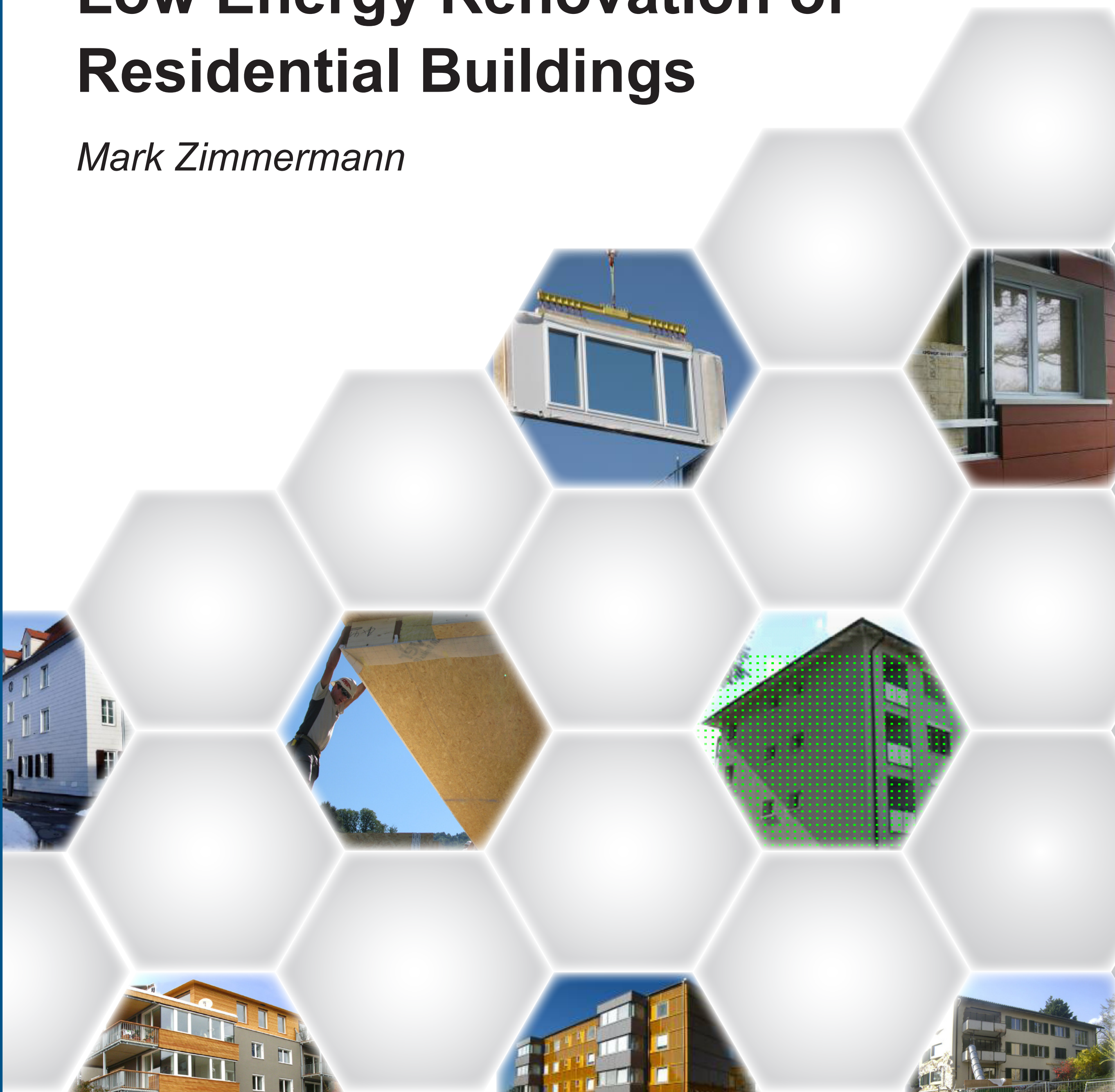
Project Summary Report

International Energy Agency
Energy Conservation in
Buildings and Community
Systems Programme

ECBCS Annex 50

Prefabricated Systems for Low Energy Renovation of Residential Buildings

Mark Zimmermann



International Energy Agency
Energy Conservation in Buildings and Community Systems Programme

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Prefabricated Systems for Low Energy Renovation of Residential Buildings

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About ECBCS

International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster co-operation among the twenty-eight IEA participating countries and to increase energy security through energy conservation, development of alternative energy sources and energy research, development and demonstration (RD&D).

Energy Conservation in Buildings and Community Systems

The IEA co-ordinates research and development in a number of areas related to energy. The mission of one of those areas, the ECBCS - Energy Conservation for Building and Community Systems Programme (**www.ecbcs.org**), is to develop and facilitate the integration of technologies and processes for energy efficiency and conservation into healthy, low emission, and sustainable buildings and communities, through innovation and research.

The research and development strategies of the ECBCS Programme are derived from research drivers, national programmes within IEA countries, and the IEA Future Building Forum Think Tank Workshop, held in March 2007. The R&D strategies represent a collective input of the Executive Committee members to exploit technological opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy conservation technologies. The R&D strategies apply to residential, commercial, office buildings and community systems, and will impact the building industry in three focus areas of R&D activities:

- Dissemination,
- Decision-making,
- Building products and systems.

The Executive Committee

Overall control of the program is maintained by an Executive Committee, which not only monitors existing projects but also identifies new areas where collaborative effort may be beneficial. To date the following projects have been initiated by the executive committee on Energy Conservation in Buildings and Community Systems (completed projects are identified in grey):

Annex 1:	Load Energy Determination of Buildings
Annex 2:	Ekistics and Advanced Community Energy Systems
Annex 3:	Energy Conservation in Residential Buildings
Annex 4:	Glasgow Commercial Building Monitoring
Annex 5:	Air Infiltration and Ventilation Centre
Annex 6:	Energy Systems and Design of Communities
Annex 7:	Local Government Energy Planning
Annex 8:	Inhabitants Behaviour with Regard to Ventilation
Annex 9:	Minimum Ventilation Rates
Annex 10:	Building HVAC System Simulation
Annex 11:	Energy Auditing
Annex 12:	Windows and Fenestration
Annex 13:	Energy Management in Hospitals
Annex 14:	Condensation and Energy
Annex 15:	Energy Efficiency in Schools
Annex 16:	BEMS 1- User Interfaces and System Integration
Annex 17:	BEMS 2- Evaluation and Emulation Techniques
Annex 18:	Demand Controlled Ventilation Systems
Annex 19:	Low Slope Roof Systems

About ECBCS

Annex 20: Air Flow Patterns within Buildings
Annex 21: Thermal Modelling
Annex 22: Energy Efficient Communities
Annex 23: Multi Zone Air Flow Modelling (COMIS)
Annex 24: Heat, Air and Moisture Transfer in Envelopes
Annex 25: Real time HEVAC Simulation
Annex 26: Energy Efficient Ventilation of Large Enclosures
Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems
Annex 28: Low Energy Cooling Systems
Annex 29: Daylight in Buildings
Annex 30: Bringing Simulation to Application
Annex 31: Energy-Related Environmental Impact of Buildings
Annex 32: Integral Building Envelope Performance Assessment
Annex 33: Advanced Local Energy Planning
Annex 34: Computer-Aided Evaluation of HVAC System Performance
Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT)
Annex 36: Retrofitting of Educational Buildings
Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx)
Annex 38: Solar Sustainable Housing
Annex 39: High Performance Insulation Systems
Annex 40: Building Commissioning to Improve Energy Performance
Annex 41: Whole Building Heat, Air and Moisture Response (MOIST-ENG)
Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM)
Annex 43: Testing and Validation of Building Energy Simulation Tools
Annex 44: Integrating Environmentally Responsive Elements in Buildings
Annex 45: Energy Efficient Electric Lighting for Buildings
Annex 46: Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)
Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings
Annex 48: Heat Pumping and Reversible Air Conditioning
Annex 49: Low Exergy Systems for High Performance Buildings and Communities
Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings
Annex 51: Energy Efficient Communities
Annex 52: Towards Net Zero Energy Solar Buildings
Annex 53: Total Energy Use in Buildings: Analysis & Evaluation Methods
Annex 54: Integration of Micro-Generation & Related Energy Technologies in Buildings
Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance & Cost (RAP-RETRO)
Annex 56: Cost Effective Energy & Carbon Dioxide Emissions Optimization in Building Renovation
Annex 57: Evaluation of Embodied Energy & Carbon Dioxide Emissions for Building Construction
Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements
Annex 59: High Temperature Cooling & Low Temperature Heating in Buildings

Working Group - Energy Efficiency in Educational Buildings
Working Group - Indicators of Energy Efficiency in Cold Climate Buildings
Working Group - Annex 36 Extension: The Energy Concept Adviser
Working Group - Energy Efficient Communities

General Information

Project leader: **Mark Zimmermann, EMPA, Switzerland**
Project duration: **2006 - 2011**
Further information: **www.ecbcs.org/annexes/annex50.htm**

The potential for energy conservation in buildings is largely dominated by the existing stock. In most industrialized countries new buildings will only contribute 10% - 20% additional energy consumption by 2050, whereas more than 80% will be influenced by the existing building stock. If building renovation continues at the current rate and with the present common policy, between one to over four centuries will be necessary to improve the building stock to the energy level of current new construction.

Currently, most building renovations address isolated building components, such as roofs, façades or heating systems. This often results in inefficient and ultimately expensive solutions, without an appropriate long term energy reduction. Optimal results cannot be achieved by single renovation measures and new problems could arise, for example local condensation or overheating.

The objective of the ECBCS research project, **'Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings'** has been the development and demonstration of innovative whole building renovation concepts for typical European apartment buildings. The concepts are based largely on standardised façade and roof systems that are suitable for prefabrication. The highly insulated new building envelope includes the integration of a ventilation system.

Figure 1 shows the prefabricated façade modules that are used to construct a new building envelope outside the existing building. This is physically optimal and does not reduce available space.

The concept is focussed on typical apartment buildings that represent appro¬ximately 40% of the European dwelling stock. The advantages include:

- Achieving energy efficiency and comfort for existing apartment buildings comparable to new advanced low energy buildings (30 - 50 kWh/m² per year);
- Optimised construction quality and cost efficiency due to prefabri-cation;
- Opportunities to create attractive new living space in the prefabrica-ted attic space and by incorporating existing balconies into the living space;
- Fast renewal process with minimal disturbances for the inhabitants.

Participating Countries:

Austria
Czech Republic
France
Netherlands
Portugal
Sweden
Switzerland

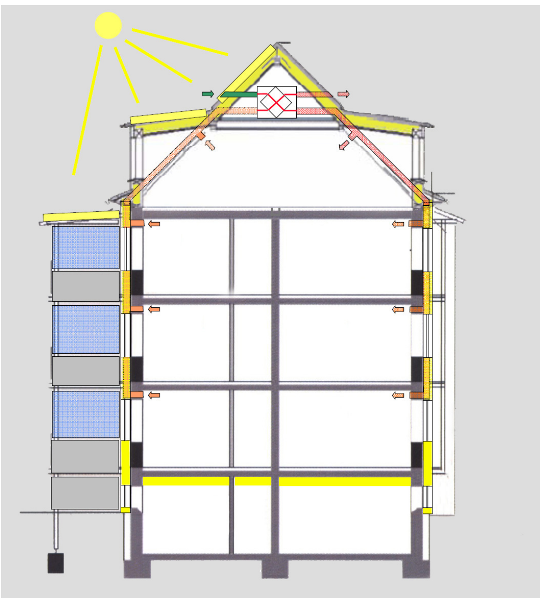


Figure 1. Prefabricated façade modules used to construct a new building envelope outside the existing building.

The project outcomes are given below.

Retrofit Strategies Design Guide

A building retrofit guide [1] has been produced documenting typical solutions for whole building renovations, including prefabricated roofs with integrated HVAC compo¬nents and for advanced façade renovation. The report is supplemented by the Retrofit Simulation Report [9] and an electronic 'Retrofit Advisor' [2], which allows a computer-based evaluation of suitable renovation strategies.

Retrofit Module Design Guide

This contains guidelines for system evaluation, design, the construction process and quality assurance for prefabricated renovation modules [3]. This publication includes the technical documentation of all developed renovation solutions.

Case Study Building Renovations

Case studies of six demonstration sites in Austria, Netherlands, and Switzerland [4] have been documented.

Additional publications are:

- Annex 50 Flyer [5], offering a short overview of the project and its achievements
- Building Typology and Morphology of Swiss [6] and French Multi-Family Homes [7] [8]
- Building Simulation Report on energy efficiency of renovated buildings [9].

Target Audiences

Prefabricated Systems for Low Energy Renovation of Residential Buildings is delivering information for building designers who focus on advanced building retrofit, energy, HVAC (heating, ventilation and air conditioning) and sustainable construction, the building industry with an interest in prefabrication of high performance energy building retrofit, apartment building owners with an interest in advanced renovation concepts, as well as a general audience.

Project Outcomes

Project leader: Mark Zimmermann, EMPA, Switzerlands
Project duration: 2006 - 2011
Further information: www.ecbcs.org/annexes/annex50.htm

Sustainable Building Stock Renewal as Major Challenge

Energy efficient new buildings are important, but the energy consumption of the existing building stock is more critical. The importance of building renewal for sustainable development is unquestionable. Until 2050 about 90% of the energy consumption of buildings will be caused by buildings built before 2000. At the same time existing buildings often offer low comfort and flexibility and can no longer compete with modern buildings. The degradation of old neighbourhoods is often just a matter of time. Repair and 'soft' renovations cannot solve the problem and partial renovations are expensive and inefficient.

The ECBCS research project 'Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings' has chosen an entirely new approach to solve this problem. This approach is based on the provision of a new building envelope that is easy to mount from the exterior and allows a lot of flexibility to improve the architecture. Interior work is reduced to a minimum. The concept is based on standardized and prefabricated renovation modules for façades and roofs. The project has focused on apartment buildings with a general need for renovation that should not only become energy efficient, but also require improvements to the architecture and living comfort. The international project partners are universities, industry, architects and building owners. The main research partners are listed on page 16.

Holistic Building Renewal

The ECBCS research project 'Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings' offers new solutions for the holistic renewal of apart¬ment buildings. Energy reduction measures are often not economic in them¬selves. They have to be combined with measures that also create added value. A comprehensive renewal is an opportunity for measures that not only repair a building, but also improve it for future generations. They allow – if needed – improvements to the architecture and layout.

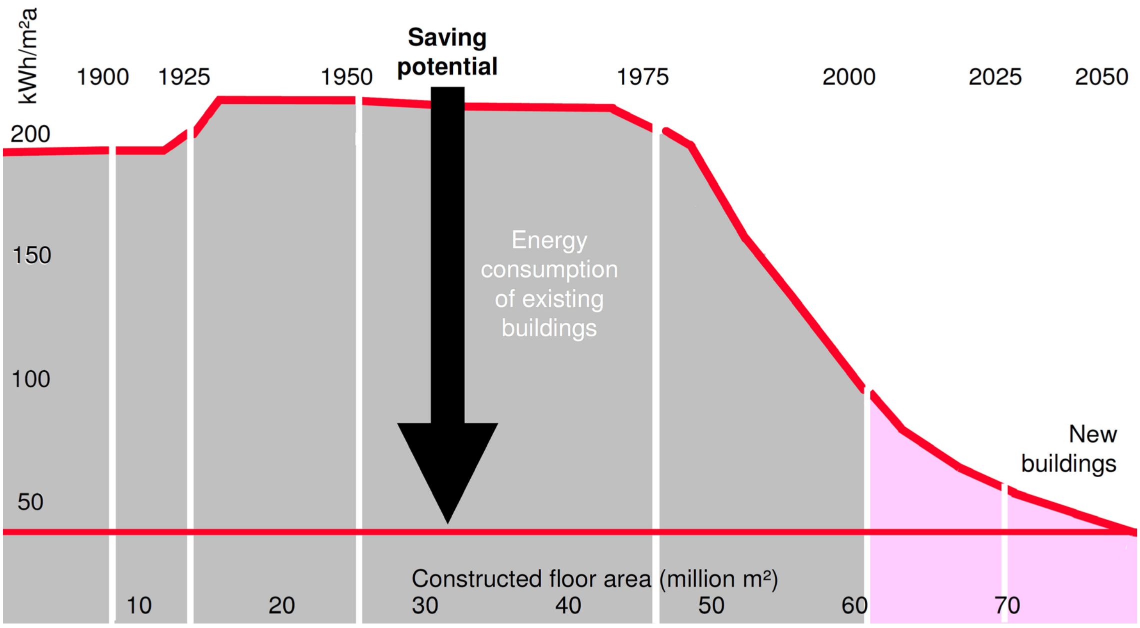


Figure 2. Constructed floor area and specific energy consumption for heating and hot water of existing buildings in Zurich and target value for sustainable renovation.

Source: Kt. Zurich

The concept that has been demonstrated is simple and clear: A new building envelope is placed around the existing building. This also allows improvements to the façades, the addition of room extensions or a new attic floor. The new building envelope has the quality of new building construction. It is well insulated, physically sound and offers excellent comfort. A new mechanical ventilation system with heat recovery – a prerequisite for low energy buildings such as Passive-Houses - is integrated within the façade and roof modules. Optimised constructions, efficient construction processes, high quality standards and reliable budgeting are important features of this concept.

High Quality Renovation Modules for Façades and Roofs

Fully integrated façade and roof modules have been developed in collaboration with European construction companies. The highly standardised modules consist of lightweight constructions, which can be prefabricated to any size by construction companies and mounted in collaboration with local contractors.

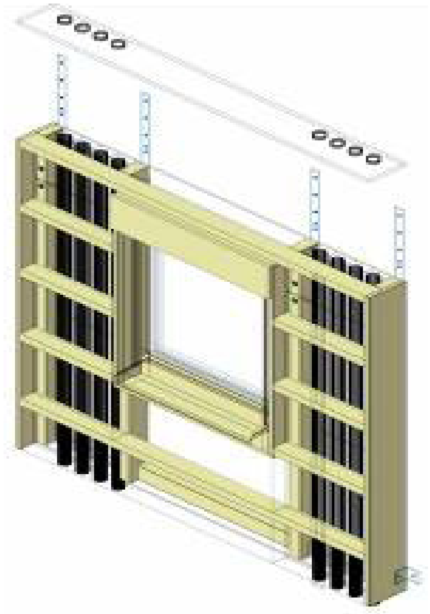
These modules still allow flexibility. Only the basic construction of the modules is standardised. The modules guarantee dimensionally correct application, excellent thermal insulation and fire protection according to individual national standards. The sizes of the modules can be adapted easily to the existing building and the final cladding is an architectural decision. This allows the architect to concentrate on the façade appearance. Ventilated cladding systems and tradition rendering are both possible with this approach.

Façade modules have been developed in Austria, France, Portugal, and Switzerland. The solutions reflect different national requirements relating to the building stock and the local climate and the preferences of the construction industry. These are documented in [3] 'Retrofit Module Design Guide'.

The Swiss façade modules only surround the window area. All details to be co-ordinated are concentrated in this area: window integration, solar shading, ventilation ducts, and additional technical services such as IT or electrical wiring. The spaces between window areas are insulated with mineral wool, foam insulation or blown-in fibres. The façade finish - ventilated cladding or rendering - is completed on site.

The starting point for the Austrian prefabricated solar façade module is an external solar comb, signi¬ficantly improving the U-value of the new envelope. The module is based on timber-framed construction, internal insulation, and solar comb mounted on medium density fibreboard, and covered with glass panels. The maximum size is determined by the transportation to the

Figure 3. The Swiss modules only surround the window area. The spaces between the modules are traditionally insulated.



Source: FHNW

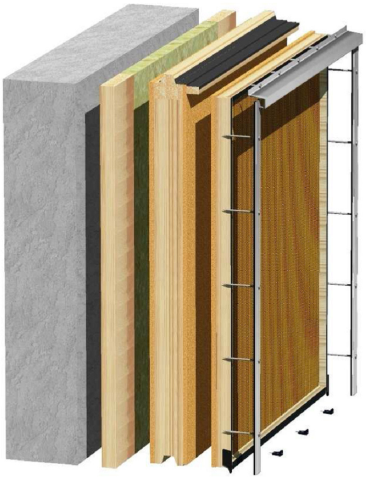


Figure 4. Layer composition of the Austrian facade module (left), factory assembling of large façade modules (right).

Source: Gap-solution GmbH

construction site. The assembly is carried out horizontally on a wooden substructure. Various other components are integrated – for example windows with venetian blinds, ventilation ducts and solar thermal collectors. This converts the element to a multi-functional solar façade module.

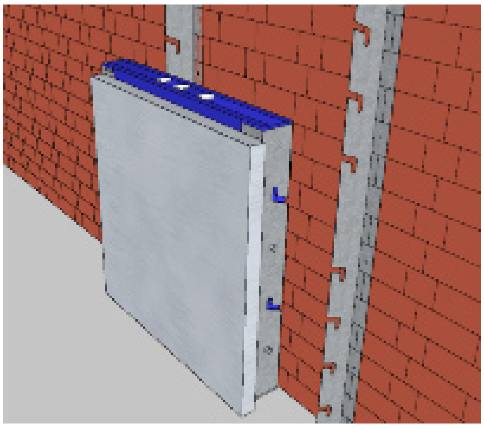
The French team has tackled the problem of renovating apartment blocks up to 8 storeys high. The loads and the linked constraints demand a strong secondary structure independent of the existing one. The multi-storey module is a combination of a light steel framed structure and several layers of mineral wool. The modules are compatible with any kind of façade finish.

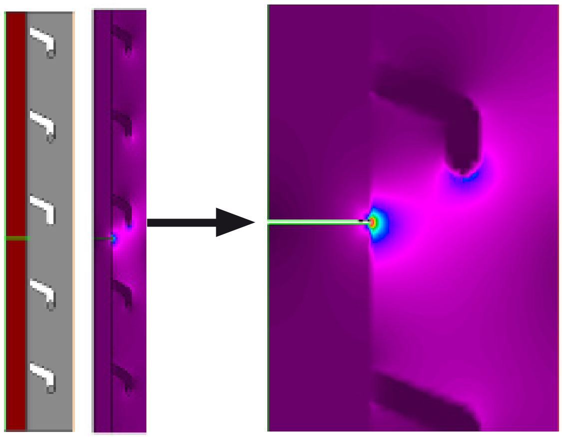
The Portuguese study concentrated on small size cassette shaped modules with insulation optimized for the Portuguese climate. The cassettes of about 1 m x 1 m size are fully prefabricated. A special mounting system allows simple assembling and disassembling. It is based on profiles on each side of the modules, with a system of pins and holes fitting into a support structure fixed to the existing wall.

Figure 5. Metal supporting structure for the French multi-storey façade module (left); test installation (right).

Source: Saint-Gobain Isover

Figure 6. Portuguese cassette system: mounting system for small façade modules (left); optimisation thermal bridges (right) (source: University of Minho).



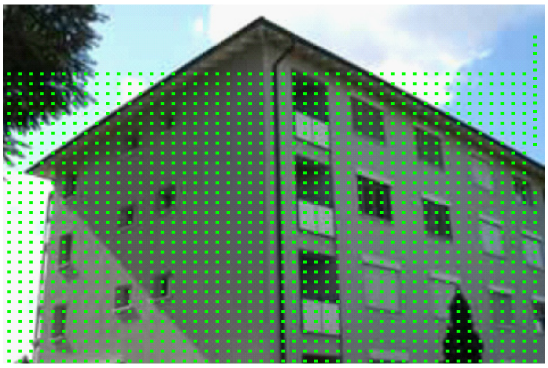


Source: University of Minho

3-D Measurement of Existing Buildings

Special 3-D laser scanning technologies and photogrammetry are applied to measure the existing building envelope precisely to guarantee the renovation modules will finally fit on the existing building envelope. This technology has been further developed for the purpose of building renovation.

Figure 7. Visualisation of the scanning process (top) and photorealistic 3D-picture extracted from measured data (bottom).



Laser scanning is an efficient method for obtaining 3-dimensional data of the building shape.

Source: FHNW

Laser-Scanning

The building is laser scanned from all sides. This allows an accurate isometric mapping of the building. Millions of recorded points allow an accurate representation of the building shape. Detailed measurements, irregularities and distortions of the building façades can be analysed and visualised by computer. The detailed data sets are then available for planning, accurate production of the prefabricated elements and for mounting of the modules.

Photogrammetry

Photogrammetry can be used for buildings with true planar façades. It is much simpler to apply than laser scanning. The building can be photographed with a good digital camera and the pictures are completed with reference measurements. Special computer programs allow nor¬malisation of the pictures, from which 3-D measurements can then be taken.

Renovation Process

Existing roofs may be completely removed and replaced by prefabricated roof modules. This allows optimised space use and the integration of modern technologies such as solar panels, mechanical ventilation, and so on. This opportunity is often used to create new and attractive attic apartments.

Figure 8. Photogrammetry allows for normalisation of digital photos, which can then be used for measurement extraction.

Sources: Architect K. Viridén, Zurich (left), gap-solution GmbH, Austria (right).

In parallel, the mounting of the façade elements is being prepared. In parallel with the roof replacement, preparations are required for mounting the façade elements. If needed, existing balconies - usually with thermal bridges - are removed and the size of window openings adjusted. The building owners decide to what extent they wish to change and improve the existing building structure. Often, the opportunity is used for optimising the layout, for example existing balconies are used to enlarge living rooms or kitchens. This can be done easily because a new external building envelope is constructed around the existing building.

Next, the prefabricated façade modules need to be fixed to the existing façade. Windows and solar shading are normally integrated in these modules, as are the ducts for the ventilation system or new electrical wiring.

If not already done, the old windows can now be removed and the air inlets and outlets drilled. Finally, the inside soffits are completed and decorated. If no other internal refurbishment is planned, the retrofit is already completed. In fact, the tenants may stay in their apartments during the renovation. The disturbance is minimal and lasts only a few days. If needed, room enlargements, roof extensions and attached elevators can be realised at the same time. The elements for roof extensions can be combined with façade elements.

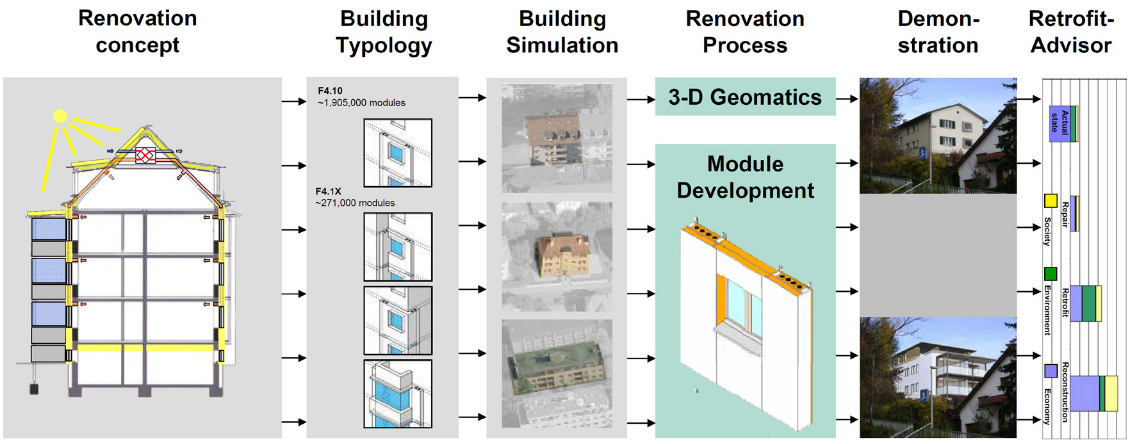
Market Analysis and Concept Development

The existing building stock has been analysed and the requirements and possibilities for advanced low energy retrofit then evaluated. The study has produced a building typology that provides basic data for the evaluation of the renovation potential of the existing building stock. It is also used for the definition of retrofit strategies and the envelope characteristics of specific building types [6] [7]. Building simulations have been

Figure 9. Mounting of pre-fabricated roof and façade elements .

Sources: Architect K. Viridén, Zurich (left), gap-solution GmbH, Austria (right).

Figure 10. Research steps of ECBCS Annex 50: from renovation concept to planning tool.



performed to ensure the proposed renovations will meet the energy goal of 30 to 50 kWh/m² per year [9].

Technology Development

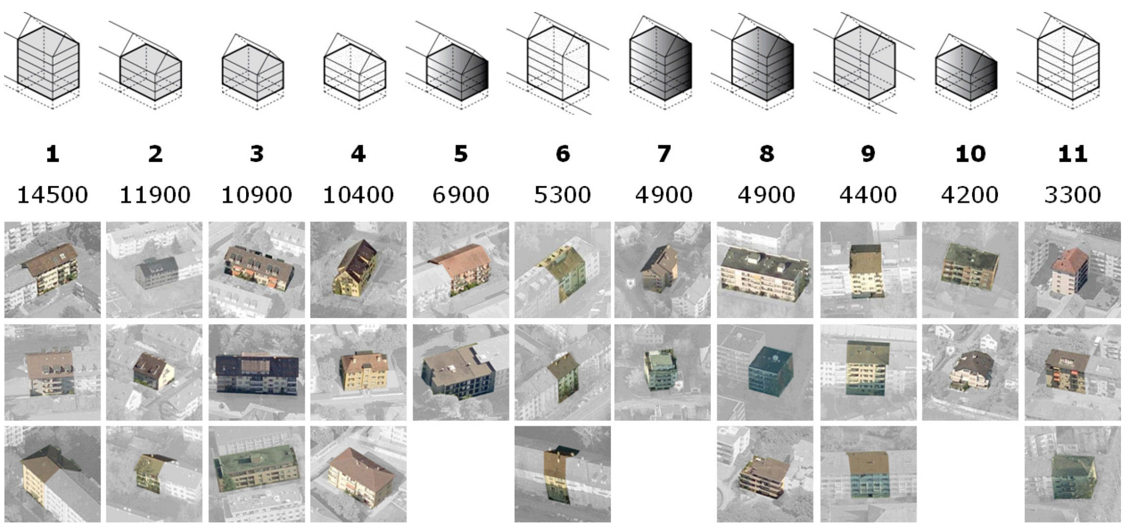
The establishment of building typologies is important for the development of standardised façade and roof modules with a large application potential. So far, the prefabrication technologies for façade and roof modules have been developed and tested. Special attention was given in the project not only to building physics, but also to fire protection and logistics. The work resulted in the development of four different renovation modules [3].

Special attention was given to laser scanning methods for building measurements. The scanning process and the post treatment of data were further developed by the University of Applied Sciences North-western Switzerland in collaboration with architects and industry partners. Due to this precise and efficient measurement methodology, good technological progress in planning, production and mounting is expected to result from the project.

Demonstration Projects

Demonstration projects are important to prove the practical feasibility of the concept. To this end, six demonstration sites including 364 renovated apartments have been successfully completed in Austria, the Netherlands, and Switzerland. The energy consumption of all renovated buildings was reduced by 80% to 90%. In fact, the goal of 30 to 50 kWh/m² per year for heating and domestic hot water was easily achieved. Solar installations on most of the buildings are further

Figure 11. Building typologies were established to adapt the concept to the market need and to quantify the application potential.



Sources: CCTP.

Figure 12. Swiss apartment building in Zurich, before and after renovation with prefabricated roof and façade elements. The renovation includes a new attic floor, living room extensions with old balconies, new enlarged balconies.

Sources: Architect B. Kämpfen, Zurich.

reducing the energy consumption to close to zero.

Further demonstration buildings are expected to be completed after termination of the project. The demonstration projects and case studies are documented in [4] 'Building Renovation Case Studies'.

Planning Tools

Successful renovation of a building is not only dependent on technical issues. The development of an optimal renovation strategy is equally important. For this purpose, the electronic 'Retrofit Advisor' was developed. This allows the evaluation and comparison of the economic, environmental and social impact of the existing situation, along with those of different renovation strategies [2].
Besides a number of renovation strategies, it also allows the user to consider repair work only as a 'minimal' solution and the demolition and reconstruction of the building as a 'maximal' solution.
The tool has an interface allowing easy use by non-specialists. It works with predefined building types and renovation scenarios that may be adjusted to the real situation of interest.

Figure 13. Austrian apartment building in Graz, before and after renovation with prefabricated façade elements. The renovation includes solar façade elements, living room extensions with old balconies, new elevators.

Figure 14. Renovation scenarios of typical buildings are used as a reference

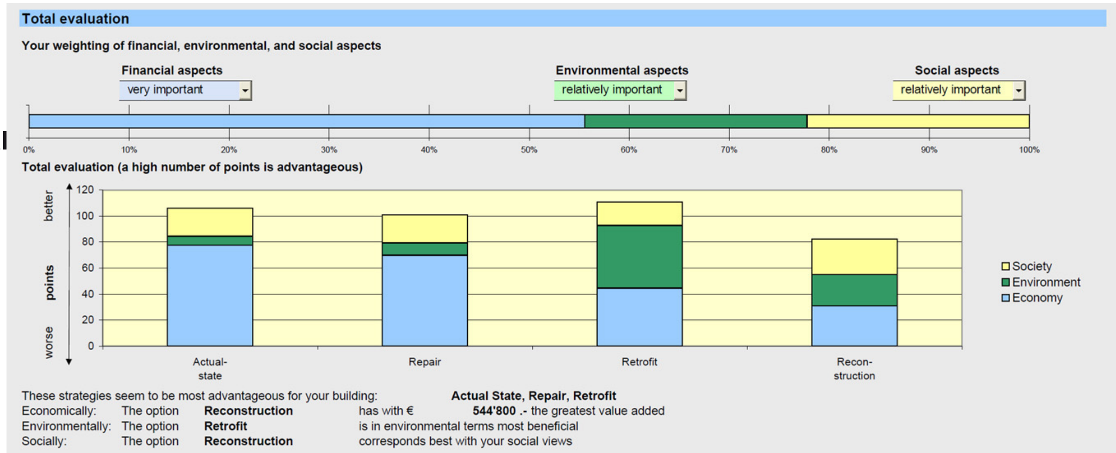


Figure 15. Examples of Retrofit Advisor results. They include a financial, environmental and social evaluation of various renovation scenarios

Project Outcomes

Further Information

[1] Peter Schwehr, Robert Fischer, Sonja Geier, *Retrofit Strategies Design Guide*, ISBN 978-3-905594-59-1, March 2011

[2] Mark Zimmermann, Hans Bertschinger, Kurt Christen, Walter Ott, Yvonne Kaufmann, Stefan Carl, *Retrofit Advisor,* Beta-version, March 2011

[3] René L. Kobler, Armin Binz, Gregor Steinke, Karl Höfler, Sonja Geier, Johann Aschauer, Stéphane Cousin, Paul Delouche, François Radelet, Bertrand Ruot, Laurent Reynier, Pierre Gobin, Thierry Duforestel, Gérard Senior, Xavier Boulanger, Pedro Silva, Manuela Almeida, *Retrofit Module Design Guide*, ISBN 978-3-905594-60-7, March 2011

[4] Sonja Geier, Karl Höfler, David Venus, Nadia Grischott, Reto Miloni, Mark Zimmermann, Chiel Boonstra, *Building Renovation Case Studies*, ISBN 978-3-905594-61-4, March 2011

Further project-related publications are:

[5] Mark Zimmermann: Annex 50 Flyer, *IEA ECBCS Annex 50 „Prefabricated Retrofit“*, March 2011

[6] Peter Schwehr, Robert Fischer, *Building Typology and Morphology of Swiss Multi-Family Homes 1919 – 1990*, January 2010

[7] Bertrand Ruot, *French housing stock built between 1949 and 1974*, October 2010

[8] Bertrand Ruot, *Elements of morphology of collective housing buildings constructed in France between 1949 and 1974*, October 2010

[9] Gerhard Zweifel, *Retrofit Simulation Report*, March 2011

Project Reports

www.ecbcs.org/annexes/annex50.htm

Project Participants

Category	Organisation
Austria	AEE - Institute for Sustainable Technologies (AEE INTEC)
Czech Republic	Enviros s.r.o. Brno University of Technology, Institute of Building Services
France	Centre scientifique et technique du bâtiment CSTB Centre scientifique et technique du bâtiment CSTB EDF AETIC, ALDES, Vinci Constructions
Netherlands	Energy Research Centre of the Netherlands ECN
Portugal	Porto University, Faculty of Engineering University of Minho, Civil Engineering Department, Construction and Technology Group
Sweden	CNA Arkitektkontor AB Energy and Building Design, Lund Institute of Technology
Switzerland	Lucerne University of Applied Sciences and Arts, Technology and Architecture University of Applied Sciences Northwestern Switzerland, School of Architecture, Civil Engineering and Geomatics Swiss Federal Laboratories for Materials Science and Technology Empa, Building Science and Technology Laboratory

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