

ReBuild

Industrial Energy Efficient
Retrofitting of Resident
Buildings in Cold Climates



Final Publishable Summary Report

Grant Agreement no: 260058 **Project acronym:** E2ReBuild

Project Titel: Industrial Energy Efficient Retrofitting of Resident Buildings in Cold Climates

Funding Scheme: Collaborative Project

Period covered: **from** 2011-01-01 **to** 2014-06-30

Scientific Representative of the Project's Coordinator:
Christina Claeson-Jonsson, NCC AB
M.Sc., Ph.D., R&D Manager NCC Construction Sverige AB

Tel: +46 31 771 5118

E-mail: christina.claeson@ncc.se

Revision: Final

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n°260058

Executive Summary

E2ReBuild investigates, promotes, and demonstrates, cost-effective and advanced energy-efficient retrofit strategies that create added value for existing residential buildings and endorse end-users to stay and build a dynamic society. The vision of E2ReBuild is to transform the retrofitting construction sector into an innovative, high-tech, energy efficient industrialized sector. The project implements research and develops new retrofitting solutions regarding planning, design, technology, construction as well as operation and use of buildings. The E2ReBuild results are generated from seven demonstration projects in Finland, Sweden, the Netherlands, France, Germany and the UK.

Today, the retrofitting sector in Europe is characterized mainly by on-site production, which may be inefficient with regard to cost and construction time. Many hours are used in the construction process, where problems are often 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. Facing also 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 construction time, and thus possibly also cost of retrofit projects, and minimize the social disturbance for tenants. To meet the overall ambition of the project, E2ReBuild is designed to cover innovation processes. The tools, methods and processes developed and refined by continuous feedback between research and demonstration were integrated into an 'Industrial Platform for Energy Efficient Retrofitting' for large-scale market deployment.

Monitoring guidelines common for all E2ReBuild demonstrations have been developed. The guidelines define a common approach and a unified methodology for the demonstrators and enable preparing and detailed metering and monitoring of the building's energy in planning, design, technology, construction, operation and use of buildings. Seven demonstration building projects, all completed by the end of the project, serve as prototypes for application, evaluation and monitoring of proposed technologies and performance and indoor environment including thermal comfort for tenants. Guidelines on Preliminaries/Survey have also been developed based on the experiences of the Augsburg demonstration in Germany. These guidelines explain the surveying and planning process and give an overview of the features of a comprehensive digital survey, including the development of a fully featured 3D model for planning and production. E2ReBuild has also developed a software tool – the European Retrofit Advisor – that is especially suited for analysing renovation strategies for residential buildings at an early design stage. It evaluates not only economic issues, but also considers ecological and social aspects of building retrofit.

E2ReBuild will enforce the notion among branch actors such as builders, housing organizations, architects etc. that modern industrialized processes cannot only save money in reduced building and energy costs but also create functional, attractive and individual housing for a great number of Europeans. The industrialized process also minimizes technical and social disturbance for the tenants as well as facilitates energy-efficient operation and use of the buildings, including encouraging energy-efficient behaviour. Moreover, the results of E2ReBuild can greatly contribute to improved working conditions as well as increase the attractiveness of the industry to workers.

Contact Data



Figure 1: Project logo

Project web site: www.e2rebuild.eu.

List of Project Beneficiaries

Coordinator

NCC AB, Sweden

www.ncc.se

Contact: Christina Claeson-Jonsson, Christina.claeson@ncc.se, +46 8 31 771 5118

Participants

Mostostal Warszawa SA, Poland

www.mostostal.waw.pl

Contact: Juliusz Zach, j.zach@mostostal.waw.pl, +48 22 548 5625

SchwörerHaus KG, Germany

www.schwoererhaus.de

Contact: Christoffer Walcher, christoffer.walcher@schwoerer.de, +49 7387 16 161

Trecodome BV, the Netherlands

www.trecodome.com

Contact: Chiel Boonstra, chiel.boonstra@trecodome.com, +31 165 538674

NCC Rakennus Oy, Finland

www.ncc.fi

Contact: Esa Eklund, Esa.Eklund@ncc.fi, +358 10 507 5774

Gumpp & Maier GmbH, Germany

www.gumpp-maier.de

Contact: Sebastian Hernandez, s.hernandez@gumpp-maier.de, +49 872 998 534

Lichtblau Architekten GBR, Germany

www.lichtblau.de

Contact: Florian Lichtblau, florian.lichtblau@lichtblau-architekten.de, +49 89 642 787.40

White Arkitekter AB, Sweden

www.white.se

Contact: Gustav Malm, gustav.malm@white.se, + 46 8 55602349

SP Sveriges Tekniska Forskningsinstitut, Sweden

www.sp.se

Contact: Carl-Magnus Capener, carl-magnus.capener@sp.se, +46 10 516 58 52

Eidgenössische Materialprüfungs- und Forschungsanstalt, Switzerland

www.empa.ch

Contact: Mark Zimmermann, Mark.Zimmermann@empa.ch, +41 58 765 4178

Hochschule Luzern Technik & Architektur, Switzerland

www.hslu.ch/technik-architektur

Contact: Doris Ehrbar, doris.ehrbar@hslu.ch, +41 41 349 3462

Technische Universität München, Germany

www.tum.de

Contact: Frank Lattke, Frank.Lattke@lrz.tu-muenchen.de, +49 821 45 44 236

Aalto-Korkeakoulusäätiö, Finland

www.aalto.fi

Contact: Yrsa Cronhjort, yrsa.cronhjort@aalto.fi, + 358 50 5660802

GWG Städtische Wohnungsgesellschaft München mbH, Germany

www.gwg-muenchen.de

Contact: Dagmar Englert-Friedrich, dagmar.friedrich@gwg-muenchen.de, +49 89 55 114 251

Office Public d'Aménagement et de Construction de l'Isère, France

www.opac38.fr

Contact: Benoît Jehl, benoit.jehl@opac38.fr, +33 476 205 074

Pohjois-Suomen Opiskelija-Asuntosäätiö, Finland

www.psoas.fi

Contact: Juha Aitamurto, juha.aitamurto@psoas.fi, +358 44 7573 151

Akelius Bostad Väst AB, Sweden

www.akelius.se

Contact: Ulf Eriksson, ulf.eriksson@akelius.se, +46 35 100 124

Stichting AlleeWonen, the Netherlands

www.alleewonen.nl

Contact: Ad van Reekum, ah.vanreekum@hetnet.nl, +31 6 3734 6680

Wohnungsbaugesellschaft der Stadt Augsburg GmbH, Germany

www.wbg-augsburg.de

Contact: Bernd Silbermann, bernd.silbermann@wbg-augsburg.de, +49 821 5044 7021

Gallions Housing Association Ltd, UK

www.gallionsha.co.uk

Contact: Richard Hazard, richard.hazard@peabody.org.uk, +44 20 7021 4271

Table of Contents

1	Description of Project Context and Objectives	6
1.1	Progress beyond the State of the Art	7
2	Description of the Main S&T Results/Foreground.....	10
2.1	Work Package 1 – Knowledge Transfer.....	10
2.2	Work Package 2 – Demonstrations	11
2.3	Work Package 3 – Innovation in Planning and Design	23
2.4	Work Package 4 – Innovation in Technology and Construction	26
2.5	Work Package 5 – Innovation in Operation and Use	29
2.6	Work Package 6 – Industrial Platform for Energy Efficient Retrofitting.....	31
3	Potential Impact.....	36
3.1	Socio-economic Impact.....	36
3.2	Dissemination.....	38
3.3	Exploitation	43

1 Description of Project Context and Objectives

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 industrialised sector.

The 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 fulfil 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 industrialised process that aims to minimise technical and social disturbance for tenants and facilitates energy efficient operation and use of the buildings including encouraging energy efficient behaviour.

These were achieved by:

- Transferring technical innovations and advances from research to application and wide use
- Changing current inefficient way of doing business to a “win-win” situation for all involved actors
- Understanding and matching the needs of stakeholders by introducing a new design and decision tool (Retrofit Advisor)
- Improving the design process for holistic renovation concepts
- Creating added values by optimising space use, improving comfort and integration of advanced technologies
- Introducing industrial manufacturing methods and standardise retrofit measures that allow a high replication potential (up to 60 % of existing apartment buildings for the studied regions and period¹)
- Re-constructing in an efficient manner, minimising energy use (during construction and operation) and waste, and, improving quality and indoor environment.
- Establishing and demonstrating sustainable renovation solutions that can reduce the energy use of existing building to 30-50 kWh/m²a primary energy for heating, ventilation and hot water
- Demonstrating, monitoring and evaluating proposed technologies, processes and measures in 7 full-scale residential building projects, with typologies representative for large geographical areas in Europe
- Integrating the proposed tools, methods and processes into an Industrial Platform for Energy Efficient Retrofitting for large scale market deployment

Today, the building industry in Europe is characterised 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. For example, using well-designed prefabricated elements can drastically reduce the production time. If

¹ Period refers to 1946-1980

completed to a large percentage before arriving to the construction site, only limited supplementary work on site will be necessary, this being a desirable goal in industrial construction.

1.1 Progress beyond the State of the Art

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. While being the second largest contributor to greenhouse gas emissions it is also responsible for 40% of the total flow of raw materials. Consequently, an increase of building energy performance can constitute an important instrument in the efforts to alleviate the EU energy import dependency (currently at about 48%) and comply with the Kyoto Protocol to reduce carbon dioxide emissions. This is also in accordance to the European Directive (EPBD 2002/91/EC) on the energy performance of buildings.

The construction sector is globally, by far the largest employer in the EU with 16 million jobs, contributing to about 10.4% of the Gross Domestic Product, with 3 million enterprises, most of them being SMEs². However, it is by tradition characterised by weak innovation and limited competition. The use of modern materials and technologies is more frequently applied in new construction than in the field of renovation, but even there to a very limited extent. A targeted use of construction materials and methodologies should form the base for the efficient renovation of a structure. This can be obtained by an enhanced use of advanced technologies and new practices, able to give an added-value to the traditional construction sector and, at the same time, to give new opportunities of work strategies to the SMEs involved in this sector.

If we look at the age-profiles of the housing stocks of the participating countries, the European housing stock appears to be fairly new. Over 2/3 of the total stock has been built after World War II, therefore the majority of the European dwellings is less than 60 years old, see Figure 2. In urban areas this percentage is often higher. In rural areas where the housing stock mainly consists of farmhouses, the average age of dwellings can be considerably older. The percentage of the housing stock that has been built after WW II varies of course from country to country.

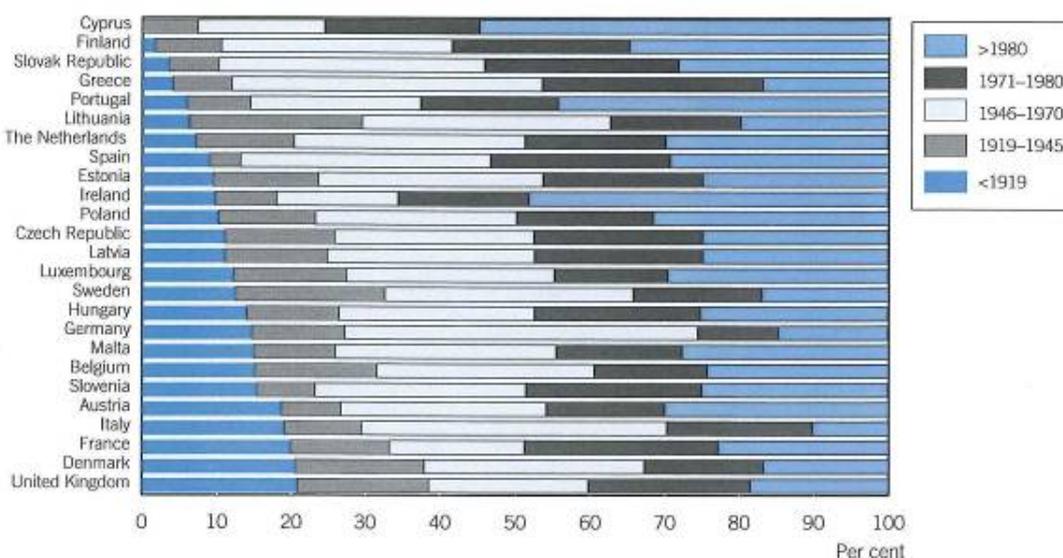


Figure 2: Age of housing stock in Europe3

² FIEC – European Construction Industry Federation. <http://www.fiec.org>

³ *Housing Statistics in the European Union 2004*, National Board of Housing, Building and Planning, Sweden & Ministry for Regional Development of the Czech Republic, Boverket 2005

Dwellings built after World War II and before the oil crisis amount to between 18% (France) and almost 50% (Germany) of the dwelling stock. On average, this is 29%. This dwelling stock, which represents almost one third of the total stock, is not very homogenous. A common characteristic, however, is that the buildings were generally poorly insulated at the time of construction and that there is a need for renovation.

In post-war Europe, the main thrust behind residential building projects was for every country to provide low-rent social housing in most job-depressed cities. This was every government's moral obligation. This building activity brought with it the fast track, low-cost pre-fabricated concrete structures and loose masonry or composite steel construction, all oblivious to upcoming social needs, rapid advances in construction technology and the importance of energy efficiency in buildings. **The challenge of today is to take stock of what is recyclable en-mass and refurbish it in the light of its structural integrity and energy efficiency by today's standards, to the tune of sustainability, for an improved quality of life for future generations.**

During the post-war era the immediate need for housing and the lack of skilled labour in Europe forced the building industry to develop new and more rationalised building processes. The solution for how to produce houses in a great extent for a low cost was to industrialise and standardise the building systems. This industrialisation reduced the construction time on site and made the buildings easier to assemble. To gain economic benefits larger quantities had to be produced, which led to decreased number of possible architectural and material options (Adler, 2005⁴; COST C16⁵). Concrete was often the chosen material in the elements, thanks to its relatively low cost, good structural performance and durable surface when used as façade elements. Loose masonry or composite steel construction were other options. In other words the flexibility of the systems was very restricted. Significant for these houses are that they were often high-rise buildings constructed of prefabricated concrete elements with visible joints (Lassl and Lövgren, 2006⁶). A typical house with prefabricated elements from the post-war era is shown in Figure 3.



Figure 3: A typical house with prefabricated elements and visible joints from the post-war era.

⁴ Adler, P. (2005): *Bygga industrialiserat*, Svensk Byggtjänst, Stockholm

⁵ <http://www.costc16.org/>

⁶ Lassl, V., Lövgren, P. (2006): *Smart connection development for industrial construction*, Master's Thesis 2006:108. Department of Structural Engineering, Chalmers University of Technology, Göteborg, Sweden, 2006, 72 p

The result of this mass housing was not positive from all points of views, even though the progression in technology development and the knowledge in the industrial building process were satisfactory. The systems did not listen to new requirements and demands, from the world around that was changing. The systems only changed due to improved technology that aimed to make the system more efficient, i.e. requirements set by the system itself. Architectural and user friendly options were not applied to a big extent. (Adler, 2005⁷)

The size of the buildings led to the fact that the tenants had problems to relate themselves to the big complexes, and the feeling of being an individual was, in a sense, lost. The buildings have also been criticised for their lack of architectural quality, being impersonal and not adjusted to fit the customers' needs, e.g. the flats' planning was restricted, since most of the walls were load bearing and not moveable. The interior, such as kitchens and bathrooms, were standardised and not possible to influence by the tenants. Together all of these factors led to that, when the most urgent housing need had decreased, the ones who could afford moved to other areas. Only the poorest stayed and many areas slowly became slum (Power, 1997⁸).

Due to this mass housing, and its social effects, industrial construction has a bad reputation among people. As a reaction to this, most of the houses erected during the late 70's and 80's were once again in-situ constructed. The houses became more expensive since all benefits of mass production were lost. When the houses became too expensive in the 90's and the beginning of this century, the building-industry had to find new methods to rationalise the building process and once again industrial construction gained interest, this time with the knowledge acquired from earlier mistakes. While we see this trend for new buildings, very little of these thoughts have been adopted in the retrofitting construction business. Furthermore, *energy efficient retrofitting and industrialised construction are together a seldom, if ever, seen combination.*

However, when dealing with the technical deficiencies, the fact that these areas in part do not function properly from a social point of view also needs to be addressed. Recent events, as the riots and fires in Paris and Stockholm, show that there is dissatisfaction amongst residents in several post war areas. We need to answer the questions: What does this place mean for the people living and working in it? How can this place progress socially and culturally? Which are the potentials of these areas that need to be addressed and spared, and which negative features have to be reduced? This is a necessary economical factor in order to make the new retrofitted energy efficient areas attractive for dwellers.

Finally, in a current study⁹ two main barriers are identified to successful sustainable retrofitting of residential buildings:

- Lack of Knowledge: the knowledge of technical solutions may be lacking or there is a problem of translating the existing knowledge into actual execution of retrofitting activities
- Cost effectiveness: The solutions are not cost effective, there are funding problems or the investors do not profit from the investments.

⁷ Adler, P. (2005): *Bygga industrialiserat*, Svensk Byggtjänst, Stockholm

⁸ Power, A. (1997): *Estates on the edge: The social consequences of mass housing in northern Europe*. MacMillan Press Ltd., London, 432 pp.

⁹ Itard et al (2008): *Building Renovation and Modernisation in Europe: State of the art review*, OTB Research Institute for Housing, Urban and Mobility Studies, Delft University of Technology

2 Description of the Main S&T Results/Foreground

E2ReBuild consists of eight work packages (WPs), organised around the demonstration projects with supporting actions. To tackle the first identified barrier, lack of knowledge, WP1 Knowledge Transfer, aims to collect previous experience from the participants and to transfer this knowledge to all, with a specific focus on the demonstrators. The demonstration, WP2, consists of 7 demonstrators throughout the colder climate regions of Europe. The demonstration objects demonstrate high energy efficient innovative retrofitting technologies and measures for low energy performing buildings, the typology of which is representative for large geographical areas in Europe. It also includes monitoring. Supporting, and also derived from the experience from the demonstrators, specific attention was given to Innovation in Planning and Design (WP3), Innovation in Technology & Construction (WP4) and Innovation in Operation & Use (WP5). The work carried out in these first five work packages was integrated in WP6 to an Industrialised Platform for Energy Efficient Retrofitting. While not providing detailed design solutions, this Industrialised Platform will provide a concept with tools, processes and procedures of how to carry out energy efficient retrofitting in a cost efficient manner. WP7 treats dissemination. Finally, the management is located to WP8.

2.1 Work Package 1 – Knowledge Transfer

The aim of this Work Package is to collect and to accelerate knowledge transfer, dissemination and collaboration in the field of sustainable renovations, in particular to the demonstration objects, utilising existing experience within the consortium and from other related European projects. During the three and a half year period, seven workshops have been held.

The first year, two workshops were organized and executed; one in Göteborg, Sweden, (February 2011) and one in Roosendaal, The Netherlands (June 2011). Both included a knowledge transfer seminar with all together 22 oral presentations. The work has been successful in lowering the barriers between partners and individuals due to intensive workshop work and active participation through presentations given, thus enhancing the probability of collaboration and knowledge transfer. The seminars have additionally resulted in input for the project website.

The annual review seminar for 2011 of the E2ReBuild project was held in March 2012, in Munich, Germany. The emphasis of the meeting was on the Munich demonstration object and annual review. However, the workshop included also a short Knowledge Transfer session regarding findings within work packages 3 and 4. The second common workshop this period for all partners in the project was organized in Grenoble, France in September 2012. The seminar included both knowledge transfer on work package progress as well as a mini-seminar on the topic of monitoring. The aim was to enhance cooperation with the CONCERTO and SESAC – projects that were represented at the seminar by Perrine Flouret, City of Grenoble and Jérôme Buffière, Energy Agency Grenoble.

The annual review seminar for 2012 of the E2ReBuild project was held in March 2013 in Oulu, Finland. The emphasis of the meeting was on the Oulu demonstration object and annual review, including knowledge transfer of ongoing developments regarding energy efficient building in Oulu and work package progress in the project. The second common workshop for all partners during the reporting period was organized in Göteborg and Halmstad, Sweden in November 2013. The seminar included a review session on finalised tasks and deliverables, knowledge transfer on the status of ongoing work. The aim was to accelerate reporting work towards the end of the project. The third workshop during the reporting period and final meeting for the project was held in London, United Kingdom in May 2014. The focus of the meeting was on the London demo and final review of work done with comparison to the original description of work, milestones and deliverables.

The Work Package also includes a task on Quality Assurance of which the primary objective has been to ensure the quality of the project's results, the overall integration and the E2ReBuild project collaboration. This objective has been obtained mainly in two ways:

- The coordination of work through cooperation between the Work Package Leaders, the Demo Leaders and the Coordinator through the monthly online meetings of the Project Technical Committee and at physical project meetings.
- The reviewing of the project deliverables according to a predefined process.

At the beginning of the project two web based applications were established: an on-line platform for sharing documents and information (WP1) and a website for public dissemination (WP7). In 2013 the dissemination and knowledge transfer within the project and beyond were strengthened through the founding of an E2ReBuild Group in the social network LinkedIn (WP7).

Task 1.1 Experts Panel has acted as a glue between the Work Packages throughout the project enabling common events including both knowledge transfer sessions on Work Package progress, current topics of interest, demonstration site presentations and mini-seminars on selected themes. Together with T1.2 Quality Assurance, Work Package 1 Knowledge Transfer has contributed to the establishment of a solid network between project partners and beyond, and an effective internal communication adding to the overall quality of the project and its end results.

Some results in numbers

- 7 workshops
- 54 presentations
- 2 annual reviews and 1 final review
- 9 knowledge transfer sessions in addition to 6 sessions on demonstration objects
- 1 exhibition on building typology
- Excursion to the VTT energy self-sufficient Test House in Oulu, Finland
- Excursion to an energy efficient new buildings area in the surroundings of Göteborg
- Excursion to the Gump & Maier element factory
- All demonstration sites have been visited by workshop attendants either during building works or upon finalization of the retrofitting
- high participation with between 30 and 40 attendants to the meetings
- knowledge transfer through web-based platforms, including SharePoint, website and LinkedIn social media discussion group (27 members)

2.2 Work Package 2 – Demonstrations

In E2ReBuild, seven different residential building demonstrations 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. The demonstration projects in E2ReBuild are the core of the project. E2ReBuild is driven by demonstration projects, whereas research activities feed into the demonstrations, and results of the demos feed into “bottom-up” research and evaluation of lessons learned in other work packages.

The objective of the work package 2 projects is to demonstrate seven high energy efficient innovative retrofitting concepts for low energy performing buildings which are representative building types for a large geographical area in Europe. Each project establishes and demonstrates sustainable renovation

solutions that will reduce the energy use to fulfil 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 %.

The seven demonstration projects highlight methods such as prefabricated timber elements and technological approaches as means to increase the energy performance, improving comfort and providing an extended service life to existing social housing stock in Europe. The approaches demonstrate how the impact of interventions can be limited and how living conditions for tenants improve.



Figure 4: The Roosendaal demonstration project (Photo: Kajsa Winnes)

These solutions focus on industrial manufacturing methods e.g. for facade elements and standardised 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).

The different demos are summarized below.

2.2.1 Munich

The demonstration in Munich, Germany, consisted 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 planning process for the necessary complete modernisation began in 2007 with a student project entitled “Weiterbauen” (Building further) at the Technical University of Munich, *Faculty of Architecture, Wood Construction*. Starting from this basis, the architects together with the building owner prepared a catalogue of target specifications concerning: perfect long time usage, sustainable construction and energy for the future: Highest conservation and efficiency, regenerative supply and overall economics.

The planning team developed a higher-density ‘Rejuvenation’ model. By incorporating a new building for the district office of GWGM, the load-bearing structure of the original buildings could be retained but the access was changed, and the flats were transformed into individual modern residential units with attractive outdoor areas. The new building envelope consists of pre-fabricated insulated wooden elements with modern highly insulated windows meeting passive-building standards, with maintenance-free wall cladding and green roofs. The thermal bridges were eliminated by cutting off the cantilevering concrete balconies and replacing them with free standing balconies. Example solutions were developed for life-cycle and energy balances, building science and structural aspects, fire safety, sound insulation and an efficient construction process. The minimal energy demand is primarily covered by renewable sources.

The first building phase was completed and fully occupied in 2012, phase 2 in 2014. Residents moved out during the renovation process. Holistic value enhancement was reached, with optimal usage quality, a wooden construction offering active climate protection and energy efficiency which is fit for the future. These qualities promise the highest total economic viability for generations.



Figure 5: Before: Demo Munich from Northeast



Figure 6: After renewal: Demo Munich from West

The main conclusions from this demo are: That ‘hard and soft facts’ of the realized and documented ‘rejuvenation project’ in our opinion do comply with the requirements that should be fulfilled for the next two generations, which means for 50 years from now. The sampled monitoring data - despite the necessary ‘swing in’ of interior temperature, humidity, system control and user behaviour – correspond to the calculated values or are even better. The decisive indoor qualities, as well as summer and winter comfort, receive highest grades by the tenants in the questionnaires.

The over-all feedback from professionals, public and the GWGM tenants (see deliverable D3.3) is more than pleasing. Finally, also the total costs for our prototypical new approach focusing on long-time orientation of ecology and economy seem to be ‘bearable’ in comparison with standard refurbishment. Not only that, we were able to gather about 20 % of building costs by normal national and local low-e subsidies for our client, also the tenants profit of stable minimum energy costs and service charge.

The Munich E2ReBuild project received important awards, conference lectures and publications, also attracting visitor groups from all over Europe and foreign countries - an ‘ecorational’ success story for the courageous owners GWGM and the City of Munich.

Brief facts

Year of construction: **1954**

Property type: **2 Multi-storey buildings**

No. of dwellings: **46**

Project owner: **GWG München, public housing company**

Energy (heat) demand before retrofit: **292 kWh/m²y**

Estimated energy demand after retrofit: **40 kWh/m²y**

Construction works: **Completed in 2012**

Participating E2ReBuild partners: **Technical University of Munich, Gump & Maier GmbH, SchwörerHaus KG, Lichtblau Architekten, GWG München**

2.2.2 Oulu

The pilot building in Virkakatu 8, Oulu, Finland, owned by PSOAS Student Housing Foundation of Northern Finland, is one of five student apartment buildings in a housing cooperative. The building has 8 apartments, and 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 was in need of a complete refurbishment and the student apartments were outdated.

Retrofit concept

The retrofit brought the building up to and above current new build standards, reduced the occupied building's space heating demand use to 26 kWh/m²y, and introduced high efficiency heat recovery ventilation. The building method has replication potential for the retrofit of façades made from concrete sandwich elements. Solutions were focussed on industrialised manufacturing methods and standardised retrofit measures with high replication potential.

Residents have completely new apartments with enlarged balconies, open plan living rooms and kitchens, improved indoor comfort and ventilation, and private saunas were added. The architects designed a contemporary architectural image for the housing in harmony with the other buildings around the shared yard.

The building exterior was retrofitted with 480m² of TES Energy Façade comprising large scale well-insulated prefabricated timber elements. The insulation level, windows specifications and airtightness targets were set to the Finnish passive house norm. The building volume was simplified to reduce thermal transmission, and the roof was replaced for additional insulation and HVAC installations. New balconies and the roof overhang shade the south facade to reduce the summer overheating risk. Building services were entirely replaced, district heating renewed and water saving fixtures installed. Remotely controlled building automation systems monitor the energy performance, indoor air quality, outdoor conditions and building physics. Attention was paid to the monitoring of the building physics, due to the need to verify the performance of the prefabricated insulating facade and the high level of insulation necessary in cold Nordic climates.

Production began on site in August 2012 and the retrofit was finished in February 2013. Site works improve site drainage and ground frost insulation. Airtightness and ventilation rates were measured prior to construction and another airtightness test and a thermal survey was conducted in winter prior to hand-over. Air leaks were detected in the existing concrete shell prior to retrofit and holes were grouted to significantly improve airtightness. One full year of monitoring data was completed in March 2014.

Research and dissemination activity has included conference papers in residential retrofits in cold climates, user energy behaviour and the analysis of building physics, the experimental application of radar survey methodology investigating structural concrete, graduate works in building automation and monitoring, and education in passive house design and timber construction. The demonstration project was nominated for the 2013 Wood Prize in Finland.



Figure 7: Oulu demonstration before retrofit in 2011 and at completion in 2013 (photos M3 Architects)

Brief facts

Year of construction: **1985**

Property type: **Two-storey building**

No. of dwellings: **8**

Project owner: **PSOAS (Pohjois-Suomen oppilajasuntolat Oy), public student housing company**

Energy (heat) demand before retrofit: **150 kWh/m²y**

Estimated energy demand after retrofit: **98 kWh/m²y**

Construction works: **August 2012 - February 2013**

Participating E2ReBuild partners: **Aalto University, PSOAS, NCC Finland**

2.2.3 Voiron

Stendhal is a multi-storey building located in Voiron, France, built in 1961. Voiron is a town located 25 km North-West of Grenoble, in the pre-Alps, at a height of around 300 m above sea level. The building has 72 dwellings (4343 m² inhabited area) and is centrally located, close to the train station, the city hall and all services and shops. It's a typical construction using concrete from the 60's and 70's and no insulation. It belongs to the buildings France wants to improve (F class from the Energy Certificate) in order to reduce the consumptions of buildings of 38 % by 2020.

Retrofit Concept

The mixed heating systems, differing from one dwelling to another (boilers using, gas, fuel... or electrical heaters), the age of the building and tenants' complaints on heating and humidity; oriented OPAC38 to carry out a deep retrofit complying with E2ReBuild goals: installing a collective heating system while reducing heating demand by a factor 4, solar panels for hot water, and reducing energy consumption down to the limit for new buildings (60 kWh/m²year). Also in line with E2ReBuild's vision on industrialisation, OPAC38 closed the balconies using prefabricated elements on the façade of the loggias.

Before retrofitting started, tenants had pointed out the inefficient heating system, leading to high temperature differences from the living room to other places in the dwelling, as an area of improvement. This had also generated high costs. Furthermore, more than half of the tenants were complaining about moisture problems. Special attention was given to tenants' participation during the process. This ensured a smooth although rather long project and the tenants now benefit from a renewed building with energy consumptions reduced by 70 %. Prefabrication was tested in accordance with the vision of E2ReBuild for industrialisation and means of improvement, also based on the

experience of the other 6 demonstration projects, have been identified for further projects using prefabrication.

Experiences gained from this demo project are:

- Commissioning and monitoring are a crucial phase to achieve initial objectives
- Participation of all stakeholders (including tenants) is a key factor for a smooth and efficient project
- Prefabrication use was too limited in the demo in Voiron to fully benefit from it. More time has to be dedicated during the design phase and specific tools such as BIM modelling are needed.



Figure 8: Chronophotography of the building's south façade

Brief facts

Year of construction: **1961**

Property type: **Multi-storey building**

No. of dwellings: **72**

Project owner: **OPAC38 (Office Public d'Aménagement et de Construction de l'Isère), public/social housing company**

Energy demand before retrofit: **258 kWh/m²y**

Estimated energy demand after retrofit: **95 kWh/m²y**

Construction works: **November 2011 - December 2012**

Participating E2ReBuild partners: **OPAC 38, SP Technical Research Institute of Sweden**

2.2.4 Augsburg

The two buildings Grüntenstraße 30-36 in Augsburg, Germany, were built in 1966 and represent a typical example for a massive brick construction with concrete ceilings built in the late 60's, early 70's throughout Germany. The building was mostly in its original state by the beginning of the retrofit,

fully rented and retrofitted in an inhabited status. Grüntenstraße 34-36, a six storey block with 48 apartments, is the E2ReBuild demo case. 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 the joints to the roof.

The vision of the competition entry, prior to the retrofit project, was to transform the building into a contemporary piece of architecture. The wrap around solution of *TES EnergyFaçade* is cladded with rough sawn, white painted spruce boards. The new design supports the visibility of the building in the urban context at the east gate of the city. The existing balconies were converted into winter-gardens or living room extensions thus offering extra interior living space and additional balconies offer outdoor space.

Retrofit concept

In May 2012 the modernization of the building envelope of the E2ReBuild demo project Grüntenstraße in Augsburg was completed. Residents have remained in their apartments during the construction work.

The envelope has been retrofitted using a prefabricated envelope system based on TES EnergyFaçade. 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 bathrooms including vertical installation shafts were completely renovated. Barrier freedom was achieved by adding new elevators as well as levelling the floors in the apartments thus making a significant change to living quality in the building.

With these measures, additional value was created, which led to higher acceptance of the whole modernization of the block. Energy consumption figures have dropped nearly 80 %. This high value performance of the building is appreciated by tenants and the land lord equally.

The modernization of the residential block in Augsburg with 60 apartments is an outstanding flagship in the portfolio of the owner and an important statement for the surrounding neighbourhood. The final result represents high end building refurbishment which is not the usual case in Augsburg.

The Augsburg demo project has received numerous prestigious awards (e.g. Holzbau Plus Prize, Deutscher Holzbaupreis Anerkennung, Deutscher Bauherrenpreis 2013) and is attracting more and more public interest for a holistic refurbishment method as it is promoted by E2ReBuild.



Figure 9: Situation before and after retrofit

Brief facts

Year of construction: **1966**

Property type: **Multi-storey building**

No. of dwellings: **60**

Project owner: **WBG Augsburg, public housing company**

Energy demand (heat) before retrofit: **142 kWh/m²y**

Estimated energy demand after retrofit: **63 kWh/m²y**

Construction works: **Completed, May 2012**

Participating E2ReBuild partners: **Technical University of Munich, Gump & Maier GmbH, WBG Augsburg**

2.2.5 Halmstad

The demonstration in Halmstad (Sweden) called Giganten 1&7, is a multi-storey building from 1963 with typical features from that period e.g., reinforced concrete load bearing frame and facade elements. It is eight stories high with businesses located on the first floor and 91 flats on the remaining floors. The building has a heated area (heated to more than 10°C) of 6178 m². The building also has a parking garage located underground.

The retrofit action for the building aimed at lowering the energy use by approximately 130 kWh/m²y.

Retrofit concept

The building represents an early example of a “million program” building, which was a program created by the Swedish government which ran between 1965 and 1974 with the goal of producing 1 million dwellings in order to combat a severe shortage in available housing. The million program buildings are now at least 40 years old and they are in need of retrofitting and renovations. In Halmstad’s case all the water and sewer pipes needed to be changed, the kitchens and bathrooms were renovated, the windows were changed, heat pumps were added, a new heat exchanger for the district heating was installed, an advanced prognosis based control system was installed and the system was optimised for the building. Tenants remained in their apartments during the retrofit construction work. Therefore, this demonstration investigated and evaluated tenant-host communication during the extensive renovation work. This demo also focused on creating (economic) win-win situations between stakeholders through, e.g., partnering.

One of the challenges for renovating the million program buildings is to keep costs at levels which are affordable to the building owner while at the same time reducing the purchased energy, extending the lifetime of the building and insuring that the indoor environment is not compromised.

Partnering was used as the form of building process in this project. This form of process had several advantages over traditional building process forms. It allowed the building owner and entrepreneur to have transparency in all areas of the project, such as economy and responsibility. This meant that the project was formed by both partners together to optimise the technical solutions with the economy.

The renovation of Giganten 1&7 was developed within the boundaries set by both the city and building owners. Some of the limitations in this project were financial, such as the project had to fulfil certain economic parameters and others from the city who expressed that the architectural look of the building be preserved. The combination of the limitations set by the owner and city meant that there were not many options available to reduce the net energy demand. For example by insulating the façade would have been too expensive and the city expressed negative opinions about changing the

look of the building. More technical solutions were needed such as prognoses control of a combination of extraction air heat pumps, outdoor air heat pumps and district heating. The result was a project which reduced the purchased energy use by 70 % with a return on investment of 18 years.

Work on Giganten 1&7 (Halmstad) began before E2ReBuild; therefore, it was one of the first projects to be completed. The monitoring started in early 2012 and continued until July 2013. An analysis of the measured energy use was done and compared to the calculated energy use. The measured specific energy use was $50 \text{ kWh/m}^2 A_{\text{temp, yr}}$ compared to $53 \text{ kWh/m}^2 A_{\text{temp, yr}}$ calculated and $174 \text{ kWh/m}^2 A_{\text{temp, yr}}$ before retrofitting.



Figure 10: The Giganten 1&7, Halmstad demonstrator

Brief facts

Year of construction: **1963**

Property type: **Multi-storey building**

No. of dwellings: **91**

Project owner: **Akelius Bostad Väst AB, private housing company**

Energy demand before retrofit: **138 kWh/m²y**

Estimated energy demand after retrofit: **42 kWh/m²y**

Construction works: **November 2010- January 2012**

Participating E2ReBuild partners: **NCC Sweden, Akelius Bostad Väst, White Arkitekter, SP Technical Research Institute of Sweden**

2.2.6 Roosendaal

The demonstration project Kroeven Roosendaal, Netherlands is part of a larger regeneration project for the whole area, which includes demolition and new construction at strategic places, but focuses on major energy renovation of terraced houses built in the 1960-ies. The overall objective of the project is to achieve affordable and healthy homes in an attractive area, which can be exploited for another 40-50 years. Therefore, renovation to meet passive house standards has been chosen as the main strategy to achieve a very low heat demand and thus affordable heating costs and a good indoor environment. The E2ReBuild demonstration concerns 50 houses, out of a total of 246 passive renovation and 90 new passive houses.

Retrofit concept

Prefabrication of façade and roof elements has been used as the main means of renovation, with the aim of reducing the disturbance of tenants, constant and high quality and good energy performance. The renovation approach includes much better insulation than current practice via the labelling system

in the Netherlands requires. Healthy and comfortable indoor climate conditions were achieved through the installation of controlled mechanical ventilation with heat recovery. Airflows have been selected with the objective to have such a ventilation rate that the internal CO₂ emission level is well below the requirements for new homes.

The renovation process was special because it allowed a systematic preparation and on site implementation whilst the tenants could stay in their homes. The approach has been tested on a pilot renovation house, and was afterwards implemented as a large scale process. Once the renovation was up to speed four houses were renovated in one week. On one day the existing roof and windows were replaced by the new prefabricated roof and façade elements. Each day one truck load for one house arrived on site, and was mounted on the same day. The preparation and completion works have been more intrusive than the renovation itself.

The energy performance is as expected. Gas heating consumption for space heating, hot water and cooking reduced by 65 %. Given that cooking is constant, and hot water reduced by 50 % because of the solar thermal system, the space heat reduction is 75 – 80 %.

Energy savings have been ensured by the landlord in such way that it was guaranteed that the result of rent increase of €65 per month would not exceed the value of the energy savings in the first five years. Less than 10 % of the tenants made use of the guarantee. These were the tenants who accepted very low indoor temperatures before renovation, and thus had smaller savings than the average.

The landlord has made significant investments which will pay off during the extended exploitation period of 40- 50 years which would not have been the case if the houses were replaced with more expensive new homes. Also the rent increase partially contributes through the pay back. Because of the energy efficient renovation, the homes remain affordable in terms of rent and energy costs, and indoor climate conditions are very good. The main drawback is the initial investment, though in life cycle terms the exploitation of these renovated homes is good.

Replication potential is large, provided that further industrialisation, product development and implementation scale result in affordable investment costs. Findings from this project have already motivated suppliers from industry to launch products along these lines. There is a huge market at the scale of 2 million homes in The Netherlands alone which can benefit from this approach; not to speak of the huge European application market, which is there once investment mechanisms aimed at integrated renovation methods are available.



Figure 11: Houses in Roosendaal, before (left) and after (right) retrofit. Photo: Chiel Boonstra/Trecodome

Brief facts

Year of construction: **1960**

Property type: **Single family, terrace houses**

No. of dwellings: **50**

Project owner: **Aramis AlleeWonen, public housing company**

Energy (heat) demand before retrofit: **136 kWh/m²y**

Estimated energy demand after retrofit: **43 kWh/m²y**

Construction works: **Completed, spring 2011**

Participating E2ReBuild partners: **Trecodome, Aramis AlleeWonen**

2.2.7 London

Thamesmead was originally conceived as a utopian “town of the 21st century” by the Greater London Council in the mid-1960s. The initial plans for the only New Town in the capital envisaged the creation of a community of 60,000 people over a 10 to 15 year period. Set in the context of London’s post-war housing shortage Thamesmead’s creation required a significant physical transformation of the Plumstead and Erith Marshes with the reclamation, remediation and preparation of a 1,300 acre site.

However, the original aspiration to create an ideal community was diluted over time. Wider housing allocations policy, a lack of investment, poor transport connections, institutional weaknesses, resources, design problems and social deprivation led to a spiral of decline. For many years consigned to the ‘too hard to do’ category of regeneration, Thamesmead remains one of the last great regeneration challenges for the capital. Within Thamesmead two focal so called ‘hubs’ were identified. Parkview Hub, which became the E2ReBuild demonstration object, is one of those.

The Parkview Hub 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.

Retrofit concept

Due to the degree of cold bridging and the complex nature of the construction type an external insulation solution was required. The preferred building envelope refurbishment technology was to use prefabricated, highly insulated façade and roof elements. This was chosen to reduce disturbances to tenants and deliver project speed gains on site. It was also foreseen that the prefabricated methodology would allow for simplified extensions to the existing building with the inclusion of a new upper storey constructed off-site using prefabricated elements which were craned into position.

The key strategies of the regeneration are reflected in the design. The ground floor level is changed into a community centre and small business and shops, whereas the apartments get a new façade around the building, covering the whole block in a new coat. The new appearance focuses on vertical elements and colours, thus emphasising the individual apartments as town houses. The new pitch roof is designed to refer to other building types than the current flat roofs throughout Thamesmead.

The demonstration project exceeds current practice by far, in achieving energy conservation through the technical solution that is used. The demonstrator shows that U values in the range of 0,15 – 0,10 W/m²K, combined with airtight construction, triple glazing and mechanical heat recovery is able to achieve 80 % reduction in space heat demand. The applied prefabricated solution points to the lesson that good quality and shorter renovation processes can easier be achieved in this way compared with traditional on site renovation work. The building is much more attractive, socially more secure, while the environmental impact of the renovation is small because of the chosen renovation method with renewable and recycled materials.

Parkview Hub offers a good opportunity for replication, both in Thamesmead as in similar locations in the UK and other European member states. There is a huge building stock that is in need of deep renovation, and Parkview Hub provides good insight in the potential achievements. Millions of homes in the UK are in need of deep renovation, since either the energy costs are hard to afford, in many cases tenants suffer from unhealthy living conditions because of fuel poverty. The potential to upgrade buildings paves the way to extend the exploitation period of buildings, increase the property value, reduce heating costs and thus generating a sound business case. This is the innovation road that the E2ReBuild demonstration project Parkview Hub is pointing to. Upgrading the existing stock at the demonstrated quality results in more affordable housing than new construction as a replacement can do.

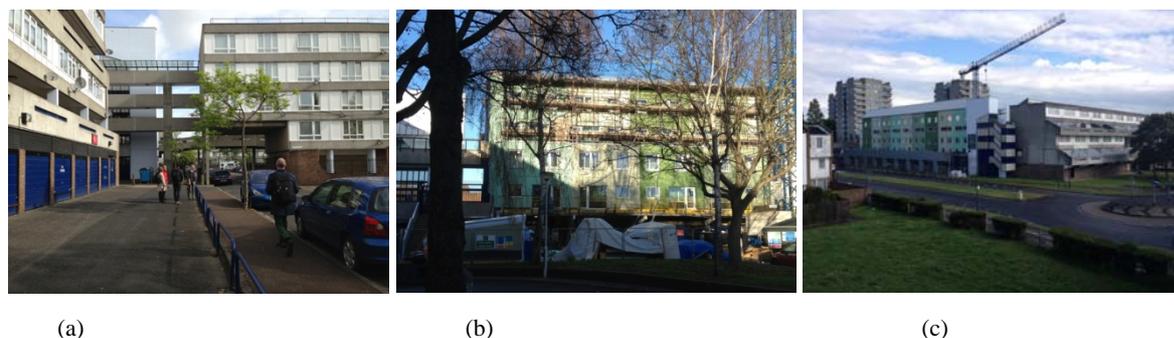


Figure 12: Thamesmead demonstration building before (a), during retrofit (b) and (c) Overview of Parkview Hub, adjacent to a similar non-renovated building. (Picture Chiel Boonstra, Trecodome)

Brief facts

Year of construction: **1974**

Property type: **Multi-storey building**

No. of dwellings: **18**

Project owner: **Gallions Housing, private housing company**

Energy (heat) demand before retrofit: **203 kWh/m²y**

Estimated energy demand after retrofit: **58 kWh/m²y**

Construction works: **March 2013 - March 2014**

Participating E2ReBuild partners: **Trecodome, Gallions Housing Association, Gump & Maier, Technical University of Munich**

2.3 Work Package 3 – Innovation in Planning and Design

2.3.1 Building Typology

The precise knowledge of the building stock is essential for prefabricated renovation. On the one hand this evaluation focuses on the existing building constructions and the applied renovation measures for the demonstration buildings and on the other hand on the stakeholders' perspective to identify added values and the replication potential for industrialised and prefabricated renovation. The gained knowledge leads to general and focus types representing the interface between typology and construction.

The key results are:

- the implementation of a method to generate a building typology that can be used for industrialized retrofit with prefabricated facade elements
- the development of a communication tool that supports the documentation of relevant characteristics of the building and decision making during the early planning stages of industrialized retrofit with prefabricated facade elements
- the implementation of a modelling method to estimate the replication potential of industrialized retrofit with prefabricated facade elements in the participating countries

The collected information about the demos as well as further case study buildings was used by the European Retrofit Advisor to describe typical buildings of all participating countries. In order to categorize the building stock all relevant features have been identified by the research of TES Energy Façade, which has been used in several demos. These features were used to set up a matrix, which serve as a communication tool between owner/investor and planer/contractor in a preliminary stage of the renovation process for industrialised and prefabricated renovation. Finally the findings of the task T3.1 are summed up in the industrialised platform of work package 6 to demonstrate the identified added values and the replication potential for renovations. Further on it might be a point of reference for contractors to estimate the market potential for industrialised and prefabricated systems.

2.3.2 Socio-architectural Processes and Added Values for Clients and Stakeholders

The *Europe 2020 strategy*¹⁰ and the recent EC staff working document *Progress on GDP and beyond actions*¹¹ indicates, from the European policy level, the need to bring aspects such as social cohesion, social innovation and local participation at the core of smart growth and sustainable development. Focusing more explicitly on sustainability within the realm of urban development the Leipzig charter states that a holistic approach, emphasizing an integrated and collaborative interaction between stakeholders, a strong participation at the local level and measures to incorporate social sustainability, is essential in order to reveal the potential of European cities in terms of cultural and architectural qualities, social integration and economic development¹².

Retrofitting the large stock of European residential buildings, originating from the decades after World War II, present many challenges as the socio-economic context often is characterized by low income levels, unemployment and a lack of social capital. Weak linkages and connectivity to surrounding areas and city centres are examples of spatial structures depicted as increasing the problems in these

¹⁰ European commission (2010), Europe 2020 – A strategy for smart, sustainable and inclusive growth.

¹¹ European Commission (2013), *Progress on 'GDP and beyond' actions*.

¹² Federal Ministry of Transport, Building and Urban Development, Germany (2012) *5 Years after the LEIPZIG CHARTER – Integrated Urban Development as a Prerequisite for a Sustainable City*.

areas.¹³ Although these aspects mostly target urban regeneration schemes rather than individual building retrofits, which are the main focus of E2ReBuild, the ambition of this task is to relate social value increases to the retrofit process and its physical outcome.

The core lesson, building on the evaluation conducted within the task, is that social value increases can harmonise with drastically decreased building energy consumption. But for this to take place strategies need to be developed for the below listed aspects:

- Initial understanding of tenants' needs;
- Strong communication and information channels before and during retrofit;
- Post retrofit information and communication for supporting tenants' adaptability to a new living situation.

A framework for a socio-architectural method was constructed harmonising with the above mentioned key lessons learned. The essential building stone is to enable perspectives to be met at an early stage of a retrofit process, what could be described as triangulation of aspects, methods and perspectives. This is the key to generate added values at later stages of the process.

Following the «Bottom-up» methodology adopted within work package 3 the results from Task 3.2 has helped highlighting the social aspects, by giving a voice to the tenant of the demonstrations, and in turn fulfilling the overall holistic approach of the E2ReBuild.

2.3.3 Renovation Opportunities, Barriers and Risks

Current renovation routines and legal frame conditions represent barriers and bear risks that hinder exploitation of opportunities given by industrialized renovation methods. The empirical «Bottom-up» methodology in Task 3.3 delivered a new understanding of the relevance of collaboration models and holistic strategy design for retrofit. Technological related barriers and risks are far less challenging than assumed. Moreover, soft skills, such as communication with sufficient know-how exchange within the teams, influenced smooth workflows and frictionless retrofit processes. Public tender did not necessarily promote cost-optimized solutions. Quality and skill oriented team set-up and holistic strategy design beyond mere financial aspects supported opportunities to increase quality, time, cost and energy efficiency and finally higher user acceptance. Therefore, new cost-break down methods based on the combined analysis of investment costs and further service life of retrofitted parts were developed. They supported a new decision-making basis for future retrofit with industrialized methods.

2.3.4 Energy and Environmental Impact Simulations

The main goal of this task was to evaluate the energy and environmental impact of the demonstrated renovation strategies, using the energy simulations and LCA-data from the design phase. The results were linked with the building typologies and retrofitting strategies of the demos to show how the energy goals can be met with a small environmental footprint. When comparing energy calculations to renovation measures, it is difficult to point out the exact measures or strategies that contribute to the largest energy savings. However, the one demo that carried out the most comprehensive renovations (Munich), both regarding the building envelope and the building services, is also the demo that has estimated the largest space heating reduction and the best energy performance after renovation. This demo also showed the greatest positive impact on the environment and this is strongly related to the reduction in space heating demand and the change from gas and electricity to district heating. One

¹³ Wassenberg et al (2007) *Strategies for upgrading the physical environment in deprived urban areas*. European Urban Knowledge Network

demo (Halmstad) focused more on improving the building services and installed very efficient heat pumps, which resulted in one of the best energy performances, but with a negative impact on the environment since the use of electricity increased after renovation.

2.3.5 European Retrofit Advisor

E2ReBuild has developed a software tool that is especially suited for analysing renovation strategies in an early design stage. With this tool – the European Retrofit Advisor – it is possible to evaluate renovation scenarios for multifamily buildings. It evaluates not only economic issues, it also considers ecological and social aspects of building retrofit.

The European Retrofit Advisor is based on a set of European building types that have been studied in the E2ReBuild project. With only a few adaptations it is possible to adapt a selected building type to the real size and situation of the building to be renovated. A catalogue of retrofit scenarios and single measures are provided for simple definition of a renovation strategy. The software is analysing this renovation scenario and compares it with the actual state of the building, a repair only scenario and a reconstruction scenario. The simple use of the tool and the detailed multi criteria analysis make the software extremely valuable during an early design stage, when no detailed data is available but a quick check of potential renovation options is needed.

The European Retrofit Advisor develops renovation strategies based on the actual situation of the building. It considers all three main aspects for sustainable housing:

- **Financial evaluation:** The financial situation of the building is analysed on the basis of the existing rent income and the status of the building. The cost for repair and retrofit are calculated based on selected renovation measures, building size, and quality standard and compared with the costs for demolition and reconstruction. The calculation takes the expected remaining service life into account (discounted cash flow method).
- **Environmental evaluation:** The program provides for all measures and new constructions also environmental data. The ecological footprint of these measures is described on the basis of life cycle inventories and expressed as primary energy need, greenhouse gas emissions and ecological scarcity (critical emissions).
- **Social evaluation:** The program helps to analyse the expected quality of living and the living costs before and after renovation.

The results of the evaluation are diagrams that compare different renovation approaches. They probably show that a deep renovation or even demolition and reconstruction are attractive solutions. However, the conclusion is not always the same for all building owners. It is very much depending on the individual situation of owner and tenants. The final conclusion has to be verified based on a concrete renovation project.

The program addresses building owners and designers (architects and engineers). For that purpose it contains a basic program part that is easy understandable and does not require specific construction knowledge. It should allow obtaining first results in less than 30 minutes. The expert program is more sophisticated and anticipates some expertise related to energy efficient buildings. It allows a detailed adjustment of parameters. A professional user should be able to obtain detailed results within approx. 4 hours.

The European Retrofit Advisor is available free of charge as internet based tool. It can be found at <http://era.empa.ch>. Program data will be maintained as required but user support is limited. New initiatives that are interested to develop the tool further for a specific use are welcomed.

Figure 13: Example page of European Retrofit Advisor (here in French), presenting the 6 building types available for France



Figure 14: 6-7 renovation scenarios are illustrated and proposed for each building type.

2.4 Work Package 4 – Innovation in Technology and Construction

Work package 4 aims to introduce industrial manufacturing methods and procedures for industrialized customized retrofitting. Work package 4 provides concepts and solutions for the retrofitting process based on industrialized construction systems including prefabrication technologies as well as an optimized digital workflow from survey, off-site production and on-site assembly in order to achieve a cost and time efficient construction process.

E2ReBuild demonstrations have revealed the complexity of holistic building refurbishment which can be tackled successfully by a team of architects, engineers and construction specialist cooperating and working together for common set goals. Construction work based on industrialized methods offers advantages, new collaboration models are the key to reach the potential advantages.

Work package 4 has documented and analysed the E2ReBuild demonstration projects throughout the whole planning and construction process. The unique situation of having access to seven construction projects at the same time offered the opportunity to collect insight information and draw lessons learnt which have been detected and documented.

2.4.1 Guidelines to Preliminaries/Survey

A comprehensive building survey as well as the analysis of the condition of the existing structure of the building to be retrofitted is an essential precondition for a successful planning, construction and life phase of a retrofit project.

Starting with the explanation of the condition of survey and planning as the intrinsic property of prefabricated solutions the deliverable describes the requirements for knowledge based retrofit processes from survey, construction planning to production and assembly.

A complete condition analysis of the existing building structure as well as building materials is a key factor in building modernisation and of great importance to create as much knowledge as possible in the early stage of the project. A checklist gives an example of the different tasks and points out the responsibility of planners and engineers.

A fully featured 3D model for planning and production is needed otherwise industrialised retrofitting based on prefabrication is highly risky. The first crucial step in industrialised retrofit for energy efficiency is to translate built reality into the planning tools. The 3D model develops in different steps. It starts with the application of specific surveying methods to develop a 3D image from the existing object. Based on this data surveyors or trained architects or engineers have to develop the building information model. It is a transformation of real 3D data into usable planning data. An overview highlights current surveying methods and describes different approaches in building measurement based on Tacheometry, 3D Laser Scan and Photogrammetry.

2.4.2 Guidelines to Off-site Production / On-site Assembly and Logistics

The report of this task explains the workflow in a set of recommendations and guidelines for off-site production, logistics and on-site assembly of prefabricated construction elements for retrofitting of existing buildings. The document is based on various individual experiences made in the E2ReBuild demonstration projects and will serve as an important input to the industrialised platform (work package 6).

E2ReBuild demonstrates sustainable renovation solutions based on a holistic industrialized process that will greatly reduce energy consumption, minimize waste and improve recycling rates, reduce technical and social disturbance for tenants and increase quality at the same time. Five of seven E2ReBuild demonstration projects were conducted with prefabricated construction systems to enhance the building envelope.



Figure 15: Illustration of the different phases of a retrofitting process

Lessons learnt focus on:

- General planning and survey
- Production
- Logistics & assembly
- Tenant's needs

Recommendations and guidelines for off-site production and on-site assembly describe the process and its control and highlight key aspects and important details. The description of workflow responsibilities is followed by practical recommendations and guidelines providing the reader with a red line of hints which can serve as a structure for future projects.

2.4.3 Multifunctional Building Envelope

Deliverable D4.4 *Building Envelope* introduces on a conceptual level a wider functionality to enhance the building envelope, and documents solutions applied in the E2ReBuild demonstration projects.

The E2ReBuild demonstrations have offered the chance to conduct different strategies and solutions of integrated components into the building envelope which more or less seem to be rather simple and robust. The demonstration projects verify that the efforts taken have been practical as well as economically justified. They prove a realistic potential for a wider application of multifunctional building envelopes in refurbishment of our large residential building stock and thus creating added values:

- Fully off-site manufactured facade elements result in shorter construction work on-site
- Integrated windows and sun shading device
- Plug-in solutions for ventilation units
- Integrated duct work
- Integrated air inlets
- Adding space (e.g. balcony extensions)
- Thermal buffer zone (e.g. winter garden)
- Integrated solar collectors or building integrated photovoltaic (BIPV)
- Various cladding surfaces
- Extra load bearing elements for extensions



Figure 16: Integrated components

Image 1: Prefabrication of envelope elements, Image 2: Cover of an air outlet at GWG Munich, Image 3: Finished façade at Grüntenstraße, Augsburg

2.4.4 Interaction Demonstration Projects

Five of seven demonstration projects were retrofitted with the application of the TES EnergyFaçade method. E2ReBuild has gained unique insights into the whole process from design, planning, production, assembly and operation. The task of this deliverable is to concentrate on the demonstration retrofitted with the TES method in order to compare the experiences made on the example and define lessons learnt as recommendations for professionals.

The deliverable D4.5 *Interaction Demonstration Projects* documents the demonstration Munich, Roosendaal, Oulu, Augsburg and London with a focus on critical issues detected during the planning and construction phase. The summary of experiences gives an overview of how information was transferred to other work packages and deliverable documentation. The overview of lessons learnt on management and coordination as well as technical issues has been developed within the E2ReBuild work package 3 and is an exclusive part of this report to demonstrate the findings from different perspective of E2ReBuild actors.

E2ReBuild gave an opportunity to implement industrialized refurbishment methods on a replicable scale mainly based on a prefabricated building envelope system, the *TES EnergyFaçade*. The experience made gave an important input to replicable results and ideas which will be further exploited

by E2ReBuild partners. In a comparative analysis added values and transfer strategies are identified and mapped.

2.5 Work Package 5 – Innovation in Operation and Use

2.5.1 Progress towards Objectives

The aim of work package 5 was to develop, implement and follow up a detailed monitoring program for the energy performance and indoor environment of residential buildings. The monitoring program was implemented in the demonstrations to verify target energy use, indoor environment and to evaluate the monitoring program. Interaction with stakeholders in the demonstrations was also a key aspect in the development of guidelines to end-users/tenants and operators.

2.5.2 Monitoring Methods

The detailed monitoring guidelines that were produced and delivered in the first year were implemented and used for the evaluation of all E2ReBuild demonstrations regarding energy use and indoor comfort. After the mainly dormant period of the second project year, data from E2ReBuild demonstrations has been collected and evaluated. During the last period of E2ReBuild several meetings with partners were held; telephone and web-meetings as well as a couple of workshops. In 2013 WP5 held a workshop at the London demonstration in Thamesmead where the input of all partners and demonstrations were discussed. Data assembly was an important topic as well as routines for continuous following up of indoor environment and energy use. In 2014 a final workshop was held in Munich where all WP5 partners participated. Here, the final results from the demonstrations were discussed along with the contents of the T5.1 deliverables described below. Also, a few smaller meetings were held with individual partners to clarify input and monitored data.

In the last period of E2ReBuild two deliverables were produced in this task, D5.2 *Measured Data from Demonstration Buildings* and D5.3 *Data Input to EU Database*. Both deliverables presents the monitored data from all E2ReBuild demonstrations except the London demonstration where monitoring was not completed within the E2ReBuild timeframe. All data have been provided by each participating demonstration and the correctness of these numbers is dependent on the accuracy of each demonstration's implemented monitoring programme.

In the reports, the monitored data are presented by demonstration and parameter separately. The monitoring period was set to one year and was carried out over different time periods for the different demonstrations depending on completion of construction work. Some demonstrations have a shorter monitoring period due to late completion of construction. The collection of data was harmonized to conform to the EU Concerto Premium programme and is ready to be sent to the EU database as described in deliverable D5.3.

2.5.3 End User/Tenants Evaluation and Behaviour

As described above there were several meetings held in the final period of E2ReBuild. At both workshops, in London and Munich, several topics within task 5.2 were discussed with good input from all partners; the end-user evaluation, methods to influence end-user energy behaviour, visualisation



Figure 17: Workshop on data analysis

and handling of tenants' complaints. During this period deliverable D5.4 *Guidelines to End-users/Tenants* was finalised.

In this deliverable, the possibilities and challenges that arise when trying to influence end-users energy behaviour, is evaluated and analysed. The report contains different methods possible to influence tenants and also give recommendations and experiences from a contractor's point of view.

Retrofitting a residential building presents the opportunity to greatly improve not only the buildings' energy performance but also to influence the tenants' energy awareness and make them more interested in their personal energy use and consumption. With increasing energy performance of buildings the end-users energy behaviour becomes more important when considering the overall energy use of the building and its inhabitants. The use of domestic hot water and electricity is something the tenants can greatly influence and this raises the importance of trying to influence the end-users and making them more aware of their personal energy use. Measures to reduce energy consumption and the cost of heating of domestic hot water have a direct impact on the ecologic footprint of a building.

A framework for evaluating and visualising tenants' energy behaviour and awareness was developed and implemented by a tenant questionnaire. The indicators covered by the questionnaire were evaluated for all E2ReBuild demonstrations and the qualities related to energy behaviour are presented in deliverable D5.4.

The last part of D5.4 presents a method for handling of tenants' complaints. The proposed methodology covers all aspects of a retrofit process, from the design phase, through the construction works and until the commissioning of the building and end of construction work. The methodology not only deals with handling of tenants' complaints but also offers an opportunity to minimize complaints and to improve the experience of the retrofit process for the tenants.

2.5.4 Operation

At both workshops, in London and Munich, as well as during several smaller meetings, the topics within task 5.3 were discussed; routines for continuous follow up of indoor environment and energy use in the buildings/apartments, including methods to reduce energy use by adjusting the automatic control system in operation as well as discussion on and evaluation of analysed data from the monitoring program. Experience/knowledge from monitoring at all demonstration buildings was shared and during this last period deliverable D5.5 *Guidelines to Operators* was finalized.

In D5.5, the E2ReBuild monitoring scheme is evaluated for all demonstrations. The different monitoring parameters are assessed and the experiences from the demonstrations are highlighted. Good input was received from all WP5 partners as well as the E2ReBuild demonstrators.

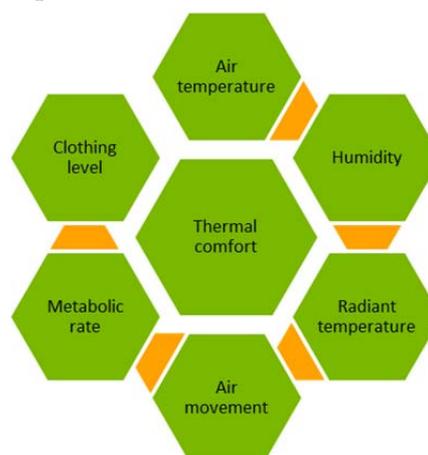


Figure 18: Identified subthemes of thermal comfort

A framework for evaluating and visualising tenants' experiences of indoor comfort was developed and implemented by the tenant questionnaire mentioned in task T5.2. The indicators covered by the questionnaire were evaluated for all E2ReBuild demonstrations and the qualities related to the experienced indoor comfort are presented in this deliverable. The E2ReBuild demonstrations are evaluated from an indoor comfort point-of-view utilising both the end-user evaluation performed through questionnaires and interviews with tenants, and the monitored indoor data on comfort. The results are compared to the evaluation and outcomes on indoor air temperatures, relative humidities, indoor carbon dioxide levels and airing habits are analysed.

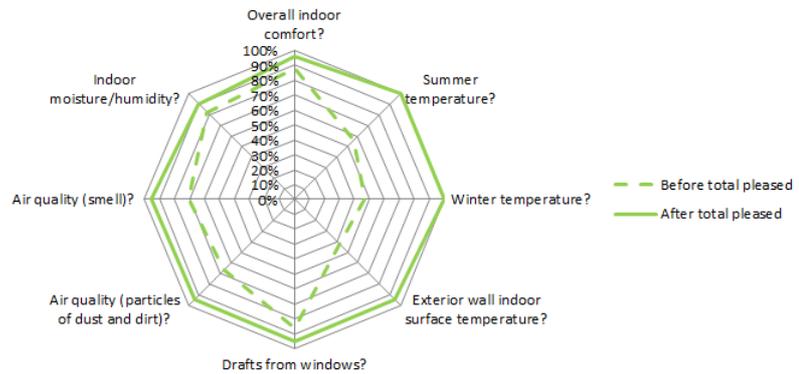


Figure 19: Evaluation of indoor comfort before and after retrofit

Guidelines for an automatic control system and routines for continuous follow-up of indoor environment and energy use are established and compared to the experiences of the E2ReBuild demonstrations.

The last part of D5.5 presents a hygrothermal study on the retrofitted building envelopes of two E2ReBuild demonstrations. To improve their energy performance, the retrofit included a façade refurbishment with the TES method utilizing timber based, prefabricated façade elements for the renewal of the building envelope and improved thermal insulation. As part of the E2ReBuild monitoring programme developed in T5.1 and D5.1, hygrothermal gauges were installed in the walls and they have been monitored for more than one year after the retrofit. In this report the findings from the monitored facades are compared with hygrothermal computer simulations and evaluated.

2.6 Work Package 6 – Industrial Platform for Energy Efficient Retrofitting

The aim of work package 6 is to develop a proposed concept for an Integrated Industrial platform, providing a structure for energy efficient retrofitting with the customer's values as the highest priority. Work package 6 is where the pieces are connected.

2.6.1 Concept of Industrial Platform for Retrofitting

E2ReBuild builds on a systematic platform for energy-efficient refurbishment. The word systematic is one key to this. It is a platform for standardised activities, prepared in advance of the point when the client comes into the process. It requires investment before there is a project. This is a paradigm shift in an industry as construction which is focused on the unique project.

The aim of task 6.1 is to develop a comprehensive, coherent set of components, methods, tools, guidelines and best practices for communication, technology and business, originating in the field, able on a generic level to be shared by several companies and organizations, and able on a concrete level to be adapted to conditions specific to the time, place and stakeholders.



Figure 20: Documentation of the industrial, energy efficient platform

The E2ReBuild definition of Industrial Retrofitting

A thoroughly developed building process for addition of new technology or features to older residential buildings and other building systems, with a well-suited organization for efficient management, preparation and control of the included activities, flows, resources and results for which highly developed components can be used in order to create maximum customer value.

The above E2ReBuild definition of industrial retrofitting is the foundation for choosing a process map as the main format of the platform. A problem with industrialising retrofit is that retrofit platforms cannot build exclusively on technology; any technology used will likely not fit with the building to be retrofitted. The merit of the definition above is that it allows for refurbishment projects to be viewed as a set of recurrent activities, a mind-set from which was developed the process-map for these activities and the headings and contents of the platform. The basic idea is to separate the projects from the platform, which is used for improving transparency, predictability, quality, experience feed-back and learning. This makes it possible to mass customise retrofitting of existing buildings.

The example below gives the considerations for prefabricated facades, divided into the phases of a retrofit project, namely, Brief development, Design, Production and Delivery.

Table 1: Considerations needed to take into account for the development, manufacturing and delivery of prefabricated facades.

1 Brief development	2 Design	3 Production	4 Delivery
<ul style="list-style-type: none"> Inventory frame Feasibility assessment of prefabrication Planning of system 	<ul style="list-style-type: none"> Design Contracting supplier Detailed design Assembly planning 	<ul style="list-style-type: none"> Production wall elements Assembly wall elements Amendments 	
<ul style="list-style-type: none"> Generic description of system 	<ul style="list-style-type: none"> Blueprints / model Assembly plan 	<ul style="list-style-type: none"> Renovated façade 	

The four phases and activities of the process map were used to identify the key lessons learned from the demonstrations and thematic work packages, which were then included. Sources were draft deliverables, presentations during E2ReBuild meetings, a questionnaire to WP leaders, workshops and email conversations.



Figure 21: The four phases of the process map

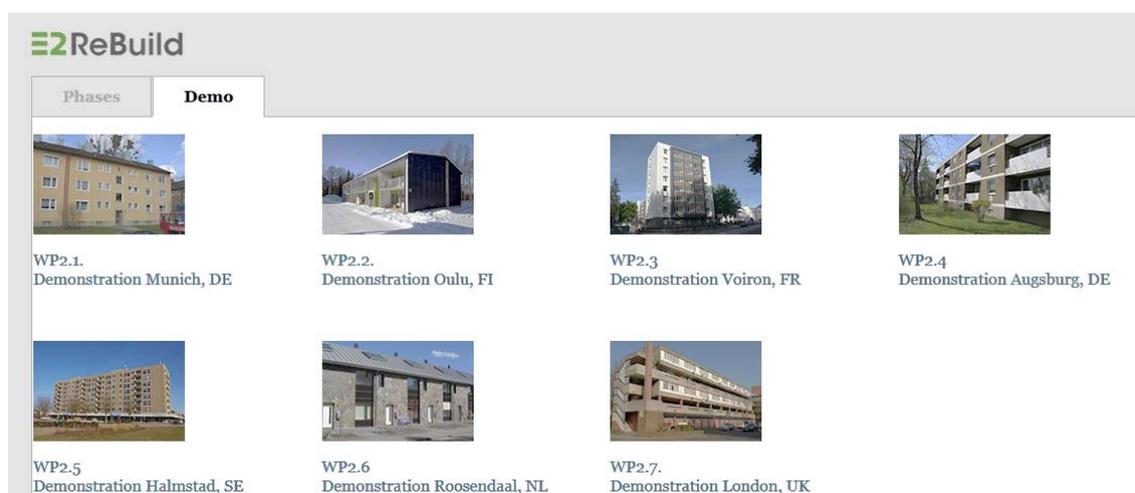


Figure 22: The demo descriptions in the process map

The process map was also developed into an interactive image where each activity and each demonstration building is a link that provides the reader with a pop-up window with a short descriptive text. The interactive map is available from the E2ReBuild website (e2rebuild.eu, which links to the map at <http://www.ncc.se/Global/e2rebuild/index.html>).

The final deliverable D6.1 *Concept of Industrial Platform for Retrofitting* was developed from the same process map and lessons-learned, in that it includes the same headings and elaborates on the key lessons-learned under the most suitable heading.

For example, clicking on *Experience feedback* under *Common organization* in the *Phase 4 Operation* yields the following result.

several stake-holders. It is clear from the E2ReBuild experiences that introduction of a systematic energy-efficient refurbishment framework requires the management of change. Generally, people do not break their paradigms easily. New research¹⁴¹⁵ shows that a supplier introducing an innovative concept into a project-based industry like construction runs a very real risk of not getting accepted by clients or by employees and colleagues because of its novelty. Another example is that energy-efficiency requires a change in tenant behaviour. This is a very complex and contextualised issue and there is no homogeneous picture for promoting energy saving measures, but tenant acceptance is important. Furthermore, tenant acceptance is vital for a smooth work progress, and is based on frequent, quality communication. *Energy savings require that the initial contact with the tenants continues even after the renovation is completed.*

Finally, the deliverable aims to put all the nuts and bolts of the project into perspective by the use of an allegory, the *Tale of the two Fishermen and the Big Fish*, an E2ReBuild original work.

¹⁴ Engström, S. (2012): Managing information to unblock supplier-led innovation in construction : barriers to client decision-making on industrialized building in Sweden, Doctoral thesis, Luleå Univerasity of Technology. <http://pure.ltu.se/portal/en/publications/managing-information-to-unblock-supplierled-innovation-in-construction%282d8dc315-167c-4574-9a89-41534e1a6ef4%29.html>

¹⁵ Hedgren, E. (2013): Overcoming organizational lock-in in decision-making: Construction clients facing innovation, Doctoral thesis, Luleå University of Technology. <http://pure.ltu.se/portal/en/publications/overcoming-organizational-lockin-in-decisionmaking%28d3e41db0-f3a6-4e87-9e71-7153ca3394d7%29.html>

3 Potential Impact

3.1 Socio-economic Impact

A retrofitting project is normally a large investment with a significant impact on the users, the local environment, on society and not least on the construction providers. E2ReBuild's strong socio-economic impact on European quality-of-life and competitiveness can be summarised in the following seven topics.

a) Reduced lifecycle costs

Reduced lifecycle costs and buildings that after retrofitting are adapted to their users' needs increase the competitiveness of European industry at large. 70 % of the total lifecycle costs are committed in the early planning phase. The architectural design of the building, external shading, internal distribution, systems for climate control, possibilities for natural lighting, etc. all contribute to reduced energy use and other major lifecycle costs. Thus, through the leading examples of the demonstration buildings, E2ReBuild will pave the way for significant reductions in total lifecycle costs.

In addition, affordable high-quality homes will increase the quality of life for European citizens. By retrofitting, buildings will be better adapted to current and future needs and more economic from a lifecycle perspective, which will increase competitiveness for European industry at large.

Positive effects from E2ReBuild include affordable housing and efficient use of public funds, a more competitive and productive European industry, buildings adapted to contemporary needs and a better, more innovative market for property development regarding retrofitting projects.

b) Efficient processes for build and operation

Efficient processes for build and operation build on true industrialisation of building production processes. This must start in the early planning phase, where product design and process design can be interlinked, and where significant changes are possible without any major costs.¹⁶ This should continue throughout the design, construction and operation phase. This is why E2ReBuild can have a major impact on retrofitting construction efficiency.

Less waste of time: A major in-depth study of seven Swedish construction projects¹⁷ reveals that only 15-20 % of a construction worker's time is spent on direct work. E2ReBuild shows that early planning of the project, notably the build stage will optimise the time each worker spends at construction site, coordinate suppliers and sub-contractors, improve logistics, etc.

Less waste of material: 10 % of the material brought to construction site is immediately sorted out as waste (some studies even indicate a 15% waste generation). While sometimes necessary, the waste is to large extent due to an uncontrolled design and purchase process, where the site manager needs to "buy a little extra" to avoid stops in production. An integrated early design and planning process, illustrated in E2ReBuild by the use of prefabricated energy efficient timber façade elements, makes it possible to calculate a more exact material use and identify suppliers capable of providing the best available products.

Right the first time: The same Chalmers study as referred to above has revealed that the cost of repairing mistakes and errors on construction site amounts to 6-12 % of the total construction cost. This number is overwhelmingly high considering our industry's average profit margin of approximately 3 %.

¹⁶ Shigeo Shingo, The Japanese Production Philosophy, 1985

¹⁷ P-E Josephson, Byggkostnadsforum's seminar: från no-tech till hi-tech Stockholm, Sweden, 2005

E2ReBuild mitigates this by demonstrating that mistakes can be avoided already in the early planning phase, e.g. by introducing early virtual mock-ups, integrated teams and 3D-modelling.

Positive effects from E2ReBuild pertaining to efficient processes include fewer workers hospitalised or facing early retirement, increased quality, predictable risks, reduced investment cost, increased transparency and radical cost savings.

c) Sustainable construction - no waste of materials, energy, and other resources

Energy efficient design, elimination of waste in construction, solutions that avoid the use of chemicals, etc., will have a significant impact on the sustainability of our sector. E2ReBuild contributes to fulfilling the European Commission directive on energy performance of buildings, EU's approach to develop lifecycle impact declarations/ statistics/ facts of buildings and building products, the Kyoto protocol, and the Commission's chemicals directive/REACH, and several other sustainability goals.

Positive effects on sustainability from E2ReBuild include: quality-of-life and comfort, the ability to meet international climate and environmental goals and to measure the rate of success; Healthy indoor environment in buildings that use less energy; Reduced waste and emissions and health increase competitiveness.

d) Improved financial instruments for energy efficient retrofitting.

PFI¹⁸, performance-based contracts, EPC¹⁹, partnering, and other purchasing/financing instruments are becoming increasingly common throughout Europe, however, today mostly for the new built sector. The fundamental challenge to make these instruments effective is to make all partners of the building value chain to meet each other and to understand the individual driving forces as to create a win-win situation for all parties involved.

E2ReBuild addresses business processes and tools that are available today in order to identify necessary change mechanisms, e.g. high-quality decision support, better collaboration and contracts, and a sounder distribution of risks. Positive effects from this include improved instruments for funding and for investments as well as new ways of doing business.

e) Improved tendering

E2ReBuild disclosed the need for action. The E2ReBuild Industrialised Platform for Energy Efficient Retrofitting enables clients to make informed decisions based on lifecycle analyses already in the planning phase. While having Return of Investment forming the basis for decision, E2ReBuild has developed methods for choosing the most advantageous solution from a lifecycle perspective. This will have a significant impact on the quality of public investments and reduce public spending in the long run. It will also create a positive competitive advantage for contractors that invest in know-how on lifecycle aspects and quality. Effects from E2ReBuild include: efficient use of public funds, focus on "best alternative from lifecycle perspective" instead of "lowest bidder" and less irrational focus on direct cost competition.

f) Easy take-up of multifunctional and nano materials and other technical innovations

The E2ReBuild Industrial Platform for Energy Efficient Retrofitting makes it possible to simulate and manage the technical and economic benefits and risk of new materials and innovations, thereby increasing the acceptance of introducing innovations in the building project, which today is the main obstacle to a widespread take-up of multifunctional materials and new product/process solutions. The

¹⁸ PFI – Private Finance Initiative

¹⁹ Energy Performance Contracting

actual demonstrations provide full-scale testing and provide the necessary basis for a scale-up and widespread replication.

Effects from this perspective from E2ReBuild include: new market for SMEs, improved products and processes for increased competitiveness, and smart and efficient products / systems and processes.

g) End-user's behaviour and well being

One of the main results from E2ReBuild is showing that retrofitting of existing residential buildings can help us save energy and decrease the emission of CO₂ substantially while still maintaining quality indoor climate and reducing moisture problems. E2ReBuild achieved this by creating new technical and socio-economic solutions to make energy efficient behaviour natural, easy and intuitively understandable for the end-users in retrofitted buildings without adventuring the well-being.

Effects from E2ReBuild include quality of life and comfort, for example a shorter, well-planned construction process which disturbs the tenants less. They also include: improved individual influence, healthy indoor environment and reliable systems easy to maintain.

3.2 Dissemination

The initial plan for use and dissemination can be found in Annex I – Description of Work. The plan was updated during the project when the dissemination strategy was written.

The objective of dissemination is to create awareness, deeper understanding, and support for the E2ReBuild project. It is also to encourage involvement in the research work, from the companies (not at least the small- and medium-sized) and academia. Finally, to make stakeholders take action to take-up the research results thereby taking the first step to a transformation of the European retrofitting building industry and the potential for a much larger replication potential.

To ensure a high impact of the project results, both from the demonstrations as well as the supporting research work, we will dedicate great effort to a widespread dissemination of results. In Table 1, the E2ReBuild's offer to the main target groups is outlined and connected to activities and channels for a high dissemination impact.

During the first period of the E2ReBuild project, dissemination efforts will focus on the build-up of a communication infrastructure, e.g. website, newsletter, press releases, information prints, marketing material and other means of mass communication, to raise awareness about the project in general, and to facilitate the dissemination of results as they are delivered later on in the project. This work also includes identifying organisations and persons within the target groups to involve in the E2ReBuild network and to contact and learn from other EU programmes that have worked successfully with dissemination, like for example the Concertoplus.

In the later stage of the project, when results start to emerge, the focus of the dissemination efforts will shift towards interaction with stake holders in the target groups, e.g., partners actively spreading results and experience at workshops, seminars, conferences and networking events, arranging a national seminar for every demonstration site, promotion of the European Retrofit Advisor, demonstration site visits and scientific publications.

In all communication, first-hand information through self-made experience and face-to-face meetings is the most efficient way of transferring knowledge. Therefore, the persons of the E2ReBuild project are the most important dissemination channels, as they are the ones who meet and interact with stake holders in all the different target groups beyond the consortium. All participants have personal and professional networks. The ability to establish new collaborations within these networks, where the E2ReBuild's vision and results can be implemented, is highly improved if all partners have good

knowledge of the project progress in RTD- and demonstration work. Therefore, internal communication and knowledge transfer is also seen as a key to a successful dissemination work.

Table 2: Targeted groups for the E2ReBuild dissemination activities

Target groups	Reasons for dissemination	What benefits we can offer	Actions and channels
Clients, Public and private building owners	Awareness Understanding Action	Better products and services. Business concepts for incentives, incl. procurement focusing on best alternative from life cycle perspective instead of lowest price. Good practice examples of energy efficient buildings adapted for today's needs. Reduced investment costs. Reliable systems easy to maintain.	Involvement of demonstration owners in all RTD WPs, through e.g. participating in WP meetings, continuous feedback on WP progress and joint planning of end-user interactions. Continuous knowledge and experience through WP1 and building site visits. Publishing of E2ReBuild results in selected journals and platforms. Knowledge transfer through publishing of E2ReBuild publications, newsletter and other information material. Participating in and presenting E2ReBuild results and concepts at seminars, conferences and networking events. Arranging one national seminar per demonstration country for national stakeholders including other client organisations.
End-users	Awareness Action	Provide means for energy efficient behaviour. Better indoor climate and improved individual influence for a more attractive living adapted for today's and tomorrow's demands.	Distributing information materials about E2ReBuild to all residents in demonstration buildings and putting up signposts at all demonstration sites. Involving end-users through questionnaires, meetings and interviews with tenants before and after retrofit for evaluation of added value. Influencing energy behaviour through visualising energy use, e.g. information about flat- and building energy use accessible through the Internet.
European construction sector	Understanding Action	New ways of working and doing business, creating a better market for property development regarding retrofitting projects. Improvement of workers health and safety. Reduced waste production and emissions. Smart and efficient products/systems and processes.	Knowledge transfer through publishing of E2ReBuild publications, newsletter and other information material. Participating in and presenting E2ReBuild results and concepts at seminars, conferences and networking events. Arranging one national seminar per demonstration country for national stakeholders including other construction companies.
Small and medium-sized companies in the construction sector	Awareness Understanding Action	New ways of collaborating with the large companies of the sector. (SMEs are often suppliers or service providers to these). Improvement of workers health and safety. Reduced waste production and emissions. Smart and efficient products/systems and processes.	Involving participating SMEs in all RTD WPs, through e.g. participating in WP meetings and continuous feedback on WP progress. Continuous knowledge and experience transfer through WP1 and building site visits. Publishing of E2ReBuild results in selected journals and platforms. Participating in and presenting E2ReBuild results and concepts at seminars, conferences and networking events. Arranging one national seminar per demonstration country for national stakeholders including other construction companies.
Industry organisations, e.g. industrial federations, workers' unions, lobby organisations, etc.	Awareness Action	Industrial transformation including meeting international climate and environmental goals, and less workers hospitalised and facing early retirement.	Publishing of E2ReBuild results in selected journals and platforms. Participating in and presenting E2ReBuild results and concepts at seminars, conferences and networking events.

European and national authorities	Awareness Understanding	Identified barriers to development. Efficient use of public funds. Improved quality of life among citizens.	Publishing of E2ReBuild results in selected journals and platforms. Participating in and presenting E2ReBuild results and concepts at seminars, conferences and networking events.
Research community	Understanding	New research topics. Take-up of innovation.	Publishing of E2ReBuild results in selected journals and platforms. Participating in and presenting E2ReBuild results and concepts at seminars, conferences and networking events.

The dissemination activities related to the E2ReBuild project include publications, conferences, workshops, web sites, press releases, flyers, articles in popular press, presentations, exhibitions, theses, interviews, films, TV clips, posters. All of the 222 activities are given in the report *Plan for Use and Dissemination of Foreground* (Table 4, chapter 3.3). The nine scientific (peer reviewed) publications related to the foreground of the project are given in Table 3 below. Further information can be found in deliverable D7.1 *Dissemination Activities*.

Table 3: List of scientific publications

	Title	Main Author	Title of periodical or series	Number, date or frequency	Publisher	Place of Publication	Year of publication	Relevant pages	Permanent identifier	Open access
1	Sustainability verification and life cycle evaluation of residential building modernization with industrialized retrofit solutions	Simon le Roux, Yrsa Cronhjort; Aalto	BSA 2012 Proceedings of the 1st International Conference on Building Sustainability	24 May 2012	Green Lines Institute for Sustainable Development	Porto, Portugal	2012	Pp 283-290	ISBN 978-989-95671-7-7 eISBN 978-989-95671-6-0	http://www.greelines-institute.org/greelines-institute/Pdfs/pdfs_bookstore/BSA2012_Content_s.pdf
2	"Collaboration Models for Industrialised Renovation Methods and Prefabrication – Experiences and Outlook on Organizational and Legal Frame Conditions"	Sonja Geier, Doris Ehrbar, Peter Schwehr, HSLU (CCTP)	Proceedings: SB13 Graz, Sustainable buildings – Construction products & Technologies	25 – 28 September 2013	Verlag der Technischen Universität Graz	Graz, Austria	2013	pp. 27-38	ISBN 978-3-85125-301-6 DOI: 10.3217/978-3-85125-301-6	http://castor.tugraz.at/doku/SB13_Graz/SB13_Graz_Fullpaper.pdf
3	Legal and economic prerequisites for sustainable refurbishment of housing companies in Finland	Yrsa Cronhjort, Simon le Roux; Aalto	Proceedings: SB13 Graz, Sustainable buildings – Construction products & Technologies	25 – 28 September 2013	Verlag der Technischen Universität Graz	Graz, Austria	2013	pp. 1563-1568	ISBN 978-3-85125-301-6 DOI: 10.3217/978-3-85125-301-6	http://castor.tugraz.at/doku/SB13_Graz/SB13_Graz_Fullpaper.pdf
4	"Collaboration Models for Industrialised Renovation – Opportunities, Barriers and Risks"	Sonja Geier, Doris Ehrbar, Peter Schwehr, HSLU (CCTP)	Proceedings Passivhus Norden 2013, The 6 th Passive house conference in the Nordic countries	15-17 October 2013	Lågan, a programme for buildings having very low energy use	Göteborg Sweden	2013	Pp 596-609		http://www.laganbygg.se/UserFiles/Presentation/s/55_Session_15_S.Geier.pdf
5	Industrialized energy efficient retrofitting of resident buildings in cold climates: General presentation of the E2ReBuild project.	Christina Claesson-Jonsson, Birgitta Berglund, NCCSE	Proceedings Passivhus Norden 2013; The 6 th Passive house conference in the Nordic countries	15-17 October 2013	Lågan, a programme for buildings having very low energy use	Göteborg Sweden	2013	Pp 586-595		http://www.laganbygg.se/UserFiles/Presentation/s/54_Session_15_C.Claesson.pdf

6	Partnering as a tool for a cost and energy efficient retrofitting of existing buildings – an example from E2Rebuild – Halmstad demonstration project	Stephen Burke, NCCSE	Proceedings Passivhus Norden 2013; The 6 th Passive house conference in the Nordic countries	15-17 October 2013	Lågan, a programme for buildings having very low energy use	Göteborg Sweden	2013	Pp 621-628		http://www.laganbygg.se/UserFiles/Presentation/s/57_Session_15_S.Burke.pdf
7	Innovation in early planning and design for energy efficient retrofitting	Kajsa Flodberg, Anders Ljungberg NCCSE	Proceedings Passivhus Norden 2013; The 6 th Passive house conference in the Nordic countries	15-17 October 2013	Lågan, a programme for buildings having very low energy use	Göteborg Sweden	2013	Pp 610-620		http://www.laganbygg.se/UserFiles/Presentation/s/56_Session_15_K.Flodberg.pdf
8	Holistic retrofit and follow-up through monitoring: Case Virkakatu, Oulu, Finland.	Yrsa Cronhjort, Simon le Roux; Aalto	NSB 2014 10th Nordic Symposium on Building Physics 15-19 June 2014 Lund,	15-19 June 2014	Editors: Jesper Arfvidsson, Lars-Erik Harderup, Anders Kumlin, Bitte Rosencrantz	Lund, Sweden	2014	pp. 1172-1179	978-91-88722-53-9 (TVBH-3061)	http://www.nsb2014.se/wordpress/wp-content/uploads/2014/07/Retrofitting_of_Buildings.pdf ,
9	Hygrothermal Performance of TES Energy Façade at two European residential building demonstrations – Comparison between Field Measurements and Simulations	Carl-Magnus Capener, SP; Stephen Burke, NCCSE; Simon le Roux, Aalto; Stephan Ott, Stephan, TUM	NSB 2014 10th Nordic Symposium on Building Physics 15-19 June 2014 Lund, Sweden	15-19 June 2014	Editors: Jesper Arfvidsson, Lars-Erik Harderup, Anders Kumlin, Bitte Rosencrantz	Lund, Sweden	2014	pp. 1244-1251	978-91-88722-53-9 (TVBH-3061)	http://www.nsb2014.se/wordpress/wp-content/uploads/2014/07/Retrofitting_of_Buildings.pdf ,

3.3 Exploitation

The project's result (the foreground) will be further exploited by the project participants in different ways. The most important exploitable results can be seen in Table 4 below. A short explanation of the exploitable result can be found below the table.

Table 4: Main (non-confidential) exploitable results of E2ReBuild

Type of Exploitable foreground	Description of exploitable foreground	Exploitable products/measures	Sectors of application	Time-table	Owner & other beneficiary involved
General advancement of knowledge	Guidelines to End-users/Tenants	Guidelines	L Real Estate Activities	2014	<u>SP</u> ; NCCse, White, HSLU, Opac38, Aalto
General advancement of knowledge	Guidelines to Operators	Guidelines	M Professional, scientific and technical activities	2014	<u>SP</u> ; NCCse, Opac38, Aramis, Aalto
General advancement of knowledge	Process map	Planning tool	F Construction	2013	<u>NCCse</u> ; MOW
Commercial exploitation of R&D results	European Retrofit Advisor	Web tool	L Real Estate Activities	2014	<u>EMPA</u> ; NCCse, SP, HSLU, MOW, GWGM
Commercial exploitation of R&D results	Socio-architectural method	Interdisciplinary method merging anthropological and architectural perspectives	M Professional, scientific and technical activities	2014	<u>White</u> ; NCCSE, HSLU, GWGM, Opac38
General advancement of knowledge	Holistic refurbishment strategies	Knowledge on strategy design background, cost break methods	M Professional, scientific and technical activities	2014	<u>HSLU</u> ;
General advancement of knowledge	Building Typology	Replication potential modelling method	L Real Estate Activities	2014	<u>HSLU</u> ;
Exploitation of results through innovation	TES Energy-Façade, Demo Augsburg	Construction method	M Professional, scientific and technical activities	2013	<u>TUM</u> , <u>Gumpp</u> , Augsburg
General advancement of knowledge	Educational material based on demonstration case study	Slide presentations of Oulu demonstration project case study	M Professional, scientific and technical activities	2013	<u>Aalto</u> , SP, TUM
General advancement of knowledge	Experiences and feedback about technologies, owner and tenant experiences	Feedback from different stakeholders	F Construction	2014	<u>Demo owners</u> (GWGM, PSOAS, Opac38, Aramis, Augsburg, ABV, Gallions)

Guidelines to End-users/Tenants

Can be used by research institutes, housing corporations and construction companies for evaluating and influencing tenants' energy behaviour and well-being during and after retrofit projects

Guidelines to Operators

Can be used by housing corporations, researchers, construction companies and other operators for implementing routines concerning following up of indoor environment and energy use in retrofitted buildings

Process map

Aimed at facilitating systematic planning. Available as a transparent planning tool for all stakeholders, notably facility management and contracting. When generally adapted and adopted by the partners, expected impact is a step-change in European refurbishment, from resource-based ad-hoc retrofitting to value-based collaborative methods.

European Retrofit Advisor

Purpose: The European Retrofit Advisor is a web-based tool that allows a simple but detailed evaluation of retrofit options for apartment buildings. It allows a detailed multi-criteria analysis of renovation options considering economic, environmental and social issues. It is a decision tool that supports the selection of an appropriate renovation strategy in the early planning stage. The renovation strategy recommended by the European Retrofit Advisor should be re-evaluated and further developed during the design phase.

Exploitation potential: The European Retrofit Advisor aims to address both, professionals (i.e. architects, energy consultants) and non-professionals (home owners). It is also well suited as a teaching tool for master of advanced study students. This web-based tool is free of charge in order to allow it to be extensively used. However, software developers, consultants or facility related companies may further develop the tool in a specific way in order to achieve an added value and a wider audience and to promote it as their own brand. The first such application was realized by the Swiss platform Immogreen "<http://www.epimmo.ch/immogreen/login-tool/>".

IPR: Intellectual property rights are owned by Empa, the Swiss Federal Laboratories for Materials Testing and Research. The web-tool is provided free of charge to any user, however the computer code is the intellectual property of Empa and will only be provided under a license agreement that has to be negotiated.

Research: The European Retrofit Advisor is already a further development of the Retrofit Advisor available as an Excel-based test version in Switzerland. By the time no further development of this tool is planned. However it offers a lot of opportunities for new initiatives and research work by third parties.

Potential / Impact: The European Retrofit Advisor has a wide application range. A lot of European buildings are waiting for an in depth renovation or even for demolition and reconstruction. The potential of the European Retrofit Advisor is not to reduce renovation costs but to plan an optimized retrofit investment. It allows a quick evaluation of the renovation potential and may show that a more comprehensive building renewal may lead to a better long time performance than a step by step building repair. Thus, it is a tool that potentially will lead to increased renovations in the housing sector.

Socio-architectural method

A method for integrating social aspects in the early stage of a renovation process and relating these to design aspects and the design process. It can be used by partners and other industry stakeholders in

future retrofit projects. The social aspects are gaining in importance and relevance as aspects such as social capital, inclusiveness and participation are increasingly researched and understood as relevant within the framework of a retrofit. The method has the potential to increase the utilization of these aspects in future renovation projects. More research is needed following implementation and evaluation of the method in use.

Holistic refurbishment strategies

Knowledge on strategy design background/ new cost break-down methods for industrialised renovation. Further research within national/international context. Potential for changes in the construction sector by a new understanding of opportunities, barriers and risk; New decision argumentation by applying new cost break down approaches;

Building typology (modelling method)

A modelling method on replication potential for industrialised renovation. Further research in national/international context. Changes in the construction sector / exploration of replication potential

TES EnergyFaçade Augsburg

Grüntenstrasse/Augsburg is an outstanding example of a renovation with the TES EnergyFaçade in Germany and serves as best practice project. Several guided tours have been done to demonstrate the project.

Educational material based on the Oulu demonstration case study

The Oulu demonstration has produced a great amount of photographic material, research studies and analysis on a variety of topics, including postgraduate studies in ground penetrating radar, condition analysis, life-cycle analysis, building physics and energy simulations, undergraduate studies in building automation equipment and monitoring data management software, refurbishment cost analysis, prefabricated timber product development, and user energy behaviour, system-loss estimation, and learning from mistakes. Presentations on such a wide set of research topics are made understandable when shown in connection with a well-documented case study, and the educational material is valuable for undergraduate students from many fields, as well as for research seminars promoting university activities.

Feedback regarding demonstration projects

Experiences and feedback about technologies, owner and tenant experiences