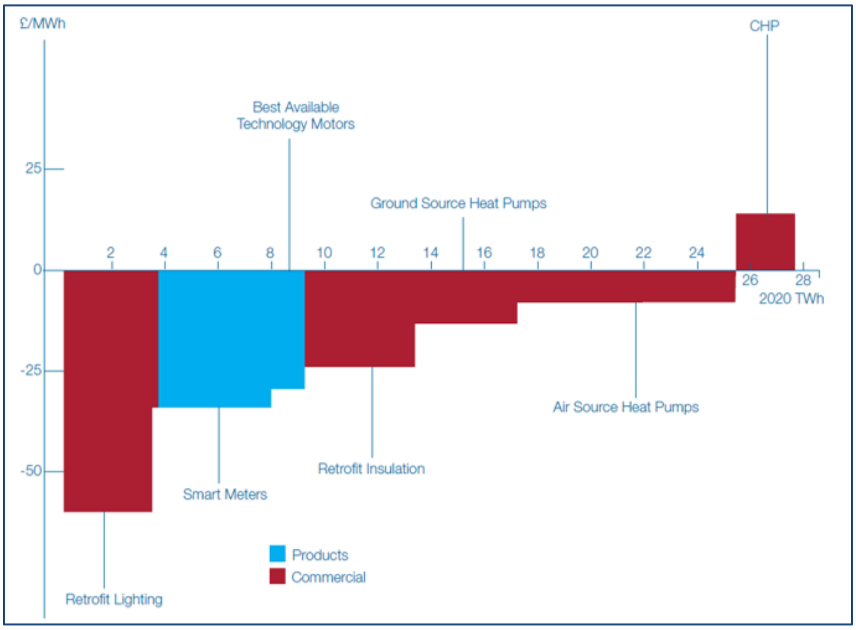
EXECUTIVE SUMMARY:

Best practices and lists of technologies to refurbish buildings & Proposed packages of measures



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Project consortium

BME	WP3 Leader
BRE	WP6 Leader
BSERC	WP2 Leader
CRES	Partner
CTI	WP1-WP7 Leader Coordination
EIHP	Partner
URBAN-INCERC	Partner
IREC	Partner
LNEG	WP5 Leader
MACEF	Partner
POLITO	WP 4 Leader
ZRMK	Partner

Project overview

The RePublic_ZEB project is focused on the energy and CO_2 emissions associated with existing public buildings and their refurbishment towards nZEB.

The **core objective** of the project is to:

- Define costs-benefit optimized "packages of measures" based on efficient and quality-guaranteed technologies for the refurbishment of the public building stock towards nZEB that are standardized and adopted by builders and building owners.

From this stems three **basic objectives:**

(i) State-of-the-art assessment of the public building stock through a country-specific evaluation of the energy consumption and CO_2 emissions;

(ii) Define reference buildings; and;

(iii) Develop a common framework and a harmonized methodology for the definition of a nZEB concept for public buildings.

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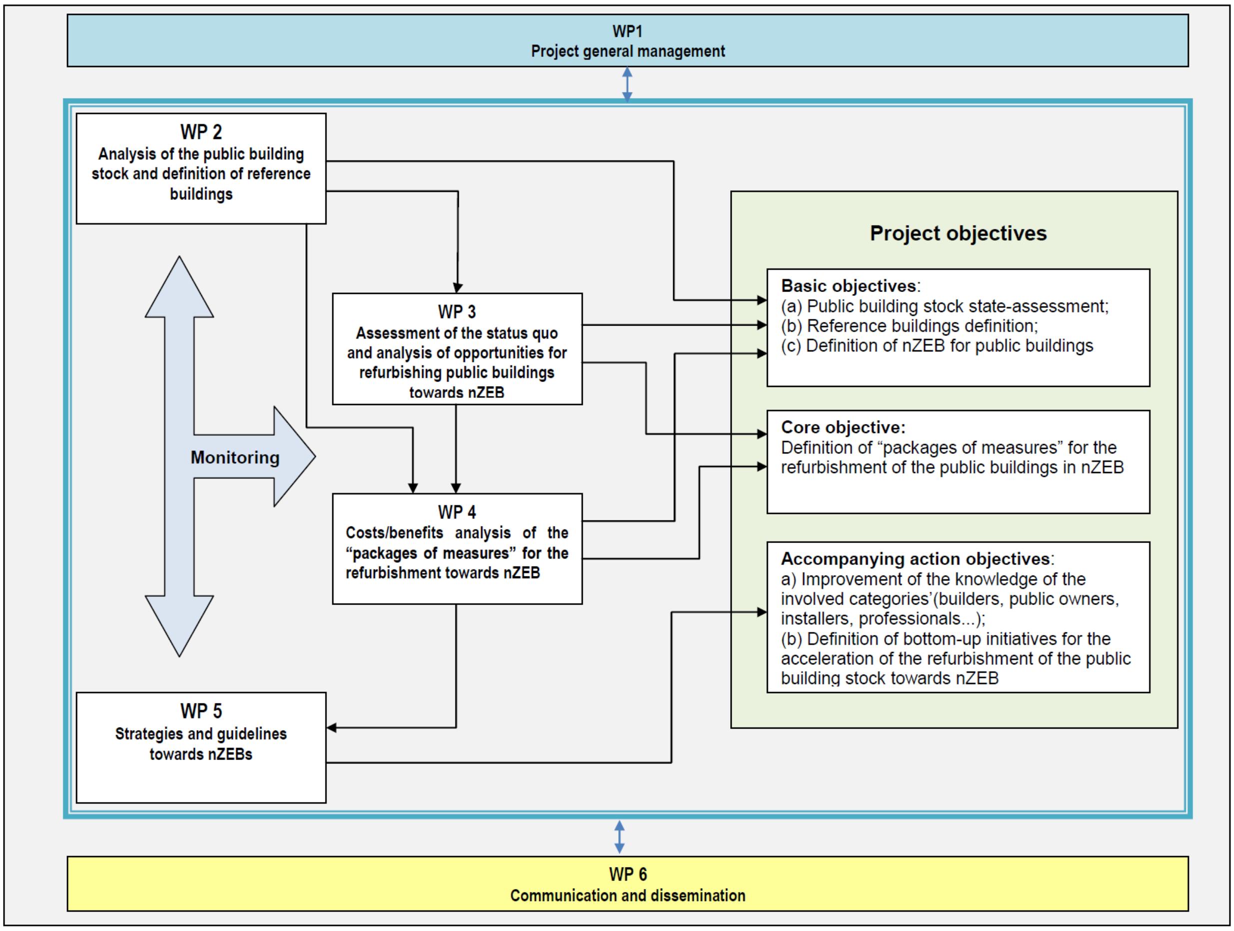
Executive Summary

This document is one of a series of executive summary of the core deliverables of the RePublic_ZEB project. This is a summary of the third and fourth deliverables (combined) in Work Package (WP) 3. The flow chart below shows its context in the overall project.



1. Objective

The objectives of this report are to:

- review refurbishment best practice in the RePublic_ZEB target countries, and,
- detail the packages of energy efficiency measures that can deliver deep refurbishment of public buildings.

2. Best practice

Best practice in refurbishment of public buildings is described for each of the target countries. In earlier work, reference public buildings in key sectors (office, health, education etc.) had been identified in each country. The report reviews the combinations of currently applied technologies for each building in each country. It highlights changes in: U-values of the building envelope (roof, walls etc.), system efficiencies, plant performance factors etc., and summarises primary energy savings and reductions in CO_2 emission attributable to refurbishment to best practice levels where this information is available.

Table 1 below gives an example of the compiled information:

	Value type	Unit	Before refurbishment	After refurbishment
Facade wall	U_{wall}	W/m²K	**0.80-0.92**	**0.28-0.33**
Windows and doors	U_w	W/m²K	**3.10**	**1.3; 1.50**
Specific heat loss coefficient of the building	q	W/m³K	**0.160**	**0.094**
Heating capacity	-	kW	**507**	**458**
Thermal solar system	-	m²	**-**	**44**
Primary energy consumption	E_p	kWh/m²a	**126.3**	**104.0**
CO_2 emission	-	t/year	**211.1**	**173.6**
Classification of energy performance	-	-	**D (nearly requirement)**	**B (better than requirement)**

Table 1. Summary of best practice refurbishment of a Hungarian office building

3. Technology descriptions

The report gives a general description of a wide range of energy efficiency technologies suitable for deep refurbishment of public buildings. The technologies described are listed in Table 2 below.

Building components	Thermal insulation of building structures	
	Window thermal insulation (window replacement)	
	Window solar control	
	Passive solar systems	
HVAC and DHW systems	Emission retrofit	Radiant heating & cooling systems
		Passive & active chilled beam
	Control retrofit	
	Distribution and storage sub-system retrofit	
	Heating/cooling generator retrofit	Condensing boiler
		Biomass boiler
		District heating/cooling
		Air source, groundwater & geothermal heat pumps
		Variable Refrigerant Flow (VRF)
		Absorption chiller
	Thermal solar energy	
	Energy efficient air handling	
	Free cooling	
Building management system (BMS)		
Lighting and power generation	Photovoltaic (PV) system	
	Illuminator changing	
	Lighting control	

Table 2. Refurbishment technologies considered

In addition to the general description, the advantages and disadvantages of the technologies are highlighted.

4. Analysis of technologies

It is evident that the energy efficiency measures have national characteristics and that the performance level of the technologies can be different in the target countries. Therefore, detailed national sections were completed so as to build lists of technologies suitable for the refurbishment of public buildings in each country. A series of tables were developed that summarised technology performance figures and specific costs for different refurbishment levels.

For each refurbishment level, different thicknesses of thermal insulation (giving different U-values) were proposed for the refurbishment of external building components (wall, roof, attic floor, etc.). In the case of windows and doors, different types (e.g. double, triple glazed) were proposed with their respective U-values. Solar shading systems are proposed for those buildings where it is necessary to reduce solar gains.

The proposed refurbishment of heating and cooling systems to different levels includes the modernization of the generation system (e.g. with a condensing boiler, geothermal heat pump, air source heat pump, VRF system, etc.), the emission system (radiator, fan-coil, radiant heating/cooling, VRF, etc.) and the control system (room thermostat, weather-dependent control, etc.). The energy efficiency measures considered includes the DHW system, i.e. thermal insulation of pipework and balancing the circulation system.

Many of the reference buildings have natural ventilation, therefore infiltration heat loss could be significant. For several public building types it was proposed to install a new mechanical ventilation system, including ductwork and an air handling unit with high heat recovery efficiency (min. 70%). The heat recovery decreases the heating energy consumption as well as the peak load of the heating system.

Refurbishment of lighting systems was also considered, which includes replacing the illuminators by T5 fluorescent lamps and/or LED, and installing a control system, such as occupancy and daylight control.

PV system and thermal solar energy utilisation were also proposed in many target countries. The suggested power of the PV system depends on the annual electricity consumption of the building, the geometric parameters of the roof and the national regulations in force. With regard to thermal solar energy, flat-plate or vacuum tube solar collectors were proposed.

In an nZEB building the performance of HVAC installations should be monitored, therefore the installation of a BMS is proposed in many cases, which increases energy savings, as energy consumption is continually monitored and means that set-points, schedules, etc. can be optimized.

The investment cost (for building envelope, lighting, PV, thermal solar energy) corresponds to average market conditions in each country and includes material and labour costs. The cost to refurbish an HVAC system depends on the reference building's characteristics, therefore the sizing of HVAC elements (e.g. boiler, heat pump, air handling unit, etc.) will be completed in the detailed energy calculations to be undertaken later in the project. As a consequence, investment costs for HVAC system refurbishment will be provided at the next stage.

By way of an example, Tables 3a and 3b give building envelope and heating system technologies in Slovenia:

1. Building envelope	Before refurbishment		Refurbishment Level 1		
	Technical data	U-value [W/m^{2}K]	Technical data	U-value [W/m^{2}K]	Specific cost [EUR/m^2]
1.1 External wall	Very little insulation	0,8	12 cm min. wool	0,28	36
1.2 Internal wall (unheated space)		1,0	8 cm EPS	0,30	6,8
1.3 Flat roof	Very little insulation	0,6	16 cm min. wool	0,20	44
1.4 Ground		1,0	6 cm XPS	0,30	12,6
1.5 Window - glass		2,4	Double glass	1,4	38
1.6 Window - frame		2,0	Aluminium frame	1,3	210
1.7 Doors		3,0	Wood/Alu	1,1	350

Table 3a. Building envelope refurbishment technologies in Slovenia

3. Heating system	Before refurbishment	Refurbishment Level 1	Refurbishment Level 2
	Technical data	Technical data	Technical data
3.1 Thermal energy generation	Permanent temperature gas boiler	Condensing boiler	Biomass boiler
3.2 Emission system	Steel panel radiator	Existing radiator and pipework	Existing radiator and pipework
3.3 Control	Central, weather-dependent control, manual radiator valves	Weather-dependent control, thermostatic radiator valves	Room thermostat

Table 3b. Heating system refurbishment technologies in Slovenia

5. Packages of measures

Packages of measures were proposed for each reference building in each country as shown in the example in Table 4:

	Package 1	**Package 2**	**Package 3**	**Package 4**	**Package 5**
1. Building envelope	Level 1	Level 1	Level 1	Level 1	Level 2
3. Heating system	Level 1	Level 1	Level 2	Level 2	Level 2
6. Ventilation system	Existing condition	Level 1	Level 1	Level 1	Level 1
7. Lighting system	Level 1	Level 1	Level 1	Level 2	Level 2
8. Photovoltaic system	Existing condition	Level 1	Level 1	Level 2	Level 2

Table 4. Summary of packages of measures for educational buildings in Romania

In addition, the report contains an extensive appendix where, for each country, the technologies are categorised on the basis of:

1. The national reference public building types where the technology can be applied,
2. The typical energy saving attributable to the technology,
3. The likely return on investment (ROI).

The technologies were listed in tables and categorised as follows:

Building type		Typical energy saving		Return on investment	
O	Office	A	>30%	A	<2 years
R	Residential	B	20-30%	B	2-5 years
E	Educational building	C	10-20%	C	5-10 years
H	Health care facility	D	<10%	D	>10 years
HR	Hotels and restaurants				
WR	Wholesale and retail				