Interreg - IPA CBC
Italy - Albania - Montenegro
REEHUB PLUS

Date: Friday **10th of December 2021**

Time range: **09^{00}-16^{55}**

REEHUB PLUS / 1ST CROSS BORDER EVENT

"SMART CITY OPEN INNOVATION FORUM"

ORGANIZED BY: **BARLETI INSTITUTE FOR RESEARCH AND DEVELOPMENT**

SUPPORTED BY: BRIDGE, UNIVERSITETI BARLETI

Speaker:

Sandra Monteiro da Silva

Ass. Prof. at the Civil Engineering

Department of the University of Minho

Title

Energy Renovation of Buildings

Environmental and cost life cycle analysis.

REPUBLIKA E SHQIPËRISË
MINISTRIA E INFRASTRUKTURËS DHE ENERGJISË

DiTNE

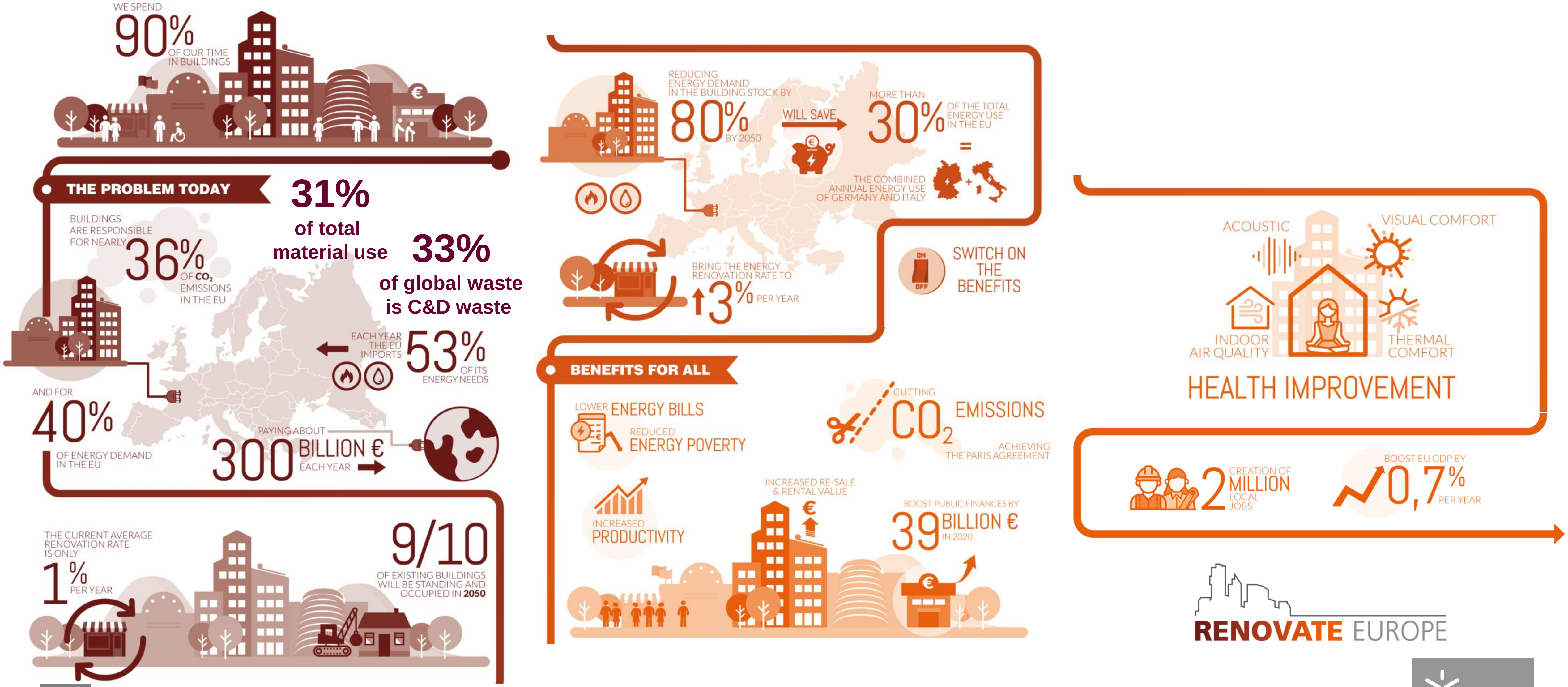
UCG Univerzitet Crne Gore

CITTÀ DI AGNONE

The Importance of the Construction Sector - EU Building Stock Facts

31% of total material use

33% of global waste is C&D waste



RENOVATE EUROPE

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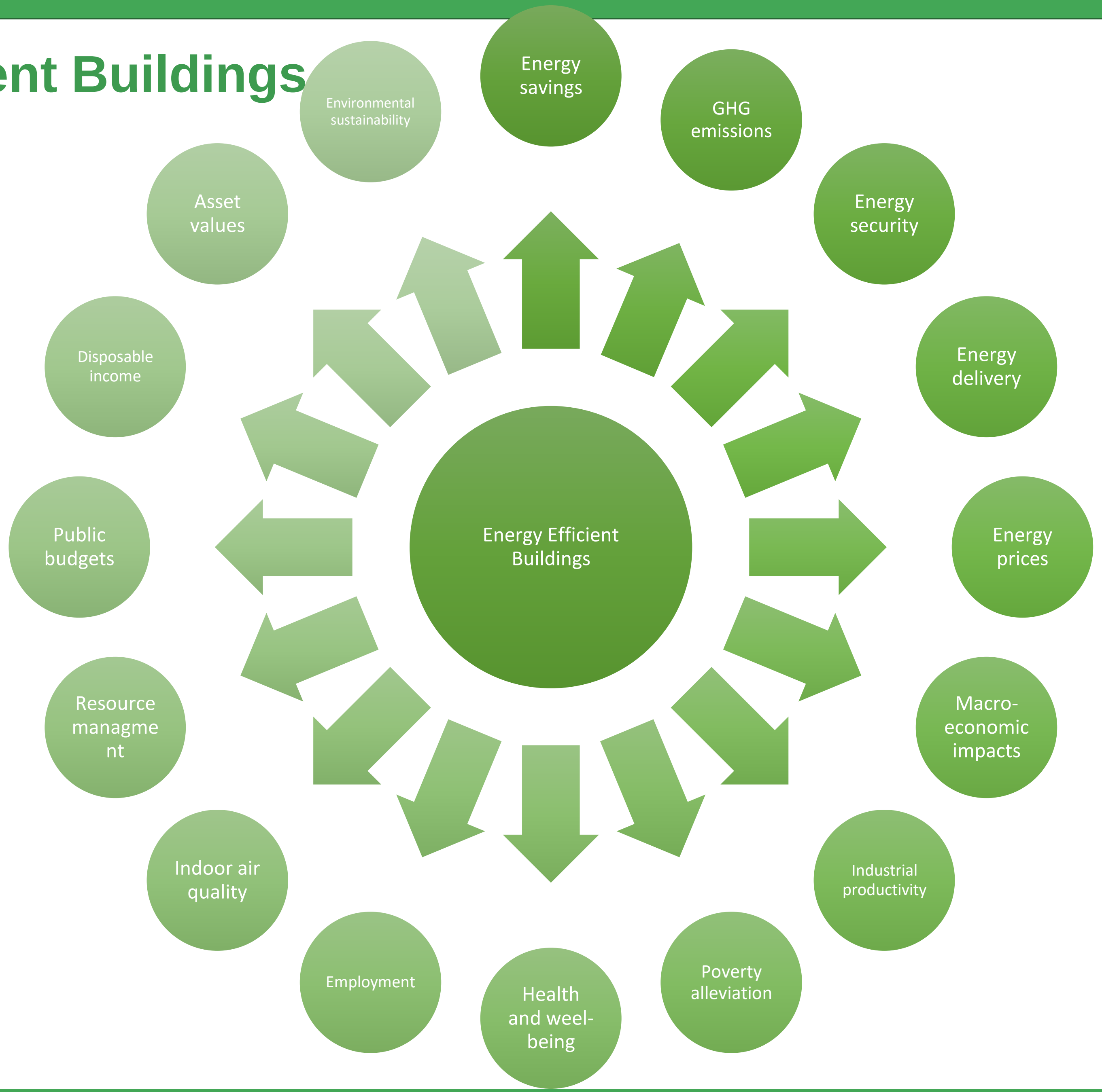
Advantages of Energy Efficient Buildings



Advantages of Energy Efficient Buildings

Added value for the renovated building

Direct benefits (energy use reduction, CO_2 emissions reduction, life cycle cost reduction …)

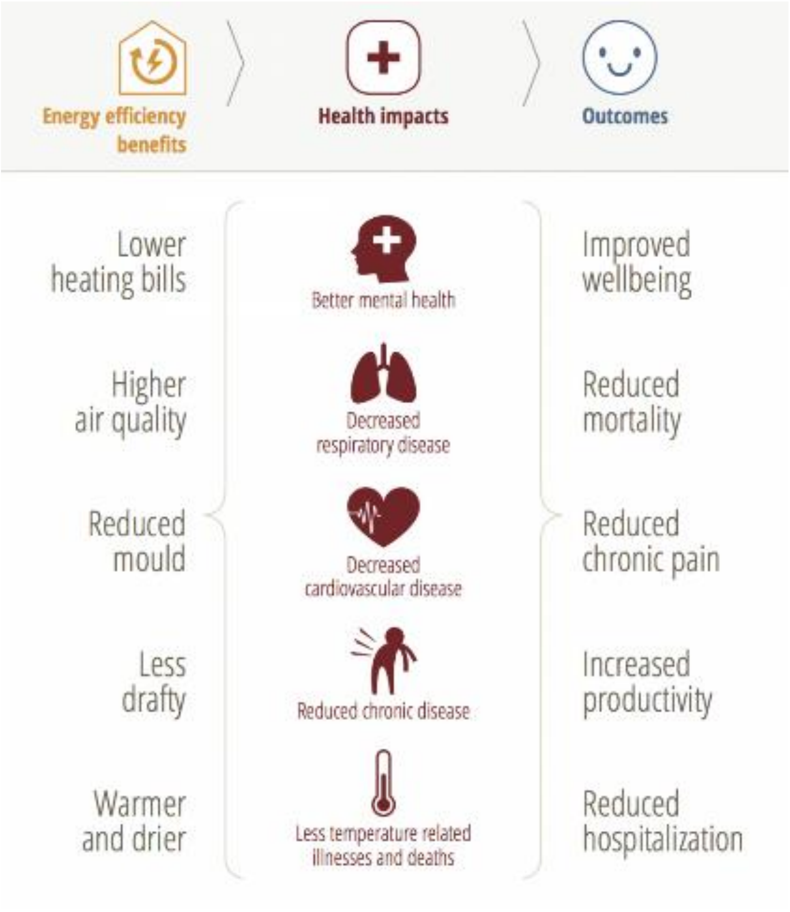
Co-benefits (improve overall quality of the building; improving IEQ and users health and well-being; economic benefits, tackles energy poverty of families)

Macro-economic benefits and co-benefits

Direct benefits (Reduce energy imports …)

Co-benefits (improved health, less money spent on health, medicines …)

Money spent in other things → Stimulating economy



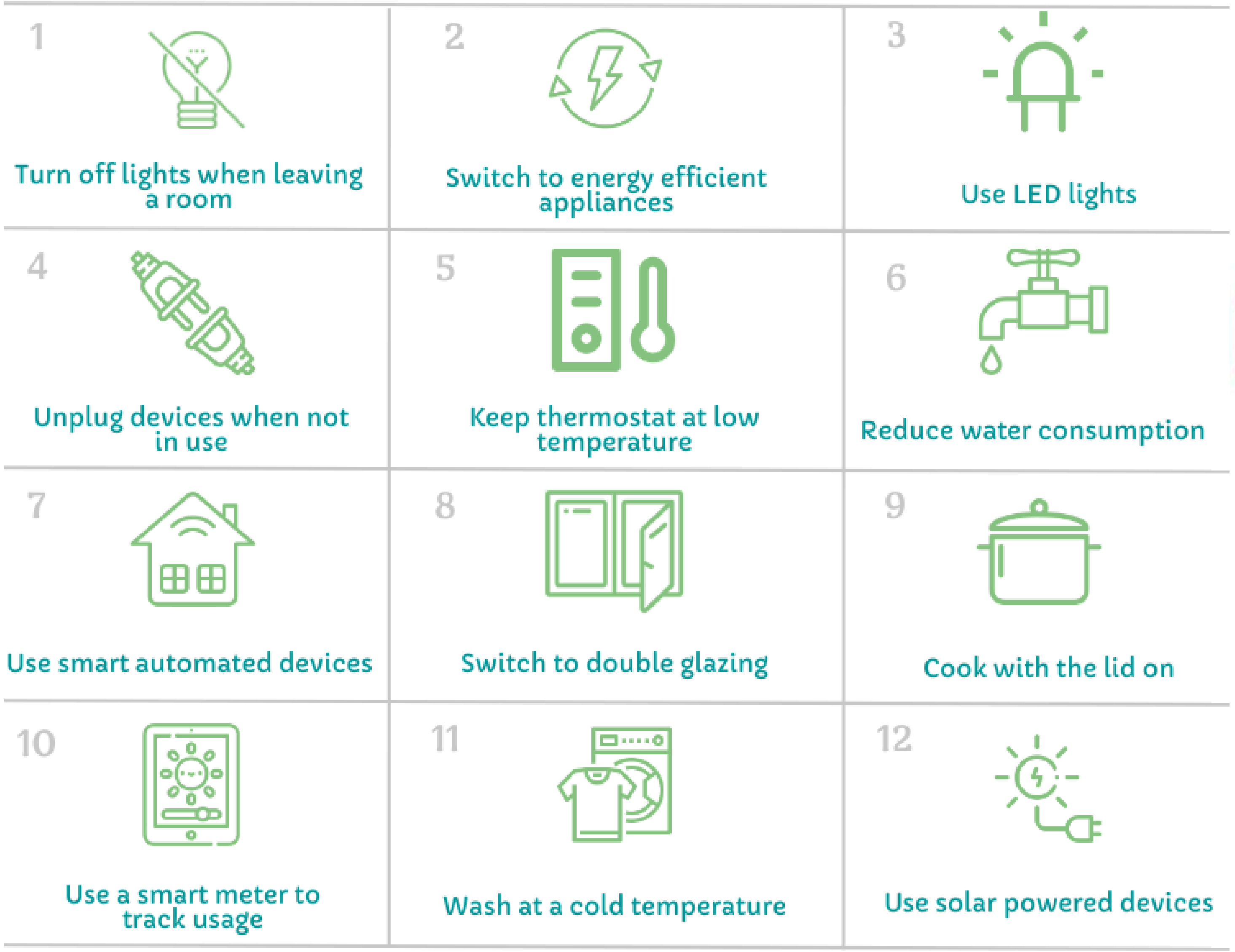
Advantages of Energy Efficient Buildings

Smart Cities / Smart Buildings / Smart Owners

Energy in City	Energy Network	Buildings	Supply Tech	Transport
City Energy Flows	Smart Grids	nZEB ZEB PEB	Integration of RES in Buildings and Grids	Electric Mobility
Urban Morphology	Shift Between Thermal and Electric Loads	Integration Between Building and Grid	Hybrid Supply Systems	Public Transportation
…	…	…	…	Cycling Walking

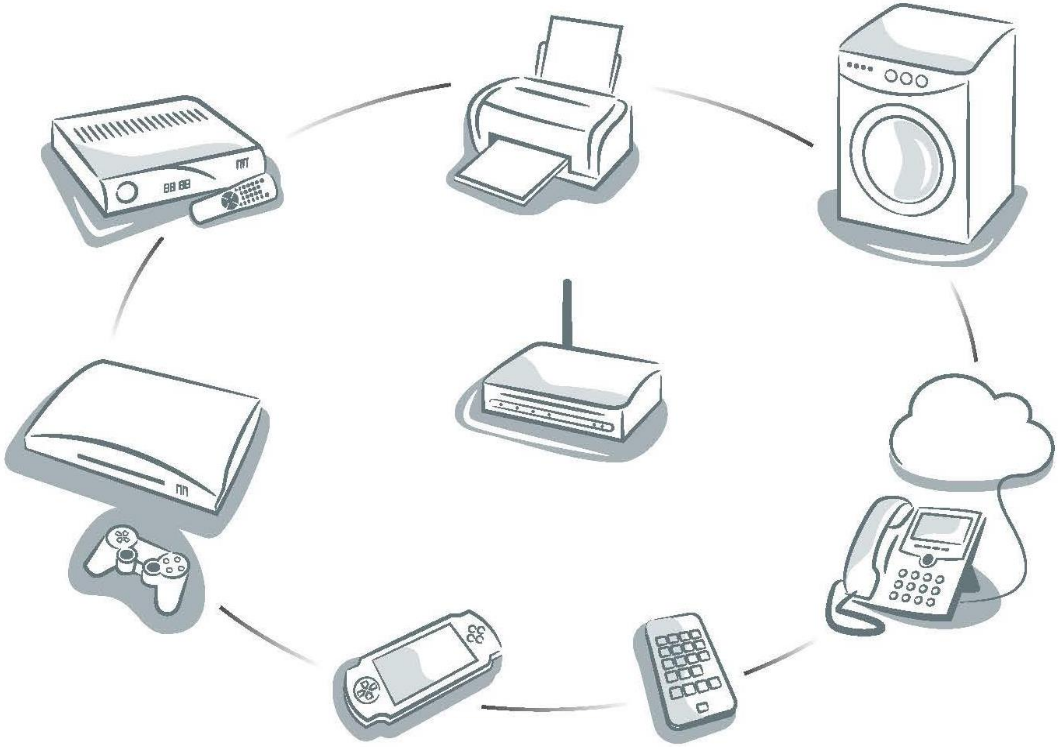
Energy Efficient Buildings

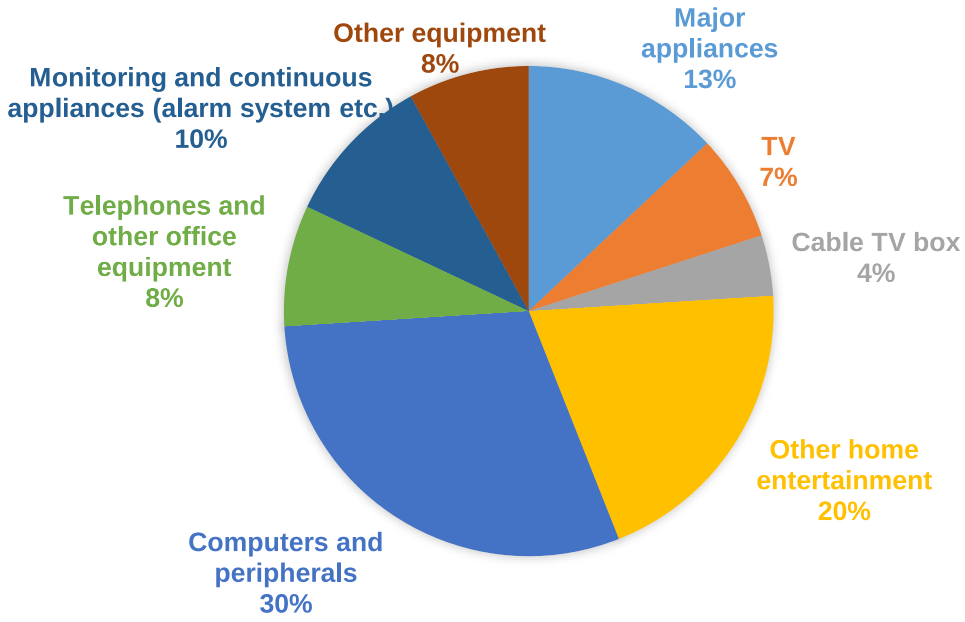
1st
Reduce energy consumption (efficient lighting systems and appliances)

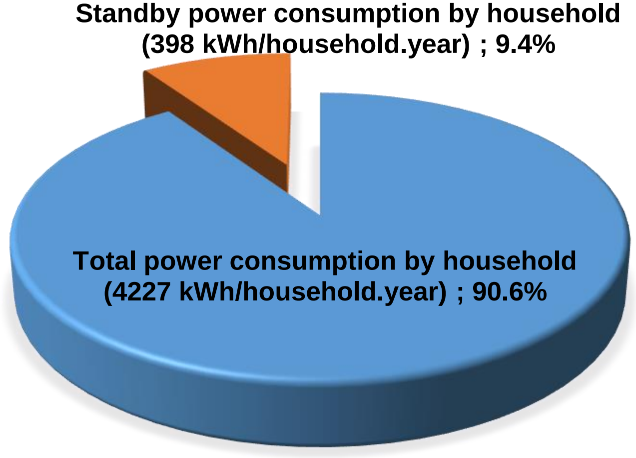


Energy Efficient Buildings

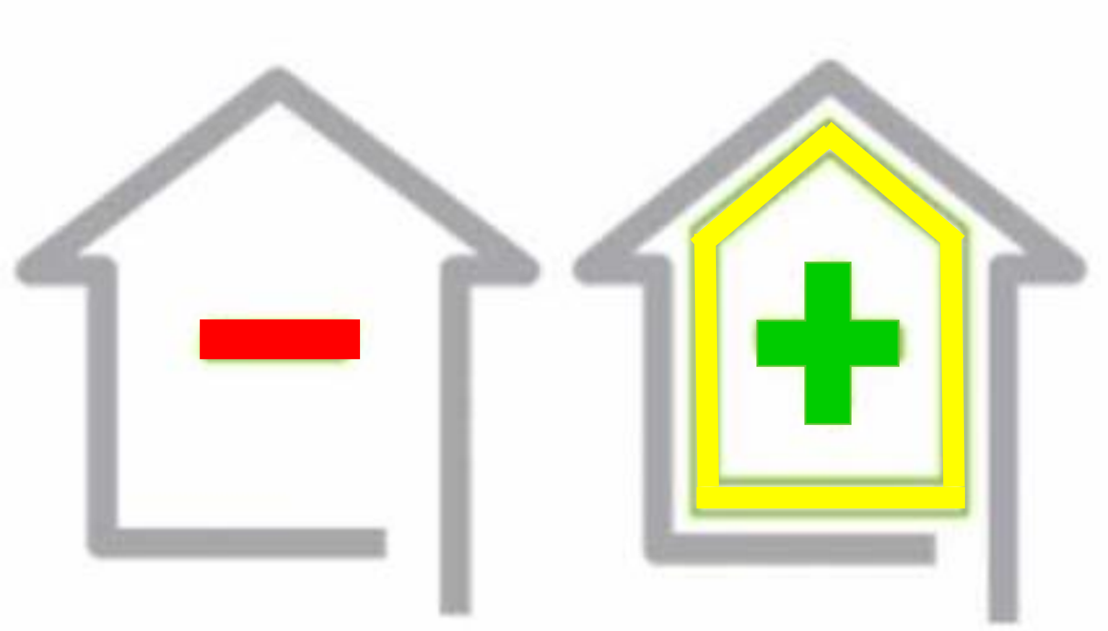
Standby Energy Consumption





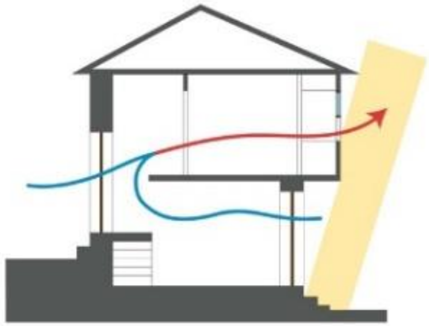


Energy Efficient Buildings



1st
Reduce energy consumption (efficient lighting systems and appliances)

2nd
Improve energy performance (passive measures → insulation, shading …)



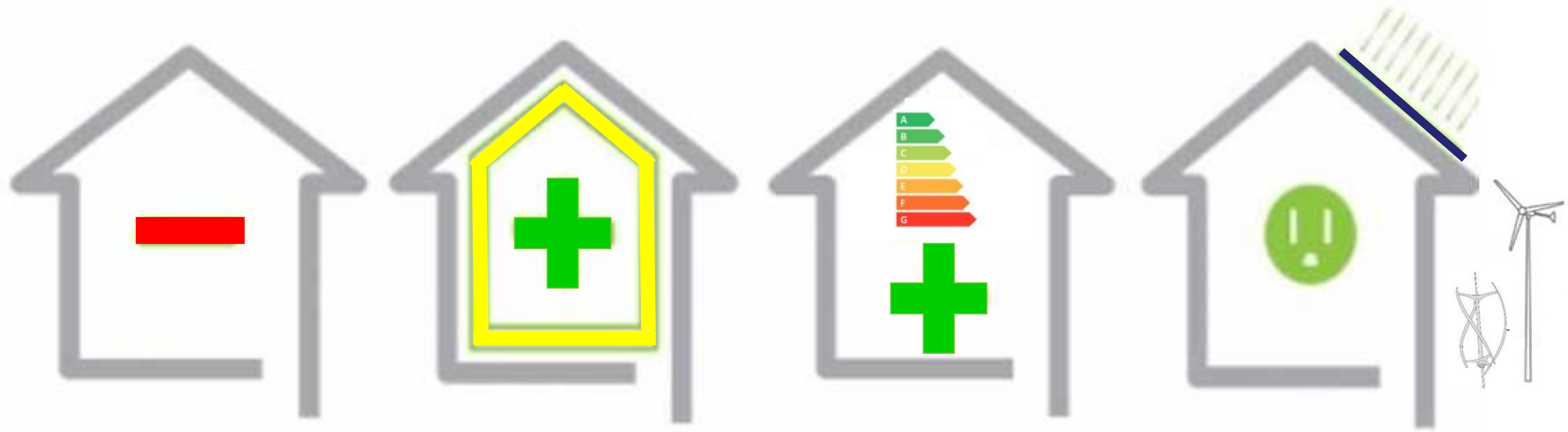
Energy Efficient Buildings

1st
Reduce energy consumption (efficient lighting systems and appliances)

2nd
Improve energy performance (passive measures → insulation, shading …)

3rd
Select energy efficient and appropriately designed systems

Energy Efficient Buildings



1st
Reduce energy consumption (efficient lighting systems and appliances)

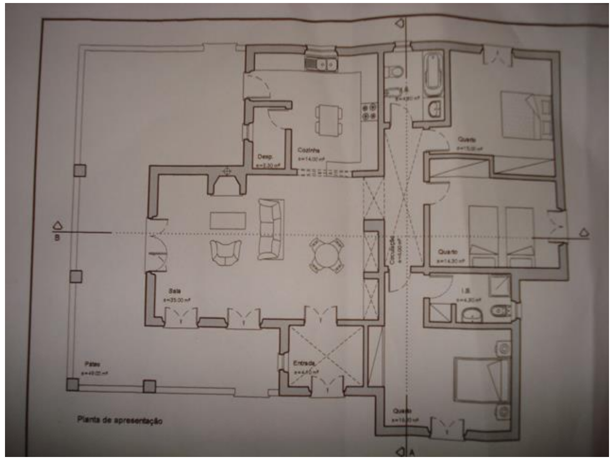
2nd
Improve energy performance (passive measures → insulation, shading …)

3rd
Select energy efficient and appropriately designed systems

4th
Onsite energy production

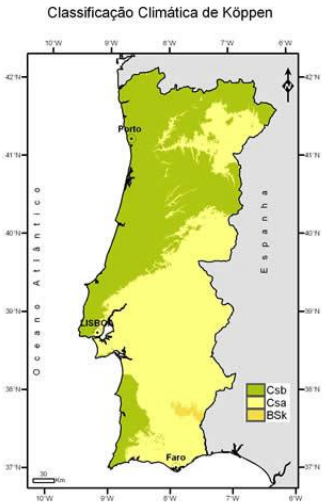
Case Study

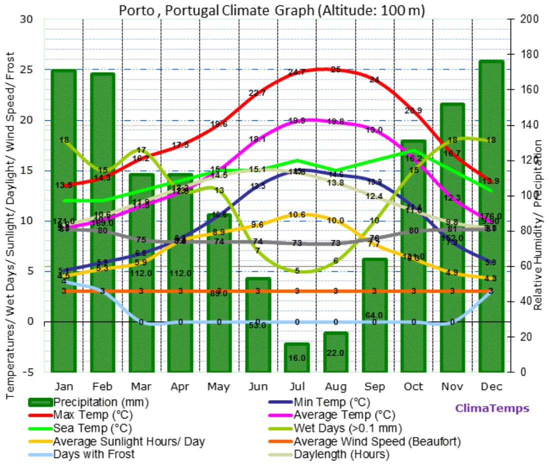
Characteristics of the building

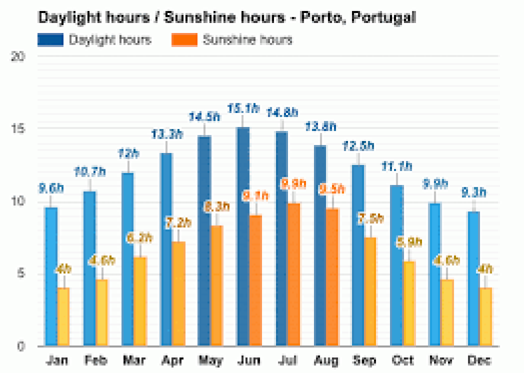


Net area: 100 m^2; Windows area: 15 m^2; 3 bedrooms

Virtual residential building (typical from 1961 – 1990)
Representing 44.5% of the buildings built until 2011







Porto Climate data

Case Study

Properties of the building before and after each of the renovation scenarios

Properties of building	Before renovation (Maintenance)	Basic renovation (minimum legal requirements)	Cost-optimal renovation	Zero Energy renovation
Thermal transmittance, $W/(m^2 \cdot K)$				
U_{wall}	1.76	0.47	0.47	0.47
U_{roof}	2.80	0.35	0.35	0.35
U_{floor}	2.10	0.39	0.39	0.39
$U_{window\ (glass/\ frame)}$	4.10	2.70	2.70	2.70
U_{door}	2.31	0.49	0.49	0.49
Linear thermal transmittance, $W/(m \cdot K)$				
$\psi_{wall/wall}$	0.50	0.40	0.40	0.40
$\psi_{roof/wall}$	0.70	0.70	0.70	0.70
$\psi_{floor/wall}$	0.70	0.50	0.50	0.50
$\psi_{window/wall}$	0.25	0.10	0.10	0.10
Internal heat gains (heat from inhabitants, appliances, equipment, and lighting)	4.0 W/m^2			
Ventilation (air change rate)	0.94 ach	0.86 ach	0.86 ach	0.86 ach
Heating system type and efficiency	Radiator (1.0)	Radiator (1.0)	HVAC (3.8)	HVAC (3.8)
Cooling system type and efficiency	HVAC system (3.0)	HVAC system (3.0)	HVAC system (5.1)	HVAC system (5.1)
DHW preparation system type and efficiency	Natural gas heater (0.89)	Solar thermal collectors and natural gas heater (0.89)	Solar thermal collectors and new heat pump (4.3)	Solar thermal collectors and new heat pump (4.3)
Renewable energy sources		-		
Solar thermal collectors for DHW, m^2	-	2.60	2.79	2.79
Solar panels for electricity production, m^2	-	-	0	12.9

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Research Methodology

The methodology is based on the analysis, for each scenario, of the:

i) **operational energy for heating, cooling, and production of DHW;**

ii) **life cycle impacts, using a standardized LCA method (EN 15978:2012);**

iii) **economic payback time (EPBT); and carbon emissions payback time (GPBT).**

For the calculation of the energy needs the methodology of the Portuguese thermal regulation for residential buildings was followed, which is based on the quasi-steady state method (ISO 13790:2008).

Research Methodology

Quantification of the Whole Building Life Cycle Impacts

- Quantified in a bottom-up approach (i.e. from building components scale to whole assembly):

1st Step: Quantification of the embodied impacts in the building components

Embodied impacts in non-linear components

Σ Ai*Ii

+

Embodied impacts in linear components

(Structures)

÷

Time boundary of the LCA Assessment

(years)

÷

Net floor area of the building

(years)

=

Whole building embodied environmental impacts

(/m^2.year)

Total embodied impacts in building components

Research Methodology

2nd Step: Quantification of the whole building life-cycle impacts

Whole building embodied environmental impacts (/m²·year) + **Environmental impacts of the maintenance scenarios (/m²·year)** + **Environmental impacts of the operation energy (HVAC + hot water) (/m²·year)** = **Total life-cycle impacts of whole building (/m²·year)**

Indicators	Units	Methods
Global warming potential (GWP)	[Kg CO_2 equiv.]	CML-IA baseline (v3.02)
Depletion of the stratospheric ozone layer (ODP)	[KgCFC-11 equiv.]	CML-IA baseline (v3.02)
Acidification potential (AP)	[Kg SO_2 equiv.]	CML-IA baseline (v3.02)
Eutrophication potential (EP)	[Kg PO_4 equiv.]	CML-IA baseline (v3.02)
Formation potential of tropospheric ozone (POCP)	[Kg C_2H_4 equiv.]	CML-IA baseline (v3.02)
Abiotic depletion potential of fossil resources (ADP_FF)	[MJ equiv.]	CML-IA baseline (v3.02)
Depletion of abiotic resources-elements (ADP_elements)	[kg.SB equiv.]	CML-IA baseline (v3.02)
Cumulative Energy Demand – non renewable (CED_{NRE})	[MJ equiv.]	Cumulative Energy Demand (v1.09)
Cumulative Energy Demand – total (CED_{TOTAL})	[MJ equiv.]	Cumulative Energy Demand (v1.09)

Results of energy simulations for the different scenarios

Energy performance

Results of energy simulations for the different scenarios

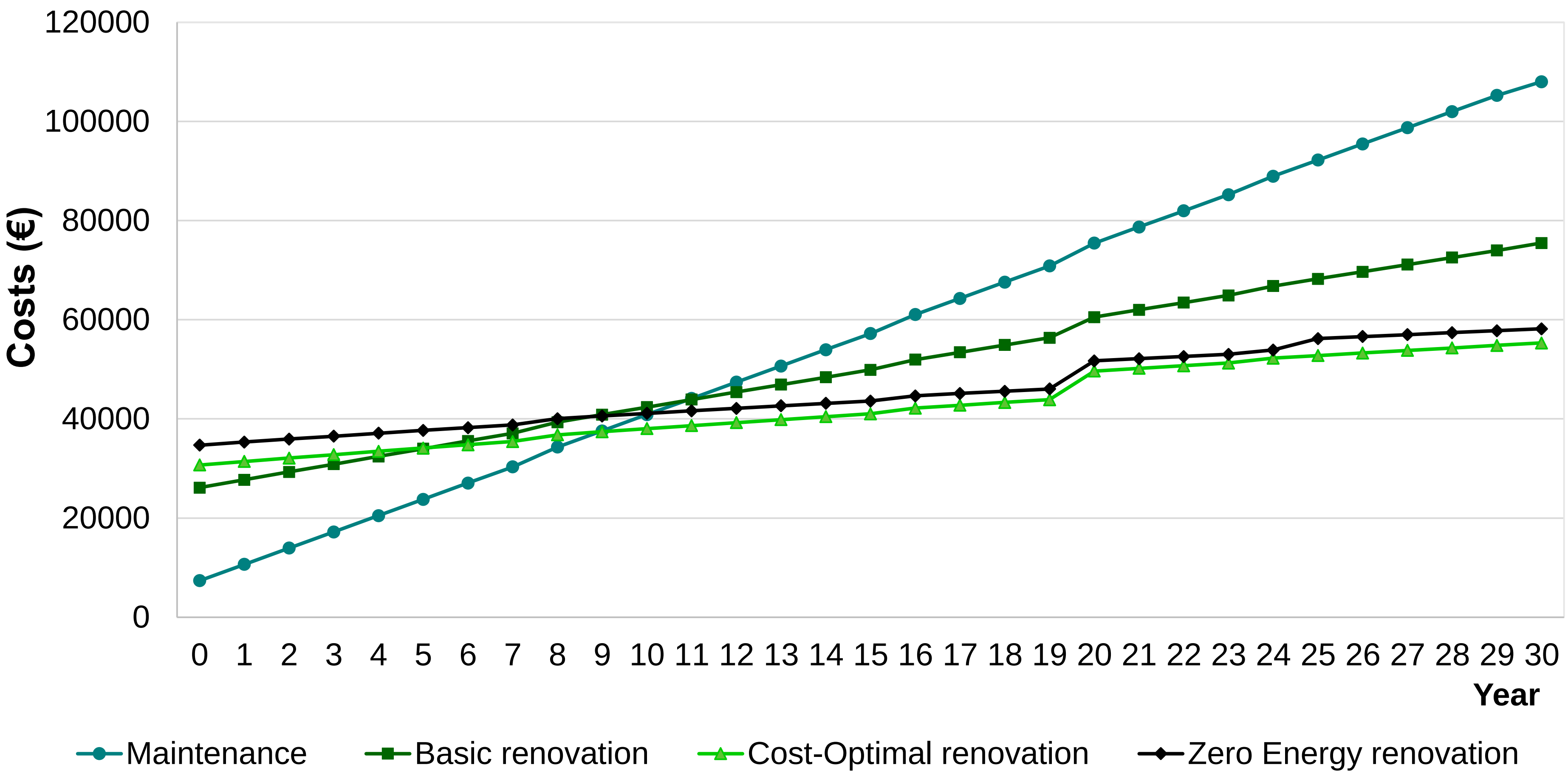
Properties of building	Before renovation (Maintenance)	Basic renovation (minimum legal requirements)	Cost-optimal renovation	Zero Energy renovation
Building's energy needs (net energy, without system losses), kWh/(m^2·year)				
Space heating	134.52	54.14	54.14	54.14
Space cooling	9.19	7.05	7.05	7.05
Domestic hot water	23.77	23.77	21.40	21.40
Delivered energy (energy use of technical systems with systems losses) net energy, kWh/(m^2·year)				
Space heating	134.52	54.14	14.25	14.25
Space cooling	3.06	2.53	1.38	1.38
Domestic hot water	26.71	7.76	0.41	0.41
Produced energy on site, kWh/(m^2·year)				
Solar thermal collectors (heat)	0.00	14.49	19.54	19.54
PV panels (electricity)	0.00	0.00	0.00	16.71 (1)
Primary energy use, kWh_{PE}/(m^2·year)				
Energy performance value, kWh_{PE}/(m^2·year)	370.67	149.45	40.10	0.00

(1) The PV system produces annually 1671 kWh, 289 kWh/year are used on-site and the remaining 1382 kWh/year are exported to the electric grid.

Results of energy simulations for the different scenarios

Life cycle costs

Lifetime cumulative energy costs of each renovation scenario



Payback time – 11 years **Payback time – 9 years** **Payback time – 10 years**

Results of energy simulations for the different scenarios

Environmental performance

Inventory of used building products

Inventory item	Before renovation (Maintenance)	Basic renovation (fulfils minimum legal requirements)	Cost-optimal renovation	Zero Energy renovation
		Lifetime material input (kg)		
Cement mortar		1900.00	1900.00	1900.00
Ceramic tile		4375.00	4375.00	4375.00
Expanded extruded polystyrene (XPS)	-	686.72	686.72	686.72
Synthetic mortar	-	4786.20	4786.20	4786.20
Water-based paint	164.16	164.16	164.16	164.16
		Lifetime windows renovation (m^2)		
PVC windows with double glazed glass, including shading devices (PVC shutters)	-	15.00	15.00	15.00

Results of energy simulations for the different scenarios

Environmental performance

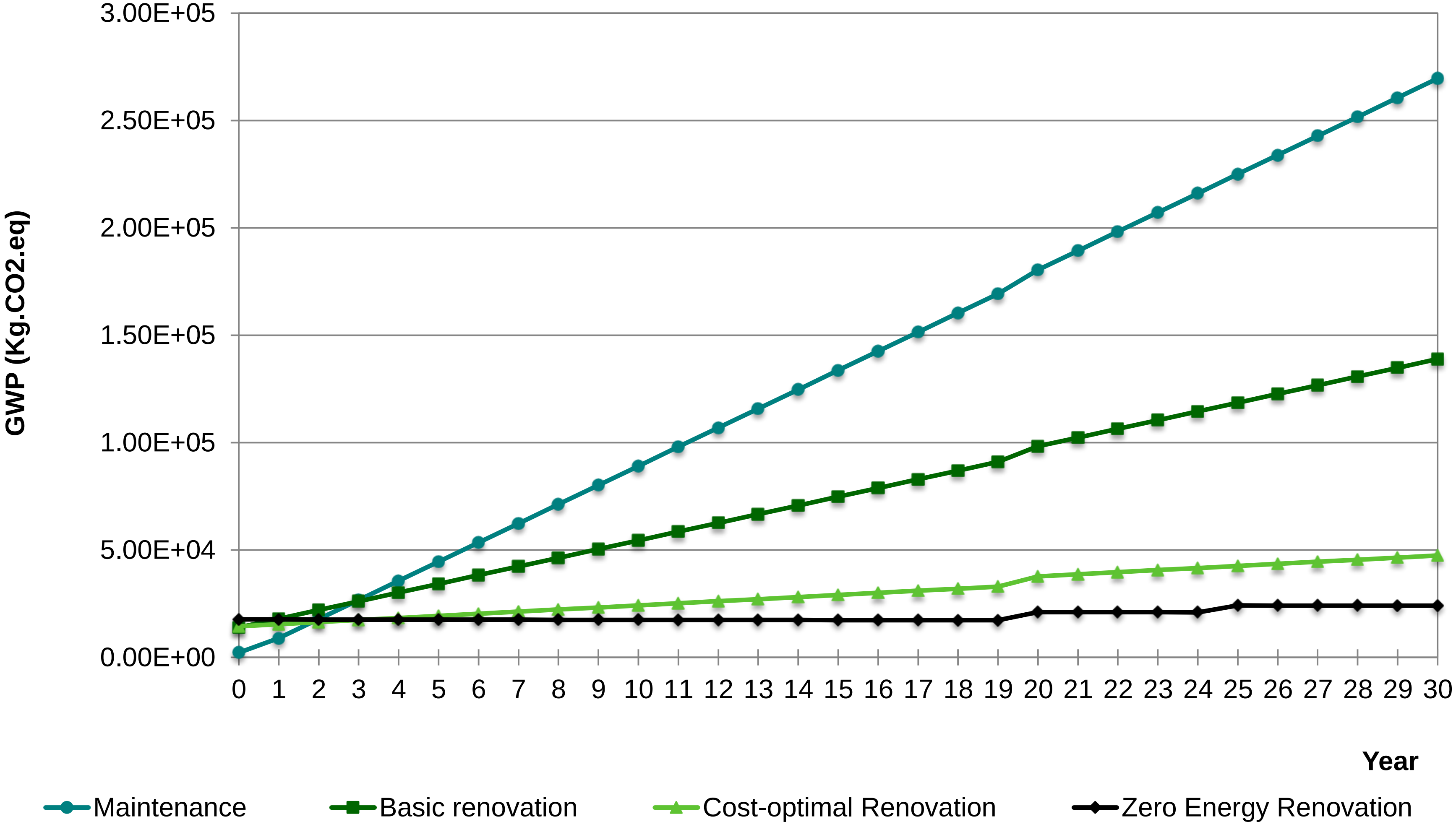
Annual equivalent **life cycle impacts per net floor area** and potential improvements resulting from each renovation scenario

Environmental indicator	Before renovation (Maintenance)	Basic renovation (fulfils minimum legal requirements)		Cost-optimal renovation		Zero Energy renovation			
	Impacts (/m^2.year)	Impacts (/m^2.year)	Improvement (%)	Impacts (/m^2.year)	Improvement (%)	Impacts of the considered boundary (/m^2.year)	Benefits outside the system boundary	Overall impacts (/m^2.year)	Improvement (%)
ADP_elements	1,62E-02	1,41E-02	13%	1,04E-02	35%	1,47E-02	1,27E-03	1,34E-02	17%
ADP_FF	1,20E+05	5,96E+04	50%	1,84E+04	85%	1,94E+04	1,30E+04	6,40E+03	95%
GWP100a	9,06E+03	4,63E+03	49%	1,46E+03	84%	1,54E+03	9,93E+02	5,52E+02	94%
ODP	2,78E-03	1,39E-03	50%	2,24E-03	19%	2,26E-03	7,14E-05	2,19E-03	21%
POCP	2,83E+00	1,44E+00	49%	4,65E-01	84%	4,98E-01	3,17E-01	1,81E-01	94%
AP	6,82E+01	3,33E+01	51%	1,01E+01	85%	1,08E+01	7,85E+00	2,92E+00	96%
EP	1,71E+01	8,78E+00	49%	3,05E+00	82%	3,43E+00	1,97E+00	1,46E+00	91%
CED_NRE	1,29E+05	6,46E+04	50%	2,02E+04	84%	2,14E+04	1,41E+04	7,38E+03	94%
CED_TOT	1,52E+05	7,61E+04	50%	2,34E+04	85%	2,48E+04	1,69E+04	7,90E+03	95%

Results of energy simulations for the different scenarios

Environmental performance

Lifetime Cumulative Global Warming Potential (GWP) of each renovation scenario



Payback time – 3 years **Payback time – 2 years** **Payback time – 2 years**

Results of energy simulations for the different scenarios

Environmental performance

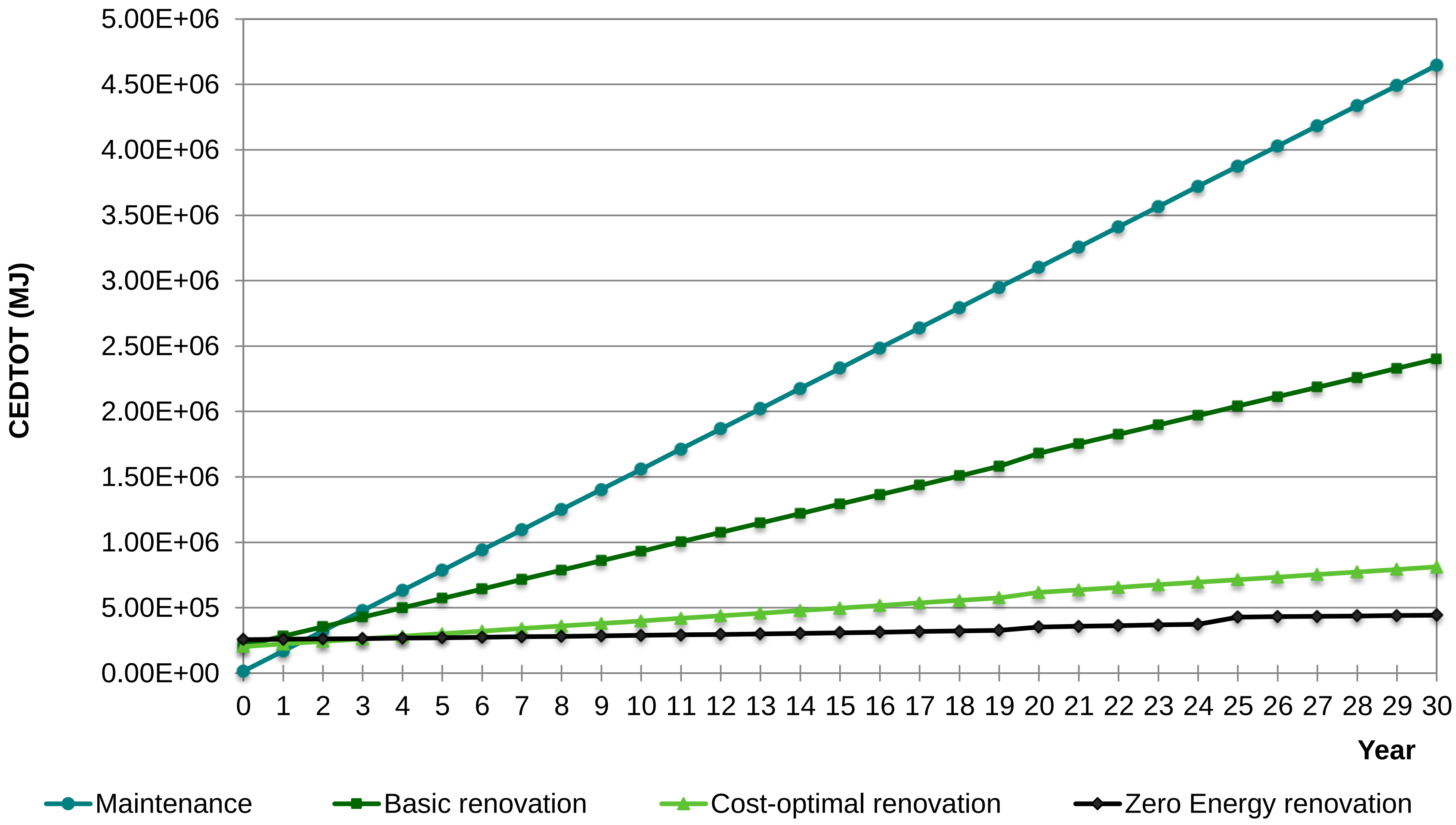
Lifetime Cumulative Energy Demand (CED_{TOT}) of each renovation scenario

The lifetime saved CED_{TOT} is

Basic: 2 245 GJ (2.4 years)

Cost-optimal: 3 834 GJ (1.5 years)

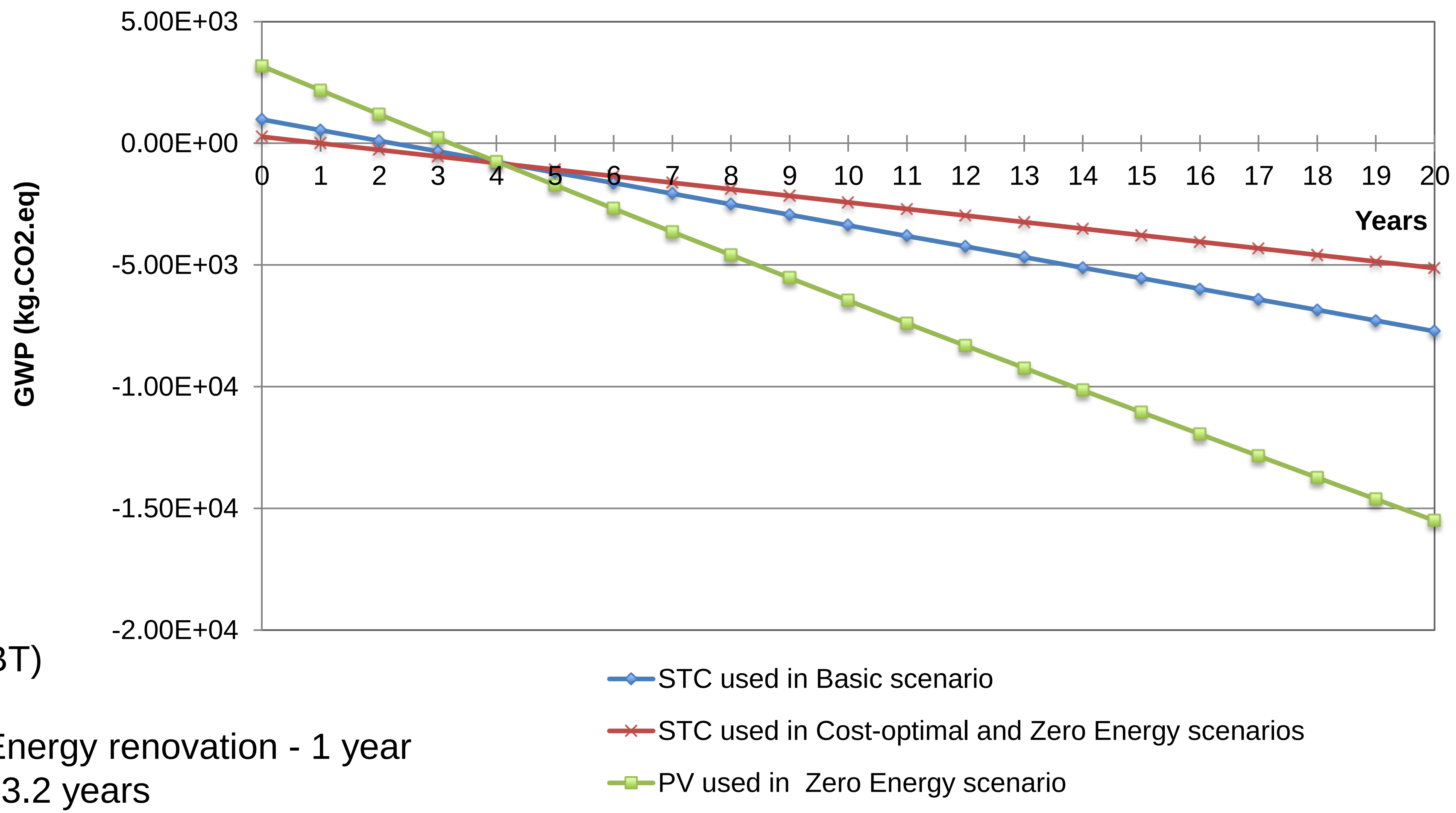
Zero Energy: 4 203 GJ (1.5 years)



Results of energy simulations for the different scenarios

Environmental performance

Cumulative GWP of each used solar system for a lifetime period of 20 years

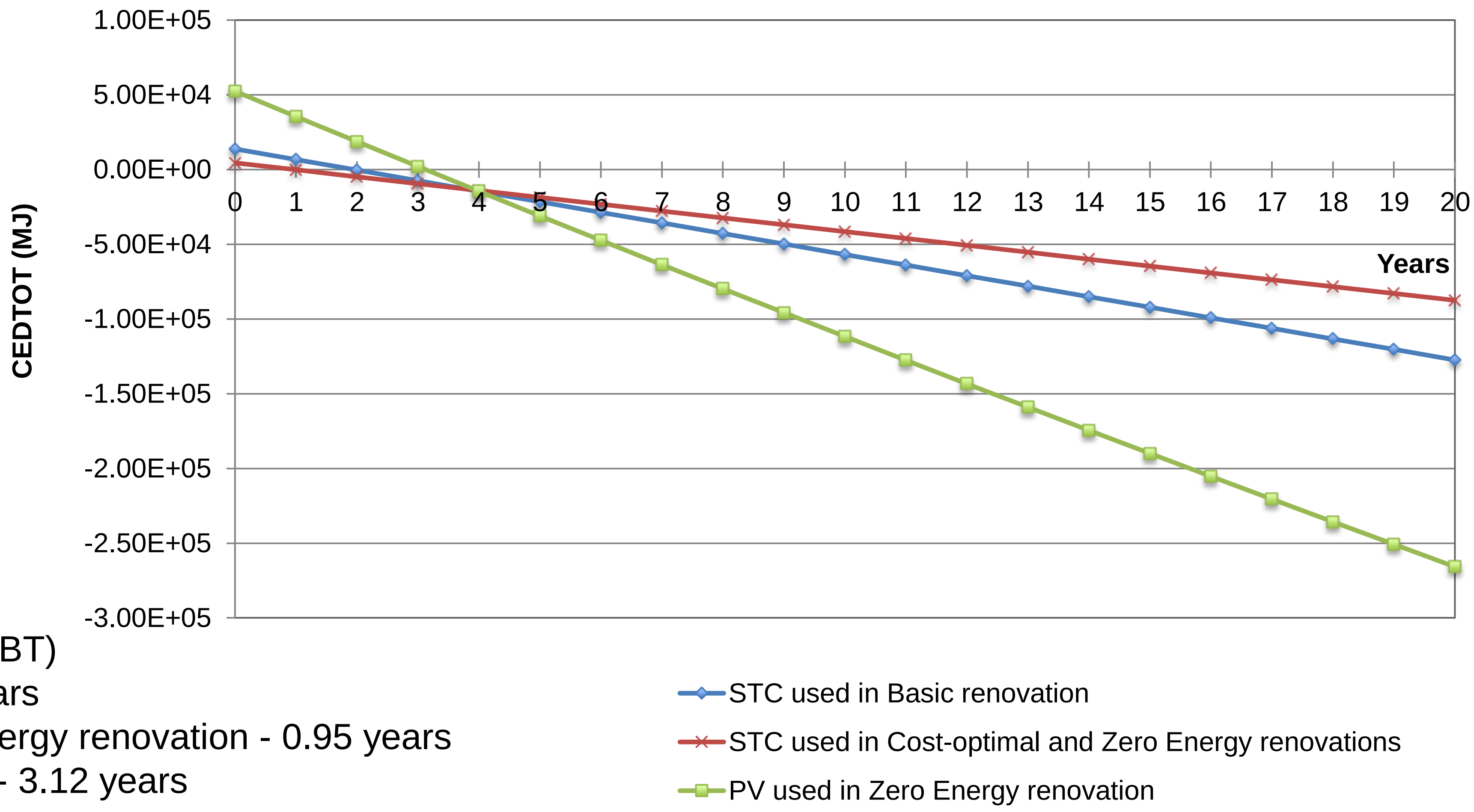


Greenhouse Gas Payback Time (GPBT)
STC: Basic renovation - 2.2 years
STC system: Cost-optimal and Zero Energy renovation - 1 year
PV system: Zero Energy renovation - 3.2 years

Results of energy simulations for the different scenarios

Environmental performance

Cumulative CED_{TOT} of each used solar system for a lifetime period of 20 years



Embodied Energy Payback Time (EPBT)
STC system: Basic renovation - 2 years
STC system: Cost-optimal & Zero Energy renovation - 0.95 years
PV system: Zero Energy renovation - 3.12 years

Conclusions

Basic renovation (minimum requirements to fulfil the national thermal regulation) ➡

renovation costs: 69% higher; annual energy needs: 60% reduction; payback time: 11 years;

building's Cumulative Energy Demand reduction: 48%

Cost-optimal renovation ➡

renovation costs: 75% increase; annual energy needs: 89% reduction; payback time: 9 years;

building's Cumulative Energy Demand reduction: 83%

Zero Energy renovation ➡

renovation costs: 78% increase; annual energy needs: 89% reduction; payback time: 10 years;

building's Cumulative Energy Demand reduction: 90%

Compared to the **Maintenance scenario**