UNIVERSITY OF MINHO
SCHOOL OF ENGINEERING
CIVIL ENGINEERING DEPARTMENT

Refurbishment challenges of nZEB

Cost optimal building renovation with zero energy target

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New Challenges for NZEB in Smart Cities
Energy Flexibility and Building to Grid Interaction

Background

Buildings are a key sector in ***EU long-term energy efficiency strategies.***

Better construction and use of buildings would influence:

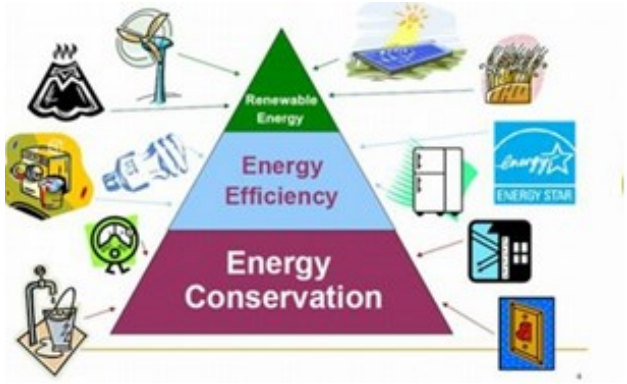
- 42% of the final energy consumption;
- about 35% of the CO_2 emissions;
- more than 50% of all extracted raw materials;
- save up to 30% of water consumption;

Therefore, *buildings energy performance* ***is an important part of the EU 2020 and 2030 energy and climate targets.***

Background

The EU targets for 2020 are:

20% reduction of the energy consumption;
20% reduction of GHG emissions;
20% increase in renewable energy use.



The 2030 targets increase this number to:

- 40% reduction of the Carbon Emissions;

- 27% increase in renewable energy use.

For 2050, the goal is the reduction in 90% of CO_2 emissions (compared to 1990 levels);

These goals will be achieved only if effective actions are implemented not only on new buildings but specially on the existing building stock

Background – European regulation to support EU efforts

Energy Performance of Buildings Directive recast (EPBD, 2010/31/EU)

That imposes to all Member States:

Minimum requirements for the energy performance of buildings based on cost-optimal energy efficiency levels

Nearly zero-energy level for new buildings from 2020 (for public buildings from 2018)

Whenever possible, renovation of the existing buildings must comply with the same energy performance requirements as long as there are no technical, functional or economical constraints.

Background

Cost optimality and **nearly zero-energy buildings (nZEB)**:

Two fundamental concepts **within the current EU policy related to the energy performance of buildings;**

- Cost optimality **is mainly focused** on costs**;**

- Nearly zero-energy buildings **are focused** on low energy consumption levels and on-site use/production of renewable energy

Methodology - Generic

The purpose here is:

- To investigate and compare these two energy levels

- To understand how can they be reached and at what cost?

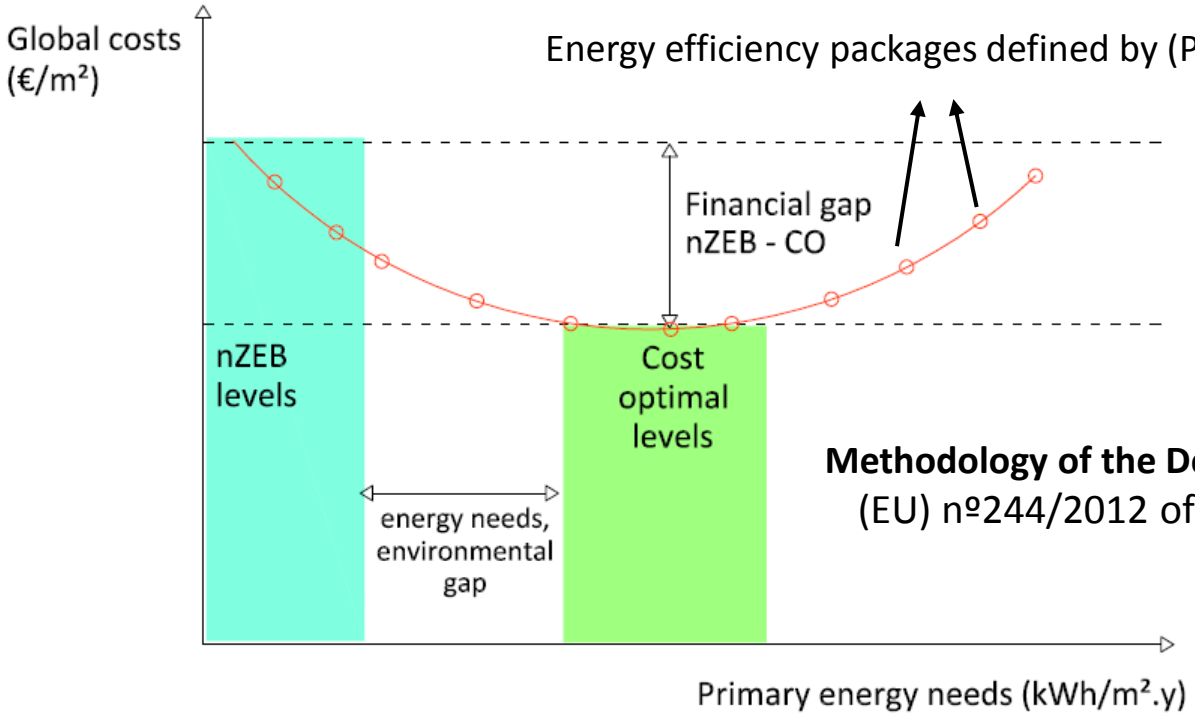
In building renovation meeting nearly zero energy targets is a challenge

In building renovation, meeting the nearly zero energy targets mainly by improving the building envelope may not be easy or cost-effective

Beyond a certain energy performance, it is often more cost-effective to use renewable energy sources than to keep on improving the building envelope

Methodology – Generic

Typical Cost-Energy curve



Methodology of the Delegated Regulation
(EU) nº244/2012 of 16 January 2012

General representation of the cost optimal and nZEB graphic results

Methodology – Cost optimal results

Primary Energy associated to the cost optimal solutions for residential buildings in Portugal

Reference building	Level of primary energy use that leads to the cost optimal level (kWh/m^2.y)
Existing building	52,97
New building	33,24

Weighted average values of the cost-optimal levels of energy use

Methodology - Generic

… in Portugal: the Decree-Law n.º 118/2013 from 20th August defines:

Article 16.º

Nearly zero-energy buildings

5 – The nearly zero-energy buildings must have an *efficiency level compatible* with the most demanding requirement that comes from the application of the *cost optimal methodology* to either new or existing buildings and for different typologies…

So, to reach the nZEB buildings we first need to find the cost optimal solutions and then add on site renewable energy production

Cost optimal → nZEB
+ on site renewable energy production

How to reach a nZEB level in Building Renovation

In building renovation meeting nearly zero energy targets is a challenge

A case-study is used to show how cost-effective is to reach a nZEB level - Multifamily building located in Porto

Considered to be representative of 20% of the Portuguese building stock due to the climate zone, its geometry and energy performance.

Case study

Buildings general characteristics:

- Multifamily building located in Porto;
- 5 floors with 2 apartments in each floor;
- Net floor area = 674m²;
- Built in 1990;
- Semi-detached;
- Oriented NE, SE, SW;

Initial energy needs:

Nic = 94,7 kWh/m².a

Nvc = 2,96 kWh/m².a

Nac =30,47 kWh/m².a

Considered to be representative of 20% of the Portuguese building stock due to the climate zone, its geometry and energy performance.

Case study – Thermal characterization before renovation

Element	Description	U-Value before	U-Value reference	η
Walls	Cavity walls	1,08	0,50	_
Roof	Lightweight slab + metallic plates	1,88	0,40	_
Floor	Lightweight slab + wood	2,50	0,40	_
Window	Aluminium frame + single glazing	4,80	2,90	_
DHW	Electric heater	_	_	0,80
Heating	Portable electric heaters	_	_	1,00

Note: There are no cooling systems installed

Renovation measures - Building envelope

Package	Wall	Roof	Floor	Window
O (base)	Maintenance	Maintenance	Maintenance	Maintenance
1	Maintenance	Maintenance	Maintenance	PVC + 2x glazing
2	Maintenance	Maintenance	30 mm XPS	PVC + 2x glazing
3	40 mm EPS	Maintenance	30 mm XPS	PVC + 2x glazing
4	40 mm EPS	40 mm XPS	30 mm XPS	PVC + 2x glazing
5	50 mm EPS	50 mm XPS	50 mm XPS	PVC + 2x glazing
6	60 mm EPS	60 mm XPS	60 mm XPS	PVC + 2x glazing
7	80 mm EPS	80 mm XPS	80 mm XPS	PVC + 2x glazing
8	100 mm EPS	100 mm XPS	100 mm XPS	PVC + 2x glazing
9	120 mm EPS	120 mm XPS	120mm XPS	PVC + 2x glazing

EPS=expanded polystyrene; XPS=extruded polystyrene; PVC= polyvinyl chloride

Renovation measures - BITS

BITS – Building Integrated Thermal Systems

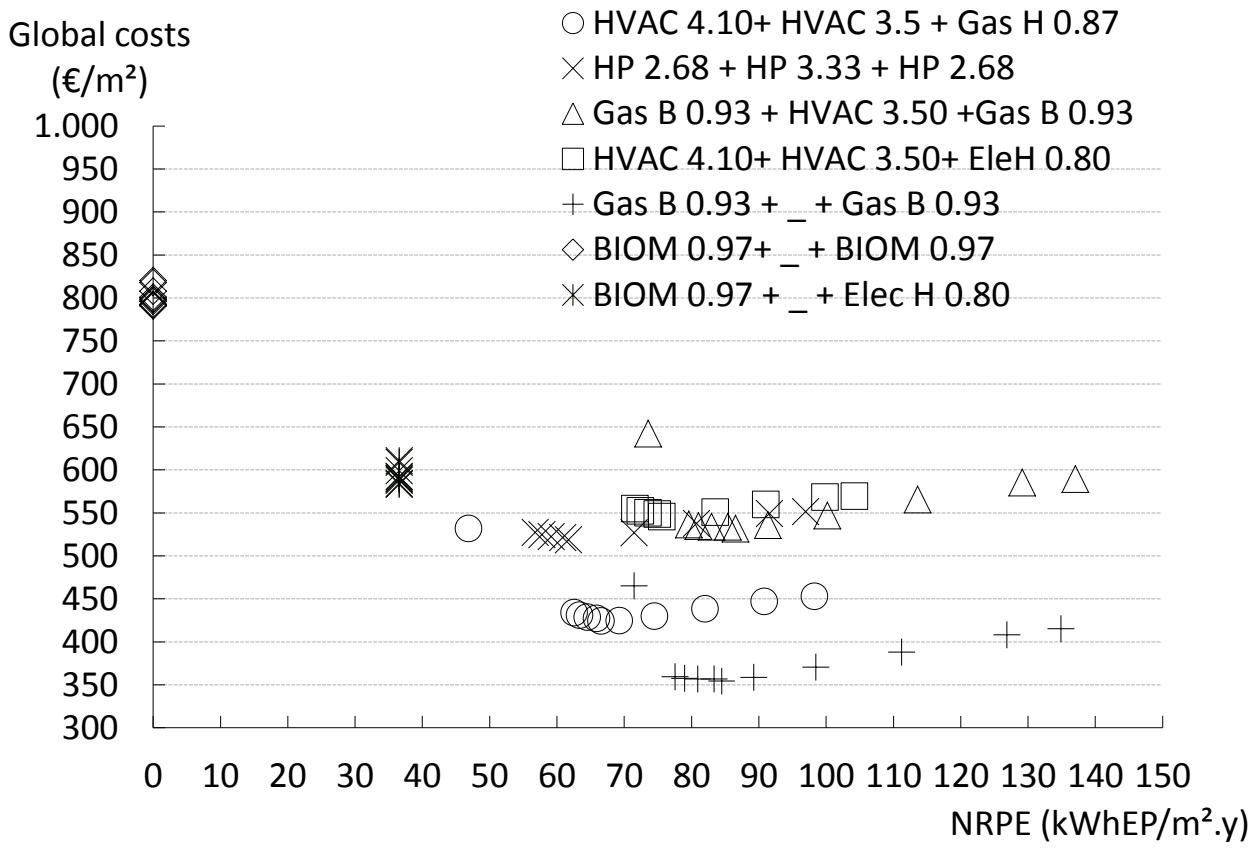
System	Heating (η)	Cooling (η)	DHW(η)
A	HVAC (4,10)	HVAC (3,5)	Gas heater (0,87)
B	Gas boiler (0,93)	HVAC (3,5)	Gas boiler (0,93)
C	Heat pump (3,33)	Heat pump (2,88)	Heat pump (3,33)
D	HVAC (4,10)	HVAC (3,50)	Electric heater (0,80) + ST
E	Gas boiler (0,93)	_	Gas boiler (0,93)
F	Biomass (0,97)	_	Biomass (0,97)
G	Biomass (0,97)	_	Elect. Heater (0,80) + ST

ST= Solar thermal panels

Renovation measures for the building envelope + Change of BITS = **70 renovation measures**

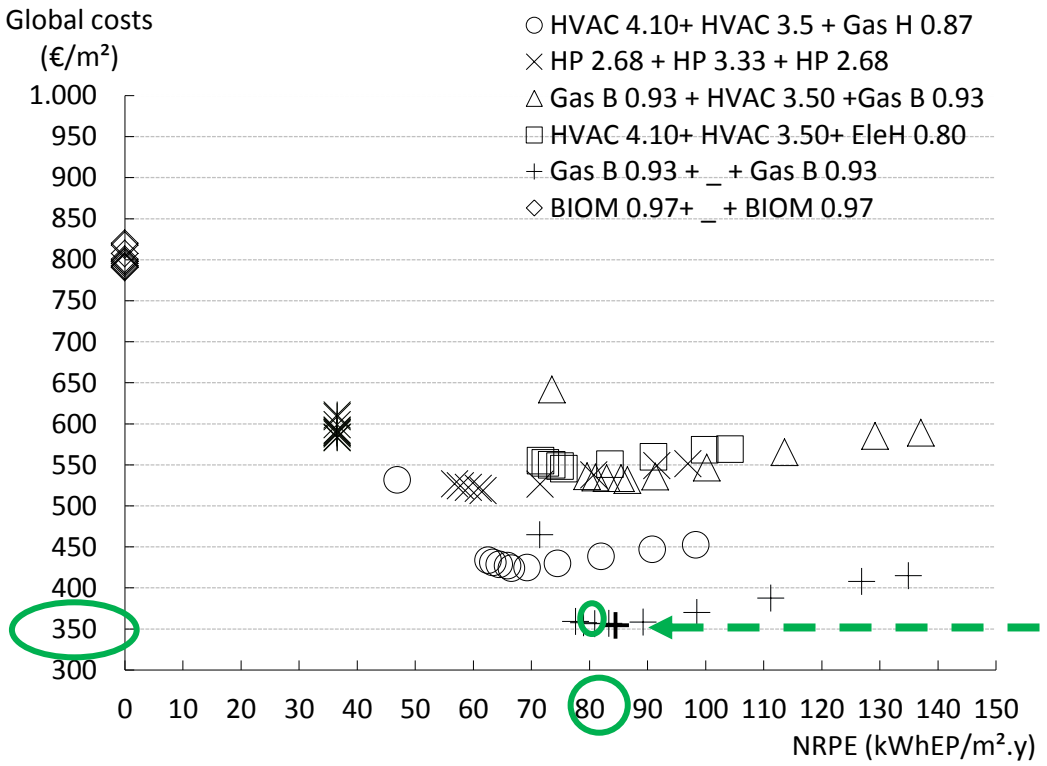
Cost optimal results

General overview



Renovation measures for the building envelope + Change of BITS = 70 renovation measures

Cost optimal results

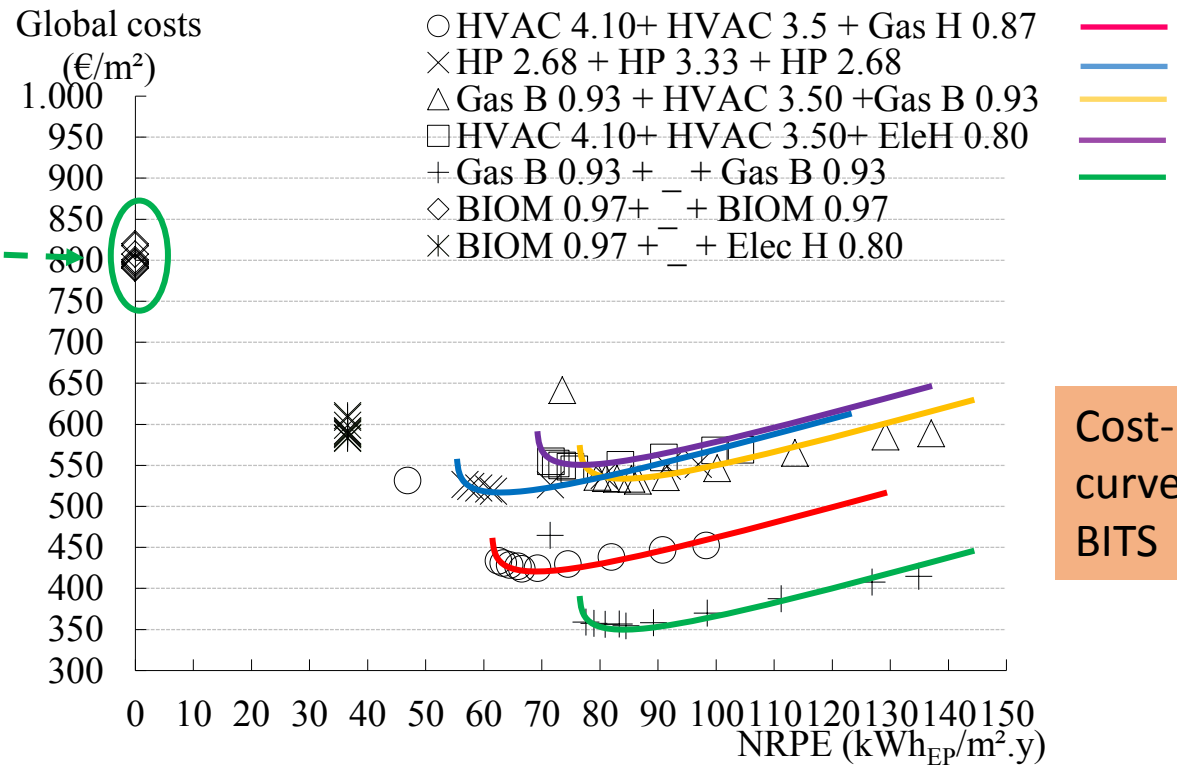


Cost optimal package:
EPS 5cm (wall) + XPS 5cm (roof) + XPS 5cm (floor) + PVC 2x glazing +
gas boiler for heating and DHW

Cost Optimal Solution vs nZEB solution

Cost optimal results

Biomass boiler already leads to **zero non-renewable primary energy use**, but at very high global costs



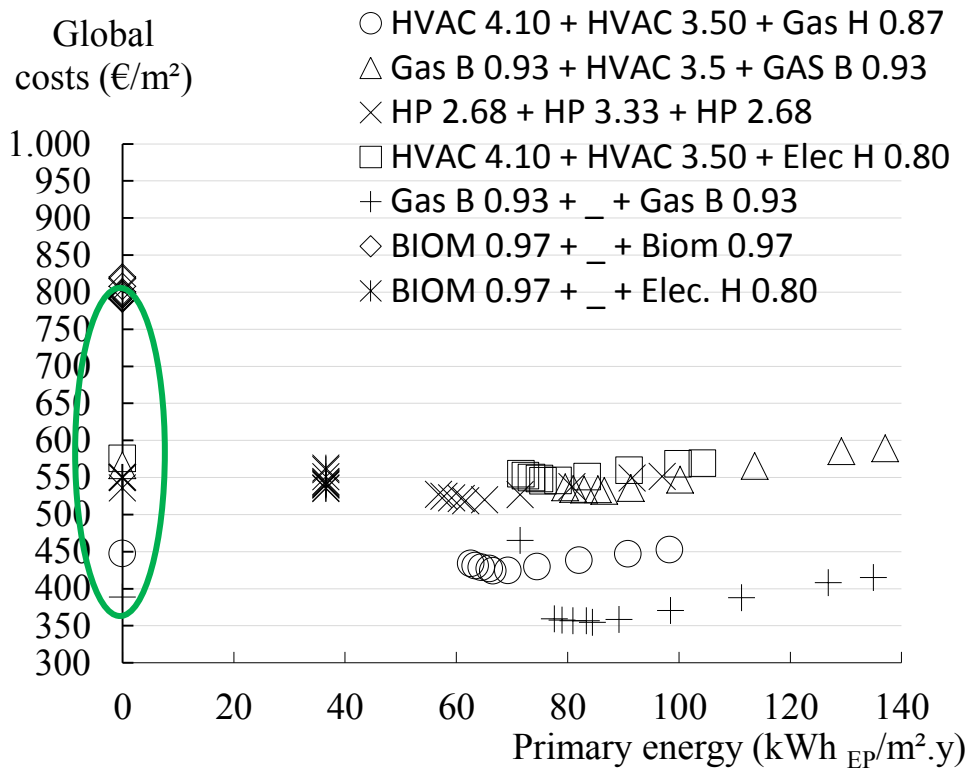
Cost-Energy curves for each BITS

Renovation Packages curves for each BITS

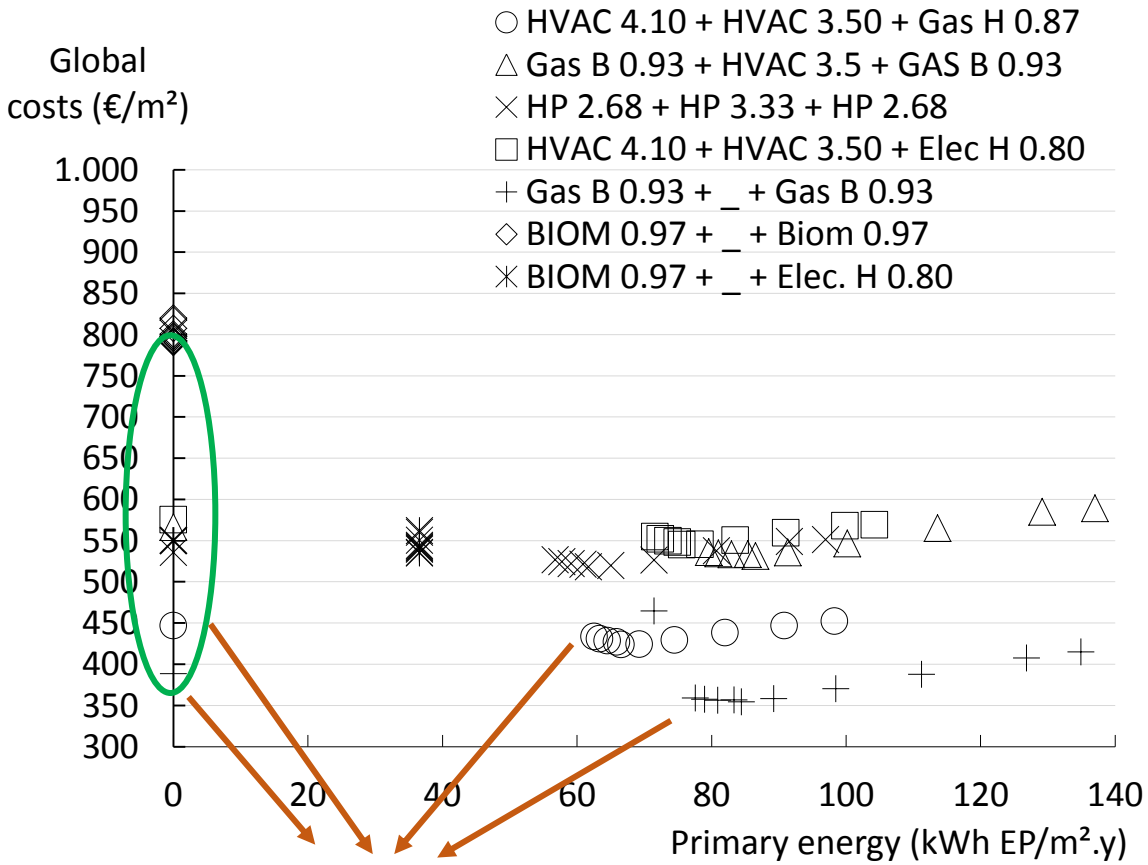
Cost optimal results – cost optimal vs nZEB

Moving from cost optimal to nZEB using PV panels

Using the cost optimal solution for each BITS and **adding PV panels** its possible to have **zero primary energy** although at different costs



Cost optimal results – cost optimal vs nZEB

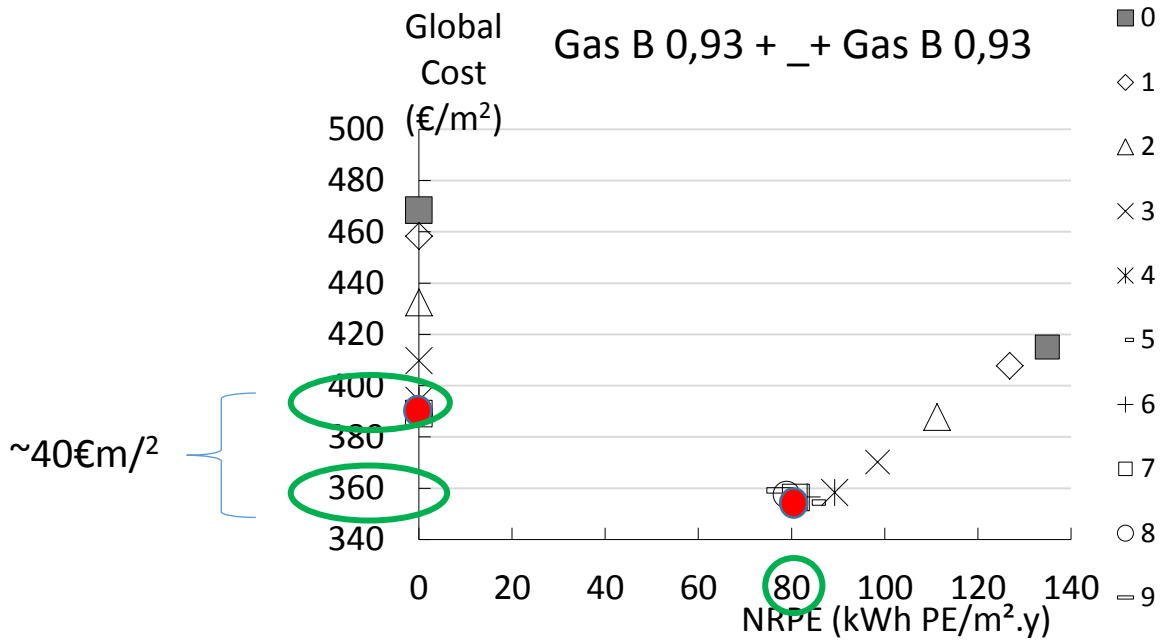


In general, whatever the BITS used, the cost optimal solution for the envelope is the same

The BITS hierarchy of costs is kept --- the cheapest solution is the one using Gas Boiler for both heating and DHW + EPS 5cm (wall) + XPS 5cm (roof) + XPS 5cm (floor) + PVC 2x glazing

Cost optimal results

Comparing lowest cost package of renovation measures in the building envelope, with and without the zero energy target.



The cost optimal package of renovation measures in the building envelope is kept - EPS 5cm (wall) + XPS 5cm (roof) + XPS 5cm (floor) + PVC 2x glazing - associated to a Gas Boiler for both heating and DHW

Conclusions

Although results refer to a single building in a certain location, some general conclusions can be drawn:

- **Cost optimal level is far from zero energy level;**
- **Without the nZEB restrictions, the cost optimal level for this type of building is found for packages that include natural gas for Heating and DHW;**
- **PV panels allow to equal non-renewable primary energy use for heating, cooling and DHW and the hierarchy of cost-effectiveness, between different BITS did not present major modifications;**
- **The cost optimal solution for the envelope is the same whatever the BITS used (in general);**

Thank you

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