

# ENERGY EFFICIENT RENOVATION OF DWELLINGS: LESSONS LEARNED

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## 1 Introduction

An analysis of the energy consumption of the built environment in Europe shows that the main challenge to achieve substantial energy reductions in this sector lies in improving the energy efficiency of the existing stock rather than in designing and building energy efficient new dwellings. This challenge is especially pungent when taking into account the building stock of former Eastern European countries, where energy efficiency was never a great issue and where investments in energy efficiency are difficult to find.

This is area where the EU - funded project Demohouse is focusing on. In this project, partners from Austria, Denmark, Greece, Hungary, the Netherlands and Spain are working together to develop, implement and demonstrate solutions to reduce the heating demand by at least 30% compared to present 'business as usual' renovations. The advantage of the European dimension of the project is that participating countries learn through sharing their experience and solutions.

## 2 The renovation projects.

The Demohouse project started in 2004 with 18 partners, and 8 building projects, of which 7 renovations and 1 new build. In the very first phases of the project, 2 renovation projects were withdrawn and one more followed in January 2007. Finally another project, in Hungary, was withdrawn in November 2007. Since the latter participated in most of the analyses and provides some useful lessons learned, it is nevertheless presented in this paper. Pictures of the 5 projects and the main architectural characteristics are summarized in Table 1 and Table 2 below.

All projects began with reducing the energy need for space heating by a good thermal insulation and air tightness of the building skin. Ventilation losses are reduced by applying a heat recovery unit or applying demand controlled ventilation, using CO<sub>2</sub>-sensors.

For all projects, the renovation is compared to a 'business as usual' or 'standard' renovation. For all buildings, including the Greek building, this is a theoretical exercise, where the building is 'virtually' renovated according to the national or local building code.

Originally, a biomass fired CHP (Combined Heat and Power) plant was planned in the Austrian renovation project, but in the end, this did not appear to be economically feasible. Figures for the case with CHP and without CHP are shown in Table 3.

Table 1: Pictures of the 5 projects.

		
The Spanish Demonstration building, after renovation	The Austrian Demonstration building, after renovation	The Danish Demonstration buildings, before renovation
		
The Greek Demonstration building, newly built	The Hungarian Demonstration building, before renovation	

Table 2: The main architectural characteristics of the 5 projects.

Country, City	Year of construct.	Characteristics	Main energy saving measures
Spain, Bilbao	1910, partly renov 1960	Old Town, historical area, 4-storey, brick walls, tiled roof	Insulation of building envelope Solar collectors + PV Building Management System
Austria, Graz	1975-76	Two blocks of flats, Social housing District heating	Insulation of building envelope Biomass-CHP-plant Quality control (e.g. IR-photography)
Denmark, Copenhagen	1965-1969	3 (of 12) building blocks, Prefab concrete District heating	Insulation of building envelope Air tightness Heat recovery unit each apartment
Greece, Athens	2005-2007	Newly Built, Concrete structure, Brick walls	Insulation of building envelope Ground heat exchangers for cooling Demand controlled ventilation (CO <sub>2</sub> )
Hungary, Budapest	1955-1960	Former military building 3 (of 11) blocks of 3 storey building bricks/concrete	Insulation of building envelope Solar collectors + PV Rooftop apartment

Table 3 shows that the simple Pay Back Time (PBT), calculated as the ratio of investment and the savings in operational cost (both compared to a standard renovation) ranges from

8 to 30 years. The first figure, from the Austrian project, is for the scenario without the biomass CHP.

Table 3: Investments and savings of the 5 projects.

	net floor area [m <sup>2</sup> ]	simple PBT [yrs]	renovation cost [€/m <sup>2</sup> ]	Space heating + DHW [kWh/m <sup>2</sup> a]	CO <sub>2</sub> -savings [%]
<b>Spain</b>	496	26	1463	80	64%
<b>Austria</b>	9860	14	130	102	52%
<b>Austria, no CHP</b>	9860	8	118	102	22%
<b>Denmark</b>	2880	21	218	40	50%
<b>Greece</b>	2787	17	115	46	48%
<b>Hungary</b>	6300	30	117	22	73%

The total cost of the renovation ranges from 115 to 220 €/m<sup>2</sup>, except for the Spanish building. The structural reinforcement that was necessary (see below) made this renovation particularly costly.

Model calculations for the heating demand, including space heating and DHW (Domestic Hot Water) show figures in the range of 22 to 100 kWh/m<sup>2</sup>a, with the low figure presenting a challenge to reach this in practice. CO<sub>2</sub> savings compared to a standard renovation range from 22% for the Austrian project without CHP to 73% for the Hungarian project, again, a challenge to achieve in practice.

### 3 Barriers for Energy Efficient Renovation

For most of the projects, the financial barrier appeared to be the most important one. In Spain, local subsidies from funds to revive the neighbourhood were found to help overcome this barrier. In all countries, lack of low cost solutions for large scale implementation of energy saving measures was a barrier. In particular, implementation of a heat recovery unit in the ventilation system requires a substantial investment. In fact, this is the reason why such system was not implemented in the Austrian renovation project.

With the aid of EU-funding some important quality oriented R&D work was carried out to overcome this barrier. In the Danish project, a cost effective heat recovery unit with high thermal efficiency, low noise and energy efficient fans was developed. The Austrian partners as well as the Spanish expressed great interest in the product, but the development came too late for application in their renovation projects.

Another example is the development of a prefab lightweight and energy neutral rooftop apartment, also by the Danish partners. The sale of such apartments, generally at a good price because of the location, will partly cover the extra investment needed for an energy efficiency renovation of the remaining building. Roof top apartment were also planned in the Hungarian project, prior to its withdrawal.

In Austria, Hungary and Spain, introduction of an EPC (Energy Performance Contracting) model was considered to overcome the split-incentive problem, where the party investing in the renovation (the owner) is not the one to profit from the energy savings (the tenants). For various reasons, the EPC concept was not implemented in these projects.

Unfamiliarity of stakeholders with energy savings was also encountered in a number of countries. A good cooperation between builders, consultants and housing association proved very valuable in the Danish project. In Austria, unfamiliarity of tenants with an energy saving concept is thought to be solved by gradual introduction of the concept with tenants of good social background.

In Spain, an architectural barrier was related to the building being of historic value where the façade had to be preserved, implying the application of thermal insulation internally. Also, the building was in a dilapidated condition, requiring extensive and expensive structural reinforcements, resulting in a substantial renovation investment (see Table 3).

In Hungary, subsidised gas prices decrease the feasibility of application of Rational Use of Energy (RUE) measures and Renewable Energy Sources (RES). Here, the subsidy system is in need of revision, but this is outside the scope of the project.

#### **4 The renovation process, what went well and what didn't**

In general, raising awareness with the stakeholders (housing association, tenants, and local authorities) went very well. In Spain, contacts with local government like EVE (Basque Energy Board) and IHOBE (Public Society for Environmental Management) resulted in cooperation on developing energy policies and guidelines /legislation. In Denmark, tenants appeared to be very pleased with the application of the low cost heat recovery unit, also because it was very silent. In Greece, its success worked against the builders: future owners asking for additional sustainable measures caused some delays.

Setbacks different from project to project. In the Spanish project it was the bad condition of the building, aggravated by the lack of information about building in general and the foundations in particular. In the Austrian project, it was the increase of the price of vegetable oil by 60% since the start of the project in 2004, rendering the application of a biomass powered CHP (Combined Heat and Power) plant economically unfeasible.

In Denmark, renovations had to be approved by a majority of the tenants. The process of reaching consensus caused delays in the renovation. As a result, roof-top apartments could not have been applied in the Demohouse project, as its application could no longer fit the time frame of the latter. The roof top apartment will however be applied in the rest of the Danish renovation project. In Greece, the cost of the BMS (Building Management System) was higher than foreseen. In Hungary, in the end, lack of support from the local authorities, both financially and cooperatively, caused the project to be withdrawn.

#### **5 Monitoring**

An important aspect, often overlooked both in renovation and new build, is the monitoring of the building after the building process is completed. Too often, contractors build what they are supposed to build and don't look back at what they did. Monitoring the building after completion can provide information to what extent the targets with respect to energy savings, indoor environment etc. were achieved.

Monitoring will be carried out according to the so-called Common Evaluation protocol, which includes measurements of energy consumption for space heating and DHW for one year and single measurements of e.g. thermal and visual comfort and indoor air quality.

The protocol also includes a methodology (the energy signature) to compare expected and achieved energy savings.

So far only limited monitoring results are available. Instructive however is the case of the Austrian renovation project. The expected energy savings of approx. 65% (compared to pre-renovation state) that were calculated using sophisticated modelling tools were not achieved at first. In the first winter (2005-2006) of monitoring, with about half of the apartments renovated, the energy consumption of the building was reduced by approx. 5%. At the same time, it was observed that windows were opened more often than before. It appeared that the control of the heating system had to be adjusted to the different thermal behaviour of the building. Also, the tenants, unaccustomed to a well insulated building envelope, will have to be instructed anew on how to operate the heating system.

## **6 Lessons Learned**

The reason for not applying energy saving measure in renovation is often unfamiliarity of the stakeholders with the approach and the consequences, and fear of extra costs. Demonstration of successful renovations therefore is crucial. Financial solutions can be found in the availability of low-cost components (such as the heat recovery unit developed in the Demohouse project), finding local subsidy funds, applying new financing models e.g. EPC or placing prefab rooftop apartments. Also, a good cooperation with and support by local authorities (preferable including financial support) is imperative.

Quality control in the course of the renovation appears to be very important in order to achieve the targets set. In the Austrian project, IR (Infrared) photography revealed missing parts of insulation of the building envelope, which the contractor could be forced to repair. In the Danish project, repeated blower door tests in the course of the renovation proved very useful to correct failures in achieving the air-tightness required.

The price of these quality control techniques is a fraction of the building cost. IR-photography for instance will cost in the order of 1000 €, giving the opportunity to correct cold bridges, air leakages, missing insulation etc.

After care also seems an important lesson. Check that the expected energy savings are indeed achieved and analyse the reasons if they don't. Too often, this stage is omitted in the process. The energy signature method can help to compare expected and achieved energy consumptions. Include the opinion of the tenants in the evaluation.

It is important to disseminate research carried out, the knowledge gained and lessons learned in order to achieve wide spread energy efficient renovation of buildings. For this reason, a Decision Support Tool was developed (Kondratenko et. al., April 2008). This instrument should facilitate decision makers on energy efficient and otherwise sustainable renovation. The DST focuses on the initiative phase of renovations since it is at this stage that the decisions about the ambition level of a renovation are taken. The DST also includes information on quality control during the renovation process and after care (e.g. the energy signature).

## **7 Literature**

**Kondratenko et. al.**, (April 2008), DST, Decision Support Tool to facilitate energy-efficient renovation of buildings