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# Cost-efficient Nearly Zero-Energy Buildings (NZEBs)

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**Abstract**. The next level of energy performance of new buildings within the European Union will be the Nearly Zero-Energy Building (NZEB). A lot of work has been spent on pilot and demonstration buildings on this and even higher energy performance levels throughout many EU countries. However, most of the high performance buildings realised so far result in additional investment costs when compared to the current national minimum energy performance requirements. The considerably higher investment costs are one of the main barriers to the early application of the NZEB-level in Europe. The EU Horizon 2020 project CoNZEBs works on technical solution sets that result in lower investment costs for NZEBs, bringing the costs close to those of conventional new buildings. The project focus is on multi-family houses. In each of the four participant countries Germany, Denmark, Italy and Slovenia a team of researchers is analysing which sets of market-ready technologies at the building envelope, the services systems for heating, domestic hot water, ventilation and cooling (where required) in combination with renewable energy systems can fulfil the NZEB requirements at lower costs than those incurred by the national mainstream NZEB application. Additional efforts are being spent on the life-cycle costs and the life-cycle analysis of the solution sets, as well as on the impact of future developments of primary energy factors, energy costs and technology efficiencies. Since details of the CoNZEBs work are presented in several additional papers, this document gives an overview of the different tasks and results that are available so far.

## 1. Introduction

The next level of energy performance of new buildings within the European Union will be the Nearly Zero-Energy Building (NZEB). The EU Member States are obliged to define the minimum energy performance requirements for the NZEB building level that will be in force for new public buildings from 2019 and for all new buildings from 2021 according to the Energy Performance of Buildings Directive (EPBD), [1]. A lot of work has been spent on pilot and demonstration buildings on this and even higher energy performance levels throughout all EU countries as reported e.g. by the Concerted Action EPBD [2], an EU country platform to support the implementation of the EPBD. However, most of the high performance buildings result in higher investment costs when compared to the current national minimum energy performance requirements. Concerted Action EPBD has published a report [3] in which the average of the additional investment costs was determined to be 11% of the total building costs or slightly above 200 €/m² based on 32 international built examples. The considerably higher investment costs are one of the main barriers to the early application of the NZEB-level in Europe.

The EU H2020 project CoNZEBs [4] (Solution sets for the Cost reduction of new Nearly Zero-Energy Buildings) works on technical solution sets that result in lower investment costs for NZEBs

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bringing the costs close to those of conventional new buildings. The focus is on multi-family houses. In each of the four participating countries Germany, Denmark, Italy and Slovenia a team of researchers is analysing which sets of market-ready technologies at the building envelope, the services systems for heating, domestic hot water (DHW), ventilation and cooling (where required) in combination with renewable energy systems can fulfil the NZEB requirements with lower costs than those of the national mainstream NZEB application. The identified solution sets and their included technologies are described in detail as result of the work. It is also analysed whether a solution set is transferable to other EU countries. All these calculations are based on four typical national multi-family houses taking into account the different building cultures of the four countries. Additional efforts are being spent on the life-cycle costs (LCC) and the life-cycle analyses (LCA) of the solution sets as well as on the impact of future developments of primary energy factors, energy costs and technology efficiencies. CoNZEBs works together closely with stakeholders such as housing organisations and housing associations which will pave the way for realising the cost-efficient solution sets in practice. National advisory boards consisting of ministry officials and staff members of subordinate authorities or energy agencies give feedback about the work in general and especially on the practicability of the solution sets with regard to the legal frameworks. A specific task focuses on the public acceptance of the NZEB buildings including end-user questionnaires and a brochure on experiences and co-benefits of living in NZEBs. Figure 1 gives an overview of the approaches towards cost-effective NZEBs included in the CoNZEBs project.

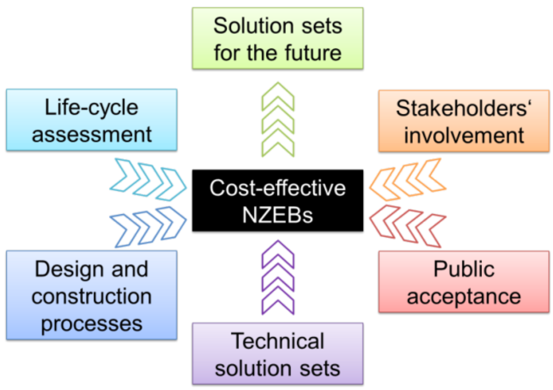


**Figure 1.** Different approaches towards cost-effective nearly zero-energy buildings included in the EU Horizon 2020 project CoNZEBs.

## 2. Setting the baseline: Investment costs for three different energy performance levels

In order to identify the currently existing investment cost gap for multi-family houses each national team has collected investment costs of buildings realised on three different energy performance levels:

1. Minimum energy performance requirements
2. Nearly zero-energy buildings (NZEBs)
3. Beyond NZEBs

The collected cost data includes the total building costs, costs for the building components and services systems costs and annual energy costs where available. Figure 2 presents the identified investment costs for building components and services systems of 46 German multi-family houses related to the specific living area. The national case studies present buildings of the housing organisations involved in the project, demonstration buildings of the included research partners and data from internet research or other publications.

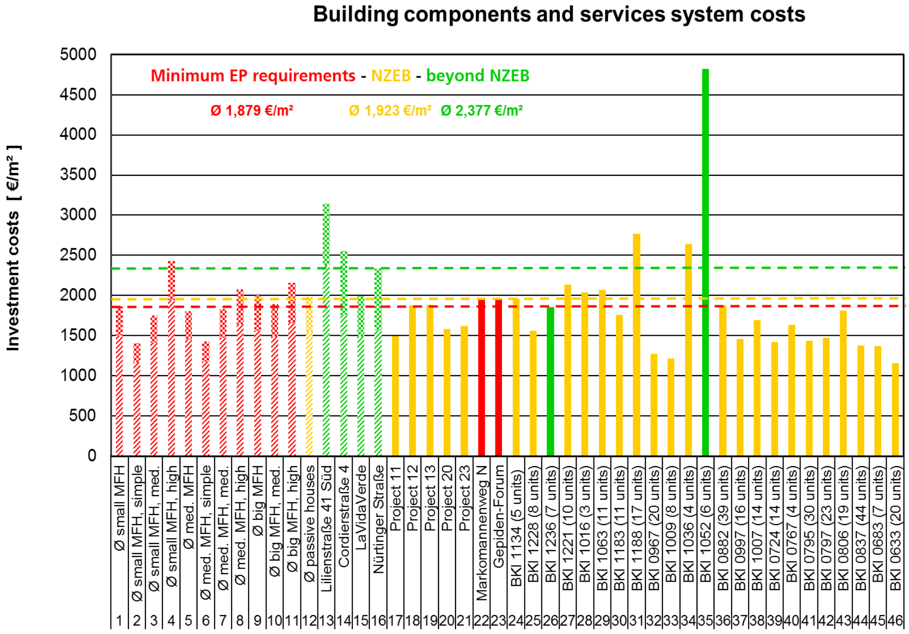


**Figure 2.** Investment costs for building components and services systems of German multi-family houses on three different energy performance levels.

Based on a total of 79 case studies, national average cost gaps between multi-family houses fulfilling the minimum energy performance requirements and nearly zero-energy buildings have been identified as presented in Table 1. It has to be noted, though, that in some countries it was difficult to find a statistically significant number of cases for representing all three energy performance levels. Based on the available data, the determined average investment-cost differences range between 44 €/m² living area in Germany and 229 €/m² useful area in Italy [5].

**Table 1.** Average investment cost difference between NZEBs and buildings built according to the minimum energy performance requirements in Germany, Denmark, Italy and Slovenia.

| Country | Difference of the average investment costs for building components and building services systems of the NZEB and the minimum energy performance building level |
|---|---|
| Germany | 44 €/m² living area[1] (= 45 €/m² net floor area) |
| Denmark | 65 €/m² gross floor area[2] (= 72 €/m² net floor area) |
| Italy | 229 €/m² useful area[3] (= net floor area) |
| Slovenia | 104 €/m² conditioned net floor area[4] (= net floor area) |

[1] Floor area defined in [6] as "Wohnfläche" and used as the basis for calculating the rent of dwellings. It basically comprises the net floor area of all rooms, but employs a reduction factor for room parts with low heights; besides, it adds the areas of balconies (also with a reduction factor).

[2] Total floor area of the building including the external walls.

[3] Italian "superficie utile" as defined in [7]. The area is equal to the net floor area, thus being the gross floor area minus the construction area (external and internal walls).

[4] Only the net floor area of the rooms that are conditioned (heated or cooled) is taken into account.

## 3. Cost savings at the design and construction processes

Literature research and a questionnaire for designers and construction companies gave insight into the average cost distribution of newly built residential buildings. In the participating countries the following average design costs have been identified [8]. Unfortunately they relate to different sums of cost groups, as used in national studies or scales of fees for services of architects and engineers:

- Germany 13% of the total building costs (median costs)
- Denmark 8 - 15% of the total construction costs

- Italy 8% of the total building costs (7% for minimum requirement buildings and 9% for NZEBs)
- Slovenia 4% of the costs for construction, finishing and installation works

The project also investigated how cost savings can be achieved in the design and construction processes. Studies were either conducted within the project or collected by literature research. Below, some of the identified measures at the building envelope and the service systems are listed, that seem to be promising, especially in the countries indicated:

- Large autoclaved concrete blocks (Italy): 48% time saving for building the external walls
- Mono-block windows (Italy): 20% cost saving, 60% time saving
- Roof-integrated photovoltaic (Denmark): 28% cost savings if compared to a conventional roof with added PV
- Hygro-sensitive ventilation (Slovenia): reduced ventilation rate leads to less heating energy demand and thus can compensate for slightly less insulation
- Cross-laminated timber panels instead of conventional walls (Slovenia): higher investment costs but significantly shorter construction time
- Unheated external staircases (Germany): reduction of the surface-to-volume ratio leads to lower heating energy use and lower costs due to a reduced façade area. As a rule of thumb: A reduction of the surface-to-volume ratio by 0.1 $m^{-1}$ results in decreasing the heating energy demand by up to 10 $kWh/m^2yr$ while saving building costs of 50 to 80 €/m² under current German boundary conditions.

CoNZEBs also studied possible cost savings due to different planning and construction processes. In many countries, experts rate the use of pre-fabricated building components as cost-saving in the future. The project could however not find any quantitative results of corresponding studies. The use of Building Information Modelling (BIM) is also creating high hopes for various advantages [9]. On the other hand, only few studies [10], [11], [12] could be found that present quantitative data with potential cost-savings between of 1.9% and 7%.

## 4. Cost savings due to alternative energy concepts

The CoNZEBs partners have conducted detailed studies comparing the conventional national way of building NZEBs with alternative energy concepts for NZEBs that can save investment costs [13]. For this purpose, three steps have been performed in the four participant countries:

1. Definition of a typical national multi-family house
2. Definition of the typical national NZEB solution as base case
3. Identifying alternative energy concepts fulfilling the NZEB requirements with lower investment costs

The typical NZEB solutions differ between the countries. While for example the German and Slovenian typical NZEB solutions contain a central heating system based on a gas condensing boiler in combination with solar thermal collectors, the Danish concept is based on district heating while the Italian concept features an air-to-water heat pump. The other components of the energy concept, e.g. the ventilation system, the domestic hot water generation and the thermal quality of the building envelope, are country-dependent as well. The national standard calculation methods for determining the energy performance of buildings have been chosen as calculation methods. The investment costs and energy tariffs are based on national cost databases and the experience of the national teams. In total, the project team was able to identify 20 solution sets (at least 3 per country and climate) that meet the goal of achieving lower investment costs. These include:

- For Germany: a) Decentral electrical space heating and DHW system combined with roof PV b) district heating as combined space heating and DHW system
- For Denmark: a) DHW solar heating, b) decentral mechanical ventilation and roof PV
- For Italy: a) Air-to-water heat pump for both, heating and DHW, b) direct electrical heating with roof PV

- For Slovenia: a) District heating as combined space heating and DHW system, b) air-to-water heat pump for either both, space heating and DHW or for DHW only, then in combination with a condensing boiler for heating

All solution sets are balanced by reduced or increased insulation levels at the building envelope and variations of ventilation systems with different heat recovery rates. Investment cost savings are derived from either alternative service system components (including partly omitted distribution systems) or from reduced insulation levels. Additional single investment cost-saving technologies are more efficient insulation material in the external walls, large autoclaved concrete bricks, mono-block windows, hygro-sensitive ventilation and decentral heat recovery from shower wastewater.

## 5. End-user survey and guide

In order to promote living in nearly-zero energy buildings the project team has investigated end-users' expectations and experiences with NZEBs and has compiled a brochure containing useful information about these high performance buildings. Figure 3 shows as one of the survey results [14] the decision triggers for moving into an NZEB as stated by people that live currently in such a building. The most important decision triggers in average are nice new apartments, good thermal comfort and low energy costs. Figure 4 presents the title page of the brochure [15] (German language version) with the gathered experiences, expectations, benefits and a case study from each participant country.

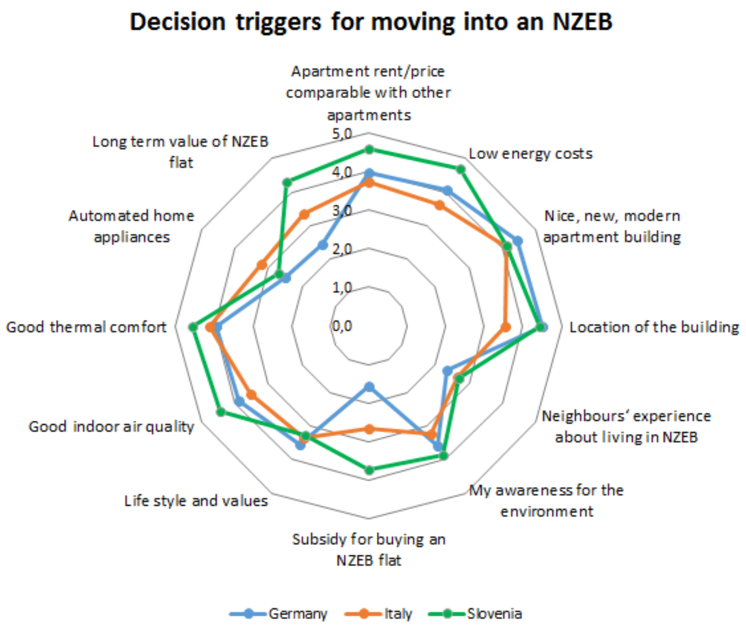


**Figure 3.** Comparison of decision triggers for moving into an NZEB. Survey among current NZEB end-users.


**Figure 4.** Title page of the German version of the brochure „Why Nearly Zero-Energy Buildings are the Right Choice".

## 6. Next steps

The CoNZEBS partners are currently working on the life-cycle cost and life-cycle assessment of the different solution sets. Another focus will be on the evolving parameters for the calculation, such as the energy tariffs, primary energy factors, technology efficiencies and costs, etc. All results will be presented and discussed during national events involving the main stakeholders of the multi-family housing sector in 2019.

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