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# Chapter 2

## Climate Adapted in NZEB Retrofitting for Residential Buildings

Marco Sala and Lucia Ceccherini Nelli

**Abstract** The climate-adapted residential nearly zero-energy building (NZEB) retrofitting project aims to update and upgrade the knowledge and competence of building designers (architects, civil engineers) as well as the specific skills of experienced building workers (site managers, craftsmen, and construction supervisors) who already have a decent background in sustainable energy solutions for the building sector gained by attending national Build Up Skills initiatives or related training. The overall objective is to increase the energy performance of European building stock as envisioned in EU Energy Efficiency Directive 2012/27/EU by supporting specific professional development through a broad roll-out of an integrated training model targeting both designers in the building sector and higher-level building workers, especially of SMEs. The training model will address, among the others, the management of the construction process and the active promotion of market uptake of cost-efficient, climate adapted Smart Retrofitting Solutions in order to reach NZEB standards in existing residential buildings.

**Keywords** Energy • Environment • Energy savings • Smart retrofitting • Sustainable energy solutions • Training model

### 1 Introduction

For a successful refurbishment towards nearly zero-energy building (NZEB), there is an urgent need for an efficient building retrofitting process. Innovative approaches should ensure practical on-site implementation of competitive, state-of-the-art retrofitting technologies using intelligent and smart “packages” for representative examples of actual building types and climate conditions. Thus, a holistic vision of the retrofitting process towards NZEB standards demonstrates the need to improve the skills and competencies of all actors involved in the retrofitting process; NZEB standards in existing buildings can only be attained if both

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designers and the workforce are efficiently upskilled and brought up to date on new technical and operative approaches.

## 2 Research Objectives

The main objective of climate-adapted residential NZEB retrofitting is to implement a large-scale, multilevel and integrated training model for the NZEB renovation of existing residential buildings based on climate-adapted energy solutions, targeting the main actors of the building sector: designers *and* higher-level on-site building workers. The project aims to fill the knowledge gap between the design phase and the on-site operational level through the improvement of NZEB retrofitting methodologies in planning and operative management practices to enable the creation of a “common language” between designers and higher-level workers at construction companies. The overall aim of the integrated training activities is to train a large number of building designers and building workers in several partner countries, targeting a high level of participation of women. Taking into account specific work constraints of the trainees, such as working hours, balancing career and family commitments (especially for women), a flexible user-friendly training solution will allow for dedicated e-learning sections through the *Adaptive ICT e-Teaching Portal*.

## 3 Methodology

The goals of the project must be combined with the economic competitiveness of smart, clean and non-invasive retrofitting technologies, through excellence in operational on-site management practices and a strong value added in terms of specific, climate-appropriate solutions, partially based on dry-building technologies, guaranteeing a low carbon footprint and high energy efficiency combined with good all-season indoor comfort. The building actors should thus be trained not only on technical and organizational issues but also on the financial mechanisms that can trigger market uptake of NZEB retrofitting.

Based on this concept, the overall approach of the project will be as follows:

- Integrated training model aimed at NZEB renovation of existing residential buildings, capable of creating a “common language” between designers and workers at construction companies
- Implementation of three rolling cycles of integrated training courses, including planning and development and a periodic review of the training model, targeting both designers and building professionals

- The development of an integrated training model with specific teaching modules for continuous professional training for designers and on-site building workers will include the following items:
  - Theory lessons (some delivered by dedicated e-learning tools)
  - Common practical applications
  - Common project workshop
  - Market orientation events aimed at involving all stakeholders of the building process “triggering empowerment of the supply/value chain
- Flexible and adaptive training will facilitate the involvement of professionals/women: family-friendly scheduling and dedicated e-learning modules through the ICT-based adaptive teaching platform
- The introduction of smart retrofitting solutions in the training model, such as innovative dry technologies aimed at fast and cost-effective retrofitting methodologies for existing residential buildings, will promote competitive, new work practices that will also be suitable for the integration of women into the building sector

### ***3.1 Best Practice NZEB Retrofitting Construction Management: Hands-on Manual for Designers and Construction Workers***

To reduce the on-site mismatch and aim at a more synergic workflow between the planning activities and the on-site works, the elaboration of a hands-on manual highlights the main technical basis for the correct execution of the works, explaining different technical solutions using a common language for the successful implementation of retrofitting technology from planning to on-site management.

The *Best Practice Hands-On Manual* outlines general planning strategies for climate-adapted solutions. The manual is geared toward higher-level construction workers and designers in the building sector, including local administrators who are actively involved in the promotion and implementation of the Energy Performance of Buildings Directive (EPBD) goals.

The *Best Practice Hands-On Manual* will contain at least the following three sections.

1. Retrofitting methodology, where the main technical issues are explained by building information modeling (BIMS) for designers with intuitive tools/outputs that will also be understandable for on-site workers, such as a graphical user interface for computer-based virtual 3D modelling;
2. Catalogue of smart NZEB retrofitting solution, including a step-by-step construction guide for smart retrofitting solutions dedicated to the construction workforce;

3. Smart retrofitting packages with construction time scheduling, estimation of degree of invasiveness, average costs and pay-back period of investment;
4. Adaptive teaching portal with dedicated e-Learning section;
5. Management of technical platform: case studies, *Best Practice Hands-On Manual*, catalogue of smart retrofitting solutions;

### **3.2 *Definition of a Climate-Oriented Approach to NZEB Retrofitting of Residential Buildings***

The project focuses on a critical evaluation of the three main climatic contexts for residential NZEB retrofitting, including the more appropriate and innovative and specific technical solutions for the integration of building technologies and systems in existing buildings; the partnership will identify climate-specific approaches regarding a highly energy-efficient retrofitting methodology, including knowledge transfer from already implemented research, assessments and monitored case studies, in order to establish a catalogue of competitive, cost-efficient technical solutions and financial models aimed at a concrete and instant applicability of NZEB retrofitting in residential buildings.

The general indicators for climate-related retrofitting potential in existing residential buildings will be divided into three significant climate areas: north-west (France/UK/Belgium), central-east (Bulgaria/Hungary/Croatia), and south Mediterranean (Italy/Spain/Greece). This evaluation grid defines the profile of climate-specific energy demands for heating, cooling and electricity of the existing European residential sector, based on the aforementioned three climatic areas, including the year of construction (“old” before 1961, “modern” 1961–1991 and “recent” after 1991) and the two building types (single houses/multiple-apartment blocks), which together represent 75 % of the gross building surface in the EU. The research project highlights the climate-related criticalities, the actual mental and economic barriers and behavioural resistances of end users. The project will investigate the actual technical mismatch between designers and builders and elaborate a common approach to the implementation of successful NZEB retrofitting within the three different climate areas (Figs. 2.1 and 2.2).

### **3.3 *Climate-Adapted Smart Retrofitting Solutions***

Considering innovative highly energy-efficient building models, first developed by countries from northern Europe, the Passivhaus Model has earned international recognition and approval, representing today a model with a large number of completed and monitored examples of new buildings and retrofitted existing buildings. Clearly, the Passivhaus Model is not automatically and completely




		CLIMATE ZONE					
YEAR OF CONSTRUCTION	NORTH-WEST		CENTRAL-EAST		SOUTH-MEDITERRANEAN		
	SINGLE	MULTIPLE	SINGLE	MULTIPLE	SINGLE	MULTIPLE	
							
HISTORICAL CONTEXT DIFFICULTIES IN APPLYING EXTERNAL INSULATION							
BEFORE 1945- MAIN CLIMATE RELATED ISSUES	<ul style="list-style-type: none"> <li>- INTERNAL /EXTERNAL INSULATION,</li> <li>-HIGH PERFORMANCE WINDOWS</li> <li>-INSTALLATION OF HVAC, HEAT RECOVERY,</li> <li>-PV AND SOLAR PANEL FOR HOT WATER ON ROOF</li> <li>-MAIN CLIMATE RELATED ISSUES</li> <li>-PASSIVE SOLAR WINTERGARTEN</li> <li>-BOWINDOWS RETROFIT</li> <li>-GREENHOUSE</li> <li>-PASSIVE SOLAR HEATING</li> </ul>		<ul style="list-style-type: none"> <li>- INTERNAL /EXTERNAL INSULATION,</li> <li>-HIGH PERFORMANCE WINDOWS</li> <li>-INSTALLATION OF HVAC, HEAT RECOVERY,</li> <li>-PASSIVE SOLAR WINTERGARTEN</li> <li>-BOWINDOWS RETROFIT</li> <li>-LOW THERMAL MASS</li> </ul>		<ul style="list-style-type: none"> <li>- INTERNAL INSULATION</li> <li>- INTERNAL / EXTERNAL SHADING DEVICES</li> <li>- VENTILATED ROOFS</li> <li>- DOUBLE GLAZING</li> <li>- PASSIVE COOLING</li> </ul>		
			<ul style="list-style-type: none"> <li>- CENTRAL HVAC, HEAT RECOVERY,</li> <li>- PV AND SOLAR PANEL FOR HOT WATER ON ROOF</li> </ul>		<ul style="list-style-type: none"> <li>- CENTRAL HEATING</li> <li>- PV AND SOLAR PANEL FOR HOT WATER ON ROOF</li> </ul>		<ul style="list-style-type: none"> <li>- CENTRAL HEATING</li> <li>- PV AND SOLAR PANEL FOR HOT WATER ON ROOF</li> </ul>
1945-1980	<ul style="list-style-type: none"> <li>- INTERNAL /EXTERNAL INSULATION</li> <li>- INNOVATIVE SOLUTIONS WITH PCM</li> <li>-HIGH PERFORMANCE WINDOWS</li> <li>-INSTALLATION OF HVAC, HEAT RECOVERY,</li> <li>-PV AND SOLAR PANEL FOR HOT WATER ON ROOF</li> <li>-MAIN CLIMATE RELATED ISSUES</li> <li>-PASSIVE SOLAR WINTERGARTEN</li> <li>-BOWINDOWS RETROFIT</li> <li>- THERMAL BRIDGES</li> <li>-GREENHOUSE</li> <li>-PASSIVE SOLAR HEATING</li> <li>-PV AND SOLAR PANEL FOR HOT WATER ON ROOF</li> </ul>		<ul style="list-style-type: none"> <li>- INTERNAL /EXTERNAL INSULATION</li> <li>- INNOVATIVE SOLUTIONS WITH PCM</li> <li>-HIGH PERFORMANCE WINDOWS</li> <li>-INSTALLATION OF HVAC, HEAT RECOVERY,</li> <li>-PV AND SOLAR PANEL FOR HOT WATER ON ROOF</li> <li>-MAIN CLIMATE RELATED ISSUES</li> <li>-PASSIVE SOLAR WINTERGARTEN</li> <li>-BOWINDOWS RETROFIT</li> <li>- THERMAL BRIDGES</li> <li>-GREENHOUSE</li> <li>-PV AND SOLAR PANEL FOR HOT WATER ON ROOF</li> </ul>		<ul style="list-style-type: none"> <li>- INCREASE THERMAL MASS FOR SUMMER COMFORT</li> <li>- INCREASE AIR EXCHANGES</li> <li>- NIGHT VENTILATION</li> <li>-HIGH PERFORMANCE WINDOWS</li> <li>-PV AND SOLAR PANEL FOR HOT WATER ON ROOF</li> </ul>		
		-AUTOMATION		-AUTOMATION		-AUTOMATION	
AFTER 1980	<ul style="list-style-type: none"> <li>- INTERNAL /EXTERNAL INSULATION</li> <li>- INNOVATIVE SOLUTIONS WITH PCM</li> <li>-HIGH PERFORMANCE WINDOWS</li> <li>-INSTALLATION OF HVAC, HEAT</li> </ul>		<ul style="list-style-type: none"> <li>- INTERNAL /EXTERNAL INSULATION</li> <li>- INNOVATIVE SOLUTIONS WITH PCM</li> <li>-HIGH PERFORMANCE WINDOWS</li> </ul>		<ul style="list-style-type: none"> <li>- INCREASE THERMAL MASS FOR SUMMER COMFORT</li> <li>- INCREASE AIR EXCHANGES</li> <li>- NIGHT VENTILATION</li> <li>-HIGH PERFORMANCE WINDOWS</li> <li>- LOW THERMAL MASS FOR</li> </ul>		

Fig. 2.1 Table of climate contextualization of existing EU residential building stock divided into three climate areas and three historical construction periods for both single houses and multiple-apartment blocks



**Fig. 2.2** Environmental building, Netherlands

transferrable to other climate areas without specific adaptation. Taking into account the previously mentioned assessment efforts and considering the significant case studies, we will focus on the knowledge transfer of residential Passivhaus experiences to residential NZEB retrofitting in different climatic areas. Climate-adapted retrofitting solutions are based on smart retrofitting solutions; the articulation of knowledge transfer is based on three main factors:

- Upgrading of building envelope performance;
- Integrated HVAC technology fostering a high percentage of renewable energy use (building integrated energy production through PV and solar hot water provision and advanced building envelope performances are becoming necessary in order to match NZEB standards;)
- Integration of passive technology (e.g., passive cooling, cool roofs and natural lighting systems)

#### A. Retrofitting Building Envelopes

- Highly energy-efficient building envelopes, dry technological packages for thermal insulation with PCM phase-change materials;
- Combining the outer shells of energy-efficient buildings with state-of-the art, building-integrated, energy-generating technology, architectural photovoltaic integration and solar panels for hot water;
- Highly energy-efficient windows and doors with high wind and airtightness guaranteed by high-performance fixing and taping systems, representing crucial problematical aspects in NZEB building;
- Dry-building and partial prefab technologies for indoor insulation, including an emphasis on taping and airtightness;
- Ventilated *façade* systems especially for hot climates;
- Green roofs and *façades*.



**Fig. 2.3** Funen Blok, Amsterdam, NL Architecten

#### B. Innovative, integrated HVAC systems for NZEB retrofitting

- Integrated renewable energy applications for buildings: solar energy and geothermal heat pumps for synergic integration of technology and building design, on the other;
- Geothermic heat pumps for innovative energy efficiency;
- HVAC calibrated specifically to the Mediterranean;
- Climate conditions (visiting building sites where this technology is applied, distributor of renewable energy technology, where possible) (Figs. 2.3, 2.4, and 2.5).

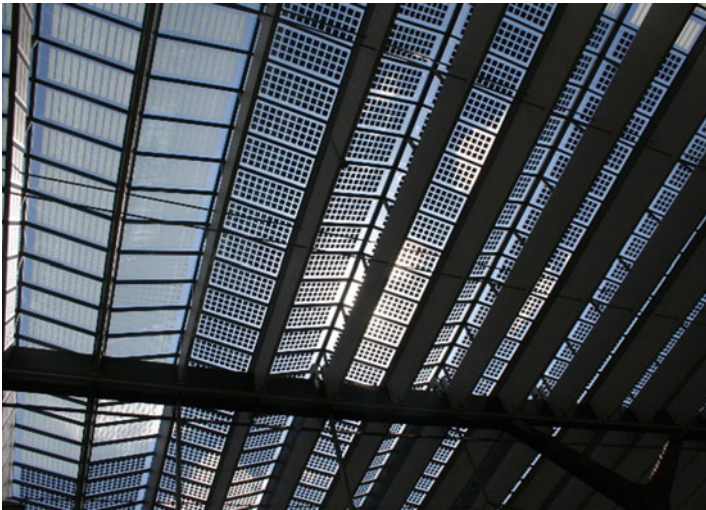
#### C. Integration of passive technologies

- The use of passive technologies and bioclimatic principles, integrated HVAC systems and heat recovery to guarantee, in addition to low energy demand, also good comfort in winter and summer, following specific end user needs in each climate area.
- Innovative passive cooling technology, combined with mechanical ventilation systems and air-to-air heat exchangers in retrofit (existing walls) and new building contexts (visit of building site where this technology is applied, where possible, thermodynamic simulation of passive cooling technology with dedicated software, demonstration by expert);





**Fig. 2.4** Bardini Museum refurbishment (EULEB)



**Fig. 2.5** Rotterdam central railway station

- Innovative highly energy-efficient heating systems suitable for retrofitting (radiant floor or ceiling based on low-temperature systems capable of ensuring heating *and* cooling, guaranteeing high indoor comfort levels);
- Use of innovative internal elements using PCM, especially for cooling in hot climates;
- Integration of sun shading systems to avoid overheating of opaque and transparent building envelopes;
- Management and control with automation systems. Systems for plant energy control cover all subsystems related to energy regulation, responding to the



**Fig. 2.6** PV integration in Amersfoort, Newland, Netherlands. Photovoltaic roof integration, Foster & Partners



**Fig. 2.7** Solar decathlon winner, 2015, Rubner [RhOME](#)

effective ambient temperature required by the occupants in single zones. In retrofitting actions, the adoption of a building automation and control system (BACS) or a home and building electronic system (HBES) is strongly recommended. These systems can be installed in housing with four different performance class levels, in relation to the energy efficiency their adoption ensures adoption (Figs. 2.6 and 2.7):

- Level 0 (no energy efficiency): this level is related to the traditional heating-and-cooling plant, without automation;
- Level I (standard): this level corresponds to standard automatic systems (i.e., one thermostatic control system that regulates the on-off of the central heat, as a function of the temperature inside the zone);

- Level II (advanced): this is related to controller plant systems with a bus automatic control (BACS/HBES) and with a centralized management of single plant systems (TBM);
- Level III (high energy performance): an advanced precision level of automatic control that can guarantee high energy performance for plant systems.

### 3.4 Environmental Impact

- A life-cycle assessment is made for the use of sustainable materials: renewable materials and low-carbon-footprint materials and technologies (e.g., structural material, plaster, moisture brakes, ventilated roof).

Based on these main themes, the project elaborates a catalogue of appropriate climatic technical solutions which will investigate highly energy-efficient retrofitting from so-called deep renovations (60–90 % less consumption), such as Passivhaus standards with respect to NZEB thresholds (over 90 % less consumption).

Renovating is an ideal time to make your house healthier for you, the community and the environment. When upgrading your mechanical systems to increase their efficiency, be sure to consider the following aspects (Figs. 2.8, 2.9, and 2.10):

- Occupant health – venting strategy for combustion appliances, adequate ventilation for occupants, addition of air filtration;



Fig. 2.8 Virtual environments and ICT Centre, Marco Sala Associati

**Fig. 2.9** Virtual Environments and ICT Centre, Lucca



- Energy efficiency – energy-efficient appliances, high-efficiency motors for fans and furnaces;
- Resource efficiency – upgraded insulation and draft proofing to reduce heating needs and allow installation of a smaller heating system;
- Environmental responsibility – energy-efficient appliances to reduce a home’s environmental impact;
- Affordability – energy-efficient fixtures to reduce ongoing operating costs.

## 4 Results

The climate-adapted residential NZEB retrofitting project expects to support innovation and sustainable energy use in building renovation, reducing technical mismatch and increasing the management skills of building designers (engineers/architects) and on-site construction workers. The project will use an integrated training model for NZEB renovation of existing residential buildings, aiming to develop a common language as a starting point for a more efficient on-site implementation of NZEB thresholds in retrofitting. The implementation of climate-oriented retrofitting using advanced bioclimatic technology and applying renewable energy management and the implementation of so-called smart and green supply chains, based on innovative materials (and taking into account LCA evaluation of the building process as a whole), will effectively open up new market opportunities. Moreover, the implementation of innovative technologies should launch a new practice of non-invasive retrofitting (where inhabitants would be able to stay while work is going on) and less expensive retrofitting solutions oriented toward specific climate contexts. The involvement of financial institutions could increase investments in innovative sustainable energy technologies.

## 5 Conclusions

The climate-adapted smart retrofitting solutions promoted within the project discussed in this chapter aim at a high level of economic competitiveness through the use of innovative and cost-effective dry technology. Moreover, the number of trained workers will make it possible to calculate the potential annual energy savings in the construction sector as well as the annual production of renewable energy, representing impacts derived from training activities (starting in 2015).

Potential NZEB energy consumption is calculated in each residential building category: energy savings over the course of the project's lifetime of 50 GWh/year and renewable energy production over the project's lifetime of 4 GWh/year.

In particular, the developed tool makes it possible to calculate the realistic impacts from two types of trainees for the renovation of residential buildings:

- Designers
- On-site workers of construction companies subdivided into three different types of professional (builders, thermo-hydraulic technicians, and electrical technicians)

## 6 Future Implementation

Climate-adapted residential NZEB retrofitting projects will ensure a positive long-term impact on the European construction sector focusing on the added value of *integrated training* in order to fill the gap between planning and on-site construction management, promoting competitive, climate-adapted NZEB retrofitting technology.

Of particular importance will be the development of a strategy for using and rolling out projects and supporting innovation in the construction sector with dedicated training programs beyond project lifetimes; also important will be the stimulation of other stakeholders to trigger top-level training courses based on the climate-adapted residential NZEB retrofitting training model (using the *Best Practices Hands-On Manual* and the guidelines developed by the project).

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