Industrialized energy efficient retrofitting of resident buildings in cold climates

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Abstracts

This paper will introduce the work carried out in E2ReBuild. E2ReBuild is a European collaborative project, researching and demonstrating industrialized energy efficient retrofitting of residential buildings in cold climates.

The existing building stock in Europe accounts for over 40 percent of final energy consumption in the EU, of which residential use represents 63 percent of total energy use in the building sector. The fast-track, low-cost pre-fabricated construction from the 1940s to the early 1980s is responsible for a vast proportion of that consumption.

For the majority of buildings from this period, there is now a pressing need for renovation and redesign of whole residential areas. The challenge of today is to take stock of what is recyclable en masse and refurbish it in the light of its structural integrity. It also needs to meet energy efficiency by today's standards, to the tune of sustainability, for improved quality of life for those living in these buildings at present and for future generations.

Today, the building industry in Europe is characterized mainly by on-site production, which may be inefficient with regard to cost and production time. The sector is negatively associated with poor quality as well as an unsafe and unhealthy working environment. Facing the enormous need for reduced energy use and renovation of buildings from the post-war era, these problems are reasons why an industrial construction process for retrofitting is needed. Using well-designed, prefabricated elements, for example, can drastically reduce the production time, and thus possibly also cost of retrofit projects, and minimize the social disturbance for tenants. The paper will give an example of a possible solution.

To meet the overall ambition of the project, E2ReBuild is designed to cover innovation in planning, design, technology, construction, operation and use of buildings. Seven full-scale demonstration building projects serve as prototypes for the application, evaluation and monitoring of proposed technologies and processes. The demonstration buildings represent different building typologies from the mid 1940s to the early 1980s found all over Europe. They provide best practice examples of retrofitting strategies for buildings in cold climates, from Finland in the north to the alpine region in southeast France. This paper will also give a briefing of the demonstrators, the particular challenges and some general results.

Keywords: Industrialized retrofitting, demonstration buildings, energy efficiency, social disturbance, prefabricated elements

Introduction

This paper will introduce the work carried out in E2ReBuild. E2ReBuild is a European collaborative project, researching and demonstrating industrialized energy efficient retrofitting of residential buildings in cold climates. Starting in January 2011, it engages 20 partners in eight different countries and will continue until mid 2014.

Objective

The existing building stock in European countries accounts for over 40% of final energy consumption in the European Union (EU) member states of which residential use represents 63% of total energy consumption in the buildings sector [Itard et al 2008]. While being the second largest contributor to greenhouse gas emissions it is also responsible for 40% of the total flow of raw materials.

The vision of E2ReBuild is to transform the retrofitting construction sector from the current craft and resource based construction towards an innovative, high-tech, energy efficient industrialized sector. Today, the building industry in Europe is characterized mainly by on-site production, which may be inefficient with respect to cost and production time. Many hours are consumed in the construction process, where problems often are treated as unique and solved on-site. Furthermore, the sector is negatively associated with poor quality as well as an unsafe and unhealthy working environment. These problems are reasons why an industrial construction process for retrofitting is needed.

In E2Rebuild we address these problems in order to speed up the development towards an energy efficient construction and building sector. Our aims are:

- To investigate, promote and demonstrate cost effective and advanced energy efficient retrofit strategies that create added value for existing apartment buildings and endorse end-users to stay and build a dynamic society
- To establish and demonstrate sustainable renovation solutions that will reduce the energy use to fulfill at least the national limit values for new buildings according to the applicable legislation based on the Energy Performance of Buildings Directives (for 2010) and to reduce the space heat use by about 75%.
- To create a holistic industrialized process that aims to minimize technical and social disturbance for tenants and facilitates energy efficient operation and use of the buildings including encouraging energy efficient behavior.

Method

To meet the overall ambition of the project, E2ReBuild is designed to cover innovation in planning, design, technology, construction, operation and use of buildings. Seven demonstration building projects serve as prototypes for application, evaluation and monitoring of proposed technologies and processes. The tools, methods and processes developed and refined by continuous feedback between research and demonstration will finally be integrated into an 'Industrial Platform for Energy Efficient Retrofitting' for large-scale market deployment.

Results

Seven different residential building demonstrations, with different owner structures, project delivery models, cultural aspects and traditions, provide best practice examples of retrofitting strategies for buildings in cold climates, from Finland in the north to the alp region in southeast France. The demonstrator also covers different building typologies representative for northern Europe. Added values for tenants, throughout the renovation and afterwards, are also studied, see Figure 1.

Figure 1 The strategies proposed by E2ReBuild bring added values for the tenants (Photo: Kajsa Winnes)

The aim is to reduce the energy use in the demonstration buildings to 30-50 kWh/m^{2}y for heating, ventilation and hot water, by introducing innovative and sustainable renovation solutions. These solutions focus on industrial manufacturing methods e.g., facade elements and standardized retrofit measures that allow a high replication potential. That potential is estimated to up to 60 percent of the existing apartment buildings in the studied region and time period (1946-1980).

Two years into the project the demonstration buildings are in different development phases, from planning and early construction to completed construction and monitoring. The following will briefly summarize the features and current status of the different demonstration buildings.

Augsburg

The Augsburg demonstration is a multi-story residential building in southern Germany with typical postwar characteristic features from the 60's and early 70's. It had originally a heat energy demand of approximately 220 kWh/m²y due to its poor building envelope and leakages around the old windows and joints to the roof. The building is owned by public housing company WBG Augsburg.

Retrofit concept

In May 2012 the modernization of the building envelope of the E2ReBuild demo project Grüntenstraße in Augsburg was completed. The building has been fully retrofitted including building services and bathrooms. Residents have remained in their apartments during the construction work. The envelope has been retrofitted adding a prefabricated envelope system, based on the TES EnergyFacade system (http://www.tesenergyfacade.com/).

The project serves as a pilot example for the implementation of prefabricated timber elements (U-value 0,13 W/m²K) with modern highly insulated windows. Thermal bridges have almost been eliminated through integrating the balconies into the heated space.

The existing balconies were converted into winter gardens and new outdoor spaces, between the former concrete balcony structure, have been created. Hence, the apartments gain extra space with an additional room as a buffer zone and an additional exterior platform, Figure 2. Table 1 presents some brief facts of the Augsburg demonstration building.

Figure 2 Facade in Augsburg, before (left) and after (right) retrofit (Photo: Frank Lattke/ TUM)

Table 1 Brief facts of the Augsburg demonstration building

Year of construction:	1966
Property type:	Multi-story building
No. of dwellings:	60
Project owner:	WBG Augsburg, public housing company
Energy demand (heat) before retrofit:	220 kWh/m²y
Estimated energy demand after retrofit:	30 kWh/m²y
Construction works:	Completed, May 2012
Participating E2ReBuild partners:	Technical University of Munich, Gumpp & Maier GmbH, WBG Augsburg

Halmstad

The demonstration in Halmstad, Sweden, is a multi-story building from 1963 with typical features from that period e.g., reinforced concrete load bearing frame and facade elements. The building contains 91 flats and is owned by the private housing company Apartment Bostad.

Retrofit concept

The retrofit included a complete exchange of main pipes (water and sewage) as well as new kitchens and bathrooms, energy efficient measures such as new, highly insulated windows, improved adjustments of control systems and increased airtightness etc. The retrofit action for the building aimed at lowering the energy use by approximately 120 kWh/m^{2}y. Residents remained in their apartments during the retrofit construction work. Therefore, this demonstration investigates and evaluates tenant-host communication during extensive renovation work. One of the greatest challenges faced within E2ReBuild is to introduce technical innovations into existing buildings together with processes that aim to minimize disturbance for the end-users. This demo also focuses on creating (economic) win-win situations between stakeholders through, e.g., partnering, and provides input to the activity based process platform that is currently under development one of the RTD work packages. Table 2 presents some brief facts of the demonstration building.

Table 2 Brief facts of the Halmstad demonstration building

Year of construction	1963
Property type	Multi-story building
No. of dwellings	91
Project owner	Apartment Bostad Väst, private housing company
Energy demand before retrofit	174 kWh/m²y
Estimated energy demand after retrofit	53 kWh/m²y
Construction works	November 2010- January 2012
Participating E2ReBuild partners	NCC Construction Sverige, Apartment Bostad Väst, White, SP Technical Research Institute of Sweden

Munich

The demonstration in Munich, Germany, consists of two blocks of residential multi-storey buildings in the suburb of Sendling, built in 1954. The buildings were typical examples of the concrete brick constructions, built throughout Germany in the post-war era. The buildings are owned by the public housing company GWG München.

Retrofit concept

The construction process on site started in July 2010 with various preparation works, a new underground garage and a fundamental conversion of the ground plans. In March 2011 the prefabrication of the timber elements started, the assembly and closing of the facades took place from May to October 2011. Meanwhile the new technics were installed for heating, ventilation, sanitary and electrics. Solar thermal facilities were mounted on the roofs and two central heat storages were added in the basement. The rest of the heat needed is served by the heating system of Munich.

In the end of 2011 the steel construction was erected for staircases, arcades and balconies, while the interior of the apartments was finalized. This may have been the most difficult part of the whole construction process.

After about one year of construction the Munich demonstration project was completed and fully occupied in the summer of 2012. The building has been fully retrofitted including the replacement of the attic by an additional floor to create more rental space. Residents had to move out during the renovation process. The building envelope has been improved by an additional layer of prefabricated insulated timber elements (U-value 0.14 W/m²K) with modern highly insulated windows. The thermal bridges were eliminated by cutting off the cantilevering concrete balconies and replacing them with free standing balconies, see Figure 3. Monitoring of energy use and indoor climate is ongoing. Table 3 summarizes some facts of the demonstrator.

Figure 3 The Munich demo, before (left) and after (right) retrofit (Photo Frank Lattke).

Table 3 Brief facts of the Munich demonstration buildings

Year of construction	1954
Property type	2 Multi-story buildings
No. of dwellings	-
Project owner	GWG München, public housing company
Energy (heat) demand before retrofit	220 kWh/m²y
Estimated energy demand after retrofit	20 kWh/m²y
Construction works	Completed in 2012
Participating E2ReBuild partners	Technical University of Munich, Gumpp & Maier GmbH, SchwörerHaus KG, Lichtblau Architekten, GWG München

Oulu

The pilot building in Oulu, Finland, is one of five student apartment buildings and one building with communal facilities in a housing corporation. The building was completed in 1985 according to a Finnish industrialized building system developed in the 1970's using prefabricated concrete units for residential buildings, called the "BES system". The building is in need of a complete refurbishment and the student flats are outdated and lacking in facilities, see Figure 4.

Retrofit concept

The retrofit concept is based on prefabricated timber framed energy facade of large scale frame elements that introduces the benefits of modern timber construction to the modernization of existing buildings. The retrofit is bringing this building up to and above current new build standards, and aims to reduce the occupied building's energy use to 30kWh/m^{2}y for heating, ventilation and hot water with innovative and sustainable renovation solutions. These solutions focus on industrialized manufacturing methods for facade elements and standardized retrofit measures with high replication potential.

As part of the retrofit strategy for reaching the energy efficiency target level, and due to the poor condition of existing roof material and façade elements, the design includes the application of the TES EnergyFacade (http://www.tesenergyfacade.com/), the infill of insets in the building volume to gain additional space and reduce thermal transmission, the remodeling of south facing balconies, and a new roof for additional insulation and HVAC installations. Building services have been entirely replaced. High efficiency rotating heat recovery ventilation units have been installed in each

apartment. Building automation will track energy performance, indoor air quality, and monitor the building physics. The building owner will evaluate the results of the demonstration project, with a view towards the modernization of the other 4 apartment buildings with the same technique.

Figure 4 The Oulu demonstration as it was before retrofitting and the architect's vision "after" (Photo: Simon le Roux, illustration: M3 Arkkitehdit)

Table 4 presents the Oulu demonstration briefly.

Table 4 Brief facts of the Oulu demonstration

Year of construction	1985
Property type	Two-story building
No. of dwellings	8
Project owner	PSOAS (Pohjois-Suomen oppilasasuntolat Oy), public student housing company
Energy (heat) demand before retrofit	148 kWh/m²y
Estimated energy demand after retrofit	30 kWh/m²y
Construction works	August 2012 - February 2013
Participating E2ReBuild partners	Aalto University, PSOAS, NCC Construction Finland

Roosendaal

The demonstration in Roosendaal, the Netherlands, consists of 50 identical, single family terrace houses build in 1968 in the area of Kroeven. The full upgrade of the Kroeven area consists of 370 houses, of which 246 will be renovated and 112 units will be newly constructed, replacing about 100 existing houses. The retrofits of the 50 houses that are part of the E2ReBuild project were completed in the beginning of 2011. The houses are owned by social housing company Aramis AlleeWonen.

Retrofit concept

The renovation in the Roosendaal pilot buildings took place with the tenants remaining in their homes through the whole renovation work. This required both a fast and non-intrusive renovation process and a continuous dialogue between the housing company, Aramis AlleeWonen, and the tenants. When the discussion of an upgrade of the Kroeven area started, it was soon realized that both the owner and the tenants were interested in the passive house concept for renovation. Two different approaches for energy efficient renovation were tested:

While two approaches were tested in the area, the one chosen for the E2ReBuild project shows how the houses can be insulated using a new 350 mm timber frame element with cellulose insulation, with triple glazed passive house window frames, and prefabricated timber roof elements, filled with 350 mm insulation. The external façade cladding is natural slates. From 2010 to 2012 this approach was implemented in 134 houses, including the 50 E2ReBuild pilot houses, see Figure 5. The heating, ventilation and domestic hot water systems were upgraded using new compact systems, which include a mechanical heat recovery system and a 200 l storage tank connected to a solar collector array, backed-up by a small condensing gas boiler.

Figure 5 Houses in Roosendaal, before (left) and after (right) retrofit. (Photo: Chiel Boonstra/Trecodome)

Table 5 presents some brief facts of the Roosendaal demonstrator.

Table 5 Brief facts regarding the Roosendaal demonstration.

Year of construction	1968
Property type	Single family, terrace houses
No. of dwellings	50
Project owner	Aramis Allee Wonen, public housing company
Energy (heat) demand before retrofit	150 kWh/m²y
Estimated energy demand after retrofit	25 kWh/m²y
Construction works	Completed, spring 2011
Participating E2ReBuild partners	Trecodome, Aramis AlleWonen

London

The Thamesmead demonstration is a linear block of maisonette style dwelling accommodation, built in 1974 and located in South East London, UK. The building has a concrete frame construction with a mixture of concrete and PVC-U façade panels with non-standard cavity brick infill to some portals. The roof is of flat construction using a timber cold deck with 3 layer mineral felt covering. The

concrete panels are of non-cavity type construction and therefore cannot be insulated by conventional means. The building is in a very poor condition and the whole neighborhood suffers of social problems.

Retrofit concept

Due to the degree of cold bridging and the complex nature of the construction type an external insulation solution is required. The preferred building envelope refurbishment technology is to use prefabricated, highly insulated façade and roof elements. This will reduce disturbances to tenants and deliver project speed gains on site. It is hoped that the prefabricated methodology will allow for simplified extensions to the existing building with the inclusion of a new upper story constructed off-site using these prefabricated elements and craned into position. Table 6 presents some facts of the demonstrator.

Table 6 Brief facts of the Thamesmead demonstration

Year of construction	1974
Property type	Multi-story building
No. of dwellings	-
Project owner	Gallions Housing, private housing company
Energy (heat) demand before retrofit	237 kWh/m²y
Estimated energy demand after retrofit	Retrofit Passivhaus Standard (<25 kWh/m²y)
Construction works	May 2013-May 2014
Participating E2ReBuild partners	Trecodome, Gallions Housing Association, Gumpp&Meier, Technische Universität München

Voiron

The French demonstration object is a multi-story building in Voiron, in the Isère Department. The building is made of concrete with no insulation. The windows are first generation PVC double-glazing 4-6-4 and the ventilation system used was natural ventilation. All dwellings had an individual gas boilers for the domestic hot water production, additionally, each dwelling had its own heat production system either using electric heaters (approximately 29 dwellings with an energy demand of 529 kWh/m²y) or fossil fuel boilers (approximately 43 dwellings with an energy demand of 202 kWh/m²y). The building's average consumption before renovation was 330 kWh/m²y.

Retrofit Concept

The retrofitting program aims to reduce the energy use to 60 kWh/m²y (2012 French thermal regulation for new buildings) and to create a structured heat and domestic hot water production through a collective heating system (gas boiler) and solar panels for hot water. Mechanical ventilation will be installed and the roof, floor and walls will be insulated. Furthermore, balconies will be closed using prefabricated elements. Table 7 presents some brief facts of the Voiron demonstrator.

Table 7 Brief facts of the Voiron demonstrator

Year of construction	1961
Property type	Multi-story building
No. of dwellings	72
Project owner	OPAC38 (Office Public D'amenagement et de constroction de l'Isere) , public/social housing company
Energy demand before retrofit	330kWh/m²y
Estimated energy demand after retrofit	60 kWh/m²y
Construction works	November 2011-April 2013
Participating E2ReBuild partners	OPAC 38, SP Technical Research Institute of Sweden

Discussion

Barriers to sustainable renovation in the owner-occupied market are low investment capacity and the lack of knowledge about technical solutions (Idlar et al. 2008). The purpose of the seven full-scale demonstration buildings is twofold; firstly acting as physical demonstrations of new technologies and methods, and, secondly, from a bottom-top approach feeding experience and results to the RTD work. Thereby, integrated holistic energy and cost-effective processes can be proposed that move the current craft and resource intensive renovation sector to an innovative, high-tech, energy efficient industrialized sector. Furthermore, using well-designed, prefabricated elements, for example, the construction time on site can drastically be reduced, and thereby minimize the social disturbance for tenants.

The monitoring period will continue until June 2014 in order for comparisons between designed and actual values to be made. The measuring phase will also deliver data to the RTD work, making refinement of proposed strategies and design processes possible.

References

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Glossary

E2ReBuild	Industrialized Energy Efficient Retrofitting of Residential Buildings in Cold Climates (www.e2rebuild.eu)
RTD	Research and Technological Development

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