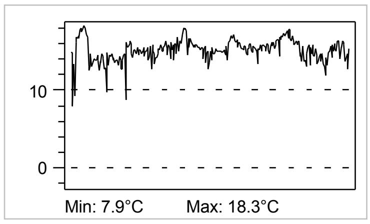
Fig. 4.2.1.

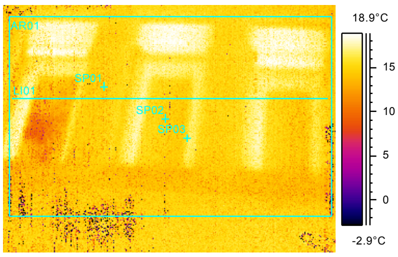


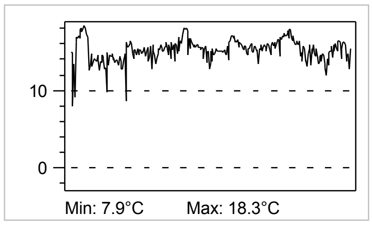


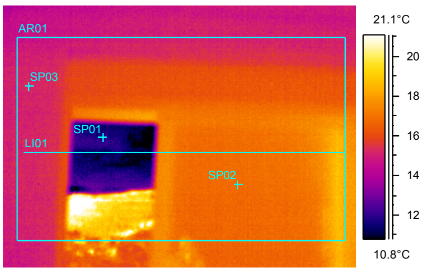


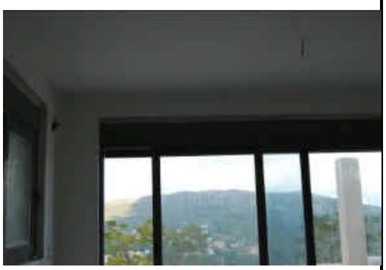


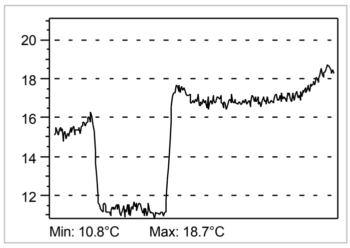












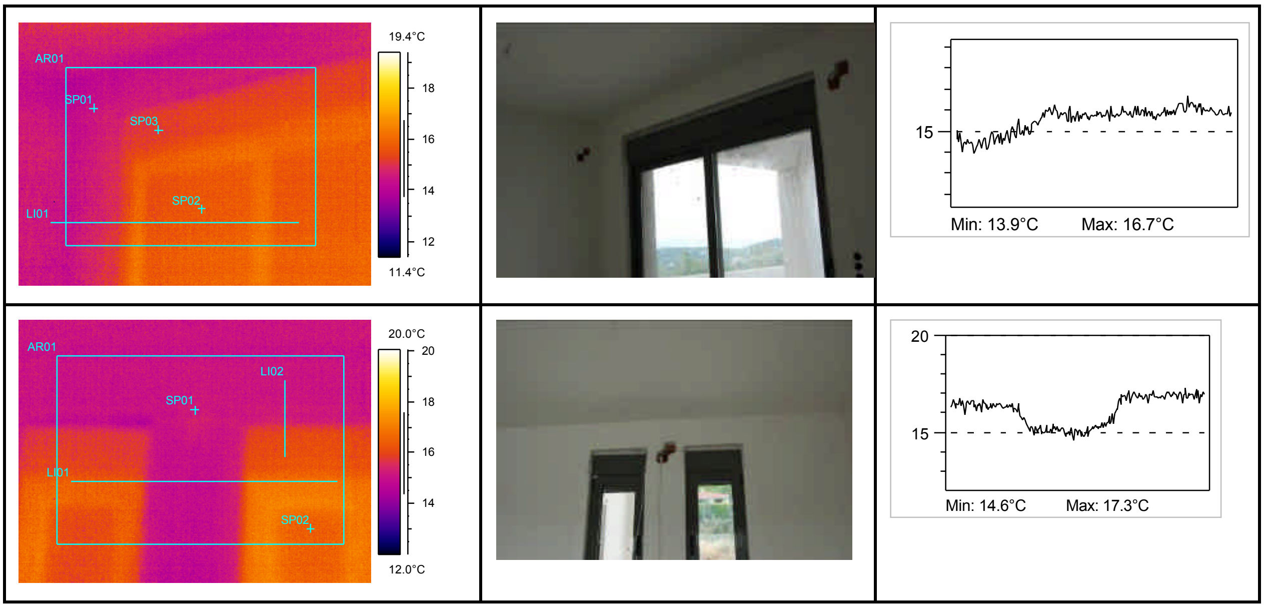


Fig. 4.2.2.

Figure 2: Thermographic analysis of dwellings I2 and I3

Results

According to the thermographic analysis:

- Homogenous surfaces temperatures between the building components were identified
- Glass temperatures were approximately 1.2 ºC higher than the external walls' surface temperatures. Also, the contribution of double low e glazing in maintaining indoor temperatures can be seen in the photographs where the windows are open.
- No problems were detected with the installed thermal insulation and the building structure.

4.3 Blower door test

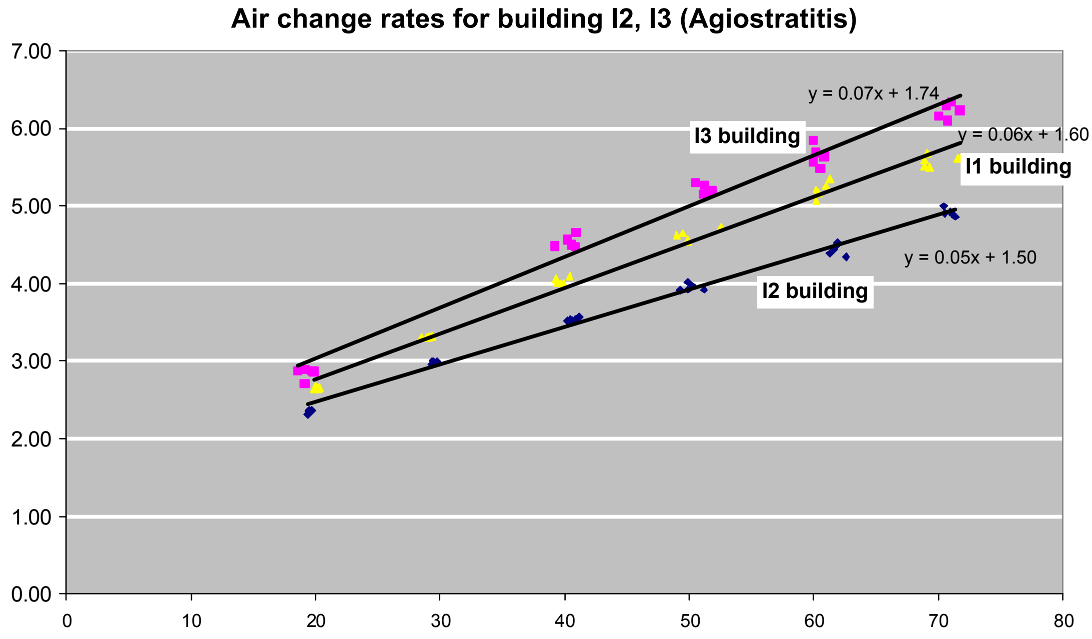
The air-tightness of the 'DEMOHOUSE' building 4 was tested using the fan pressurization method (blower door test).
The fan pressurization method is intended to characterize the air-permeability of the building envelope. This method does not measure the air infiltration rate of the building. The results of the fan pressurization test can be used to estimate the air infiltration by means of calculation. It is better to use the fan pressurization method for diagnostic purposes and measure the actual infiltration rate with tracer gas methods.
Ideal conditions for the test are small temperature differences and low wind speeds. Standard **EN 13829** is intended for the measurement of the air leakage of building envelopes of single-zone buildings. For the purpose of this standard, many multi-zone buildings can be treated as single-zone buildings by opening interior doors.
The test is carried out by taking measurements of air flow rate and indoor – outdoor pressure difference over a range of applied pressure differences, from 30 Pa to 70Pa for best accuracy.

The air change rate $\mathbf{n_{Dpr}}$ at the pressure difference, e.g. 50 Pa is calculated by dividing the mean air leakage rate at 50 Pa by the internal volume.

$$n_{50}=V_{50} / V$$

Figure 4.3.1.: Blower door test - entrance of dwelling I2

Results



Graph 1: Air change rates at different pressure differences for dwelling I2, I3

Fig. 4.3.2.

The graph shows the air change rates over a range of applied pressure differences for dwellings I2 and I3. At 50 Pa the air change rate is calculated to:

4.42 ach for dwelling I1

3.90 ach for dwelling I2

5.23 ach for dwelling I3.

The difference between the two dwellings is attributed to the fact that I3 is exposed at its three sides while I2 dwelling is attached to dwellings I1 and I3.

According to EN standards the envelope tightness level of I2 and I3 dwellings is characterised as high and medium respectively.

Air change rate (h^{-1}) at 50 Pa	Ventilation rate (h^{-1}) for naturally ventilated single family houses	Envelope tightness level
10	1.5	Low
4-10	0.8	Medium
4	0.5	High

Table 4.3.1.: Air change rates and building air tightness according to EN 832 standards (EN 13790)

4.4 Tracer gas results

Figure 4.4.1.: Tracer gas in dwelling I2

The measurements using tracer gas resulted in:

Dwelling I2: Ventilation rate: 0,17 h^{-1} < 0.5 (from Table 1)

Dwelling I3: Ventilation rate: 0,29 h^{-1} <0.8 (from Table 1).

The measurements carried out by the tracer gas comply with the EN standards 13790 (table 1) for the dwellings I2 and I3 with envelope tightness level high and medium respectively.

4.5 Lighting levels – Visual comfort

Spot measurements of lighting levels were carried out in representative areas of the dwellings, in the living rooms and bedrooms of the first floor. The measurements were carried out using lux meters for a typical day of autumn between 12.00 pm to 14.00 pm.

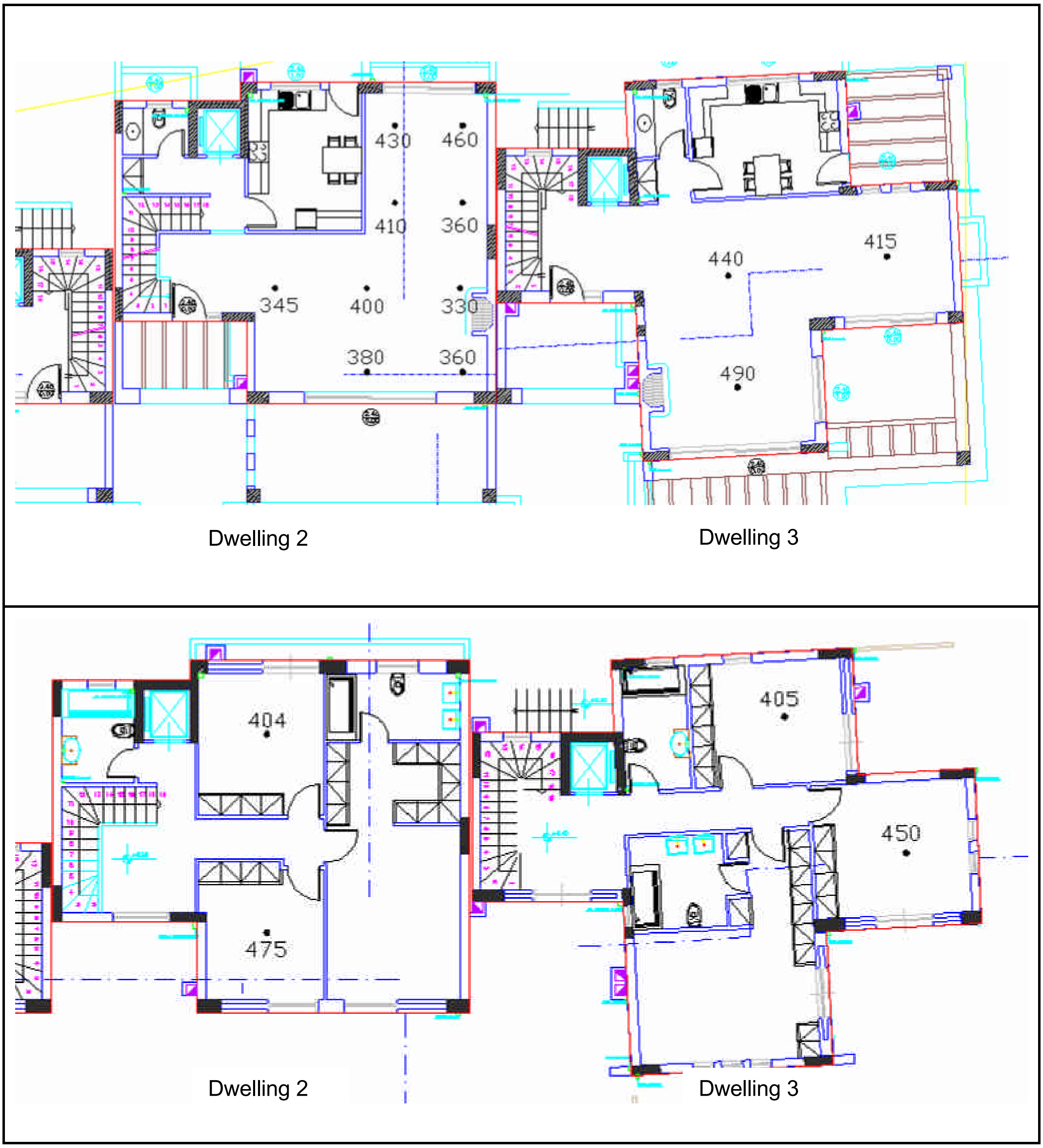


Fig 4.5.1.

Results

The measurements showed that the daylight levels are satisfactory in all the living areas in both dwellings. Also, the lighting levels are homogenous in the different zones of the buildings.
In dwelling 2, the living room has a depth of 10 metres, with windows facing north and south. The lighting levels at 13.00 pm in the zone facing south were approximately 370 lux while the lighting levels near the windows facing south were 445 lux .
The lighting levels in the living room of dwelling 3 are quite homogenous and vary from 415 lux to 490 lux as this area has a depth varying from 3.70m to 7.40m.
The lighting levels in the bedrooms (first floor) with windows facing south are approximately 400 lux, and

450-475 lux in the bedrooms with windows facing north.

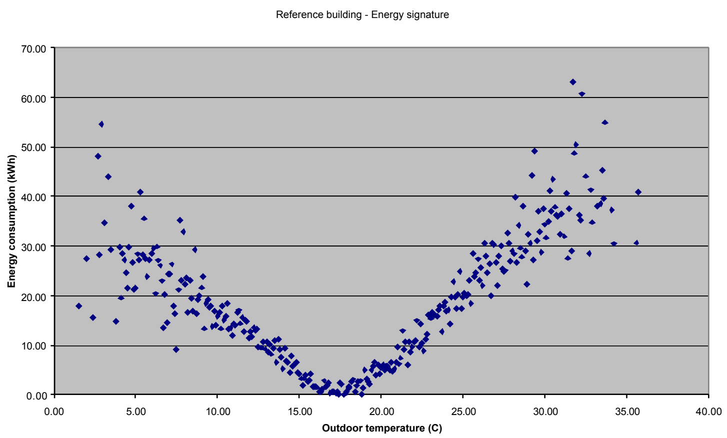
4.6 Air quality

As soon as the buildings are occupied, air quality will be monitored in terms of: VOC levels, CO_2 and CO. The analysis will be carried using tracer gas. The monitoring will be carried out along one day. The pollutants are expected to be negligible.

4.7 Energy signature (based on simulations)

According to deliverable 4 the energy signature will be used to assess the reduction in energy consumption before and after the construction works.
The following graphs show the energy demand for the reference and Demohouse buildings, and are based on the simulation results that were carried out within the Demohouse project.

Before construction



After construction

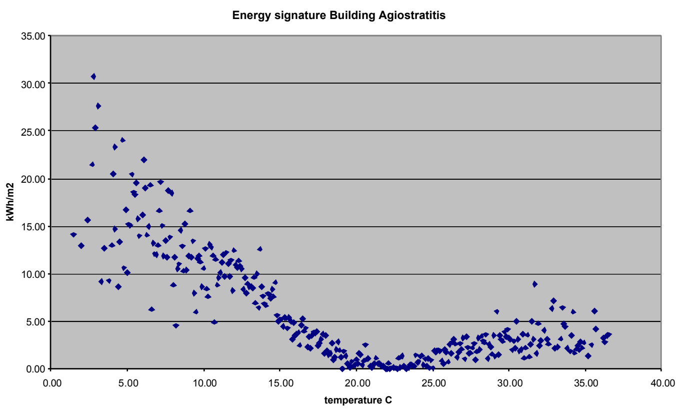


Fig. 4.7.1.
The comparison of the two graphs shows the estimated energy savings in the area of heating and cooling. The estimated savings are higher in the area of cooling because of the climatic characteristics in Greece.

After the completion of the building construction, a post-evaluation will be done based on the measurements recorded during the monitoring period. The measurements will be carried out by the BMS of each dwelling.

4.8 BMS monitoring – Energy consumption

Global measurements
The Building Management System of each dwelling will take daily readings of the following systems:
-Heating
-Cooling systems (if installed-depends on the occupants)
-Day light levels in the living rooms and operation of the shading system
-Internal temperatures
-Climatological data (Ambient temperature, solar radiation)
-CO_2 concentration and demand control

Water and electricity consumption
The water and electricity consumption will be measured based on bills that the occupants will provide.

Measurements concerning specific components

The performance of the ground heat exchangers will be assessed by monitoring the air temperature at the inlet/outlet of the exchangers and the wind velocity. The Building Management System of each dwelling will take daily readings of the temperatures and wind velocity.

The BMS monitoring will start as soon as the buildings are occupied within the year 2007.

4.9 Overview of measurements

Measurement	Duration	Regularity	No. of flats	Comments
Global measurements				
Total energy	1 year	Hourly/ Monthly	3	BMS
Electricity consumption	1 year	Monthly	3	bills
Water consumption	1 year	Monthly	3	bills
Climatological data	1 year	Hourly /monthly	3	Sensors, BMS (ambient temperature, solar radiation)
More detailed measurements				
Thermal comfort	1 year	Hourly	3	BMS, internal temperatures
Visual comfort	1-2 days/1 year	Once/ Hourly	3	Lighting levels, spot measurements using luxmeters & daylight levels in the living rooms by the BMS
Air quality	1-2 days	Once	3	Spot measurements, tracer gas (VOC, CO_2, CO)
Specific measures				
Air tightness	1-2 days	Once	3	EN 13829, EN 13790
ACH		Once	3	EN 13829, EN 13790
DHW flow rate		Once	3	All water taps
IR-Thermography		Once	3	
Specific components				
Earth to air heat exchangers	1 year	Hourly/ Monthly	---	Inlet & outlet temperatures

Table 4.9.1.

5 Spanish demonstration project

The building is located in a site of 187 m^2. It is placed in the centre of the city of Bilbao, so it has an urban environment. It is located in the corner of the confluence of Cortes and Cantera streets having façades in both streets. The shape is approximately rectangular with five levels and one space under the roof.

The building is 90 years old and it was built with wooden gates and brick closures. The inner walls were made in brick as well. The roof has a wooden structure and ceramic tiles.

Following table shows the areas in the building:

Area of basement	187 m^2
Area of zero level (commercial use)	187 m^2
Area of levels 1, 2 and 3 (dwelling use) (165 x 3)	495 m^2
Area of the "penthouse"	70 m^2

Total area commercial use	374 m^2
Total area dwelling use at the present	565 m^2

Renovation project plans to achieve 12 dwellings: 3 dwellings per floor (except basement and penthouse).

5.1 Energy signature

Results of energy consumption will be plotted versus external temperature obtaining an energy signature type of graph. This will permit an easy comparison of energy demand estimated in the pre-evaluation and the measurements recorded during the monitoring period.

After the renovation has finished, a post-evaluation will be done based on monitoring of several parameters, divided into four different groups.

5.2 Global measurements

5.2.1 Total energy consumption

Along the monitoring period energy consumption will be controlled including all energy sources, which will be mainly electricity and natural gas.

Electricity consumption will be individually monitored for each flat every month. Common equipment will be used for heating and domestic hot water, boiler based on natural gas consumption. Energy consumption for domestic hot water will be calculated from data corresponding to summer period, where no heating is required and it will be assumed to be approximately constant along the year. Demanded energy exceeding the value for DHW will be considered as heating. Natural gas consumption will be also recorded every month.

Since no cooling devices will be implemented in the building, no monitoring protocol will be programmed

5.2.2 Water consumption

Water consumption will be monitored for each flat every month.

5.2.3 Climatological data

Energy demands assessment requires a good knowledge of the climatological conditions of the place where the building is located in order to correlate the consumption with the external conditions. Meteorological information for the Spanish pilot building will be monitored according to the data collected in the Deusto weather station (managed by the Basque Government), located also in Bilbao and separated approximately 4 Km. This weather station measures following parameters every 10 minutes:

- Ambient temperature (°C)
- Relative humidity (%)
- Precipitation (L/m²)
- Solar radiation (W/m²)
- Average wind speed (m/s)
- Average wind direction (° from N)
- Maximum wind speed (m/s)

5.3 More detailed measurements

This set of measurements will be carried out once the renovation is finished. They will be performed in 4-5 different flats for a period of 7 days.

5.3.1 Thermal comfort

Measurements for thermal comfort evaluation will involve mainly globe temperature, which combine air and radiant temperature. Other parameters affecting thermal comfort are humidity and air movement. The latter is complex to be monitored and only a qualitative approach will be considered identifying local discomfort points due to air draughts. Discomfort derived from air humidity is very unusual and it would involve very extreme values, above 80% or below 30% approximately, which are not expected. Anyway relative humidity in the building will be monitored.

5.3.2 Visual comfort

Monitoring of visual comfort will be carried out by means of a luxmeter to measure the illuminance level inside the building and detect possible discomfort conditions because of excessive or lack of illuminance. Since the visual comfort depends strongly on exterior shadings (other buildings in the demonstration case), significant variations are expected between the flats of the building, demanding different artificial lighting.

5.3.3 Air quality

Air quality depends on different parameters, some of them considered in other sections such as relative humidity or air renovation. In addition, levels of different air pollutants can be measured. In the Spanish demonstration building volatile organic compounds (VOCs), formaldehydes, NO_x, CO,… levels will be monitored, which are parameters related to the use of solvents (e.g. paints), resins (e.g. chipboard), and occupancy. Since significant levels of these substances are not expected to be present, only one measure will be performed in order to ensure their absence.

Measurements will involve two parts: sampling and analysis. Since pollutants are expected to be very low or negligible, sampling will be carried out along one day to reach high sampled air volume and then low detection limits, which can provide results about the presence of these compounds. Samples will be collected in cartridges (e.g. activated carbon) and then analysed by means of chromatography or other techniques depending on the compound.

5.4 Specific measurements

5.4.1 Air tightness

The airtightness of the building envelope will be tested by carrying out the blower-door-test, according to ISO 9972. As Spanish building is small, containing merely 12 dwellings, renovation works will take place more or less at he same time in all of them. Therefore only one set of air tightness measurements is planned in 3-4 flats.

5.4.2 Ventilation rate (ACH)

In order to determine the ventilation rates (air changes per hour) in the building the tracer gas dilution method (ISO 12569) will be applied. These measurements will be performed during the day and during the night for 3-4 buildings.

5.4.3 DHW flow rate

For monitoring Domestic Hot Water flow a simple procedure will be employed: collecting water in a graduated container during a measured period of time. This method will be applied in all the DHW taps existing in the dwelling. As all the dwellings will have the same set of taps, repetition of this procedure in 3-4 dwellings will be considered enough.

5.4.4 IR-Thermography

IR-Thermography provides very useful information in the assessment of both the envelope of the buildings and heating equipment. It permits to detect and analyzed heat losses points in the façade of a buildings. It can be also employed for the evaluation of the proper performance of heating equipment, for instance, detecting blocks in the ducts or leakages.

In this case this technique will be focused on thermal bridges detection. IR-thermography will be used once the renovation is finished, and a general assessment will be carried out in the façade and in any sensible area where heating losses through thermal bridges are presumed. These measures will be performed according to ISO 6781.

5.5 Overview of measurements

Measurement	Duration	Regularity	No. of flats	Comments
Global measurements				
Total energy	1 year	Monthly	12	
Electricity consumption	1 year	Monthly	12	
Water consumption	1 year	Monthly	12	
Climatological data	1 year	Hourly	---	Weather station
More detailed measurements				
Thermal comfort	4-7 days	Hourly	4-5	Globe temperature/Humidity
Visual comfort	4-7 days	Hourly	4-5	
Air quality	4-7 days	Once	4-5	
Specific measures				
Air tightness		Once	3-4	ISO 9972
ACH		Once (day + night)	3-4	ISO 12569
DHW flow rate		Once	3-4	All water taps
IR-Thermography		Once	Whole building	ISO 6781
Specific components				
PV	1 year	Monthly	---	
Solar collectors	1 year	Hourly	---	Inflow/Outflow temperature

6 Hungarian demonstration project

Figure: The project building before and after the retrofit

The project site is situated at the northern border of Budapest, 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 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.

The renovations and the demonstration activities will be assisted with quality control and monitoring.

6.1 Blower door test and thermography

The air-tightness will be measured by blower-door tests after installing the new windows and after finishing the whole building.
The thermal bridge free installation will be approved by thermograph as well as leakage detection.

6.2 Energy consumption

The consumption and energy production values (gas, wooden chips, water, DHW, electricity, green electricity, performance of solar collectors) will be monitored and registered during one year. The performance (air-flow, temperatures before and after the heat exchangers and acoustic parameters) of the heat recovery units will be measured, too.

6.3 Energy signature

In the energy signature, the energy consumption values will be plotted versus external temperature. This allows an easy comparison of the estimated and the measured consumption.

6.4 Heat Recovery Ventilation Systems

In the first demo phase innovative heat recovery ventilation systems 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.

6.5 Solar Systems

In the initial phase the produced electricity from the PV system 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. Solar DHW contribution will also be monitored.

6.6 Climatic data

Climatic data, such as outdoor temperature, humidity, solar irradiation and wind will also be registered by a weather station installed on the construction site.

6.7 Thermal comfort

Finally, the comfort parameters will be monitored by movable data loggers positioned at representative points of the buildings. Most sensors will register air temperature, but some will measure relative humidity and light as well. Light is necessary to see how the shading devices are used.

The representative data pattern will enable statistic analysis to determine stochastic relations between parameters. This will improve the scientific value of the project.

7 Conclusion with overview of monitoring of building projects

In the EU-Demohouse project a common evaluation protocol D22 was developed by the partners. This is used as the input to all national monitoring programmes.
Also information from the deliverables D4 on the Green Build Quality Building Process and D5 on airtightness of constructions has been used as input to the development of the national monitoring programmes.

The monitoring programs for the pilot building projects will allow a detailed analysis of the energy balance for each project. In this way it will also be possible to compare the pilot projects.

The table below provides an overview of the monitoring programs for each project.

	Danish	Austrian	Greek	Spanish	Hungarian
Blowerdoor test	X	X	X	X	X
Thermography	X	X	X	X	X
Heating consumption	X	X	X	X	X
Cooling consumption	n/a	n/a	X	n/a	n/a
Electricity consumption	X		X	X	X
Water consumption	X		X	X	X
Solar thermal production	X	n/a	n/a	X	X
PV production	X	n/a	n/a	X	X
Energy Signature	X			X	X
Internal temperature	X		X	X	X
Relative humidity	X			X	X
CO_2-concentration		X		X	
VOC's/formaldehyde		X		X	
Moulds		X			
Climatic measurements	X	X	X	X	X
Other			Performance of ground heat exchanger	Natural gas consumption	