POWER HOUSE NEARLY ZERO ENERGY CHALLENGE

Co-funded by the Intelligent Energy Europe Programme of the European Union

NEARLY ZERO ENERGY HOUSING FOR WARM/MEDITERRANEAN CLIMATE ZONES

# The nearly-Zero Energy Challenge in Warm and Mediterranean Climates

## Cost effectiveness of nZEB in Warm / Mediterranean Climates

## Authors

Anna Maria Pozzo (Federcasa, IT)
Giancarlo Tofanelli ((Consorzio Nazionale CasaQualità, IT)
Alain Lusardi (Consorzio Nazionale CasaQualità, IT)
Carlos De Astorza (AVS, ES)
Maria Jesus Gascò (AVS, ES)
Begona Serrano Lanzarote (IVE, ES)

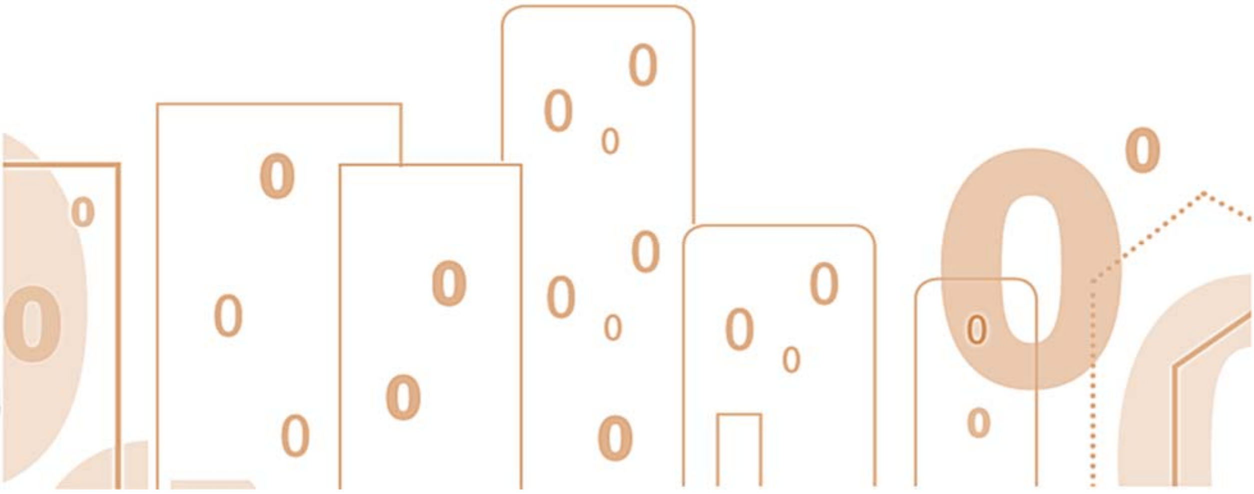


## Tanks for the contribution to:

Marco Corradi, Acer Reggio Emilia
Massimo Davi, Ater Latina
Carlos De Astorza, AVS
Giorgio Federici, Apes Pisa
Cosimo Gambuti, Publicasa SpA
Maria Jesus Gascò, AVS

## Date of finalisation:

March 2015

## Contents

# 1 Reflection on methods for measurement of cost effectiveness

Under article 5(2) of the Directive 2010/31/EU on Energy Performance of Buildings, Member States have to communicate to the European Commission (EC) all input data and assumptions used for the calculations of cost-optimal levels of minimum energy performance requirements using the Delegated Regulation (EU) No 244/2012.

Considering that EC has recently received National reports on calculation of cost-optimal levels of minimum energy performance requirements for Italy, France and Spain.

Avalaible at the EC website:

http://ec.europa.eu/energy/efficiency/buildings/implementation_en.htm

The cost effectiveness assessment of each selected study case will based on these key documents.

In fact, in order to report the Energy Efficiency Action Plans at EU Commission, each EU Member State I requested to relate the minimum energy performance requirement with "Reference Building". The "Reference Building" is a tool to compare all the European legislation as requested by EU Commission. They are defined in Annex III as *"(…) representative of their functionality and geographic location, including indoor and outdoor climate conditions. The reference building shall cover residential and non-residential building, both new and existing ones".*

The reference building shall be defined for the following categories of buildings: (1) single-family buildings, (2) apartment blocks and multifamily buildings, (3) office buildings, and (4) other optional buildings: schools, hotels, restaurants, sport buildings, shopping centres or other buildings with relevant energy consumption.

The definition of Reference Building for Italy are adopted by Italian Ministry of Economic Development and ENEA (Italian National Agency for New Technologies Energy and Sustainable Economic Expansion) in order to define an Italian Reference Building and is resented on the National reports on calculation of cost-optimal levels of minimum energy performance requirements for Italy.

## ✓ References


- BPIE, 2011. “Principles for nearly-Zero Energy Buildings. Paving the way for effective implementation of policy requirements”.

Available at: www.bpie.eu/documents/BPIE/publications/HR_nZEB%20study.pdf

- BPIE, 2013. “Implementing the cost-optimal methodology in EU countries. Lessons learned from three case studies”.

Available at:

www.bpie.eu/documents/BPIE/publications/cost_optimal_methodology/BPIE_Implementing_Cost_Optimality.pdf

- BPIE & e7, 2013. “Implementing the cost-optimal methodology in EU countries. Case study Austria”.Available at:

http://www.bpie.eu/documents/BPIE/publications/cost_optimal_methodology/BPIE_Cost_Optimality_Austria_Case_Study.pdf

- BPIE & IWU, 2013. “Implementing the cost-optimal methodology in EU countries. Case study Germany”. Available at:

www.bpie.eu/documents/BPIE/publications/cost_optimal_methodology/BPIE_Cost_Optimality_Germany_Case_Study.pdf

- EC, 2012a. European Commission. “Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements”.

Available at: eur-lex.europa.eu/LexUriServ/LexUriServ.do

- EC, 2012b. European Commission. “Guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 supplementing Directive 2010/31/EU by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements (2012/C 115/01)”.

Available at: eur-lex.europa.eu/LexUriServ/LexUriServ.do

- kfW, 2012. “Housing, home modernisation and energy conservation. Energy efficient construction.”

Available at: https://www.kfw.de/inlandsfoerderung/EN/Domestic-Promotion/Our-offers/Housing-home-modernisation-and-energy-conservation/index-2.html

# 2 Data gathering

As aforementioned in section 3 "operating costs", the global cost collection for each selected study case is still on progress.

At current day, for each study case, the MED task force members have collected the starting investment costs – so the summa of all investments costs, including design and all taxes.

All collected data are reported on **Annex B**

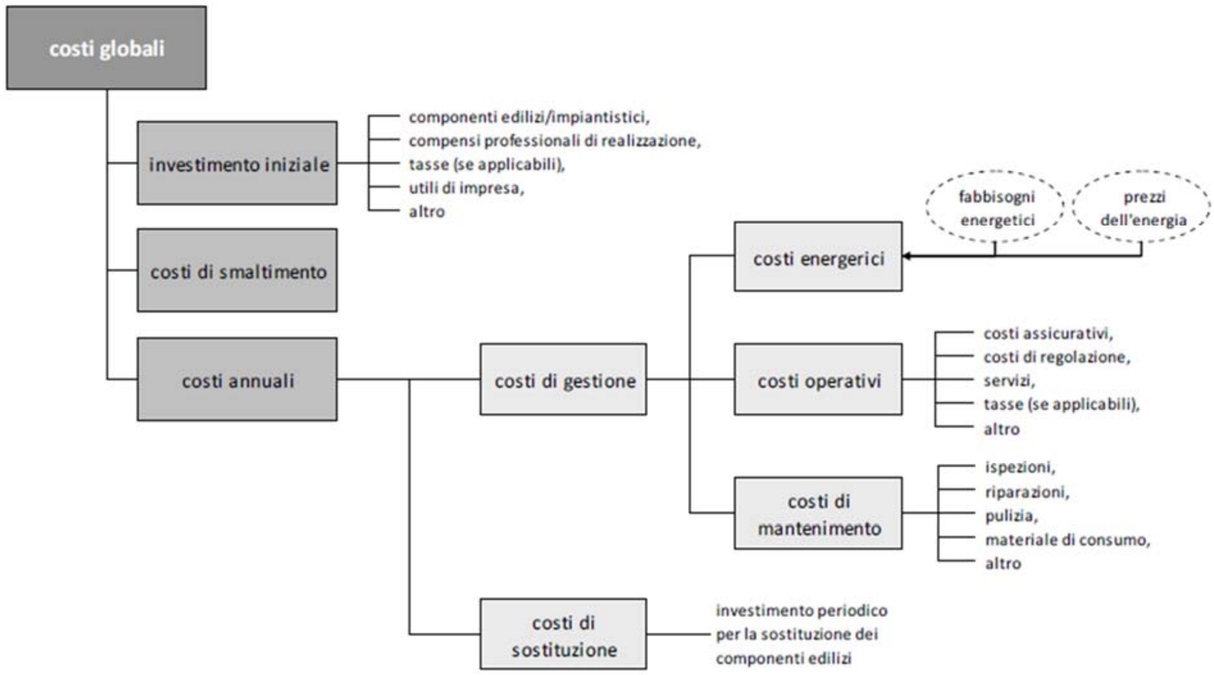



Table 1: Costs included in calculation

## For Spain

The following costs and general input data have been defined in order to the overall calculation of the cost - optimal from various technical alternatives that will be mentioned below. Firstly, we define the common cost to both housing developments studied. Secondly, the technical alternatives and the construction costs considered separately for each building as the constructive solutions of the thermal envelope and systems, are specific to each of them.

## ✓ Maintenance costs

The maintenance costs have been calculated, for the elements and systems of the two buildings. In this regard, it is noted that it was difficult to obtain the official price of the maintenance operations, and finally we worked out its real value, by setting a percentage of the construction cost of the elements and facilities, considering the varying durability of these elements.

## ✓ Energy costs

The energy prices have been fixed in December 2012, and they are updated in accordance with the following document, referenced in Annex II of the Delegated Regulation. http://ec.europa.eu/energy/observatory/trends_2030/index_en.htm

The price of biomass keeps consistent as indicated in the table of cost evolution as shown in the document elaborated by CENER for IDAE: "Study of optimum utilization of renewable energies in buildings for incorporation into the Technical Building Code CTE"

For the District Heating, the cost remains constant given that the various sources of supply and fuel flexibility can provide the energy needed for its operation at a constant price

You can find the projections of the energy prices development over a period of 30 years (natural gas, electricity, and biomass) used for this study in the table n.2

| Cost €/kWhf | Natural Gas | Electricity | Biomass |
|---|---|---|---|
| 2012 | 0,0680 | 0,2090 | 0,046 |
| 2013 | 0,0715 | 0,2135 | 0,046 |
| 2014 | 0,0750 | 0,2180 | 0,046 |
| 2015 | 0,0785 | 0,2225 | 0,046 |
| 2016 | 0,0820 | 0,2270 | 0,046 |
| 2017 | 0,0855 | 0,2315 | 0,046 |
| 2018 | 0,0890 | 0,2360 | 0,046 |
| 2019 | 0,0925 | 0,2405 | 0,046 |
| 2020 | 0,0960 | 0,2450 | 0,046 |
| 2021 | 0,0982 | 0,2460 | 0,046 |
| 2022 | 0,1004 | 0,2470 | 0,046 |

| Cost €/kWhf | Natural gas | Electricity | Biomass |
|---|---|---|---|
| 2027 | 0,1118 | 0,2476 | 0,046 |
| 2028 | 0,1142 | 0,2464 | 0,046 |
| 2029 | 0,1166 | 0,2452 | 0,046 |
| 2030 | 0,1190 | 0,2440 | 0,046 |
| 2031 | 0,1246 | 0,2440 | 0,046 |
| 2032 | 0,1302 | 0,2440 | 0,046 |
| 2033 | 0,1358 | 0,2440 | 0,046 |
| 2034 | 0,1414 | 0,2440 | 0,046 |
| 2035 | 0,1470 | 0,2440 | 0,046 |
| 2036 | 0,1542 | 0,2440 | 0,046 |
| 2037 | 0,1614 | 0,2440 | 0,046 |

| Cost €/kWhf | Natural Gas | Electricity | Biomass |
|---|---|---|---|
| 2023 | 0,1026 | 0,2480 | 0,046 |
| 2024 | 0,1048 | 0,2490 | 0,046 |
| 2025 | 0,1070 | 0,2500 | 0,046 |
| 2026 | 0,1094 | 0,2488 | 0,046 |

| Cost €/kWhf | Natural gas | Electricity | Biomass |
|---|---|---|---|
| 2038 | 0,1686 | 0,2440 | 0,046 |
| 2039 | 0,1758 | 0,2440 | 0,046 |
| 2040 | 0,1830 | 0,2440 | 0,046 |
| 2041 | 0,1918 | 0,2440 | 0,046 |

Table 2: Evolution of energy cost (€/kWhf)- Natural Gas, Electricity, biomass

### ✓ Useful life of the building elements

In Table n. 3 are shown the estimated lifespan of the most important building elements and systems used in the analysis for the "cost - optimal".

| Element | Calculation Period |
|---|---|
| Building envelop, opaque structures and insulation | 50 years |
| Windows | 20 years |
| Systems | Individual carrier products according to annex A, UNE-EN 15459 Regulation |

Table 3: Useful Life of Building Elements

### ✓ Other input data

Other relevant input data, which have been taken into account for calculating the cost-optimal levels, are summarized below:

The calculation period has been taken according to the "REGULATIONS DELEGATE (EU) No 244/2012 OF THE COMMISSION of 16th January 2012." In the case of a residential building, it´s considered a calculation period of 30 years. In general terms, it should be noticed that the impact of the duration of the observation period in the total result is limited due to the longer life of the building elements and their residual values.

In real terms, it´s assumed that the price for maintenance and replacement would not increase, as the nominal price will be in line with the general inflation rate.

Since the building costs shown in Table 12 do not include the cost of professional fees for designing and building management, it has been considered an average additional cost of 10% of the overall building costs approx.

Other expenses like insurance from damage to the elements have been considered having into account that they may have some weight of the total.

✓ **"Roc Borontat"**

### *Various energy solutions*

In total, we have defined 12 packages of energy solutions for the analysed building, trying to quantify energy consumption and demand. The ultimate goal is to create three blocks of improvement measures each one corresponding to various regulatory periods related to CTE, covering the period 2006 - 2013 and what could be the future regulation in 2020 incorporating the criteria of Nearly Zero Energy Buildings.

The elements of the different techniques are the following:

- **Thermal transmittance** U (W/m²K), of the various solid elements of the thermic envelope of the building (facade, roof, floor, walls). Different values have been assigned for the fulfilment of the three scenarios: CTE06, CTE13 y NZEB

| Combinations | | U (W/m²K) facade | U (W/m²K) Roof | U (W/m²K) walls | U (W/m²K) floor |
|---|---|---|---|---|---|
| **C1-C4** | **CTE06** | 0,73 | 0,41 | 1,00 | 0,50 |
| **C5-C8** | **CTE13** | 0,24 | 0,22 | 0,62 | 0,49 |
| **C9-C12** | **NZEB** | 0,20 | 0,20 | 1,00 | 0,50 |

Table 4: Thermal transmittances of constructive elements of each technical - regulatory combination

- **Thermal transmittance** U (W/m2K), of the holes in the thermal envelope: Different values have been assigned for the fulfilment of the three scenarios: CTE06, CTE13 y NZEB

| Combinations | | U (W/m²K) Glass | U (W/m²K) frame | U (W/m²K) hole | solar factor |
|---|---|---|---|---|---|
| C1-C4 | CTE06 | Double glass 4-12-4 2,80 | Wood medium - low density 2,00 | 2,60 | 0,58 |
| C5-C8 | CTE13 | Double glass - low emission 4-12-4 (0,1-0,2) 2,00 | Wood medium - low density 2,00 | 2,00 | 0,51 |

| Combinations | | U (W/m²K) Glass | U (W/m²K) frame | U (W/m²K) hole | solar factor |
|---|---|---|---|---|---|
| C9-C12 | NZEB | Double glass - low emission <0,03 4-15-4 1,40 | PVC three coats 1,80 | 1,48 | 0,57 |

Table 5: Transmittances of the holes for each technical - regulatory combination

- **Permeability of the windows** (m3 / hm2) in the thermal envelope: different values have been assigned for the fulfilment of the three scenarios: CTE06, CTE13 y NZEB

| Combinations | | Permeability of windows |
|---|---|---|
| C1-C4 | CTE06 | 27 (casement, good fit and weather strip) |
| C1-C4 | CTE13 | 3 |
| C1-C4 | NZEB | 3 |

Table 6: Permeability of the windows

For each of the regulatory periods CTE06, CTE13, and NZEB, we have considered different heat supply systems; district heating, condensing gas boiler, biomass boiler and heat pump, with the following characteristics:

| Heat supply | Nominal Power (kW) | Electric Power Consumption (kW) | Performance (%) | Accumulation (l) | Solar Contribution (%) |
|---|---|---|---|---|---|
| Distrit Heating | | | | | |
| Caldera de gas | 550 | | 97 | 4.000 | 30 |
| Caldera biomasa | 550 | | 90 | 4.000 | 30 |
| Bomba de calor | 701 | 157 | | | |

Table 7: Heat supply systems: Characteristic

From all these technical variations, we have defined 12 packages of energy solutions as follows:

| Measurement Combination | Combinations |
|---|---|
| Initial | Initial |
| C1 | CTE06 + district heating |

| | |
|---|---|
| C2 | CTE06 + gas boiler |
| C3 | CTE06 + biomass boiler |
| C4 | CTE06 + heat pump |
| C5 | CTE13 + district heating |
| C6 | CTE13 + gas boiler |
| C7 | CTE13 + biomass boiler |
| C8 | CTE13 + heat pump |
| C9 | NZEB + district heating |
| C10 | NZEB + gas boiler |
| C11 | NZEB + biomass boiler |
| C12 | NZEB + heat pump |

Table 8: Full list of solutions analysed

### *Building costs of the 12 variations in the thermal envelope*

The costs associated with the different technical variations of the thermal envelope of the building have been, calculated from the “Base de Datos de Construcción 2014 Valencia“ (Valencian Institute of Building), that in its new edition focuses its efforts on gathering constructive solutions that meet the new requirements contained in the updated DB-HE Basic Document "Energy saving" of CTE, (Order FOM / 1635/2013 of 10th September) aimed at improving the energy efficiency of new buildings and interventions in existing buildings and public spaces.

From the required demands of transmittance (U) of each of the building elements (walls, roofs and holes in the envelope), in order to the fulfilment of the three regulatory periods considered (CTE06, CTE13, NZEB) we have calculated the following costs:

| Constructive Element | U (W/m2K) | Cost (€/m2) | Cost (€/ud) |
|---|---|---|---|
| Facade Insulation | | | |
| CTE06 | 0,73 | 44,13 | |
| CTE13 | 0,24 | 64,71 | |
| NZEB | 0,20 | 95,00 | |
| Roof Insulation | | | |
| CTE06 | 0,41 | 90,97 | |

| Constructive Element | U (W/m2K) | Cost (€/m2) | Cost (€/ud) |
|---|---|---|---|
| CTE13 | 0,22 | 156,91 | |
| NZEB | 0,20 | 200,00 | |
| Windows Insulation | | | |
| CTE06 | 2,00 | | 1.284,82 (*) |
| CTE13 | 2,00 | | 1.284,82 (*) |
| NZEB | 1,80 | | 582,07 (*) |
| Roof Insulation | | | |
| CTE06 | 2,00 | 38,82 | |
| CTE13 | 2,00 | 45,63 | |
| NZEB | 1,80 | 46,42 | |

(*) Average cost of the unit taking into account their useful life (replacement at 20 years)

Table 9: .List of construction costs by variations in the thermal envelope.

The constructive solutions are based on increasing the insulation in facades with rock wool and XPS in roofs. Moreover, the traditional facade has been changed to a ventilated facade by incorporating double insulation.

The different solutions assigned to the holes in windows, involve changes in frames and glazing according to the properties specified in Table 6

✓ **"Bulevar Salburua"**

### *Various energy solutions*

In total, we have defined 9 packages of energy solutions for the analysed building, trying to quantify energy consumption and demand. The ultimate goal is to create three blocks of improvement measures each one corresponding to various regulatory periods related to CTE, covering the period 2006 - 2013 and what could be the future regulation in 2020, incorporating the criteria of Nearly Zero Energy Buildings.

The elements of the different techniques are the following:

**Thermal transmittance** U (W/m2K), of the different solid elements of the thermal envelope of the building (facade, roof, floor, walls). Different values have been assigned for the fulfilment of the three scenarios: CTE06, CTE13 y NZEB

| Combinations | | U (W/m²K) facade | U (W/m²K) roof | U (W/m²K) walls | U (W/m²K) floor |
|---|---|---|---|---|---|
| C1-C3 | CTE06 | 0,66 | 0,21/0,41 | 1,00 | 0,41 |
| C5-C7 | CTE13 | 0,27 | 0,21/0,41 | 0,95 | 0,41 |
| C9-C11 | NZEB | 0,20 | 0,21 | 0,95 | 0,41 |

Table 10: Thermal transmittances of constructive elements of each technical - regulatory combination

**Thermal transmittance** U (W/m²K), of the holes in the thermal envelope. Different values have been assigned for the fulfilment of the three scenarios: CTE06, CTE13 y NZEB

| Combinations | | U (W/m2K) Glass | U (W/m2K) Frame | U (W/m2K) Hole | Solar Factor |
|---|---|---|---|---|---|
| C1-C3 | CTE06 | Low emission 4-6-4 (0,1-0,2) 2,70 | Wood medium – low density 4,00 | 3,09 | 0,52 |
| C5-C7 | CTE13 | Low emission 4-12-331(0,1-0,2) 2,00 | Iron with broken thermal bridge 4-12mm 4,00 | 2,60 | 0,52 |
| C9-C11 | NZEB | Double, low emission <0,03 4-15-6 1,40 | PVC three coats 1,80 | 1,50 | 0,54 |

Table 11: Transmittance of the holes for each technical - regulatory combination

**Permeability of the windows** (m3 / hm2) in the thermal envelope: different values have been assigned for the fulfilment of the three scenarios: CTE06, CTE13 y NZEB

| Combinations | | Permeability of windows |
|---|---|---|
| C1-C3 | CTE06 | 27 (casement, good fit and weather strip) |
| C5-C7 | CTE13 | 27 (casement, good fit weather strip) |
| C9-C11 | NZEB | 3 |

Table 12: Permeability of the windows:

For each of the regulatory periods CTE06, CTE13 and NZEB, we have considered different heat supply systems; district heating, condensing gas boiler, biomass boiler, and heat pump, with the following characteristics:

| Heat supply | Nominal Power (kW) | Electric – Power consumption (kW) | Performance (%) | Accumulation (l) | Solar Contribution (%) |
|---|---|---|---|---|---|
| Cogeneration | 1790+109 | | 93/85 | 10.000 | 0 |
| Gas boiler | 2542 | | 100 | 4.000 | 0 |
| Biomass boiler | 2542 | | 90 | | 0 |

Table 13: Heat supply systems characteristics

From all these technical variations, we have defined 9 packages of energy solutions as follows:

| Measurement Combination | Combinations |
|---|---|
| Initial | Initial + cogeneration |
| C1 | CTE06 + cogeneration |
| C2 | CTE06 + gas boiler |
| C3 | CTE06 + biomass boiler |
| C5 | CTE13 + cogeneration |
| C6 | CTE13 + gas boiler |
| C7 | CTE13 + biomass boiler |
| C9 | NZEB + cogeneration |
| C10 | NZEB + gas boiler |
| C11 | NZEB + biomass boiler |

Table 14: Full list of the analysed solutions.

### *Building costs of the 9 variations in the thermal envelope*

The costs associated with the different technical variations of the thermal envelope of the building have been, calculated from the “Base de Datos de Construcción 2014 Valencia“ (Valencian Institute of Building), which in its new edition focuses its efforts on gathering constructive solutions that meet the new requirements contained in the updated DB-HE Basic Document "Energy saving" of CTE, (Order FOM / 1635/2013 of 10th September) aimed at improving the energy efficiency of new buildings and interventions in existing buildings and public spaces.

From the required demands of transmittance (U) of each of the building elements (walls, roofs and holes), in order to the fulfilment of the three regulatory periods considered (CTE06, CTE13, NZEB) we have calculated the following costs

| Constructive Element | U ($W/m^2K$) | Cost (€/$m^2$) | Cost (€/ud) |
|---|---|---|---|
| Facade Insulation | | | |
| CTE06 | 0,66 | 54,32 | |
| CTE13 | 0,27 | 69,82 | |
| NZEB | 0,20 | 82,02 | |
| Roof insulation | | | |
| CTE06 | 0,21/0,41 | 45,53/ 74,66 | |
| CTE13 | 0,21/0,41 | 45,53/ 74,66 | |
| NZEB | 0,21 | 45,53 | |
| Windows insulation | | | |
| CTE06 | 4,00 | | 507,90 (*) |
| CTE13 | 4,00 | | 507,90 (*) |
| NZEB | 1,80 | | 380,93 (*) |
| Glazing insulation | | | |
| CTE06 | 2,70 | 36,13 | |
| CTE13 | 2,00 | 45,63 | |
| NZEB | 1,40 | 73,45 | |

(*)Average cost of the unit taking into account their useful life (replacement at 20 years)

Table 15: List of construction costs by variations in the thermal envelope.

The constructive solutions are based on increasing the insulation in facades with rock wool and XPS in roofs. Moreover, the traditional facade has been changed to a ventilated facade by incorporating double insulation.

The different solutions assigned to the holes in the facades, involve changes in frames and glazing according to the properties specified in Table 8

# 3 Results of calculation cost effectiveness

## For Spain

Based on the packages of technical solutions we have worked on the Directive 2010, which obliges the Member States to ensure that minimum energy performance requirements for buildings are set to achieve optimum levels of effectiveness.

According to the Article 5, the Commission should establish a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements. In this regard, the European Commission prepared a Delegated Regulation to establish such a comparative methodology framework to be used by Member States for calculating the cost-optimal for new and existing buildings and their components.

To calculate the demand has been used the method "multi-zone time calculation engine, hypothesis, and modelling level" of the 2012 version of the official tool CERMA. For installations, it has been considered a seasonal average.

Energy demand is considered in the calculations of energy for heating, cooling and hot water. In addition, consumption of electrical household appliances is not included in the calculations below.

For this report, It has been considered the following conversion factors final energy to primary, as shown in Table 16.

| | |
|---|---|
| Elect. conventional peninsular | 0,224 tep primary energy /MWh final energy |
| Elect. conventional extra-peninsular<br>(Baleares, Canarias, Ceuta y Melilla) | 0,288 tep primary energy /MWh final energy |
| Elect. conventional in low cost night hours (0-8h),<br>for system for electric accumulation in the peninsula | 0,174 tep primary energy /MWh final energy |
| Elect. conventional in low cost night hours (0-8h),<br>for system for electric accumulation in outside the peninsula | 0,288 tep primary energy /MWh final energy |
| Gas-oil, Fuel-oil y GLP | 0,093 tep primary energy /MWh final energy |
| Natural Gas | 0,087 tep primary energy /MWh final energy |
| Coal | 0,086 tep primary energy /MWh final energy |

Table 16: Conversion Factors from primary energy to final energy

✓ **"Roc Boronat"**

### *Calculation of demand and energy*

The table 17, shows the values obtained from energy demand and consumption, reached by each package of solutions and its energy rating.

| | | | Demand kWh/m² year | Consumption kWh/m² year | Qualification |
|---|---|---|---|---|---|
| Initial | | | 34,50 | 5,80 | A |
| CTE06 | District heating | C1 | 53,20 | 10,00 | B |
| CTE06 | Gas boiler | C2 | 53,20 | 46,60 | C |
| CTE06 | Biomass boiler | C3 | 53,20 | 65,60 | A |
| CTE06 | Heat pump | C4 | 53,20 | 15,70 | C |
| CTE13 | district heating | C5 | 28,50 | 5,50 | A |
| CTE13 | Gas boiler | C6 | 28,50 | 27,40 | B |
| CTE13 | Biomass boiler | C7 | 28,50 | 40,90 | A |
| CTE13 | Heat pump | C8 | 28,50 | 9,10 | B |
| NZEB | district heating | C9 | 22,80 | 4,60 | A |
| NZEB | Gas boiler | C10 | 22,80 | 21,80 | A |
| NZEB | Biomass boiler | C11 | 22,80 | 33,10 | A |
| NZEB | Heat pump | C12 | 22,80 | 7,50 | A |

Table 17: Full list of the analyzed solutions.

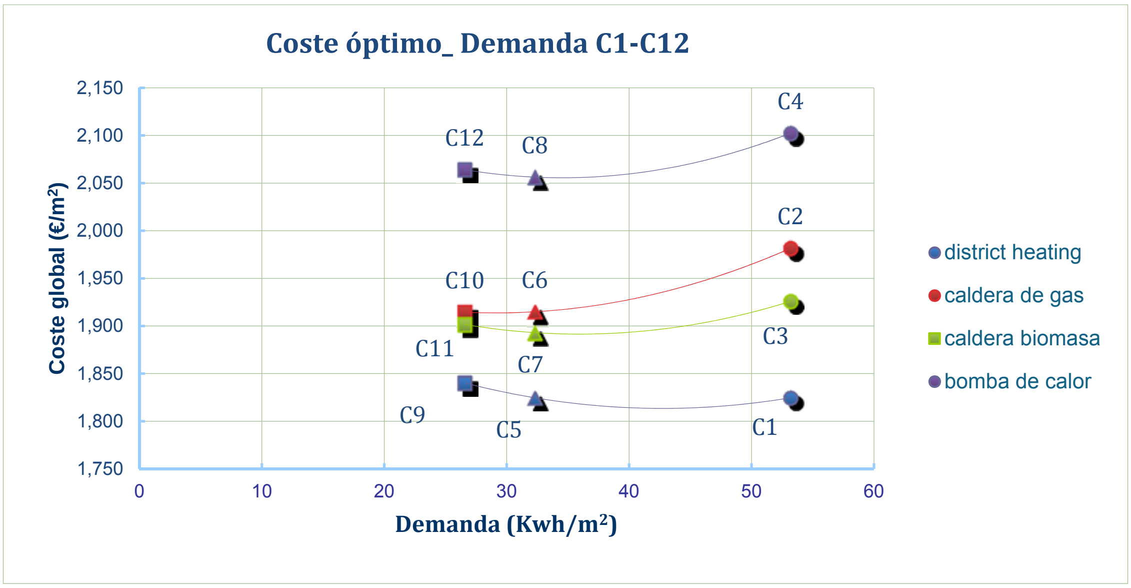
### *Results*

In the following two graphs, we present the results of calculations for the 12 essential packages of technical solutions in which we worked on the development of "Roc Boronat." The figures show the differences in costs compared to the requirements of each solution.

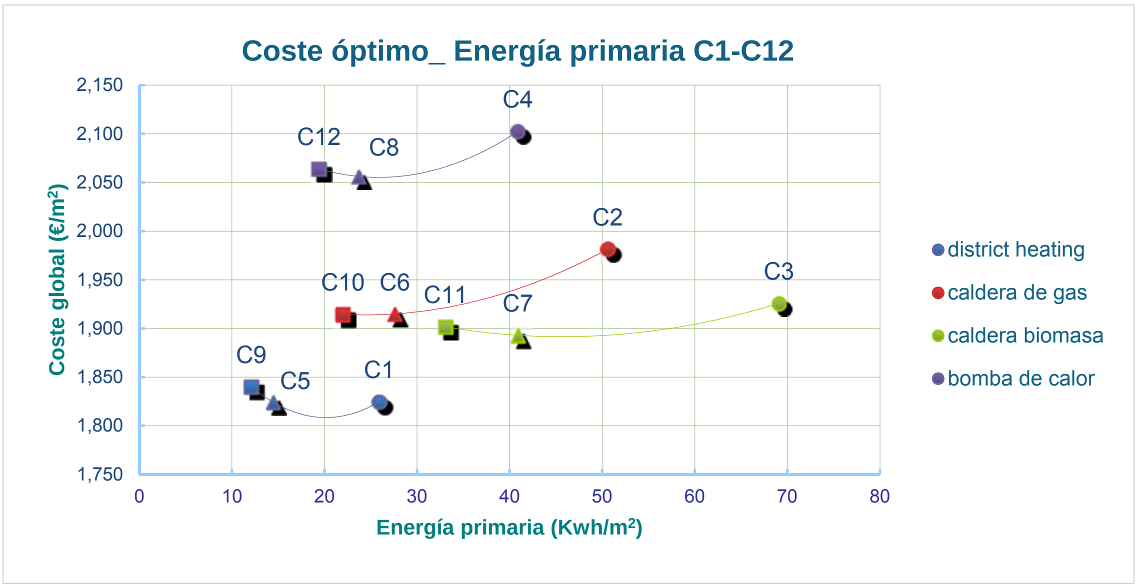
 Graph 1: It Represents energy demand (kWh / m2) of each of the 12 technical solutions in relation to the overall cost (€ / m2). The solutions are grouped by colours representing each defined heat supply (district heating, gas boiler, biomass boiler and heat pump). Also, by figures of each defined regulatory period (square_NZEB, triangle_CTE13, circle_CTE06)

 Graph 2: It Represents the primary energy (kWh / m2) of each of the 12 technical solutions in relation to the overall cost (€ / m2). Solutions grouped by colors are represented, for each defined supply heat (district heating, gas boiler, biomass boiler and heat pump)

Also by figures of each defined regulatory period (square_NZEB, triangle_CTE13, circle_CTE06)




Graph 1: Optimal-cost .Demand C1-C12




Graph 2, Optimal-cost. Primary energy C1-C12

✓ **"Bulevar Salburua"**

### *Calculation of demand and energy consumption*

The Table 18, shows the values obtained from energy demand and consumption reached by each package of solutions and its energy rating.

| | | | Demand kWh/m² year | Consumption kWh/m² year | Qualification |
|---|---|---|---|---|---|
| Inicial | | | 44,10 | 41,15 | A |
| CTE06 | Cogeneration | C1 | 56,10 | 51,90 | B |
| CTE06 | Gas boiler | C2 | 56,10 | 52,40 | B |
| CTE06 | Biomass boiler | C3 | 56,10 | 80,80 | B |
| CTE13 | Cogeneratión | C5 | 43,20 | 40,32 | A |
| CTE13 | Gas boiler | C6 | 43,20 | 40,10 | A |
| CTE13 | Biomass boiler | C7 | 43,20 | 63,20 | A |
| NZEB | cogeneration | C9 | 28,10 | 26,82 | A |
| NZEB | Gas boiler | C10 | 28,10 | 26,10 | A |
| NZEB | Biomass boiler | C11 | 28,10 | 42,10 | A |

Table 18: Full list of the analysed solutions

### *Results*

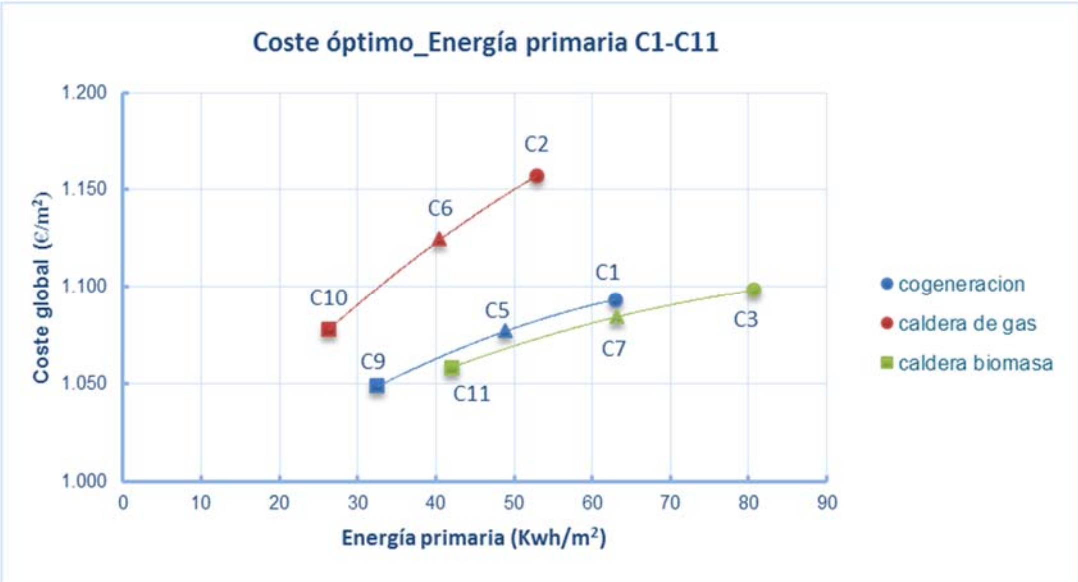
In the following two graphs, the results of calculations for the 9 essential packages of technical solutions which worked on the development of "Bulevar Salburua" are presented. The figures show the differences in costs compared to the requirements of each solution.

- Graph 3: It represents energy demand (kWh / m2) of each of the 9 technical solutions in relation to the overall cost (€ / m2). The solutions are grouped by colors representing each defined heat supply (district heating, gas boiler, biomass boiler and heat pump). Also by figures of each defined regulatory period (square_NZEB, triangle_CTE13, circle_CTE06)

- Graph 4: It represents the primary energy (kWh / m2) of each of the 9 technical solutions in relation to the overall cost (€ / m2). Solutions grouped by colors are represented, for each defined supply heat (district heating, gas boiler, biomass boiler and heat pump)

Also by figures of each defined regulatory period (square_NZEB, triangle_CTE13, circle_CTE06)


Gráfica 4: Optimal-cost  Demand C1-C11




Gráfica 5: Optimal-cost. Primary energy C1-C11

# 4 Conclusions and Recommendations

## For Spain- General conclusions

It is difficult in Spain, to find samples of social housing buildings, with an energy rating "A". Besides, the buildings selected are not yet fully occupied, so the monitoring results are not yet reliable.

There is a lack of information on the costs of maintenance and a more or less stable market regarding other centralized systems, but unfortunately not relating to the aforesaid solutions for the building elements. It is also important to consider the poor building maintenance culture in Spain, a fact that has led the housing sector to premature aging in need of major repair and renovation, which leave little room for energy efficiency.

The lack of a "culture of maintenance" has also led that the solar system installations even in new buildings in which, the maintenance is compulsory under current regulations in Spain, are not working properly and are used systematically to support the heating equipment. It would be absurd to install efficient and innovative equipment if subsequently are not maintained. It is a mixed question of misinformation, lack of compliance with certain laws, negative practices and habits ... that leads to many problems, not only for energy efficiency.

There are currently in the market, innovative solutions for the design of NZE buildings, but its diffusion is too poor and consequently, the implementation also slow. It increases by the uncertainty about the savings they can achieve, and the inertia of a construction sector still rather conservative in Spain, with some reluctance towards the use of new solutions. In addition, we have a lack of validated expertise. To achieve good energy rating -A- is crucial to design a building without energy losses (good insulation) and connected to a "district heating" in the promotion and construction of public housing.

The end users, both rented and owned, are usually persons with low incomes, so it is necessary to implement highly efficient systems, to enable them to reach energy savings.

## For Spain- “Roc Boronat”- Optimal-Cost

First and generally, the graphs show that the curves for the variants of a heat supply system (with variations in the thermal envelope) generally show a horizontal trend. If you look, for example, the cost curve for the variant of "biomass boiler" which represents a gradual improvement of the building envelope from the requirements (CTE-06, CTE13 and NZEB), the variation of cost is only 33 € / m2 during the calculation period of 30 years. This represents only 9 cents / m2 and month. Each of the variants of heat supply has a slight optimal cost-value for CTE13 requirements, both values as primary energy demand. However, differences in costs are very small in its trend toward NZEB. Only when we compare solutions by introducing variants of heat supply more "cost gap" occurs. For example, comparing the C8 (CTE13-heat pump) and C5 (CTE13-district heating) solutions, with the same thermal envelope solution, the change in cost is 231 € / m2 during the calculation period of 30 years. This represents 65 cents / m2 and month. That is, in the cost analysis, until the optimal value, the calculation is much more sensitive to the choice of the heat delivery system that improves the thermal envelope. We can see as originally designed district heating in the building presents the overall lower costs compared to other systems. On the contrary, the heat pump appears to be the most expensive. This fact is justified by the price forecast is higher than in other energies. Surprisingly the biomass system, generates greater consumption, although the cost is very close to the district heating.

Comparing all technical variants of both the thermal envelope, and delivery systems heating / cooling, the global optimum cost corresponds to the solution of CTE13_District heating, as shown in Table 19.

| Optimal – Cost | | | |
|---|---|---|---|
| Supplies | Periods | | |
| | CTE06 | CTE13 | NZEB |
| Heat pump | C4<br>2.103 | C8<br>2.056 | C12<br>2.064 |
| Gas boiler | C2<br>1.962 | C6<br>1.915 | C10<br>1.914 |
| Biomass boiler | C3<br>1.926 | C7<br>1.893 | C11<br>1.902 |
| District heating | C1<br>1.825 | C5<br>1.825 | C9<br>1.840 |

Table 19: Global Optimal-Cost

For each delivery system heating / cooling, the optimal cost is shown in Table 21. While it is observed that the optimal cost largely corresponds to CTE13 solutions, this is slightly higher than the costs obtained for NZEB, reducing the cost of energy from being minor.

Looking, for example, at the cost curve for the variant of "biomass boiler", to move from a C7 (CTE13) solution to C11 (NZEB), with a cost increase of 4%, a decrease of 19% in primary energy is obtained.

| Optimal Cost | | | |
|---|---|---|---|
| Supplies | Periods | | |
| | CTE06 | CTE13 | NZEB |
| Heat pump | C4<br>2.103 | C8<br>2.056 | C12<br>2.064 |
| Gas boiler | C2<br>1.962 | C6<br>1.915 | C10<br>1.914 |
| Biomass boiler | C3<br>1.926 | C7<br>1.893 | C11<br>1.902 |
| District heating | C1<br>1.825 | C5<br>1.825 | C9<br>1.840 |

Table 20: Optimal-Cost by supply system cold/heat

The climatic conditions of Barcelona, cannot be considered extremes, there are four cold months and two hot months, so no major energy efforts (economic) are needed to achieve energy efficiency in building.

 The results of the monitoring are not definitive because it is necessary to repeat that process once the building is fully occupied. So that we can see if this social housing promotion is energy (and economic) efficient.

## For Spain- “Bulevar Salburua”- Optimal-cost

First and generally, the graphs show that the curves for the variants of a heat supply system (with variations in the thermal envelope) generally show an increasing trend. If we look, for example, the cost curve for the variant of "biomass boiler" which represents a gradual improvement of the building envelope from the requirements (CTE-06, CTE13 and NZEB), although the trend is increased, The variation of the cost is only 40 € / m2 during the calculation period of 30 years. This represents only 11 cents / m2 by month. Each of the variants of heat supply has a small optimal-cost value for CTE13 requirements, both values as primary energy demand. However, differences in costs are very small in its trend toward NZEB.

Only when we compare solutions by introducing variants of heat supply more "cost gap" occurs. For example, comparing the C1 (CTE 06-CHP) and C2 (CTE06-gas-boiler) solutions, with the same thermal envelope solution, the change in cost is 231 € / m2 during the calculation period of 30 years. This represents 65 cents / m2 and month. That is, in the cost analysis, until the optimal value, the calculation is much more sensitive to the choice of the heat delivery system that improves the thermal envelope.

It can be seen as the originally designed cogeneration system presents the overall lower costs compared to other systems. On the contrary, the gas-boiler appears to be the most expensive. This fact is justified by the price forecast is higher than in other energies. Surprisingly the biomass equipment generates greater consumption, although the cost is very close to the district heating.

 Comparing all technical variants of both the thermal envelope, and delivery systems heating / cooling, the global optimum cost corresponds to the solution of NZEB-Cogeneration, as shown in Table 21.

| Optimal - Cost | | | |
|---|---|---|---|
| Supplies | Periods | | |
| | CTE06 | CTE13 | NZEB |
| Gas boiler | C2<br>1.157 | C6<br>1.124 | C10<br>1.078 |
| Biomass boiler | C3<br>1.098 | C7<br>1.084 | C11<br>1.058 |
| Cogeneration | C1<br>1.093 | C5<br>1.077 | C9<br>1.049 |

Table 21: Optimal-Cost by supply system cold/heat

For each delivery system heating / cooling, the optimal cost is reflected in Table 22. We can see that the optimal-cost mainly corresponds to solutions NZEB, being common to all graphs that at a lower cost, corresponds a greater decrease in energy. The cost is less than the decrease of energy obtained

| Optimal - Cost | | | |
|---|---|---|---|
| Supplies | Periods | | |
| | CTE06 | CTE13 | NZEB |
| Gas boiler | C2<br>1.157 | C6<br>1.124 | C10<br>1.078 |
| Biomass boiler | C3 | C7 | C11 |

| | | | |
|---|---|---|---|
| | 1.098 | 1.084 | 1.058 |
| Cogeneration | C1<br>1.093 | C5<br>1.077 | C9<br>1.049 |

Table 22: Optimal-Cost by supply system cold/heat

The climatic conditions of Vitoria, cannot be considered extremes, there are four cold months and two hot months, so no major energy efforts (economic) are needed to achieve energy efficiency in building.

The results of the monitoring are not totally real because it is necessary to repeat that process once the building is fully occupied. So that we can see if this social housing promotion is energy (and economic) efficient.

# 5 Cost optimal general conclusions

As a general conclusion, we found the difficulty of applying the methodology of the optimal cost, given that some of the data on costs, necessary to apply this methodology, are difficult to quantify and should not have been considered or has had to resort to some hypotheses, as in the case of maintenance costs.

It was found that in the evaluation of the optimal cost parameters related to the heating supply system are much more sensitive than those relating to the improvement of the thermal envelope.

In general it is difficult to assess the impact of user behaviour, variable not included in the calculation method. Our experience has shown that the misbehaviour of users can produce differences compared to values calculated between 10 and 30%.

Finally, it is concluded that a building designed following long term economic profitability criteria will be always more energy efficient that if it is only designed following the Construction Code actual requirements. The knowledge generated can be useful to define the NZEB concept and can have very important political implications, because it challenges the idea that high energy efficiency regulations are prohibited due to the high costs that it requires.

For further information, please visit www.powerhouseeurope.eu

Co-funded by the Intelligent Energy Europe
Programme of the European Union