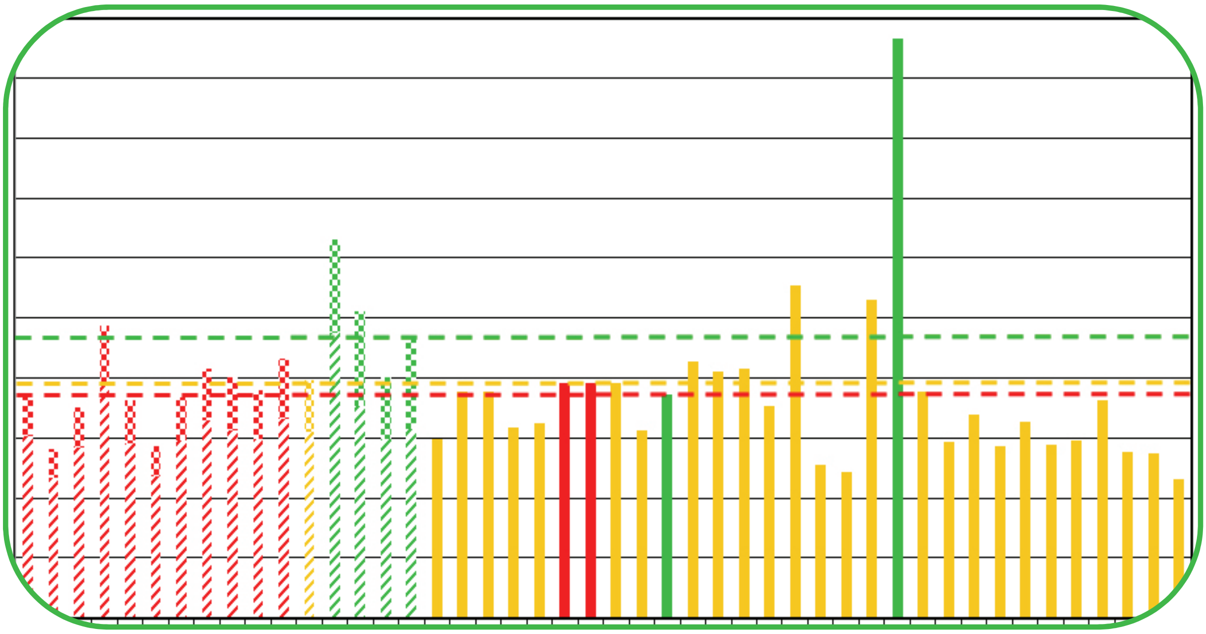

Solution sets for the Cost reduction of new Nearly Zero-Energy Buildings – CoNZEBs

EU H2020-EE-2016-CSA

Projekt ID: 754046

Overview of Cost Baselines for three Building Levels

Deliverable D2.1

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Content

About CoNZEBs

This report is one of the outcomes of the work within CoNZEBs. CoNZEBs is an EU Horizon 2020 project on the topic 'Cost reduction of new Nearly Zero-Energy Buildings' (call H2020-EE-2016-CSA, topic EE-13-2016). As such it receives co-funding by the European Union under the Grant Agreement No. 750046. The project period is from 01/06/17 to 30/11/19.

The planned work can be summarised as follows:

CoNZEBs identifies and assesses technology solution sets that lead to significant cost reductions of new Nearly Zero-Energy Buildings. The focus of the project is on multi-family houses. Close cooperation with housing associations allows for an intensive interaction with stakeholders and tenants. The project starts by setting baseline costs for conventional new buildings, currently available NZEBs and buildings that go beyond the NZEB level based on the experience of the consortium. It analyses planning and construction processes to identify possible cost reductions.

An investigation of end-users' experiences and expectations together with a guide on co-benefits of NZEBs promotes living in these buildings and enhances the energy performance by conducive user behaviour.

The technology solution sets include approaches that can reduce costs for installations or generation systems, pre-fabrication and construction acceleration, local low temperature district heating including RES, and many more. All solution sets are assessed regarding cost savings, energy performance and applicability in multi-family houses. A life cycle assessment of different building levels and NZEBs using the solution sets provides a longer term perspective.

Communication to stakeholders and dissemination of the project results includes events and discussions with the national housing associations.

The CoNZEBs project team consists of 9 organisations from 4 different countries:

Table 1: Project partners within the CoNZEBs consortium

Project partner		Country	Website
1	Fraunhofer Institute for Building Physics (Coordinator)	Germany	www.ibp.fraunhofer.de
2	Aalborg Universitet	Denmark	www.sbi.aau.dk
3	Kuben Management AS	Denmark	http://kubenman.dk
4	Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile (ENEA)	Italy	www.enea.it/en
5	Gradbeni Institut ZRMK doo	Slovenia	www.gi-zrmk.si/en
6	ABG Frankfurt Holding Wohnungsbau- und Beteiligungsgesellschaft mit beschränkter Haftung	Germany	www.abg-fh.com
7	Boligselskabernes Landforening (BL)	Denmark	www.bl.dk/in-english
8	Azienda Casa Emilia Romagna della Provincia die Reggio Emilia (ACER Reggio Emilia)	Italy	www.acer.re.it
9	Stanovanjski Sklad Republike Slovenije, Javni Sklad (SSRS)	Slovenia	http://ssrs.si/

In Germany, national co-funding is provided by Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit within the research initiative Zukunft Bau (SWD-10.08.18.7-17.33).

1. Introduction

This report documents the work of the CoNZEBs project on setting the cost baselines for different building energy performance levels. It analyses and compares the investment and energy costs in four different countries (Germany, Denmark, Italy and Slovenia) for:

- New multi-family houses built according to current national minimum energy performance requirements
- Existing examples of NZEBs (nearly zero-energy building) multi-family houses
- Multi-family houses that go beyond the NZEB-level

The work is based on literature on building costs, on the knowledge gained by the different research organisations and complemented by the cost experience of the national housing organisation. The work of Concerted Action EPBD on NZEBs is used as well.

The result of these efforts is the starting point (baseline) for evaluating the technical solution sets for nearly zero-energy buildings that were identified to reduce the additional costs currently required to build a better energy performing multi-family house than determined by the minimum energy performance level of the national building laws. This exercise will be documented in deliverable D2.2 "Comparison of costs for new multi-family houses, NZEBs and beyond".

2. The different building levels

While the three building energy performance levels to be investigated in this report are described with the same three terms (new multi-family houses built according to current national minimum energy performance requirements, existing examples of NZEBs multi-family houses, multi-family houses that go beyond the NZEB-level) for all four countries, they represent different building levels in reality, influenced by national building legislation, calculation methods, building culture, climate, and many other factors. The following chapters describe the three building levels for each country.

2.1 New multi-family houses built according to current national minimum energy performance requirements (status as of 2017)

Minimum energy performance requirements for new buildings, but also for existing buildings in case of major renovations, have been determined in most EU Member States before the Energy Performance of Buildings Directive (Directive 2002/91/EC, [1]) cam into force. In the recast of the Energy Performance of Buildings Directive (Directive 2010/31/EU, [2]), the EU Member States were required to perform so-called cost-optimum calculations based on reference buildings in order to compare their minimum energy performance requirements with cost-optimum energy performance levels. For a few countries this led to a tightening of the minimum energy performance requirements. Several countries had similar regular checks for a possible tightening based on economic assessments in place and therefore their requirements were already on a cost-optimal level. The next round of cost-optimal calculations is coming up in 2018. In parallel (connected to it or not) further tightening of energy performance requirements is planned in the Member States.

2.1.1 Germany

The currently valid German minimum energy performance requirements for buildings are defined in the energy saving ordinance EnEV (Energieeinsparverordnung, [DE 1]), which includes further tightening valid from May 2015 onwards compared to 2013. For new residential buildings the requirements are defined in Article 3. The article requires that new residential buildings have to meet the maximum annual primary energy demand for space heating, domestic hot water, ventilation and cooling of a mirror baseline building (in the EnEV called “reference building”) of the same geometry, usable floor area and orientation, using the technical characteristics defined in Annex I, table 1 (so-called reference technologies). The further tightening from May 2015 is represented by a reduction of the primary energy demand resulting from the listed reference technologies by factor 0.75 (25% tightening compared to 2013).

Table 2: Technical characteristics of the mirror baseline building, [DE 1]

Building component/service systems	Reference technologies	
External wall, ceilings to outside air	U-value	0.28 W/m²K
External wall to ground, floor slab, walls and ceilings to unheated zones	U-value	0.35 W/m²K
Roof, ceilings to attic, jamb walls	U-value	0.20 W/m²K
Windows, glazed doors	U-value	1.3 W/m²K
	g-value	0.60
Roof windows	U-value	1.4 W/m²K
	g-value	0.60
Domelights	U-value	2.7 W/m²K
	g-value	0.64
External doors	U-value	1.8 W/m²K
Thermal bridge surcharge	Δ U	0.05 W/m²K
Airtightness of the building envelope	With available airtightness test / category 1	
Solar shading	Without solar shading system	
Heating system	• Oil condensing boiler (improved) • ≤ 500 m² usable floor area: located within the heated zone, > 500 m² usable floor area: located outside the heated zone • Supply/return temperature: 55/45 °C, central distribution within the heated zone, central distribution pipes, standard pipe lengths, pump demand control with constant pressure difference control, heating network hydraulically balanced • Delivery via free static heating surfaces located at external walls, thermostats with 1 K proportional band	
Domestic hot water system	• Central DHW system, in combination with heating • Solar flat plate collector and storage as defined in DIN V 18599-8, table 15 respectively DIN V 4701-10, table 5.1-10 • Distribution within the heated zone, central distribution pipes, common installation wall, standard pipe length • With circulation	
Cooling	No cooling system	
Ventilation	Central exhaust system, demand-controled with DC fan	

Additionally the building must not exceed the maximum value of the transmission heat loss coefficient defined in Annex I, number 1.2.

Table 3: Maximum values of the transmission heat loss coefficient related to the building envelope area, [DE 1]

Building type		Maximum specific transmission heat loss coefficient
Detached residential buildings	$A_N^* \leq 350$ m²	$H'_T = 0.40$ W/m²K
	$A_N^* > 350$ m²	$H'_T = 0.50$ W/m²K
Semi-detached residential buildings		$H'_T = 0.45$ W/m²K
All other residential buildings		$H'_T = 0.65$ W/m²K
Extensions of buildings		$H'_T = 0.65$ W/m²K

* A_N = 0,32 * heated gross building volume

The annual primary energy demand has to be calculated by using either

a) DIN V 18599:2011-12 [DE 2] with some adjustments made to certain parts of the standards in 2013 or
b) DIN V 4108-6: 2003-06 [DE 3] and DIN V 4701-10:2003-08 [DE 4] (in case of no cooling system) with the climate data specified in DIN V 18599-10: 2011-12 (region Potsdam).

Both standards are monthly balancing methods. If building or services systems technologies are used that can't be assessed using generally recognised codes of practice or reliable experience values, dynamic simulations using the same boundary conditions as the standards may be applied. Both, the mirror baseline building and the real building have to be calculated with the same standard(s).

Annex I, number 3 contains definitions for the heat protection in summer. The requirements are laid down in DIN 4108-2:2013-02 [DE 5] section 8. The heat protection in summer can be either proven by comparing the solar transmittance value of the planned building with the maximum allowable solar transmittance value or by performing a dynamic simulation using defined boundary conditions, ascertaining that the maximum excess temperature degree hours (1,200 Kh/year for residential buildings) is not exceeded. Both proofs have to be performed for the rooms running the highest risk of overheating.

The solar transmittance of the real building is dependent on the window area, the solar heat gain coefficient of the glazing, the reduction factors for solar shading systems and the net floor area of the room. The maximum allowable solar transmittance value is dependent on the climate region, the building mass, possible night ventilation or other passive cooling, the window area related to the net floor area, a possible solar glazing and the window inclination and orientation.

In case of an available cooling system, investments into summer heat protection only have to be realised if they can be amortised within the useful lifespan of the building.

Annex 4 defines the minimum airtightness of buildings. The maximum air change rate at 50 Pa pressure difference is:

- For buildings without ventilation systems: 3.0 h^{-1}
- For buildings with ventilation systems: 1.5 h^{-1}

Buildings with air volumes greater than 1,500 m³ need to meet maximum air change rates at 50 Pa pressure difference of:

- For buildings without ventilation systems: 4.5 $m*h^{-1}$
- For buildings with ventilation systems: 2.5 $m*h^{-1}$

The minimum efficiency of heating boilers is defined in Annex 4a of the EnEV. The start of operation is only allowed if the product of the generation expenditure factor (e_g) and the primary energy factor (f_p) is not higher than 1.30.

Annex 5 of the EnEV defines minimum insulation thicknesses related to a thermal transmittance of 0.035 W/mK for heating, DHW and cooling pipes and corresponding fittings dependent on the type and size.

EnEV Article 5 defines that electricity which is generated from renewable energy in direct connection to the building, which is primarily used by the building (including the possible use of a battery) and only the remainder of which is fed into the grid, can be subtracted from the calculated delivered energy use up to the calculated monthly electricity demand. Note: Only the electricity part used by the building can be subtracted (up to the calculated monthly electricity use).

The Erneuerbare-Energien-Wärmegesetz (EEWärmeG) [Renewable Energies Heat Act, DE 6] requires the proportional use of renewable energy for the heating and cooling of new buildings. The minimum ratio of renewable energy required to cover the heating and cooling energy demand is dependent on the type of the renewable energy system:

- Solar thermal energy: 15%
- Biogas: 30%
- Biomass or biooil: 50%
- Geothermal or ambient energy: 50%

Article 7 defines so-called compensating measures:

- Combined heat and power units covering 50% of the heating and cooling energy demand
- Increased energy performance of the building concerning maximum primary energy use and maximum specific transmission heat loss coefficient (both 15% less than required by EnEV)
- Use of district heating or district cooling with
  - a significant share of renewable energy
  - a minimum of 50% waste heat
  - a minimum of 50% combined heat and power
  - a minimum of 50% generated by a combination of the first three alternatives

The Annex to EEWärmeG includes specific information such as sizing of the renewable energy systems. For example, a multi-family house meets the requirements with a solar thermal aperture of at least 0.03 m^2 per m^2 usable floor area. The solar thermal system needs to be certified with the European label “Solar Keymark”.

Since May 2014 the German energy performance certificate for buildings includes energy performance classes, in addition to the green-to-red scale for indicating the energy performance level of residential buildings. On the top the scale shows the calculated delivered energy use and on the bottom the calculated primary energy use. The delivered energy classes start with A+ (best class), subsequently ranging from A to G. In case of existing residential buildings with 5 and more apartments the energy performance certificate can also be issued on the basis of the average measured energy consumption of 3 years. The design and content of the energy performance certificate are presented in Annex 6 of the EnEV.

2.1.2 Denmark

The Danish Building Regulation 2015 (BR2015, [DK 1]) sets minimum energy performance requirements for all types of new buildings, including NZEB requirements.

The minimum energy performance sets the limit in terms of a maximum allowed primary energy demand for a building, including, e.g., thermal bridges, solar gains, shading, infiltration, ventilation, heat recovery, cooling, lighting (for non-residential buildings only), boiler and heat pump efficiency, electricity for operating the building, as well as sanctions for overheating. The overheating penalty is calculated as a fictious energy demand, equal to the energy demanded by an imaginary mechanical cooling system in order to maintain the indoor temperature at 26 °C. This additional energy demand is included in the calculated overall energy consumption of the building by the monthly based compliance checking tool "Be15" [DK 2].

Renewable energy is included in the calculation. However, for all buildings, the maximum electricity production to be factored in from renewable energy systems (such as solar cells and wind turbines) corresponds to a reduction of the need for supplied energy of 25 kWh/m².yr in the energy performance framework (primary energy). The primary energy factor is 1.0 for heating - except for district heating, where it is 0.8. Electricity has a factor of 2.5.

The minimum energy performance for the BR2015 requirements (A2015) is: 30 + 1,000 / A [kWh/m² per year] for residential buildings, and 41 + 1,000 / A [kWh/m² per year] for non-residential buildings where A is the heated floor area in m²

Buildings that comply with BR2015 must prove that they have a good thermal indoor climate during hot periods. The indoor temperature in residential buildings must not exceed 27 °C for more than 100 hours per year, respectively 28 °C for more than 25 hours per year. This can be done either through Be15 or via a dynamic simulation tool. In non-residential buildings, the building owner decides the temperature limits, and summer comfort must be proven using a dynamic simulation tool.

Air changes through leakages in the building envelope must not exceed 1.0 l/s/m² of the heated floor area when tested at a pressure difference of 50 Pa.

The Danish Building Regulations include requirements for a wide range of technical building systems. There are specific energy-related requirements for boilers based on coal, biomass and similar fuels. Boilers operating on coal, biofuels and biomass should, as a minimum, meet the energy requirements of boiler class 5 specified in the standard EN 303-5.

The Ecodesign Regulations include requirements for ventilation units, CHP appliances, oil/gas boilers, heat pumps and circulation pumps for installations. These requirements are included in BR2015. In the long term these references will be phased out as it will be the duty of the owner to stay up-to-date on existing and new requirements in EU regulations.

Additionally, the energy balance of windows and glazed outer walls must not be less than -17 kWh/m².year (equal to a B-label window in the voluntary Danish window labelling scheme [DK 3]). The energy gain through roof lights and glazed roofs must not be less than 0.0 kWh/m².yr. The energy balance is being calculated for a standard-sized window assuming standardized outdoor conditions.

New buildings must be built such that the design transmission loss does not exceed 4.0 W per m² of the building envelope in the case of single-storey buildings, 5.0 W/m² for two-storey buildings and 6.0 W/m² for buildings with three storeys or more. The calculation does not take into account the area of windows and doors nor transmission losses through them.

Furthermore, minimum thermal insulation requirements exist, which are not only a response to the requirements for energy savings, but also a means of providing comfort and avoiding the risk of condensation.

2.1.3 Italy

Energy requirements for new buildings are set in [IT 1], which is the national transposition of the Directive 2010/31/CE EPBD recast. Focusing on residential buildings, the primary energy performance (EP) is expressed with the formula:

$EP_{gl}=EP_{H}+EP_{C}+EP_{V}+EP_{W}$

Where:

gl: global
H: space heating
C: space cooling
V: ventilation
W: domestic hot water

The energy performance is expressed as non-renewable primary energy. Lighting is not taken into account for residential buildings.

The national scheme is not based on absolute energy performance levels to assess the compliance with the minimum requirements and the pertinent energy class; in fact such performances are assigned by comparison with the reference/notional building. The latter is defined as a building having the same geometry and use of the building to be evaluated, but with pre-assigned performances and properties for all the energy related components and systems. Some relevant figures related to the reference building are presented in the following.

Table 4 presents the U-values of building components according to the Italian climatic zones, defined according to heating degree days calculate with a base temperature of 20°C. These figures apply to external components, as well as to those towards unheated zones. An additional requirement is fixed for structural elements separating buildings or dwellings. In this case the component U-value has to be lower than 0.80 W/m²K. The solar factor of glazing, including shading device, has to be lower than 0.35 for all orientations between east and west on the south side.

Table 4: Building envelope U-values of the reference building in the Italian scheme

Climatic zone	HDDays (base 20°C)	U_Wall (W/m^2K)	U_Roof (W/m^2K)	U_Ground floor (W/m^2K)	U_Windows (W/m^2K)
A+B	< 900	0.45	0.38	0.46	3.20
C	> 900 - < 1400	0.38	0.36	0.40	2.40
D	> 1401 - < 2100	0.34	0.30	0.32	2.00
E	> 2101 - < 3000	0.30	0.25	0.30	1.80
F	> 3000	0.28	0.23	0.28	1.50

Some relevant examples concerning the energy systems are: distribution efficiencies have to be higher than 0.81 for the cooling and heating systems, and higher than 0.70 for the domestic hot water system. Table 5 presents the seasonal generation efficiencies of different systems.

Table 5: Seasonal generation efficiencies of the reference building in the Italian scheme

Generation efficiency	Space heating	Space cooling	DHW
Liquid generator	0.82	---	0.80
Gas generator	0.95	---	0.75
Solid biomass	0.72	---	0.75
Compression heat pump/chiller	3.00	2.50	2.50
Absorption heat pump	1.20	1.20	1.10
District heating/cooling	0.97	0.97	---

The energy performance of the new residential building has to be better than that of the reference building. In particular the minimum requirements of the new building are defined in Table 6 . Concerning the contribution of renewable energy, according to [IT 2] and next modifications, the minimum requirements is 35% until 31/12/2017. From the beginning of 2018 the share will rise to 50%. It has to be noted that the contribution of the renewable energy, that must be generated on site, cannot exceed the energy use of the homologous source on monthly basis (e.g. electricity produced by PV cannot compensate thermal energy generated using fossil fuels).

Table 6: Minimum requirements for new multi-family houses in Italy

Parameter	Description
H'_T (W/m^{2}K)	Average global heat loss coefficient per unit external area
$A_{sol,est}/A_{useful\ area}$ (-)	Equivalent surface area per unit of useful gross area
$EP_{H,nd}$ (kWh/m^2.year)	Net energy use for space heating
η_h	Seasonal average efficiency of the heating system
EP_H (kWh/m^2.year)	Primary energy use for space heating (non-renewable or total)
$EP_{H,nd}$ (kWh/m^2.year)	Net energy use for DHW
η_w	Seasonal average efficiency of the DHW system
EP_w (kWh/m^2.year)	Primary energy use for DHW system (non-renewable or total)
$EP_{C,nd}$ (kWh/m^2.year)	Net energy use for space cooling
η_c	Seasonal average efficiency of the cooling system
EP_C (kWh/m^2.year)	Primary energy use for space cooling (non-renewable or total)
EP_V (kWh/m^2.year)	Primary energy use for ventilation (non-renewable or total)

It has to be noted that H'_T limits depend on the form factor of the building and the climatic zone, while the equivalent area has the same value for all the country. The energy class of the building is assigned applying the limits defined in Table 7.

Table 7: Upper and lower limits for the energy classes in Italy

Lower limit	Energy Class	Upper limit
	A4	$\leq 0,40\ EP_{gl}$
$0,40\ EP_{gl} <$	A3	$\leq 0,60\ EP_{gl}$
$0,60\ EP_{gl} <$	A2	$\leq 0,80\ EP_{gl}$
$0,80\ EP_{gl} <$	A1	$\leq 1,00\ EP_{gl}$
$1,00\ EP_{gl} <$	B	$\leq 1,20\ EP_{gl}$
$1,20\ EP_{gl} <$	C	$\leq 1,50\ EP_{gl}$
$1,50\ EP_{gl} <$	D	$\leq 2,00\ EP_{gl}$
$2,00\ EP_{gl} <$	E	$\leq 2,60\ EP_{gl}$
$2,60\ EP_{gl} <$	F	$\leq 3,50\ EP_{gl}$
$3,50\ EP_{gl} >$	G	

It has to be noted that the Italian process follows two parallel tracks: Regions are empowered to define their schemes, which however must not be in conflict with the national system; the latter, in turn, is valid in all the regions that have not implemented their own scheme. Currently regional schemes are implemented in Lombardia and Emilia Romagna.

Energy performances of residential buildings in national and regional schemes are based on calculation procedures defined in Italian technical standards [IT 3 - IT 7]. Such standards are in some case the national transposition of relevant EU standards, e.g. [IT 3] is derived from the relevant [IT 8].

It has to be noted that, since the national energy performance and certification schemes are purely theoretical, there is no certainty that the calculated performances will be achieved in real operation conditions. This also applies to the data provided in Table 17. Several buildings listed in Table 17 were built before the new building code came into force in 2015, thus the data provided in the energy performance certificate did not include all the current energy service requirements (e.g. cooling). In this sense energy costs, which are derived from the energy certificate, might not be representative of actual performances.

2.1.4 Slovenia

The currently valid Slovenian minimum energy performance requirements for buildings are defined in the Slovenian Building Codes PURES 2010, [SI 1]. The regulation covers calculation methodology and minimum requirements for new buildings and renovation. On 1 January 2015 PURES 2010 put in place more severe minimum energy performance requirements according to the existing transitional provisions.

Performance-based minimum requirements in PURES 2010 are focused on bioclimatic architectural concepts and on low energy losses in building envelopes featuring high airtightness. They also treat thermal bridges by limiting the linear thermal transmission coefficients (therefore, the simulation of thermal bridges is becoming a frequent design practice). A special set of minimum requirements refers to the energy efficiency of components and systems. As required by Directive 2010/31/EU, before designing Heating, Ventilation and Air-Conditioning (HVAC) systems, the potential of shading, passive cooling and night ventilation must be utilised to reduce the energy needs below the required levels. Fixed shading devices and automatically controlled shading systems are considered in the energy performance calculations. Mechanical ventilation with heat recovery is not a mandatory technology (natural ventilation is also allowed), but in practice it is needed for buildings with an Energy Performance Certificate (EPC) of class B or higher. If mechanical ventilation is used, then heat recovery is mandatory. Thermal comfort and indoor air quality requirements are given in the Regulation on ventilation and AC systems of buildings (2002), together with the relevant design rules.

For new multi-family residential buildings the core minimum requirements are given in Art. 7 and Art. 16. Compliance with PURES 2010 must be demonstrated by fulfilling minimum requirements related to the maximum allowed specific transmission heat losses (H_t'), maximum annual heat demand for space heating (Q_{nh}), maximum energy needs for cooling (Q_{nc}), and maximum primary energy for the energy systems operation (HVAC and lighting). Maximum U-values of the envelope elements are prescribed for all buildings.

Current maximum U-values and H'_T are presented in Table 8, while maximum allowed specific heat transfer by transmission H'_T (W/m²K) is limited following to the expression (see also Figure 1):

$$H'_T \leq 0{,}28 + \frac{T_L}{300} + \frac{0{,}04}{f_0} + \frac{z}{4},$$

Where:

T_L is the mean annual temperature at the location in °C,
f_o is a shape factor, i.e. the thermal envelope area in m² (external dimensions) divided by the gross heated volume in m³, and
z is a ratio of glazed surface devided by the thermal envelope area.

Table 8: Minimum requirements for U-value of the envelope (PURES 2010)

Part of thermal envelope	U_{max} [W/m²K]
Walls	0.28
Floors between flats	0.90
Flat roofs	0.20
Windows	1.3
Glazing	1.1
Doors	1.6

For all residential buildings the following minimum requirements for the energy performance indicators are given:

- Maximum heating need (Q_{NH}) per unit of useful conditioned floor area (A_u):

  for residential buildings: $Q_{NH}/A_u \leq 45 + 60\ f_0 – 4{,}4\ T_L$ (kWh/(m².yr),

- Maximum cooling need (Q_{NC}) per unit of useful conditioned floor area (A_u):

  for residential buildings: $Q_{NC}/A_u \leq 50$ kWh/(m².yr);

- Maximum primary energy (Q_p) per unit of useful conditioned floor area (A_u):

  for residential buildings: Q_p/A_u = 200 +1.1 *(60 f_0 – 4.4 T_L) kWh/(m².yr);

Additional requirements for cooling initially refer to the obligatory shading of the envelope, and then to efficiency requirements for cooling systems. Taking into account the glazing characteristics, the total shading factor resulting from the positioning of natural or artificial shading objects, as well as from the position and type of the shading devices at windows, must be lower than 0.5 (g < 0.5). Internal shading devices are not considered as solar protection. There is a requirement for the minimum allowed efficiency for cooling generators; cooling bodies must permit local adjustment in the range of 1.5 K, and central control is obligatory for large cooling systems.

The use of RES has been mandatory in Slovenia for all new buildings since 2008, i.e.,

- a minimum of 25% of the total final energy used for the building's energy systems' operation must be covered by RES.

Alternatively, the RES requirement is considered to be fulfilled if the share of RES used for space heating, space cooling, and Domestic Hot Water (DHW) is obtained in one of the following ways:

- 25% from solar energy,
- 35% from gas biomass,
- 50% from solid biomass,
- 70% from geothermal energy,
- 50% from heat from the environment (through heat pumps),
- 50% from Combined Heat and Power (CHP), or
- 50% from energy efficient district heating/cooling.

The requirement is also considered fulfilled if the building demonstrates at least 30% lower annual heat demand than the demand defined in the minimum requirements. This is often the case if the local energy concept prescribed the use of gas, and consequently condensing gas boilers are used for heating.

In PURES 2010 the contribution of the renewable energy generated on site, cannot exceed the energy use of the homologous energy source on a monthly basis (e.g. electricity produced by PV cannot compensate thermal energy generated using fossil fuels and can only be accounted up to covering the corresponding energy demand).

Additional minimum requirements refer to the the airtightness of the envelope:

- for naturally ventilated buildings $n_{50} < 3\ h^{-1}$, and
- for buildings with mechanical ventilation and obligatory heat recovery $n_{50} < 2\ h^{-}$

Blower door tests are not obligatory under the 2010 Building Code. However, if implemented, a specific protocol (SIST EN 13829) is prescribed. In practice, the airtightness tests are done frequently as they are also a prerequisite to be eligible for the Eco fund subsidy for passive buildings ($n_{50} \leq 0.6\ h^{-1}$) and for the low energy renovation of existing buildings ($n_{50} \leq 1.2\ h^{-1}$).

In PURES 2010 and in the corresponding Technical guidelines TSG-01-004, [SI 2], requirements refer to energy efficiency characteristics of installations in new buildings (and major renovations). The requirements are given for heating, hot water systems, and AC and large ventilation systems, if relevant. The system energy efficiency is achieved by selecting products that fulfil the energy efficiency requirements, with corresponding design and construction rules for sub-systems. Overheating must be reduced through passive measures (fixed and movable shading, night ventilation), and the remaining cooling needs must be covered by energy efficient cooling systems. Heat recovery in mechanical and hybrid ventilation systems is mandatory.

As a rule, domestic hot water (DHW) should be prepared centrally with a hot water storage, solar panels or alternative renewable solutions should be used for DHW (in case of heat pumps for DHW: $COP_{min} = 3$). If decentralized DHW production is proven be a cost effective solution, heat pumps must be used.

The regulation has imposed system performance requirements via many rules on product and sub-system energy efficiency. The minimum required heat recovery in ventilation and/or AC systems (if relevant) is 65%, and 75% in low-energy buildings. Individual electrical heaters for DHW are not allowed unless they are economically reasonable.

Low temperature heating systems (max. 55 °C), as well as condensing gas boilers or, alternatively, high efficiency gas heat pumps, are obligatory in new buildings. As a rule:

- heat generators must be placed inside the thermal envelope;
- thermal losses of the distribution system must be less than 5%;
- specific use of electricity for transport in the heat exchanger must be below 16 ($W_{electricity}/kW_{heat}$);
- variable speed drives are obligatory;
- automatic control of operation of heating devices and distribution systems is required;
- when using liquid and gaseous fuels, only energy-efficient heating devices are allowed;
- heat losses of heating generators below 100 kW on stand-by are limited to 2.5% and to 2% for generators with power above 100 kW;
- a minimum COP is defined for heat pumps for heating and DHW preparation;
    - ground coupled pump (earth/water): $COP_{min} = 4.3$
    - water/water heat pump: $COP_{min} = 5.1$
    - air/water heat pump: $COP_{min} = 3.1$

- the minimum insulation of the pipes in distribution systems is defined;
- thermostatic valves on the heat emission systems are obligatory.

2.2 NZEB multi-family houses

The EPBD (Directive 2010/31/EU, [2]) gives a general framework for the definition of nearly zero-energy buildings in Article 2, number 2, namely:

"'nearly zero-energy building' means a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby;"

In Article 9 of the EPBD Member States are required to ensure that

" (a) by 31 December 2020, all new buildings are nearly zero-energy buildings, and

(b) after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings."

The same article also requests that

"Member States shall draw up national plans for increasing the number of nearly zero-energy buildings" that shall include *"the Member State's detailed application in practice of the definition of nearly zero-energy buildings, reflecting their national, regional or local conditions, and including a numerical indicator of primary energy use expressed in kWh/m² per year."*

Therefore the national applications of the NZEB definition are different from each other. Concerted Action EPBD [3] is following up the progress of the national NZEB definitions in the EU Member States and has compiled a report on the status in April 2015 [4]. An updated overview report will be available in 2018. The following subchapters are summarising the national NZEB definitions in Germany, Denmark, Italy and Slovenia.

2.2.1 Germany

Germany has transposed the general NZEB definition of Article 2 of the EPBD in the Energy Saving Act [DE 7] (latest update in July 2013). It includes verbal requirements in accordance with the EPBD, leaving specifications to be set out by an ordinance replacing the currently valid Energy Saving Ordinance [DE 1]. Instead of specifying the detailed NZEB definition in the updated ordinance it was decided to include it in the new Building Energy Law [DE 8]. A draft of this new law including a draft NZEB definition for non-residential buildings was distributed for consultation in 2017, but did not succeed in being adopted by the council. The detailed NZEB definition for residential buildings was foreseen to be included in the follow-up version of the Building Energy Law. Due to the federal election in autumn 2017 the further work on the law was postponed to the next legislative period and the date of entry into force is not yet fixed. However the NZEB definition for residential buildings discussed during the preparation for the draft law is being used as a basis for the German work in CoNZEBs because it provides the best possible assumption of the future German NZEB definition.

The probable NZEB definition is based on the current requirements for receiving funding within the KfW efficiency house 55 promotion scheme [DE 9]. It includes the following detailed requirements in addition to the general energy performance requirements for new buildings as defined in chapter 2.1.1:

Maximum non-renewable primary energy use:

- 45% less primary energy demand than a mirror baseline building with the same size and use and applied “reference technologies” (see Table 2). This is 26% less than the current primary energy requirements.
- Included energy uses (heating, ventilation, cooling [if appl.], auxiliary, self-used self-generated renewable electricity for HVAC)

Other maximum values:

- 30% less than the mean transmission heat loss coefficient of the ”reference building“

Other conditions like the required RES contributions (minimum of 15% depending on the type of RES), minimum thermal resistance values to avoid condensation and mould, minimized thermal bridge effects (surface temperature and heat transfer), restriction on air tightness while ensuring minimum ventilation rates, protection against overheating in summer apply in the same way as to all new buildings (see chapter 2.1.1).

For residential buildings, the KfW efficiency house 55 promotion scheme foresees an alternative way of proving that the corresponding energy performance requirements are being met. It defines minimum values for construction elements that fulfil the building energy level in case that one of several HVAC system combinations is used. In order to develop this system a detailed study was performed to ensure that these building envelope and services system combinations will fulfil the requirements for all building geometries. The possible combinations are listed in Table 9 and Table 10, as they provide a grasp of the foreseen energy performance level of the German NZEB:

Table 9: Alternative proof for KfW efficiency house 55 as demonstration of the probable German NZEB requirements: Minimum reference values for construction elements

Minimum reference values for construction elements (in combination with the possible HVAC solutions of Table 10)	Roof	$U \leq 0.14$ W/m²K
	Window	$U_w \leq 0.90$ W/m²K
	External wall	$U \leq 0.20$ W/m²K
	Other opaque elements (to attic or ground)	$U \leq 0.25$ W/m²K
	Doors to cellar and external	$U_D \leq 1.2$ W/m²K
	Thermal bridges: ⌂ Maximum heat loss ⌂ Minimum surface temperature coefficient	 $\Delta U_{TB} \leq 0.035$ W/m²K $f_{Rsi} > 0.7$
	Minimum airtightness of the construction	$n_{50} \leq 1.5$ h^{-1}

Table 10: Alternative proof for KfW efficiency house 55 as demonstration of the probable German NZEB requirements: Possible HVAC solutions

Possible HVAC solutions (in combination with the minimum reference values for construction elements of Table 9)	⌂ Condensing boiler, solar collectors for DHW, mechanical ventilation with heat recovery (> 80%) ⌂ District heating with certified primary energy factor PEF (≤ 0.7), mechanical ventilation with heat recovery (> 80%) ⌂ Biomass boiler (pellets or wood), exhaust ventilation system ⌂ Brine/water heat pump, floor heating system, exhaust ventilation system ⌂ Water/water heat pump, floor heating system, exhaust ventilation system ⌂ Air/water heat pump, mechanical ventilation with heat recovery (> 80%)

Note: Until 2014 the KfW promotion bank accepted that the KfW efficiency house 55 level was fulfilled by proving that the German passive house requirements were met, with the additional requirement that the primary energy demand excluding the household electricity was 40 kWh/m².yr or less. Within CoNZEBs it was therefore decided to sort the built passive house examples into the German NZEB level in Table 14 of Chapter 5.1. Far into 2016, passive houses had to meet the following four requirements:

- Annual heat demand calculated with the calculation method of the Passivhaus Projektierungs-Paket [Passive House Planning Package, DE 10] ≤ 15 kWh/m²yr
- Heat load ≤ 10 W/m²

- Airtightness (tested by pressure test at 50 Pa pressure difference) ≤ 0.6 1/h
- Non-renewable primary energy demand ≤ 120 kWh/m²yr

The passive house calculation method differs from the national German energy performance calculation method and uses a different type of floor area for the related values.

2.2.2 Denmark

In addition to the minimum requirements, BR2015 also sets requirements for a voluntary low-energy class: 'Building Class 2020' (BK2020, equivalent to NZEB level).

The minimum energy performance for the voluntary Building Class 2020 (NZEB - A2020) is:

20 [kWh/m^2 per year] for residential buildings, and

25 [kWh/m^2 per year] for non-residential buildings.

The primary energy factors are 1.0 for heating except for district heating, where it is 0.6. Electricity has a factor 1.8.

Buildings that comply with the voluntary low-energy class must prove that they have a good thermal indoor climate during hot periods. The indoor temperature in residential buildings must not exceed 27 °C for more than 100 hours per year, respectively 28 °C for more than 25 hours per year. This can be done either through Be15 or via a dynamic simulation tool.

Additionally, BK2020 must prove, through a pressurization test, their compliance with the maximum infiltration rates (0.5 l/s/m² at a pressure difference of 50 Pa).

The Danish Building Regulations include requirements for a wide range of technical building systems. There are specific energy-related requirements for boilers based on coal, biomass and similar fuels. Boilers operating on coal, biofuels and biomass should, as a minimum, meet the energy requirements of boiler class 5 specified in the standard EN 303-5.

Additionally, the energy balance of windows and glazed outer walls must not be less than 0.0 kWh/m².yr (equal to an A-label window in the voluntary Danish window labelling scheme). The energy gain through roof lights and glazed roofs must not be less than 10.0 kWh/m².yr. The energy balance is being calculated for a standard-sized window with assuming standardized outdoor conditions.

New buildings must be built such that the design transmission loss does not exceed 3.7 W/m² of the building envelope in the case of single-storey buildings, 4.7 W/m² for two-storey buildings and 5.7 W/m² for buildings with three storeys or more. The calculation does not take into account the area of windows and doors nor transmission loss through them.

Minimum thermal insulation requirements exist, which are not only a response to the requirements for energy savings, but also a means of providing comfort and avoiding the risk of condensation.

2.2.3 Italy

Energy requirements for new buildings are set in [IT 1], which is the national transposition of the Directive 2010/31/CE EPBD recast and introduces the definition and the requirements for nearly zero energy buildings. According to the current scheme, a new NZE multi-family house has to respect the requirements compiled in Table 7, with the reference building U-values being indicated in Table 11.

Table 11: Building envelope U-values of the NZEB reference building in the Italian scheme

Climatic zone	HDDays (base 20°C)	U_Wall (W/m^2K)	U_Roof (W/m^2K)	U_Ground floor (W/m^2K)	U_Windows (W/m^2K)
A+B	<900	0.43	0.35	0.44	3.00
C	>900 - <1400	0.34	0.33	0.38	2.20
D	>1401 - <2100	0.29	0.26	0.29	1.80
E	>2101 - <3000	0.26	0.22	0.26	1.40
F	>3000	0.24	0.20	0.24	1.10

A substantial difference with respect to the minimum requirements is that the current NZEB has to cover 50% of its global energy use by renewable energy instead of 35%. It has to be noted, however, that the difference in the energy performance between a building meeting the minimum energy performance requirements and a NZEB will depend only on the small U-value differences given in Table 4 and Table 11, starting from 01/01/2018 and according to the requirements set in [IT 2]. This implies that, from this date, very small cost differences can be expected to arise between a conventional and a nearly zero-energy building; also, reducing the costs of new nearly zero-energy multi-family houses means reducing the costs for such houses in general.

Because the scheme is purely theoretical, there is no certainty that the calculated performances will be achieved in real operation conditions.

2.2.4 Slovenia

The Slovenian national definition of the NZEB is given in the Slovenian national plan for NZEB (AN sNES, 2015, [SI 3]) adopted on 22 April 2015, based on the Energy Act (EZ-1) [SI 4] that transposed NZEB obligations from the EPBD directive. In new NZEB multi-family buildings, the following requirements must be met (on top of the obligations in Building Codes PURES 2010):

- The nearly zero or very low amount of energy required is achieved by the limitation of energy needs for heating (Qh,nd/Ak) (net energy) to a maximum value of 25 kWh/m².K (i.e. EPC class A1, A2 or B1).
- The primary energy (for EPBD energy uses) is limited to 80 kWh/m².yr for a new multi-family building.
- Minimum 50% share of RES in the final energy use must be fulfilled in NZEB.

Alternative solution:

- If there is no possibility to use RES on-site or nearby and no possibility to go for any of RES alternatives (i.e. connection to energy efficiency district heating) then more severe requirements on the energy needs for heating must be considered, i.e. $Q_{h,nd}/A_k$ < 15 kWh/m².K.

By the end of 2018/2020 NZEB is a voluntary standard. The integration of NZEB requirements into an update of PURES is currently in process (PURES 2018 is expected to be finalized in mid-2018). It is considered to adjust the NZEB minimum requirements to the local climate and to the shape factor of the building (envelope-to-volume ratio), to impose new thresholds for U-values and H'_T, to introduce obligatory blower door tests to prove the designed airtightness level and, above all, to adopt new sets of EPB standards and energy indicators as given in EN ISO 50001-1 and -2 for expressing the NZEB indicators.

The revision of the Building Codes (PURES) will contain detailed technical requirements for NZEB, based on the technical definition given in the national NZEB action plan (April 2015), and the revision of the calculation methodology according to new set CEN EPBD standards. Figure 1 presents the maximum allowed specific heat transfer coefficient by transmission (H_T') as prescribed over the years including the NZEB level proposal for 2018 in the 2017 revision of PURES:

$$H_T^{'} \leq 0{,}25 + \frac{T_L}{300} + \frac{0{,}04}{f_0} + \frac{z}{4}.$$

Table 12 gives the planned U-values for NZEBs to be specified in the 2018 update of PURES Building Codes (proposal of 2017).

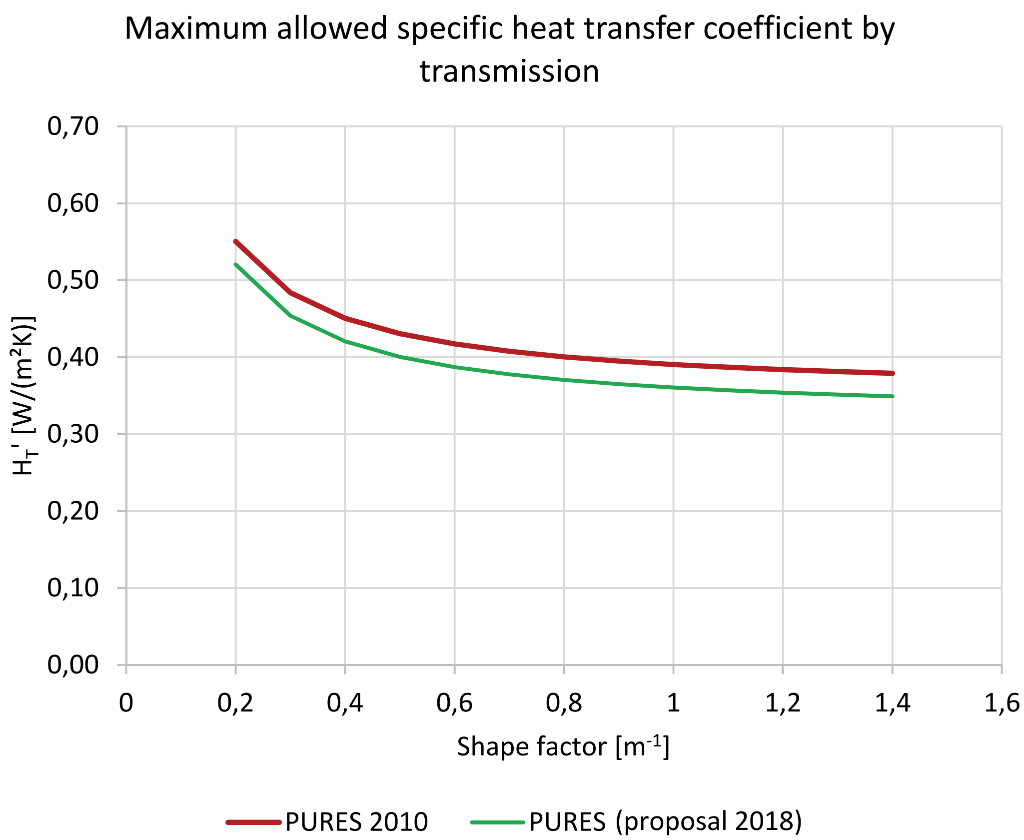

Figure 1: **Maximum allowed specific heat transfer coefficient by transmission (H_T') with respect to shape factor (A/V) of the building; development of regulation from 2010 to proposed 2018 level in compliance with cost optimal study.**

Table 12: **Minimum requirements for the elements of the building envelope, current status (2017) and proposal for revised regulation expected in mid-2018.**

Minimum requirements for U-value of the envelope	Status as of 2017 (as in current PURES 2010)	Proposed new max. U-values (NZEB)
Walls	0.28 W/m^2.K	0.20 W/m^2.K
Floors between flats	0.90 W/m^2.K	0.90 W/m^2.K
Flat roofs	0.20 W/m^2.K	0.18 W/m^2.K
Windows	1.3 W/m^2.K	1.0 W/m^2.K

In the meantime, the Eco fund [SI 5] (national public fund for environmental investments) offers incentives for new NZEB buildings, where the criteria follow the German passive house standard. Most of the subsidies are allocated to individual passive houses and to public tertiary buildings (kindergartens, schools). The incentives are higher with lower energy needs and use of ecological building material.

The subsidies for passive multi-family buildings are available for physical persons buying these flats. The subsidy of maximum 8,000 EUR per apartment is available "at a purchase of a person's dwelling in NZEB multi-family buildings". The criteria follow the German passive house standard:

- Energy need for heating $Q_{h,nd}$ < 15 kWh/m^{2}a.
- The airtightness $n_{50} \leq 0.6$ h^{-1} must be proven by blower door test.
- Windows, doors U ≤ 0,9 W/m^{2}K, triple glazing, RAL based installation and sealing of windows.
- Central ventilation system: with central ventilation unit with minimum heat recovery 80% (except for the enthalpy heat exchanger, where the minimum heat recovery is limited to 75%); for all central ventilation units specific inlet power (SPI) is limited to 0.45 W/(m^3/h).
- Only heat and cold generators with high energy efficiency performance are allowed (a list is provided).
- Direct electrical heating of building and DHW may not exceed 10% of the total annual heating need, except in the case of self-supply with electricity produced from renewables on-site.
- 50% of delivered energy (per year) for heating, cooling, ventilation, DHW and lighting must be provided by renewables, except if the building is connected to district heating or cooling or if the energy supply comes from high efficiency cogeneration of heat and electricity (CHP), as defined in the related regulation [SI 6] about support scheme for electricity from high efficiency CHP

Note: In comparison to NZEB national criteria the Eco fund rules do not include a specific limit for a primary energy performance indicator.

In addition to that, many municipal public housing funds and above all the Slovenian national housing fund (SSRS) has the policy to build high energy performance buildings:

- Multi-family buildings of public housing funds (SSRS and other) are built in EPC class B1, i.e. an energy need for heating $Q_{h,nd}$ < 25 kWh/m^2.K, which corresponds to the initially presented NZEB requirement.
- Further NZEB requirements on primary energy and the share of RES are considered as a design priority in line with the efforts for realizing early NZEBs. These rules are implemented pragmatically, i.e. with respect to the energy supply priorities at the location of the building defined in the local energy concepts with respect to the alternatives in the current Building Codes PURES 2010 for meeting the share of RES targets.

Classes as defined in the energy performance certificate (per net energy for heating) are:

- A1: 0 to 15 kWh/m².year
- A2: 10 to 15 kWh/m².year
- B1: 15 to 25 kWh/m².year
- B2: 25 to 35 kWh/m².year
- C: 35 to 60 kWh/m².year
- D: 60 to 105 kWh/m².year
- E: 105 to 150 kWh/m².year
- F: 150 to 210 kWh/m².year
- G: above 210 kWh/m².year

In Slovenia there are pilot projects of new passive multi-family buildings in public (BRDO F3, SSRS) and private (FP7 EE_HIGHRISE) sectors. The lack of continuous incentive schemes provided in this field most likely resulted in a moderate ambition of investors with regard to construction of early NZEB apartment buildings.

2.3 Multi-family houses beyond NZEB

A multitude of terms for high performance buildings are used within the EU. In January 2011 the Concerted Action EPBD has published a report on “Terms and definitions for high performance buildings” [5], that presents the types of high performance buildings known in the different EU Member States and reflects on the corresponding definitions and energy requirements. The collected terms are shown in Figure 2.

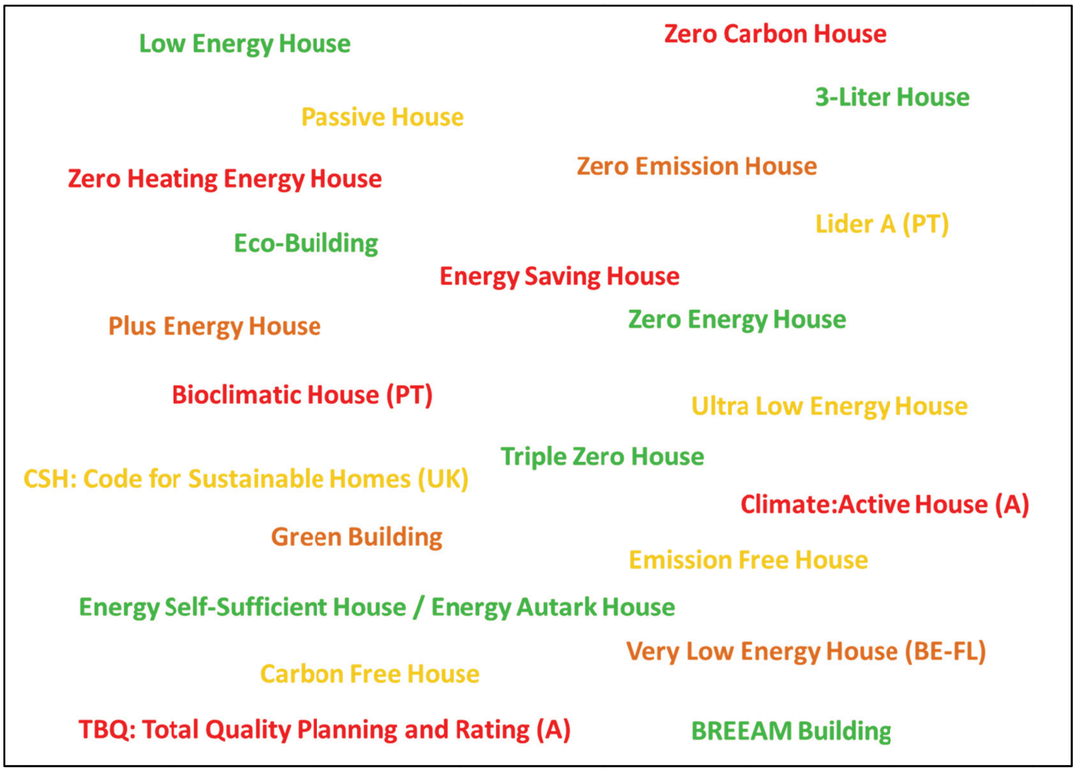

Figure 2: **Terms known in the EU Member States collected by Concerted Action EPBD in 2010 [5]. The terms with country abbreviations in brackets have been only known in the country indicated.**

CA EPBD indicates that the terms relate mostly to one of the three following options:

- low energy consumption (low energy house, energy saving house, ultra-low energy house, 3-litre-house, zero-heating energy house, zero-energy house, plus-energy house, very low energy house, energy self-sufficient house, energy autarkic house), or to
- low emissions (zero-emission house, zero-carbon house, emission-free house, carbon-free house), or to
- sustainable or green aspects (eco-buildings, green buildings, CSH, bioclimatic house, climate: active house).

One of the terms refers to a national standard (lider A used in Spain), while two others refer to private organisations (passive house) or public bodies (BREEAM buildings). Finally, some terms for high performance buildings try to incorporate more than one of the mentioned issues (triple zero house, TBQ).

Since the overview was made in 2010 (before the EPBD recast [1]) it is in some cases unclear whether the terms have to be sorted to NZEB level or to the level beyond NZEB level. It can be assumed though that at the time of the report the energy performance of all these building types has been better than minimum energy performance requirements of the EU Member States.

For each CoNZEBs country (Germany, Denmark, Italy and Slovenia) the terms and definitions used to describe buildings beyond the NZEB level are presented in the following chapters.

2.3.1 Germany

The best known terms for high performance buildings in Germany are **KfW efficiency houses** [DE 9] and passive houses. Efficiency houses are defined by the promotion programmes of the state-owned KfW bank. Here the level of funding (loans with favourable conditions and partly repayment subsidies) is dependent on the energy performance level of the building. The levels are defined by the ratio of overachievement of the legal national energy performance requirements for buildings. For new buildings the following KfW efficiency house levels are offered:

- KfW efficiency house 55:
  - Primary energy demand ≤ 55% of the primary energy demand of the mirror baseline building as defined in the energy saving ordinance
  - Mean transmission heat loss coefficient ≤ 70% of the mirror baseline building as defined in the energy ordinance
- KfW efficiency house 40:
  - Primary energy demand ≤ 40% of the mirror baseline building as defined in the energy ordinance
  - Mean transmission heat loss coefficient ≤ 55% of the mirror baseline building as defined in the energy ordinance
- KfW efficiency house 40 plus:
  - Primary energy demand ≤ 40% of the mirror baseline building as defined in the energy ordinance
  - Mean transmission heat loss coefficient ≤ 55% of the mirror baseline building as defined in the energy ordinance
  - Plus package:
    - Electricity generation in direct connection with the building or auxiliary building (≥ 500 kWh/yr and residential unit and 10 kWh/m².yr)
    - Stationary battery
    - Mechanical ventilation systems with heat recovery (heat recovery rate ≥ 80%)
    - Visualisation of the electricity generation and electricity use

While KfW efficiency house 55 is used as probable NZEB definition, KfW efficiency houses 40 and KfW efficiency houses 40 plus are buildings beyond NZEBs.

The minimum energy performance requirements for **passive houses** are defined according the Passivhaus Projektierungspaket [DE 10]. However as described in chapter 2.2.1 the passive houses are regarded as NZEBs level for the German part of the report and not as beyond NZEB. Chapter 2.2.1 also includes the detailed minimum requirements for a passive house. Since August 2016 a new version of the passive house requirements is valid that distinguishes between passive house classic, plus and premium. The difference between the three passive house types is dependent on the renewable primary energy demand and the amount of required energy generated from renewable energy sources. Passive houses plus and premium would be sorted into buildings beyond NZEB. It is however assumed that the passive house buildings in Table 14 are "classic" passive houses since they were completed in the year 2016 or earlier.

Other terms and definitions used for realised buildings with an energy performance beyond NZEBs in Germany are:

- **Efficiency house plus**: [DE 11], [Effizienzhaus Plus] (Research programme of the Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit)
  - Definition according to a pilot project programme launched the Federal Ministry of Buildings:
    - Primary energy generation from renewable energy sources > primary energy demand of the building in an annual balance
    - Delivered energy generation from renewable energy sources > delivered energy demand of the building in an annual balance
    - The energy balance takes a default value for household electricity into account and allows the accounting of the total generated renewable energy in the energy balance
- **Active House** [DE 12] / **Active House Plus** [DE 13] [Aktivhaus / Aktivhaus Plus]
  - Private initiative "Aktivhaus" by five different German university professors supported by international industry organisations such as VELUX.
  - Now divided into Active House organised by one group and Active House Plus by another group
  - Active House: Triple Zero® sustainability concept:
    - Zero energy use from external energy sources as an annual balance
    - Zero emission: zero CO_2 emission calculated based on the primary energy demand, no combustion on the building ground or in the building
    - Zero waste: All building components can be recycled
  - Active House Plus: concept based on the pillars energy, user, smart grid and life cycle assessment:
    - 14 different characteristics, partly the same as

the general legal requirements. Examples:
- Net energy demand < 30 kWh/m².yr
- Self-generated energy > 25%
- CO_2 emission ≤ 660 kg/user and year

- Both standards include mobility energy

2.3.2 Denmark

There is no official building energy performance level beyond the 2020 NZEB level in Denmark. However, there is a number of voluntary schemes that go beyond the 2020 level.

BOLIG+

BOLIG+ [DK 4] is about energy neutral housing units of high architectural standard with a significant reduction of CO_2 emissions.

BOLIG+ must comply with the following 5 overall rules:

1. Must be an NZEB building, energy neutral on a yearly basis, including electricity for private equipment and lighting. Additionally, it must at least comply with Building Class 2020 - which is 25% better than demanded by the DK building regulations 2015 - but without deduction of locally produced electricity.
2. Must be intelligent and user-friendly, i.e. support the energy conscious behaviour of the users either by smart feed-back or by set-and-forget control systems.
3. Must be flexible – in use and over time, i.e. allow for extension or reduction of the habitable area (upon availability among neighbours).
4. Have a good and healthy indoor climate – including a high level of daylight.
5. Be of high architectural quality and adapted to the context (architecturally and relating to the local energy infrastructure).

BOLIG+ neither sets specific requirements to the insulation level of the thermal envelope nor to the technical systems of the building. However, it is required that the energy neutrality is calculated (and measured) using more realistic boundary conditions than prescribed in the normal Danish energy performance calculation procedure as shown in Table 13 below.

Table 13: Differences in the boundary conditions for calculations according to BOLIG+ scheme and the Danish national procedure.

Parameter	BOLIG+	DK national procedure
Indoor temperature	22 °C	20 °C
Domestic hot water usage	375 l/m² per year	250 l/m² per year
Electricity for light and appliances	1.75 kWh/m² per year	3.5 kWh/m² per year

Active house

The Active House label [DK 5] is a worldwide quality stamp for comfortable and sustainable buildings. The certificate provides advice on elements that are important to human life and living at home. The Active House label can be issued to buildings that have been evaluated in accordance with the Active House specifications and meet the minimum demands for indoor comfort, energy efficiency and environment.

Active House does not set specific requirements to individual products or solutions. It is recommended to optimise the design solutions for the whole building and its installations and to choose the best performing products and solutions and evaluate those on a cost optimal basis. This will, among other things, require that individual solutions should be compared on the basis of their performance, service and life time and not only in terms of price. As an example, a circulation pump that has intelligent control can be more cost effective than one which is running constantly, even though the initial costs are higher. It can also be relevant to develop a water based heating system divided into zones, and to use individual solutions for each zone, rather than for one larger zone.

The calculation of primary energy follows the principles stated in national legislations, which in Europe are derived from the Energy Performance of Buildings Directive. Most often, primary energy is calculated only for the difference between the total energy demanded by the normal building operation and the renewable energies used in/on the building or plot to cover the demand. Only if this approach is used, one can speak of zero-energy buildings or energy-plus buildings, one of which is also the Active House, where the total demand is supplied by renewable energy, or the amount of energy produced from renewable sources is even higher than the building energy demand. In the former case, the surplus of energy may be transferred to collective energy systems like the grid or district heating piping to be used by other end-users.

Passive House

For a building to be considered as Passive House [DK 6], it must meet the following criteria (same as in Germany):

1. The space heating energy demand is not to exceed 15 kWh per m² net living space (conditioned floor area) per year or 10 W per m² as peak demand.
   In climates where active cooling is needed, the requirements for the space cooling energy demand roughly match the requirements for the heat demand above, with an additional allowance for dehumidification.

2. The renewable primary energy demand (PER, according to PHI method), the total energy to be used for all domestic applications (heating, hot water and domestic electricity) must not exceed 60 kWh per square meter of conditioned floor area per year for Passive House Classic.
3. In terms of airtightness, a maximum of 0.6 air changes per hour at 50 Pascal pressure (ACH50), as verified with an onsite pressure test (in both pressurized and depressurized states).
4. Thermal comfort must be met for all living areas during winter as well as in summer, with not more than 10% of the hours in a given year exceeding 25 °C.

Passive House buildings are planned, optimised and verified with the Passive House Planning Package. All of the above criteria are achieved through intelligent design and implementation of the five Passive House principles: thermal bridge free design, superior windows, ventilation with heat recovery, quality insulation, and airtight construction.

Additionally, there are specific requirements for different parts of the thermal envelope:

- All opaque building components of the exterior envelope of the house must be very well insulated. For most cool-temperate climates, this means a heat transfer coefficient (U-value) of 0.15 W/m²K at the most, i.e. a maximum of 0.15 Watts per degree of temperature difference and per square metre of exterior surface are lost.
- The window frames must be well insulated and fitted with low-e glazing filled with argon or krypton to prevent heat transfer. For most cool-temperate climates, this means a U-value of 0.80 W/m²K or less, with g-values around 50% (g-value= total solar transmittance, proportion of the solar energy available for the room).
- Efficient heat recovery ventilation is a key feature, allowing for a good indoor air quality and saving energy. In Passive House, at least 75% of the heat from the exhaust air is transferred to the fresh air again by means of a heat exchanger.
- Uncontrolled leakage through gaps must be smaller than 0.6 of the total house volume per hour during a pressure test at 50 Pascal (both pressurised and depressurised).
- All edges, corners, connections and penetrations must be planned and executed with great care, so that thermal bridges can be avoided. Thermal bridges which cannot be avoided must be minimised as far as possible.

2.3.3 Italy

There are no national and official schemes for energy performances going beyond NZEB in Italy. Some national and international voluntary schemes, however, are in force in the country, such as CasaClima [IT 9] and Passive House [IT 10]. These schemes support high energy standards in residential and non-residential buildings, reaching performances that can go beyond the performance of the NZEB. This is generally achieved with a super-insulation of the building envelope and a high share of renewable energy. Generally the improvement of building component U-values is in the 20-30% range compared to the NZEB requirements, while the renewable energy contribution can reach shares close to 100%, especially for buildings with a very low energy demand.

As an example, a Passive House in Italy must comply, among other things, with the following prescriptions:

- Space heating energy performance ≤ 15.4 kWh/m².yr
- Space cooling energy performance ≤ 15.4 kWh/m².yr
- Overheating hours frequency ≤ 10%
- Air tightness ≤ 0.64 h^{-1}

It has to be noted though that renewable energy at the utmost can compensate the energy consumption of the same sources, according to the national scheme; this implies that no plus energy buildings can be built. Therefore energy neutrality is the top performance that is achievable.

Because the schemes are purely theoretical, there is no certainty that the calculated performances will be achieed in real operation conditions.

2.3.4 Slovenia

In Slovenia there is no official building energy performance level beyond the 2020 NZEB level. Based on the cost optimality analysis in 2014 [SI 7] that demonstrated that the usual solutions for NZEB buildings are still beyond the cost optimal level, it is likely that further developments of NZEBs will focus on building smartness and on holistic environmental performance as well as on sustainability criteria (and not only on the further reduction of the energy needs). Further integration of RES, supported with heat storages and/or batteries in combination with on-site PV power plants (with self-supply as preference) is a priority, mainly due to the goal that by the year 2030 nearly 2/3 of the energy in buildings have to be produced from renewables [SI 8]. This will however result in a further reduction of primary energy and CO_2 emissions at a building level.

Buildings beyond the NZEB level also rely on district and urban NZEB solutions, i.e. on the integration of a building into a smart grid. The ongoing large Slovenian-Japanese demonstration project NEDO [SI 9] on smart meters and smart grids is addressing the development of a national smart grid infrastructure and advanced ICT solutions for the optimization of the energy use in districts and buildings.

Based on the development trends and the anticipated novelties in the EPBD directive the buildings of the beyond NZEB level comply with one of the following principles on top of the NZEB criteria:

- Plus energy building: An NZEB building producing energy from RES on-site to cover primarily its own needs and exporting the rest of the produced energy to the grid. Due to the compensation the primary energy balance is positive. PV electricity is stored and e-mobility can be included.
- Smart house: Smart NZEB buildings with innovative technologies like demand response, are integrated into a smart grid. The buildings are an active member of a NZEB district, with innovative services - like car sharing in e-mobility.
- Green building: An NZEB building built with environmentally friendly building materials. The building can be LEED, BREEAM, DGNB certified or similar, i.e. built according to levels the EC guidelines for building sustainability performance [SI 10].
- Nearly zero CO_2 emission building: Since a 2050 target is the decarbonisation of the building stock, nearly zero emission buildings in the whole life-cycle is one of the priorities of the green house gas reduction strategy in Slovenia [SI 11].

3. Investment costs

The CoNZEBs project partners have decided to gather the investment costs of the realised example buildings in different depths:

1. Total costs including ground (costs of the building plot on which the multi-family house is built, includes also planning costs and administrative fees)
2. Total costs excluding ground (includes as above also planning costs and adminisatrtive fees)
3. Building component costs (CIB SfB [6] cost groups 1.12, 1.13, 2, 3 and 4 or DIN 276 [7] cost group 300)
4. (Building) services systems costs (CIB SfB cost groups 5 and 6 or DIN 276 cost group 400)
5. Total building component and building services system costs (CIB SfB cost groups 1.12, 1.13, 2, 3, 4, 5 and 6 or DIN 276 cost groups 300 and 400)
6. Cost difference between NZEB building level or beyond NZEB building level and the building level fulfilling the minimum energy performance requirements. It is assumed that these cost differences are due to differences in the building component and building services systems costs.

Table 14 to Table 18 show the gathered investment costs for a list of national example buildings. However not all costs could be inserted since the sources of the data did not include all information. This leads to different information depths and sometimes limited data. The focus of the data collection is on finding out the average investment cost difference between NZEB building level and the building level fulfilling the minimum energy performance requirements. While for most of the examples this cost data is not available, comparing the average total building component and building services system costs of the buildings fulfilling the minimum energy performance requirements with those of the NZEBs can be used as an alternative approach to calculate this cost difference.

It would be very interesting to present the costs of building envelope components instead of all building components, since usually only the building envelope (separating the heated zone from the unheated zone and the exterior) is influenced by the energy performance level of the building. However, these costs are difficult to separate from other building component costs, which is why the building envelope costs are rarely included in cost catalogues or project documentation.

It has to be noted that investment costs differ depending on the year(s) of construction and the country, but also on the national region. For each example building the year of construction is indicated in the tables. The tables are split into the four countries. A comparison between the costs arising in the 4 countries is very problematic because technology costs differ depending on the market, and labour costs differ as well. Even regional differences in the country apply. BKI [DE 14] shows building cost differences between German regions ranging from factor 0.638 (Nienburg) to factor 1.419 (Munich) in 2017.

It can be attempted to balance the influence of the year of construction and the location by using annual and regional factors. The CoNZEBs project team has discussed this issue and has decided that the risk of falsifying the data is higher than the possible benefit.

4. Energy costs

CoNZEBs also tried to collect annual energy costs for the example cases. In case only annual energy consumptions divided in energy sources were available, energy costs were calculated using average energy tariffs as indicated in the remarks following each database. Unfortunately this was not possible for all buildings. Especially building cost catalogues like BKI [DE 14] do not include annual energy costs or annual energy consumptions.

The following energy costs have been taken into account:

1. Building-related electricity: Electricity used by the building services systems (auxiliary energy for pumps, controls, fans of ventilation systems, etc.), but also including

electricity for heating and DHW in case of electrical heating e.g. with heat pumps. As there is usually only one common electricity meter installed (in addition to the electricity meter per residential unit) this might include common electricity used for lighting of staircases, cellars, etc.

2. Household-related electricity: User dependent electricity for lighting, domestic appliances like dishwashers, ovens, cookers, fridges, etc., computers, TVs, etc.)
3. Total electricity: Sum of building related electricity and household electricity
4. Gas: Building related energy costs for the energy source gas
5. District heating: Building related energy costs for the energy source district heating
6. Biomass: Building related energy costs for the energy source district heating
7. Others: Building related energy costs for other energy sources (e.g. oil, coal, etc.). The other energy source per building used is defined in the remarks below each database. In a few cases this column contains energy cost benefits from renewable electricity feed-in.
8. Total building: Sum of all building related energy costs (1. + 4. + 5. + 6. + 7.)
9. Total: Sum of all energy costs (3. + 4. + 5. + 6. + 7.)

5. Database of investment costs and energy costs in the four countries

Based on the discussions set out in chapters 3 and 4, one table per country was developed which, on the one hand, includes all gathered information on the investment and energy costs, but on the other hand also clarifies which costs and energy consumptions are included in the data. Since the details of the collected information vary, not all costs can be compared.

The CoNZEBs project group considers a cross national comparison as very difficult, because the energy performance levels differ between the countries, the investment costs vary a lot, also dependent on technologies that are popular in one country, but not so much in another, and the energy prices differ as well. Other considerations discussed into more detail in chapters 3 and 4 apply.

The information includes cost index databases from literature, data from building catalogues or networks of energy efficient buildings and specific example cases. The source of each cost data item is given.

5.1 Database – Germany

Table 14: Investment cost and energy cost database for Germany

No.	Name of data	Source	Year	Location	Size: Floor area = living area	Level			Investment costs							Energy costs									Remarks
									Total		Building components (BC) and services systems (SS) costs			Δ costs compared to minimum EP requirements		Electricity									
						Minimum EP requirements	NZEB	Beyond NZEB	Incl. ground	Excl. ground	BC: CIB SfB cost groups 1.12, 1.13, 2, 3, 4 = DIN 276 cost group 300	SS: CIB SfB cost groups 5, 6 = DIN 276 cost group 400	Total (BC + SS)			(1) Building related	(2) Household	(3) Total: (1) + (2)	(4) Gas	(5) District heating	(6) Biomass	(7) Others	(8) Total building related ((1) + (4) + (5) + (6) + (7))	(9) Total ((3) + (4) + (5) + (6) + (7))	
					m²				€/m²	€/m²	€/m²	€/m²	€/m²	€/m²	%	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	
1	Ø small MFH	[DE 14]	2016	Germany	n.a.	X			n.a.	n.a.	1,505	356	1,861	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(1)
2	Ø small MFH, simple	[DE 14]	2016	Germany	n.a.	X			n.a.	n.a.	1,165	243	1,408	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(2)
3	Ø small MFH, med.	[DE 14]	2016	Germany	n.a.	X			n.a.	n.a.	1,413	336	1,749	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(3)
4	Ø small MFH, high	[DE 14]	2016	Germany	n.a.	X			n.a.	n.a.	1,943	490	2,433	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(4)
5	Ø med. MFH	[DE 14]	2016	Germany	n.a.	X			n.a.	n.a.	1,449	355	1,804	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(5)
6	Ø med. MFH, simple	[DE 14]	2016	Germany	n.a.	X			n.a.	n.a.	1,179	248	1,427	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(6)
7	Ø med. MFH, med.	[DE 14]	2016	Germany	n.a.	X			n.a.	n.a.	1,475	357	1,832	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(7)
8	Ø med. MFH, high	[DE 14]	2016	Germany	n.a.	X			n.a.	n.a.	1,641	433	2,074	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(8)
9	Ø big MFH	[DE 14]	2016	Germany	n.a.	X			n.a.	n.a.	1,560	444	2,004	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(9)
10	Ø big MFH, med.	[DE 14]	2016	Germany	n.a.	X			n.a.	n.a.	1,489	400	1,889	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(10)
11	Ø big MFH, high	[DE 14]	2016	Germany	n.a.	X			n.a.	n.a.	1,656	503	2,159	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(11)
12	Ø passive houses	[DE 14]	2016	Germany	n.a.		X		n.a.	n.a.	1,549	432	1,981	289	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(12)
13	Lilienstraße 41 Süd	[DE 15]	2014	Munich	1,010			X	n.a.	n.a.	2,370	777	3,147	n.a.	n.a.	0.52	n.a.	n.a.	2.17	-	-	-2.11	0.58	n.a.	(13)
14	Cordierstraße 4	[DE 16]	2013	Frankfurt	1,238			X	n.a.	2,661	1,758	793	2,551	328	12	n.a.	n.a.	6.46	4.80	-	-	-	n.a.	11.26	(14)
15	LaVidaVerde	[DE 17]	2014	Berlin	1,072			X	n.a.	n.a.	1,490	508	1,998	257	n.a.	2.41	1.88	4.29	-	-	-	-4.87	-2.46	-0.57	(15)
16	Nürtinger Straße	[DE 18]	2013	Tuebingen	891			X	n.a.	2,898	1,569	764	2,333	n.a.	n.a.	2.46	5.73	8.19	-	4.83	-	-2.82	4.47	10.20	(16)
17	Project 11	[DE 19]	2013	Frankfurt	17,988		X		n.a.	n.a.	n.a.	n.a.	1,492	n.a.	n.a.	2.31	n.a.	n.a.	-	3.57	-	-	5.88	n.a.	(17)
18	Project 12	[DE 19]	2012	Frankfurt	7,265		X		n.a.	n.a.	n.a.	n.a.	1,878	n.a.	n.a.	0.42	n.a.	n.a.	-	5.84	-	-	6.26	n.a.	(18)
19	Project 13	[DE 19]	2013	Frankfurt	11,712		X		n.a.	n.a.	n.a.	n.a.	1,886	n.a.	n.a.	0.37	n.a.	n.a.	-	5.46	-	-	5.83	n.a.	(19)
20	Project 20	[DE 19]	2012	Frankfurt	4,176		X		n.a.	n.a.	n.a.	n.a.	1,586	n.a.	n.a.	2.82	n.a.	n.a.	3.50	-	-	-	6.32	n.a.	(20)
21	Project 23	[DE 19]	2014	Frankfurt	9,680		X		n.a.	n.a.	n.a.	n.a.	1,619	n.a.	n.a.	1.90	n.a.	n.a.	3.60	-	-	-	5.50	n.a.	(21)
22	Markomannenweg N	[DE 19]	2014	Frankfurt	2,772	X			n.a.	n.a.	n.a.	n.a.	1,955	0	0	0.74	n.a.	n.a.	4.02	-	-	-	4.76	n.a.	(22)
23	Gepiden-Forum	[DE 19]	2014	Frankfurt	3,102	X			n.a.	n.a.	n.a.	n.a.	1,958	0	0	0.98	n.a.	n.a.	6.47	-	-	-	7.45	n.a.	(23)
24	BKI 1134 (5 units)	[DE 14]	2016	Dueren	378		X		n.a.	n.a.	n.a.	n.a.	1,957	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(24)

No.	Name of data	Source	Year	Location	Size: Floor area = living area	Level: Minimum EP requirements	Level: NZEB	Level: Beyond NZEB	Investment costs: Total: Incl. ground	Investment costs: Total: Excl. ground	Investment costs: Building components (BC) and services systems (SS) costs: BC CIB SfB cost groups 1.12, 1.13, 2, 3, 4 = DIN 276 cost group 300	Investment costs: BC and SS costs: SS CIB SfB cost groups 5, 6 = DIN 276 cost group 400	Investment costs: Total (BC + SS)	Δ costs compared to minimum EP requirements	Δ costs compared to minimum EP requirements	Energy costs: Electricity: (1) Building related	Energy costs: Electricity: (2) Household	Energy costs: Electricity: (3) Total: (1) + (2)	Energy costs: (4) Gas	Energy costs: (5) District heating	Energy costs: (6) Biomass	Energy costs: (7) Others	Energy costs: (8) Total building related ((1) + (4) + (5) + (6) + (7))	Energy costs: (9) Total ((3) + (4) + (5) + (6) + (7))	Remarks
					m²				€/m²	€/m²	€/m²	€/m²	€/m²	€/m²	%	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	
25	BKI 1228 (8 units)	[DE 14]	2016	Potsdam	516		X		n.a.	n.a.	n.a.	n.a.	1,558	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(25)
26	BKI 1236 (7 units)	[DE 14]	2016	Dortmund	1,108			X	n.a.	n.a.	n.a.	n.a.	1,854	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(26)
27	BKI 1221 (10 units)	[DE 14]	2016	Hamburg	1,559		X		n.a.	n.a.	n.a.	n.a.	2,136	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(27)
28	BKI 1016 (3 units)	[DE 14]	2016	Dresden	351		X		n.a.	n.a.	n.a.	n.a.	2,043	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(28)
29	BKI 1063 (11 units)	[DE 14]	2016	Berlin	1,334		X		n.a.	n.a.	n.a.	n.a.	2,071	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(29)
30	BKI 1183 (11 units)	[DE 14]	2016	Berlin	2,645		X		n.a.	n.a.	n.a.	n.a.	1,760	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(30)
31	BKI 1188 (17 units)	[DE 14]	2016	Hamburg	874		X		n.a.	n.a.	n.a.	n.a.	2,767	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(31)
32	BKI 0967 (20 units)	[DE 14]	2016	Freiburg	1,900		X		n.a.	n.a.	n.a.	n.a.	1,277	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(32)
33	BKI 1009 (8 units)	[DE 14]	2016	Karlsruhe	1,142		X		n.a.	n.a.	n.a.	n.a.	1,212	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(33)
34	BKI 1036 (4 units)	[DE 14]	2016	Berlin	1,187		X		n.a.	n.a.	n.a.	n.a.	2,642	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(34)
35	BKI 1052 (6 units)	[DE 14]	2016	Flensburg	794			X	n.a.	n.a.	n.a.	n.a.	4,821	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(35)
36	BKI 0882 (39 units)	[DE 14]	2016	Münster	3,050		X		n.a.	n.a.	n.a.	n.a.	1,878	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(36)
37	BKI 0997 (16 units)	[DE 14]	2016	Freiburg	2,128		X		n.a.	n.a.	n.a.	n.a.	1,460	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(37)
38	BKI 1007 (14 units)	[DE 14]	2016	MT-Kreis	1,516		X		n.a.	n.a.	n.a.	n.a.	1,692	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(38)
39	BKI 0724 (14 units)	[DE 14]	2016	Dresden	2,228		X		n.a.	n.a.	n.a.	n.a.	1,423	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(39)
40	BKI 0767 (4 units)	[DE 14]	2016	Lindau	367		X		n.a.	n.a.	n.a.	n.a.	1,636	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(40)
41	BKI 0795 (30 units)	[DE 14]	2016	Hamburg	3,424		X		n.a.	n.a.	n.a.	n.a.	1,433	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(41)
42	BKI 0797 (23 units)	[DE 14]	2016	Balingen	3,024		X		n.a.	n.a.	n.a.	n.a.	1,469	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(42)
43	BKI 0806 (19 units)	[DE 14]	2016	Berlin	2,280		X		n.a.	n.a.	n.a.	n.a.	1,810	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(43)
44	BKI 0837 (44 units)	[DE 14]	2016	Darmstadt	3,977		X		n.a.	n.a.	n.a.	n.a.	1,374	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(44)
45	BKI 0683 (7 units)	[DE 14]	2016	Freiburg	1,078		X		n.a.	n.a.	n.a.	n.a.	1,371	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(45)
46	BKI 0633 (20 units)	[DE 14]	2016	Stuttgart	3,862		X		n.a.	n.a.	n.a.	n.a.	1,153	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(46)
Average of minimum EP requirements						X			n.a.	n.a.	n.a.	n.a.	1,879	-	-	(0.86)	n.a.	n.a.	n.a.	n.a:	n.a.	n.a.	(6,11)	n.a.	(47)
Average of NZEB							X		n.a.	n.a.	n.a.	n.a.	1,923	44	-	(1.56)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(5,96)	n.a.	(48)
Average of beyond NZEB								X	n.a.	n.a.	n.a.	n.a.	2,377	498	-	(1.80)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(-1,47)	n.a.	(49)

Remarks pertaining to Table 14:

(1) The included investment costs are average gross costs for small multi-family houses (with up to 6 residential units included). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(2) The included investment costs are average gross costs for small multi-family houses (with up to 6 residential units included) built in a simple building standard. The data is based on 10 different buildings. The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(3) The included investment costs are average gross costs for small multi-family houses (with up to 6 residential units included) built in a medium building standard. The data is based on 15 different buildings. The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(4) The included investment costs are average gross costs for small multi-family houses (with up to 6 residential units included) built in a high building standard. The data is based on 12 different buildings. The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(5) The included investment costs are average gross costs for medium-sized multi-family houses (with 7 to 19 residential units included). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(6) The included investment costs are average gross costs for medium-sized multi-family houses (with 7 to 19 residential units included) built in a simple building standard. The data is based on 6 different buildings. The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(7) The included investment costs are average gross costs for medium-sized multi-family houses (with 7 to 19 residential units included) built in a medium building standard. The data is based on 23 different buildings. The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(8) The included investment costs are average gross costs for medium-sized multi-family houses (with 7 to 19 residential units included) built in a high building standard. The data is based on 11 different buildings. The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(9) The included investment costs are average gross costs for big multi-family houses (with 20 or more residential units included). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(10) The included investment costs are average gross costs for big multi-family houses (with 20 or more residential units included) built in a medium building standard. The data is based on 16 different buildings. The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(Note: there is no data available for big multi-family houses in simple building standard)

(11) The included investment costs are average gross costs for big multi-family houses (with 20 or more residential units included) built in a high building standard. The data is based on 12 different buildings. The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(12) The included investment costs are average gross costs for passive houses. The data is based on 20 different buildings. The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. The Δ costs compared to minimum EP requirements have been calculated by comparing the passive house costs with the costs for medium-sized multi-family houses (see 5). There are no corresponding average energy costs (or energy consumptions) available.

(13) Lilienstraße 41 Süd, Munich


Photo: © GWG München.

Together with 4 renovated multi-family houses, this timber frame building is connected to a small local district heating unit based on a gas motor heat pump, a gas condensing boiler as back-up and supported by solar thermal panels. The aim of the building was a CO_2-neutral heating taking into account the feed-in electricity generated by PV panels. The gross investment costs for the common heating and PV system parts are taken into account distributed by the size of the floor area per building. Energy costs are not available in the report [DE 15]. However the energy costs for heating and DHW (gas) and auxiliary energy (electricity) have been calculated based on the documented measured energy consumption of the building, using the following average base prices and energy tariffs. The column “energy costs – other” presents the gains from feeding generated electricity into the national grid. Since the household electricity use is not available, no total energy costs have been calculated.

- Gas: base price: 150 €/yr, consumption tariff: 0.04 €/kWh
- Electricity: base price: 120 €/yr, consumption tariff: 0.29 €/kWh
- Feed-in of PV generated electricity: feed-in tariff: 0.12 €/kWh

The given floor area is the heated living area.

(14) Cordierstraße 4, Frankfurt


Photo: © faktor10

The building is an efficiency house plus, i. e. a house that generates in an annual balance more final and primary energy from renewables than it consumes for heating, ventilation, DHW, auxiliary energy and household electricity. Based on a building envelope in passive house level the technical features of the building include solar thermal vacuum collectors, a combined heat and power unit with gas as fuel, decentral mechanical ventilation with heat recovery and PV on the façade, roof and carport. The heating energy costs are distributed to the tenants as a part of the rent (flat charge, heat-inclusive rent). In order to use the electricity generated by the building, the tenants receive a budget for electricity and have to pay for additional electricity at a price slightly lower than usual electricity tariffs. As "energy costs – total electricity" Table 14 shows the sum of the electricity budget and the average costs of the additional electricity. In "energy costs – gas" the flat charge for heating as part of the rent is shown. The presented investment costs are gross costs [DE 16]. The given floor area is the living area.

(15) LaVidaVerde, Berlin


Photo: © LaVidaVerde Planung, Dr. Beetstra + Körholz

The building is an efficiency house plus, i. e. a house that generates in an annual balance more final and primary energy from renewables than it consumes for heating, ventilation, DHW, auxiliary energy and household electricity. The building realised in massive construction with external thermal insulation composite system. The building services systems comprise PV, exhaust ventilation plus grey water connected a heat pump, and for the remaining heating energy needs a wood pellet boiler. As "energy costs - electricity – building" Table 2 shows the electricity consumption of the heat pump used for space heating and DHW. The remaining electricity costs (household + auxiliary electricity) are included in column "energy costs – electricity – household". The column "energy costs – other" presents the gains from feeding generated electricity into the national grid. The ownership-model of the building is owner-occupier. The presented investment costs are gross costs [DE 17]. The given floor area is the living area.

(16) Nürtinger Straße, Tübingen

Photo: © Architect Wamsler

The building is an efficiency house plus, i. e. a house that generates in an annual balance more final and primary energy from renewables than it consumes for heating, ventilation, DHW, auxiliary energy and household electricity. The exterior walls are made of timber frame constructions with ventilated PV elements. The windows are triple-glazed. The building is connected to a district heating network with a primary energy factor of 0. A central ventilation system with a heat recovery of > 80% was installed. PV generated electricity is stored in a battery to increase the self-use of the building. Table 2 shows as “energy costs – other” the gains from feeding in generated electricity into the national grid. Energy costs are not available in the report [DE 18]. However the energy costs for heating and DHW (district heating) and the electricity have been calculated based on the documented measured energy consumption of the building, using the following average base prices and energy tariffs indicated in [DE 18]:

- District heating: base price: 2,250 €/yr, consumption tariff: 0.0845 €/kWh
- Electricity: base price: 102 €/yr incl. meters (9 households + one extra meter for common electricity), consumption tariff: 0.29 €/kWh
- Feed-in of PV generated electricity: base price: 15.20 €/yr, feed-in tariff: 0.15 €/kWh

The given floor area is the living area.

(17) The building is a passive house built by ABG Frankfurt Holding in massive construction. It is connected to a district heating system. The available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). Additionally the annual energy costs for general electricity (electricity for the building and HVAC systems) and the district heating costs have been provided. The given floor area is the living area [DE 19].

(18) The building is a passive house built by ABG Frankfurt Holding in massive construction. It is connected to a district heating system. The available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). Additionally the annual energy costs for general electricity (electricity for the building and HVAC systems) and the district heating costs have been provided. The given floor area is the living area [DE 19].

(19) The building is a passive house built by ABG Frankfurt Holding in massive construction. It is connected to a district heating system. The available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). Additionally the annual energy costs for general electricity (electricity for the building and HVAC systems) and the district heating costs have been provided. The given floor area is the living area [DE 19].

(20) The building is a passive house built by ABG Frankfurt Holding in massive construction with a gas-driven heating system. The available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). Additionally the annual energy costs for general electricity

(electricity for the building and HVAC systems) and the costs for gas have been provided. The given floor area is the living area [DE 19].

(21) The building is a passive house built by ABG Frankfurt Holding in massive construction with a gas-driven combined heat and power unit (CHP). The available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). Additionally the annual energy costs for general electricity (electricity for the building and HVAC systems) and the costs for gas have been provided. The given floor area is the living area [DE 19].

(22) The building was built according to minimum energy performance requirements by ABG Frankfurt Holding in massive construction with a gas-driven heating system. The available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). Additionally the annual energy costs for general electricity (electricity for the building and HVAC systems) and the costs for gas have been provided. The given floor area is the living area [DE 19].

(23) The building was built according to minimum energy performance requirements by ABG Frankfurt Holding in massive construction with a gas-driven heating system. The available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). Additionally the annual energy costs for general electricity (electricity for the building and HVAC systems) and the costs for gas have been provided. The given floor area is the living area [DE 19].

(24) The building is a passive house with 5 residential units built in Dueren in mainly massive construction. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(25) The building is a passive house with 8 residential units built in Potsdam in masonry construction. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(26) The building is a plus energy house with 7 residential units built in Dortmund in massive construction. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(27) The building is a passive house with 18 residential units built in Hamburg in masonry construction. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(28) The building is a passive house with 3 residential units built in Dresden in masonry construction. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(29) The building is a passive house with 11 residential units built in Berlin in masonry construction. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They

have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(30) The building is a passive house with 22 residential units built in Berlin with reinforced concrete construction and a timber panel facade. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(31) The building is a passive house with 17 residential units built in Hamburg in masonry construction. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available. Note: the living area (874 m²) is rather small compared to the gross floor area (1,821 m²) due to a common area. This results in rather high gross investment costs related to the living area.

(32) The building is a passive house with 20 residential units built in Freiburg im Breisgau in masonry construction. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(33) The building is a passive house with 8 residential units built in Karlsruhe in masonry construction. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(34) The building is a passive house with 4 residential units built in Berlin as a reinforced concrete structure. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(35) The building is a plus energy house with 6 residential units built in Schleswig-Flensburg as a reinforced concrete structure with a multi-layer façade system. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(36) This is a combination of 3 buildings achieving the passive house level with a total of 39 residential units built in Muenster. The construction is realised in masonry. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(37) The building is a passive house with 16 residential units built in Freiburg im Breisgau in massive construction. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(38) The building is a passive house with 14 residential units built in the Main-Taunus district in massive construction. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum

[DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(39) The building is a passive house with 14 residential units built in Dresden in reinforced concrete construction. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(40) The building is a passive house with 4 residential units built in Lindau (Lake Constance) as timber post structure. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(41) This is a combination of 4 buildings achieving the passive house level with a total of 30 residential units built in Hamburg. The construction is realised in masonry. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(42) The building is a passive house with 23 residential units built in Balingen (Zollernalb) as a reinforced concrete structure. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(43) The building is a passive house with 19 residential units built in Berlin as a timber frame structure. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(44) This is a combination of 2 buildings achieving passive house level with a total of 44 residential units built in Darmstadt. The construction is realised in masonry. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(45) The building is a passive house with 7 residential units built in Freiburg im Breisgau in masonry construction with reinforced concrete ceilings and a flat roof. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(46) The building is a passive house with 20 residential units built in Stuttgart in masonry construction. The only available gross investment costs are the sum of building construction and building services systems costs (German DIN 276 cost groups 300 and 400). The costs have been gathered by BKI Baukosteninformationszentrum [DE 14]. They have been recalculated to be related to the living area. There are no corresponding average energy costs (or energy consumptions) available.

(47) The calculation of the average values of the multi-family houses on the minimum energy performance level does not use all data included in Table 14. This is because the data taken from BKI (numbers 1 to 11) is presented twice: first as average data for small, medium and big multi-family house buildings (numbers 1, 5 and 9) and second for each building size divided into average data for buildings built in simple, medium and high standard (numbers 2 to

4, 6 to 8 and 10 to 11). It was decided to use the three main average values multiplied by the number of included building examples together with the collected multi-family house data based on buildings realised by ABG Frankfurt Holding (numbers 22 and 23) for the calculation of the arithmetic average. For calculating the average of the buildings meeting the minimum energy performance requirements the following data was used: 1, 5, 9, 22 and 23. For information on the average energy costs calculation see chapter 6.1.

(48) The calculation of the average values of the multi-family houses on the minimum energy performance level does not use all data included in Table 14. This is because the data taken from BKI (numbers 12, 24, 25, 27 to 34 and 36 to 46) is presented twice: first as average building data (number 12) and second as single building data. The average data is however not using all of the available single data. Since the cause for this is not explained in the source it might be that there are specific reasons for leaving out some of the buildings when calculating the averages. It was therefore decided to use the average multiplied by the number of included building examples together with the collected multi-family house data based on buildings realised by ABG Frankfurt Holding (numbers 17 to 21). For calculating the average of the buildings on the NZEB level the following data was used: 12, 17, 18, 19, 20 and 21. For information on the average energy costs calculation see chapter 6.1.

(49) The calculation of the average values of the multi-family houses on the minimum energy performance level does not use all data included in Table 14. Building example number 35 resulted in so high investment costs that it was not included in the average. We assume that costs for other issues than the high performance building level led to these high costs. For calculating the average of the buildings on the beyond NZEB level the following data was used: 13, 14, 15, 16 and 26. For information on the average energy costs calculation see chapter 6.1.

5.2 Database – Denmark

Table 15: Investment cost and energy cost database for Denmark

No.	Name of data	Source	Year	Location	Size: Gross heated floor area	Level			Investment costs							Energy costs									Remarks
									Total		Building components (BC) and services systems (SS) costs			Δ costs compared to minimum EP requirements		Electricity									
						Minimum EP requirements	NZEB	Beyond NZEB	Incl. ground	Excl. ground	BC CIB SfB cost groups 1.12, 1.13, 2, 3, 4 = DIN 276 cost group 300	SS CIB SfB cost groups 5, 6 = DIN 276 cost group 400	Total (BC + SS)			(1) Building related	(2) Household	(3) Total: (1) + (2)	(4) Gas	(5) District heating	(6) Biomass	(7) Others	(8) Total building related ((1) + (4) + (5) + (6) + (7))	(9) Total ((3) + (4) + (5) + (6) + (7))	
					m²				€/m²	€/m²	€/m²	€/m²	€/m²	€/m²	%	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	
1	Æblelunden	[DK 7]	2017	Hjortshøj	4,110		X		3,076	1,562	798	412	1,210	n.a.	n.a.	0.70	7.08	7.78	-	-	-	-	0.70	7.78	(1)
2	Fasanvangen	[DK 7]	2016	Ishøj	1,977		X		3,045	n.a.	866	303	1,169	n.a.	n.a.	0.67	7.08	7.75	-	-	-	-	0.67	7.75	(2)
3	Orienten	[DK 7]	2019	Kbh.	11,256		X		3,144	n.a.	1,047	372	1,420	n.a.	n.a.	0.29	7.08	7.37	-	1.96	-	-	2.25	9.33	(3)
4	Vingen	[DK 7]	2017	Hillerød	1,620	X			3,076	2,015	1,190	275	1,465	n.a.	n.a.	1.03	7.08	8.11	-	2.08	-	-	3.11	10.19	(4)
5	Vingen	[DK 7]	2017	Hillerød	1,620	X			2,686	1,625	960	222	1,182	n.a.	n.a.	1.03	7.08	8.11	-	2.08	-	-	3.11	10.19	(5)
6	Vingen	[DK 7]	2017	Hillerød	1,620		X		2,693	1,632	960	229	1,189	7.40	0.5	0.33	7.08	7.41	-	2.08	-	-	2.41	9.49	(6)
7	BOLIG+	[DK 4]	2016	Søborg	1,048		X		n.a.	2,067	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-	n.a.	-	-	n.a.	n.a.	(7)
8	BOLIG+	[DK 4]	2016	Søborg	1,048			X	n.a.	2,264	n.a.	n.a.	n.a.	197	9.5	0.00	0.00	0.00	-	n.a.	-	-	0.00	0.00	(8)
"Average" of minimum EP requirements						X			2,686	1,625	960	222	1182			1.03	7.08	8.11					3.11	10.19	(9)
Average of NZEB							X		2,990	1,754	918	329	1247			0.50	7.08	7.58					1.51	8.59	(10)
„Average" of beyond NZEB								X		2,264						0.00	0.00	0.00					0.00	0.00	(11)

Remarks pertaining to Table 15:

Social housing in Denmark is highly regulated regarding the allowed total construction cost – i.e. the housing must be constructed within a certain cost-frame. This means that social housing that complies with the minimum energy performance requirements in the current building code generally costs the same as buildings that comply with the voluntary 2020 building class. The only difference is that the building that complies with building class 2020 will have introduced savings elsewhere in the construction of the building to free capital needed to meet the more strict 2020 requirements. These may be cheaper kitchens, cheaper floor covering, etc. The table below shows the 2017 cost-frame for social housing in Denmark.

Table 16: Total 2017 cost-frame for social housing in Denmark

	Total sum	Excl. cost for the plot
	€ per m²	€ per m²
Greater Copenhagen	3050	2545
Major rail towns	2600	2170
Rest of Denmark	2455	2045

The cost-frame can be extended if the housing is to be used for special purposes, e.g. people with special needs, but not to meet energy performance requirements extending further than the current minimum requirements as stated in the Danish Building regulations 2015.

General comments to Table 15:

Information on the examples originates from the consultants, generated for proof of compliance with the Danish environmental certification scheme, DGNB.

Energy consumption calculations were made using the Danish calculation tool Be15.

Energy costs: The following costs are used in DKK exclusive VAT:

- Electricity 1.77 DKK/kWh
- District heating 520 DKK/MWh
- Solar cells -1.51 DKK/kWh

-1.51 DKK/kWh is a price for solar power used in LCCByg in DGNB context. Some of the solar electricity can displace the purchase of power for 1.77 DKK/kWh excl. VAT and surplus solar power may be sold for 0.60 DKK/kWh.

(1) Æblelunden

Æblelunden consists of 38 social dwellings in Hjortshøj, owned by the Housing association AAB Århus. Turnkey contractor: Thorntoft & Mortensen, Architect: Ginnerup Arkitekter; Consultant: Rambøll a/s.

- Semi-detached houses in two floors.
- Costs originate from the contractor's tender list.
- The houses fulfil Building Class BK2020 cf. Be15. Electricity for households is estimated to be 30 kWh/m².yr.
- Energy costs are based on the above energy prices and an exchange rate of 7.5 DKK/Euro.
- First-time occupancy is scheduled for 1 November 2017.

(2) Fasanvangen

Fasanvangen consists of 18 social dwellings in Ishøj, owned by the social housing company Lejerbo Køge Bugt dept. 259. Turnkey contractor: Skara Byg; Architect: Vilhelm Lauritzen; Consultant: Orbicon a/s.

- Two-plan terraced houses.
- Costs originate from the contractor's tender list.
- The houses fulfil Building Class BK2020 cf. Be15. Constructed according to the concept of “Social Housing+”. Electricity for households is estimated to be 30 kWh/m²yr.
- Energy costs are based on the above energy prices and an exchange rate of 7.5 DKK/Euro.
- First-time occupancy was in June 2015.

(3) Orienten

Orienten consists of 135 social dwellings in Copenhagen North harbour, owned by the social housing company Domea. Architect: Dorte Mandrup architects and KHS architects; consultant: Dines Jørgensen and Cenergia.

- Multifamily building with 4-6 storeys.
- Costs originate from the advisor's price estimate.
- The buildings fulfil Building Class BK2020 cf. Be15. Electricity for households is estimated to be 30 kWh/m².yr.
- Energy costs are based on the above energy prices and an exchange rate of 7.5 DKK/Euro.
- First-time occupancy is scheduled for June 2019.

(4 + 5) Vingen

Vingen consists of 20 dwellings for young people with special needs, owned by the social housing company Lejerbo. Arcihitect Mangor & Nagel A/S; Consultant: Wissenberg A/S.

- One-plan housing + service area.
- Costs originate from the contractor's tender list.
- Complies with BR15 cf. Be15. Electricity for households is estimated to be 30 kWh/m².yr.
- Energy costs are based on the above energy prices and an exchange rate of 7.5 DKK/Euro.
- First-time occupancy was in June 2015.

Vingen is represented in 3 rows (rows 4, 5 and 6) in the table above. The first row shows the data for the building as constructed for young people with special needs. The next row shows the cost data if the building was constructed as normal dwellings (the allowed costs for special needs dwellings is 24% higher [DK 8] than for normal dwellings. The third row represents a calculated example than complies with the NZEB requirements by addition of a PV system with a capacity of 4 kWh/m² per year - equal to an annual electricity production of 6,470 kWh. The additional cost in row 6 is the additional cost for the imaginary PV system, priced at 200 €/m², in total 12,000 €, which moves the building from BR2015 to the BR2020 (NZEB) minimum requirement. The cost of the PV system is approx. 7.40 €/m² of heated floor area.

(6 + 7) BOLIG+

BOLIG+ consists of 10 apartments on 4 floors and an above-ground “basement”, 3 apartments on each of the 2 lower floors and 2 apartments on each of the 2 upper floors. The building is designed to be energy neutral on an annual basis, including the residents’ electricity consumption for light and appliances. The building is connected to the local district heating grid that supplies heat for space heating and domestic hot water. Building-integrated photovoltaic (roof and facades) covers the residents’ estimated electricity consumption plus the uptake of district heating. The additional cost required to meet energy neutrality is 194 €/m², compared to the cost of meeting the Danish voluntary building class 2020 (NZEB).

- Four-plan multi-family apartment building including above ground “basement”.
- Costs originate from the building owners’ accounts.
- Complies with the Danish building class 2020 (20 kWh/m² per year primary energy), without local production of electricity.
- Energy costs are based on the average energy prices and an exchange rate of 7.5 DKK/Euro.
- Additional cost is relative to the cost of complying with building class 2020 (remark 7 in Table 15).
- First-time occupancy was in March 2016.

5.3 Database – Italy

Table 17: Investment cost and energy cost database for Italy

No.	Name of data	Source	Year	Location	Size: Useful floor area (m²)	Level: Minimum EP requirements	Level: NZEB	Level: Beyond NZEB	Investment costs – Total: Incl. ground (€/m²)	Investment costs – Total: Excl. ground (€/m²)	Building components (BC) and services systems (SS) costs – BC: CIB SfB cost groups 1.12, 1.13, 2, 3, 4 = DIN 276 cost group 300 (€/m²)	SS: CIB SfB cost groups 5, 6 = DIN 276 cost group 400 (€/m²)	Total (BC + SS) (€/m²)	Δ costs compared to minimum EP requirements (€/m²)	Δ costs compared to minimum EP requirements (%)	Energy costs – Electricity: (1) Building related (€/m²/yr)	(2) Household (€/m²/yr)	(3) Total: (1) + (2) (€/m²/yr)	(4) Gas (€/m²/yr)	(5) District heating (€/m²/yr)	(6) Biomass (€/m²/yr)	(7) Others (€/m²/yr)	(8) Total building related ((1) + (4) + (5) + (6) + (7)) (€/m²/yr)	(9) Total ((3) + (4) + (5) + (6) + (7)) (€/m²/yr)	Remarks
1	NZEB Borghesiana	[IT 11]	2016	Rome	378		X		n.a.	n.a.	1,085	555	1,640	n.a.	n.a.	1.20	n.a.	n.a.	-	-	-	-	1.20	n.a.	(1)
2	Casa Fiorita	[IT 12]	2015	Cesena	320			X	n.a.	n.a.	3,343	370	3,713	n.a.	n.a.	0.50	n.a.	n.a.	-	-	-	-	0.50	n.a.	(2)
3	NZEB Prato	[IT 13]	2017	Prato	2,360		X		n.a.	n.a.	1,141	385	1,526	n.a.	n.a.	0.00	n.a.	n.a.	0.47	-	-	-	0.47	n.a.	(3)
4	ATER Treviso 1	[IT 14]	2014	Moglia. V	789		X		n.a.	n.a.	1,122	502	1,624	n.a.	n.a.	1.59	n.a.	n.a.	-	-	-	-	1.59	n.a.	(4)
5	ATER Treviso 2	[IT 14]	2014	Moglia. V	788		X		n.a.	n.a.	1,019	465	1,484	n.a.	n.a.	1.85	n.a.	n.a.	-	-	-	-	1.85	n.a.	(5)
6	Case di luce	[IT 15]	2016	Bisceglie	3,200		X		n.a.	n.a.	1,250	219	1,468	n.a.	n.a.	0.55	n.a.	n.a.	-	-	-	-	0.55	n.a.	(6)
7	Solaria	[IT 16]	2014	Capurso	2,045		X		n.a.	n.a.	742	258	1,000	n.a.	n.a.	n.a.	n.a.	n.a.	-	-	-	-	n.a.	n.a.	(7)
8	Housing classe A+	[IT 17]	2013	Verbania	846		X		n.a.	n.a.	1,756	323	1,759	n.a.	n.a.	1.20	n.a.	n.a.	0.72	-	-	-	1.92	n.a.	(8)
9	ZEB Borgomanero	[IT 18]	2011	Borgom	840			X	n.a.	n.a.	4,040	613	4,653	n.a.	n.a.	0.00	n.a.	n.a.	-	-	-	-	0.00	n.a.	(9)
10	Tuxa	[IT 19]	2014	Milano	854		X		n.a.	n.a.	2,225	351	2,576	n.a.	n.a.	0.00	n.a.	n.a.	1.20	-	-	-	1.20	n.a.	(10)
11	Ed. M.te Cucco	[IT 20]	2017	Torino	2,146		X		n.a.	n.a.	1,165	275	1,440	n.a.	n.a.	0.96	n.a.	n.a.	-	1.70	-	-	2.64	n.a.	(11)
12	ACER RE 1	[IT 21]	2013	Reggio. E.	1,471	X			n.a.	n.a.	1,519	431	1,950	n.a.	n.a.	1.67	n.a.	n.a.	-	4.68	-	-	6.35	n.a.	(12)
13	ACER RE 1	[IT 21]	2014	Reggio. E.	991	X			n.a.	n.a.	1,301	441	1,742	n.a.	n.a.	1.95	n.a.	n.a.	-	6.00	-	-	6.95	n.a.	(13)
14	Ca' del Parco	[IT 22]	2015	Treviso	3207		X		n.a.	n.a.	1,249	316	1,565	n.a.	n.a.	1.86	n.a.	n.a.	-	-	-	-	1.86	n.a.	(14)
15	Daniela Cond.	[IT 23]	2016	Venezia	860		X		n.a.	n.a.	1,401	280	1,682	n.a.	n.a.	1.40	n.a.	n.a.	-	-	-	-	1.40	n.a.	(15)
Average of minimum EP requirements						X			n.a.	n.a.	1,051	295	1,386	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(16)
Average of NZEB							X		n.a.	n.a.	1,196	382	1,579	229	16	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(17)
Average of beyond NZEB								X	n.a.	n.a.	(3,692)	(492)	(4,183)	(2,834)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(18)

Remarks pertaining to Table 17:

(1) The building is located in Rome. It is an expansion of an existing building consisting of three dwellings, which was completely rebuilt and now hosts nine dwellings. Costs are provided by energy consultants and are available on-line (www.enup.it). Energy costs under real operation conditions are not available. They are calculated based on the data contained in the Energy Performance Certificate and on energy prices provided by the Authority for Energy (http://www.autorita.energia.it).

(2) The building, designed by arch. S. Piraccini is located in Cesena and is a certified Passive House and a NZEB according to the Italian scheme. Costs are provided by the architect in charge of the design of the building. Energy costs under real operation conditions are not available. They are calculated based on the data contained in the Energy Performance Certificate and on energy prices provided by the Authority for Energy (http://www.autorita.energia.it).

(3) The building was designed by RES Architecture studio (www.resarchitetture.it) and is on of the first examples of NZEB social housing in Italy. The building has 29 flats (from 45 to 95m^2) and a 230m^2 civic centre, and it is located in Prato, Tuscany. The construction process was delayed by financial problems, the building is now under construction and expected to be completed in the first months of 2018. Energy costs are derived from the Energy Performance Certificate compiled during the planning phase. Energy costs are derived from national prices provided by the Authority for Energy (http://www.autorita.energia.it).

(4) The building is funded by the Social Housing Company of Treviso, Veneto (ATER). Costs are provided by the architect in charge of the design of the building. Energy costs under real operation conditions are not available. They are calculated based on the data contained in the Energy Performance Certificate, provided on single flat basis and then averaged, and on energy prices provided by the Authority for Energy (http://www.autorita.energia.it).

(5) The building, very similar to (4) is funded by the Social Housing Company of Treviso, Veneto (ATER). Costs are provided by the architect in charge of the design of the building. Energy costs under real operation conditions are not available. They are calculated based on the data contained in the Energy Performance Certificate, provided on single flat basis and then averaged, and on energy prices provided by the Authority for Energy (http://www.autorita.energia.it).

(6) The building, built by Pedone Working Construction Company (http://www.pedoneworking.it, via Sant'Andrea 87/4, Bisceglie _BT, tel.080 399 11 26), is located in Bisceglie, province of Barletta, Apulia, and was awarded with the Green Building Solutions Award 2016 for hot climates. Costs are provided by the architect and energy costs under real operation conditions are not available. They are calculated based on the data contained in the Energy Performance Certificate and on energy prices provided by the Authority for Energy (http://www.autorita.energia.it). The energy costs indicated in the table refer to the average of the typical flats of the 5-storey building.

(7) The building, built by Gruppo Edilizia Stolfa construction company (www.gruppostolfaedilizia.it), is located in Capurso, province of Bari, Apulia. Construction costs are provided by the construction company. The building performances make it an NZEB, however it is not possible to provide the energy cost. The building achieves the Level 3 of Protocollo Itaca, the national scheme for sustainability in building construction and was awarded in the framework of the Sustainable Urban Building Contest, organised by the Construction21 platform in 2014.

(8) The construction was funded by the Municipality of Verbania, to be used as social housing. Most of the energy is used for domestic hot water. The renewable energy share is 43%, so the requirement to be NZEB is not formally fulfilled, lackiung a small quantity (required is > 50%). For this reason it is included in the list as an excellent example of energy efficient social housing. The building also reached the score 3.2 of the national sustainability scheme Protocollo Itaca. Data is provided by Edilclima srl (www.edilclima.it), who also provide consultancy on the energy design. Details of the building are availabe at: https://www.edilclima.it/assets/repository/software/informazioni/700-casehistoryVB.pdf. Energy costs under real

operation conditions are not available. They are calculated based on the data contained in the Energy Performance Certificate and on energy prices provided by the Authority for Energy (http://www.autorita.energia.it).

(9) The NZEB building in Borgomanero was funded by the Piedmont Region to demonstrate the potentiality of new buildings in reaching the energy neutrality. The high construction costs are strictly connected with the initial objectives, and a very high standard building was needed as an exemplary case. Data is provided by Edilclima srl (www.edilclima.it), who also provide consultancy on the energy design. Energy costs under real operation conditions are not available. They are calculated based on the data contained in the Energy Performance Certificate and on energy prices provided by the Authority for Energy (http://www.autorita.energia.it).

(10) The building was designed as a passive building, without space heating and cooling system, even if a gas boiler was installed for extreme conditions. Data is provided by Arch. R. Pugliese, who worked as an energy consultant for the building envelope solutions. Most of the energy is required for domestic hot water. The renewable energy share is 34%, so the requirement to be NZEB is not formally fulfilled, lacking a small quantity (required is > 50%). For this reason it is included in the list as an excellent example of energy efficient building. The building was awarded with the CasaClima Gold, voluntary scheme for high performance buildings. Energy costs under real operation conditions are not available. They are calculated based on the data contained in the Energy Performance Certificate and on energy prices provided by the Authority for Energy (http://www.autorita.energia.it).

(11) The building was designed and built by LL Italia (Corso Monte Cucco, 131 - 10141 Torino, www.llitalia.com) and got the A4 class in the Piedmont Energy Certification Scheme. The design criteria were to build a NZEB building featuring high environmental quality standards and an energy management system at reduced costs. Details of the construction phase are available at: https://www.montecucco128.it/cantiere. Energy costs under real operation conditions are not available. They are calculated based on the data contained in the Energy Performance Certificate of a reference apartment and on energy prices provided by the Authority for Energy (http://www.autorita.energia.it).

(12) The building is managed by the Social Housing Company of Reggio Emilia, Emilia Romagna (ACER). The costs of the electrical supply of the common parts are provided by the company under real operating conditions. They are calculated on the basis of the data extracted from the bills of the last thermal season 2016/2017 with the energy prices charged in the bills. The costs of the district heating service are calculated based on the data contained in the Energy Performance Certificate, provided on single flat basis and then averaged, and on energy prices reported by the billing.

(13) The building is managed by the Social Housing Company of Reggio Emilia, Emilia Romagna (ACER). The costs of the electrical supply of the common parts are provided by the company under real operating conditions. They are calculated on the basis of the data extracted from the bills of the last thermal season 2016/2017 and on the energy prices charged in the bills. The costs of the district heating service are calculated based on the data contained in the Energy Performance Certificate, provided on single flat basis and then averaged, and on energy prices reported by the billing.

(14) The building was built by the Construction Company Cazzaro (www.cazzarocostruzioni.it). The construction costs in Table 17 do not include costs for cellar and underground parking, in order to keep uniform construction typologies for both NZEB and buildings fulfilling the minimum energy performance requirements. Energy costs under real operation conditions are not available. They are calculated based on the data contained in the Energy Performance Certificate of a reference apartment and on energy prices provided by the Authority for Energy (http://www.autorita.energia.it).

(15) The building was built by the Construction Company Tosatto (www.tosatto.it). An additional check for the cooling energy performance confirmed the overall energy target of the building, which was initially not included in the Energy Performance Certificate. Energy costs under real operation conditions are not available. They are

calculated based on the data contained in the Energy Performance Certificate of a reference apartment and on energy prices provided by the Authority for Energy (http://www.autorita.energia.it).

(16) The average costs are derived from the publication "Prezzi - Tipologie Edilizie" [Costs - Building Typologies] by the publishing house DEI - Tipografia del Genio Civile in 2012 (www.build.it/). DEI publishes the official costs for the construction industry and market in Italy. "Tipologie Edilizie" is a special issue, published every few years, which intend to provide total and disaggregated costs for typical Italian residential and non-residential buildings.

(17) Note: The quality and the quantity of data on NZE and beyond NZE multifamily houses do not allow the calculation of reliable average energy costs.

(18) Casa Fiorita and Borgomanero projects had high standard demonstrative objectives, hence they cannot be used as real benchmark for beyond NZE but remain as shining examples of very high performance buildings. The data on extra cost for beyond NZE multifamily house is thus not provided.

5.4 Database – Slovenia

Table 18: Investment cost and energy cost database for Slovenia

No.	Name of data	Source	Year	Location	Size: Conditioned net floor area	Level: Minimum EP requirements	Level: NZEB	Level: Beyond NZEB	Investment costs: Total: Incl. ground	Investment costs: Total: Excl. ground	Investment costs: Building components (BC) and services systems (SS) costs: BC CIB SfB cost groups 1.12, 1.13, 2, 3, 4 = DIN 276 cost group 300	SS CIB SfB cost groups 5, 6 = DIN 276 cost group 400	Total (BC + SS)	Δ costs compared to minimum EP requirements		Energy costs: Electricity: (1) Building related	Electricity: (2) Household	Electricity: (3) Total: (1) + (2)	(4) Gas	(5) District heating	(6) Biomass	(7) Others	(8) Total building related ((1) + (4) + (5) + (6) + (7))	(9) Total ((3) + (4) + (5) + (6) + (7))	Remarks
					m²				€/m²	€/m²	€/m²	€/m²	€/m²	€/m²	%	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	€/m²/yr	
1	Nad Dolinsko	[SI 12]	2010	Koper	1,651	X			1,795	1,508	1,130	200	1,330	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(1)
2	Ob Borovniščici	[SI 12]	2013	Borovnica	12,850	X			1,248	959	829	129	959	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4.12	n.a.	n.a.	(2)
3	F5.1 Brdo	[SI 12]	2014	Ljubljana	10,872	X			1,780	1,295	791	180	971	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(3)
4	F4 Brdo	[SI 12]	2014	Ljubljana	11,473	X			1,920	1,444	1,008	228	1,236	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(4)
5	Gorica	[SI 12]	2015	Velenje	3,120	X			1,020	860	738	122	860	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(5)
6	F5.2 Brdo	[SI 12]	2016	Ljubljana	5,650	X			1,850	1,332	786	198	984	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(6)
7	F3 Brdo	[SI 13]	2016	Ljubljana	3,276		X		2,550	2,090	1,250	371	1,621	312	35%	1.39	n.a.	n.a.	n.a.	n.a.	1.39	n.a.	2.78	n.a.	(7)
8	F6.1 Brdo	[SI 12]	2017	Ljubljana	1,353	X			n.a.	n.a.	846	178	1,024	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(8)
9	F2 Brdo	[SI 12]	2017	Ljubljana	5,978	X			n.a.	1,405	808	123	931	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(9)
10	Eco Silver House	[SI 14]	2014	Ljubljana	12,859			x	n.a.	n.a.	726	331	1,057	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(10)
Average of minimum EP requirements						X			1,602	1,258	867	170	1,037	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(11)
Average of NZEB *							X		(2,550)	(2,090)	(1,250)	(371)	(1,621)	(584)	(25%)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(12)
Average of beyond NZEB *								X	n.a.	n.a.	(726)	(331)	(1,057)	(20)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(13)

* the averages for the NZEB and beyond NZEB level reflect the data only one multi-family building in each category. We expect more such buildings will be completed during the project lifetime and thus we will try to increase the number of collected buildings during the project and might come to better results at the end of the project.

Remarks pertaining to Table 18:

(1) Nad Dolinsko, Koper

Nad Dolinsko is multi-apartment building, located in Koper.

Building details

- Number of apartments: 24
- Floors: G+3
- Garage: two-level underground garage with 41 parking places

Technical description

- Structure: masonry construction
- Windows, balcony doors: PVC, double glazing
- Heating: radiators connected to a gas boiler of each apartment
- Ventilation: natural ventilation
- Energy standard: energy class B2 (average 35 kWh/m^2.yr)

There are no corresponding average energy costs (or energy consumptions) available. Building components (BC) and service system (SS) costs are based on calculations.

(2) Ob Borovniščici, Borovnica

Ob Borovniščici consists of eleven multi-apartment buildings (units: A1, A2, A3, B1, B2, B3, B4, B5, B6, B7, B8).

Building details

- Number of apartments: 186
- Floors: G+2 or G+3 (A units); G+3+T or G+3 (B units)

- Garage: All units share a one-level underground garage separated into 3 parts, with a total of 186 parking places.
- Net floor area: 12,850 m²

Technical description

- Structure: reinforced concrete structure
- Windows, balcony doors: PVC, triple glazing
- Heating: radiators connected to a common heating oil boiler
- Ventilation: natural ventilation
- Energy standard: energy class B2 (average 30 kWh/m².yr)

Data of corresponding average energy costs (or energy consumptions) is currently collected. Building components (BC) and services systems (SS) costs are based on calculations.

(3) F5.1, Ljubljana

F5.1 consists of five multi-apartment buildings, located in the Zeleni Gaj residential development in Ljubljana's Brdo district.

Building details

- Number of apartments: 187 (26 - 47 dwellings per unit) and 5 business premises.
- Floors: G+3+T (unit A2 and C2); G+4+T (unit A3, C3, C4)
- Garage: All units share a one-level underground garage with a total of 336 parking places.

Technical description

- Structure: reinforced concrete structure
- Windows, balcony doors: Aluminium - PVC, triple glazing
- Heating: radiators connected to a common condensing gas boiler of each unit
- Ventilation: humidity-sensitive ventilation
- Energy standard: energy class C (average 37 - 40 kWh/m².yr)

There are no corresponding average energy costs (or energy consumptions) available.

(4) F4, Ljubljana

F4 consists of five multi-apartment buildings (A, B1, B2, D1, D2), located in the Zeleni Gaj residential development in Ljubljana's Brdo district.

Building details

- Number of apartments: 185 (30 - 50 dwellings per unit)
- Floors: G+3+T (unit B1, B2, D1) or G+4+T (unit A, D2)
- Garage: All units share a one-level underground garage with a total of 376 parking places.
- Net floor area: 11,473 m²

Technical description

- Structure: reinforced concrete structure, masonry construction
- Windows, balcony doors: PVC, triple glazing
- Heating: radiators connected to a common condensing gas boiler for each unit
- Ventilation: humidity-sensitive ventilation
- Energy standard: energy class C (average 35 - 39 kWh/m².yr)

There are no corresponding average energy costs (or energy consumptions) available.

(5) Gorica Velenje

Gorica Velenje consists of 65 social dwellings in Velenje, owned by the Housing Fund of the Republic of Slovenia.

Building details

- Number of apartments: 65
- Floors: G+4
- Garage: one-level underground garage with a total of 98 parking places.

Technical description

- Structure: reinforced concrete structure, prefabricated balcony
- Windows, balcony doors: PVC, triple glazing
- Heating: radiators connected to a district heating
- Ventilation: natural ventilation
- Energy standard: energy class B2

There are no corresponding average energy costs (or energy consumptions) available. Building components (BC) and service system (SS) costs are based on calculations.

(6) F5.2, Ljubljana

F5.2 consists of three multi-apartment buildings (B, C1, A1), located in Zeleni Gaj residential development in Ljubljana's Brdo district. F5.2 was designed according to new energy requirements (PURES 2010).

Building details

- Number of apartments: 85 (unit B – 26, unit C1 – 38, unit A1 – 21) and 3 business premises.
- Floors: G+3+T
- Garage: All units share a one-level underground garage with a total of 175 parking places.
- Net floor area: 5,650 m^2

Technical description

- Structure: reinforced concrete structure
- Windows, balcony doors: PVC, triple glazing
- Heating: radiators connected to a common condensing gas boiler for each unit
- Ventilation: humidity-sensitive ventilation
- Energy standard: energy class B2 (average 25 - 27 $kWh/m^2.yr$)

There are no corresponding average energy costs (or energy consumptions) available.

(7) F3, Ljubljana

F3 is a single, multi-apartment building divided vertically into four lamellas (lamella A, B, C, D). The building is located in new Zeleni Gaj residential development in Ljubljana's Brdo district. The building as a whole is a low-energy structure. Part of the building meets the passive standard and part meets the low energy standard. PHPP energy performance certificates have been obtained for 31 passive dwellings. Some individual dwellings have mechanical ventilation with heat recovery, while others have humidity-sensitive ventilation.

Building details

- Number of apartments: 52 (lamella A: 13, lamella B: 13, lamella C: 11, lamella D: 15) and 1 nursery school and 1 business premises unit.
- Floors: G+3+T
- Garage: one-level underground garage with 68 parking spaces under an outdoor car park with 42 parking spaces
- Net floor area of lamellas A, B, C, D: 3,276 m²

Technical description

- Structure: G+2 reinforced concrete structure; 3+T wooden structure
- Windows, balcony doors: aluminium, wood, triple glazing
- Heating:
  - Lamella A: underfloor heating connected to a heat pump and supported by a biomass boiler system.
  - Lamellas B, C, D: underfloor heating connected to a common biomass boiler (woodchips) and solar energy collectors. Bathrooms also have towel radiators.
- Ventilation: mechanical ventilation with heat recovery or humidity-sensitive ventilation
- Energy standard: energy class A2 (14 kWh/m².yr)

(8) F6.1, Ljubljana

F6.1 consists of 2 multi-apartment buildings, located in Zeleni Gaj residential development in Ljubljana's Brdo district. Each unit has 6 apartments (two different types: G and G+1+T). Apartments are designed as »house on house«, which means that the roof of ground apartment serves as a terrace for the upper apartment at the same time, making it a G+1+T type of apartment.

Building details

- Number of apartments: 12 (6 dwellings per unit)
- Floors: G+1+T
- Garage: Each apartment has integrated ground garage.

Technical description

- Structure: reinforced concrete structure
- Windows, balcony doors: wood, triple glazing
- Heating: radiators connected to a condensing gas boiler in each apartment
- Ventilation: humidity-sensitive ventilation
- Energy standard: energy class C (58 kWh/m^2.yr)

There are no corresponding average energy costs (or energy consumptions) available.

(9) F2, Ljubljana

F2 consists of four multi-apartment buildings (A1, A2, B, C), located in new Zeleni Gaj residential development in Ljubljana's Brdo district. F2 was designed according to minimum energy performance requirements and it was later improved and adjusted to new energy requirements (PURES 2012). Currently the F2 is in a process of obtaining an operating permit.

Building details

- Number of apartments: 102 (24 – 30 dwellings per unit)
- Floors: G+3 (2 units); G+2 (2 units).
- Garage: Two units have a one-level underground garage, while the two other units have a two-level underground garage. The basement garage has a total of 205 parking places. One unit is connected to the underground garage with an underground hall.
- Net floor area: 5,978 m^2

Technical description

- Structure: reinforced concrete structure (balconies and attic are designed with Schöck Isokorb elements to prevent thermal bridges)
- Windows, balcony doors: wood, triple glazing
- Heating: radiators connected to a common condensing gas boiler for each unit
- Ventilation: humidity-sensitive ventilation

⌂ Energy standard: energy class B1 (21 kWh/m².yr)

There are no corresponding average energy costs (or energy consumptions) available.

(10) Eco Silver House (FP7 EE-HIGHRISE), Ljubljana

The Eco Silver House (ESH) is a multi-residential high-rise building located in Ljubljana, Slovenia. The building is a private investment by the developer Akropola and an FP7 EE-HIGHRISE demonstration project constructed in 2013 - 2016 (www.ee-highrise.eu).

Building details

The net total area of the building is 23,455 m² distributed on 17 floors (12.859 m² net conditioned residential area in 128 flats). The fundamental principles of sustainable design of the ESH are reflected through the comprehensive planning of energy efficiency features with respect to the passive house standard and the national nearly zero-energy building (NZEB) criteria. The ESH, with up-to-date thermal envelope characteristics and integrated building systems, fulfils the commonly accepted passive house standard characteristics with a annual heating demand of 14 kWh/m².yr calculated according to PHPP.

According to the national energy performance certificate, the ESH is ranked in the energy performance class A1. The total delivered energy is 48 kWh/m².yr and the corresponding primary energy is 76 kWh/m².yr (69.5 kWh/m².yr with consideration of the exported energy from a PV power plant). The ESH presents a new standard of the energy-efficient apartment buildings in the Slovenian construction sector, meeting the new 2015 definition of the NZEB in Slovenia that sets the maximum allowed annual primary energy limit for apartment buildings at 80 kWh/m².yr.

The building is connected to the energy efficient municipal district heating, with wood biomass co-burning and cogeneration. Each apartment has its own heat substation for space heating and domestic hot water, while electricity is used for the operation of the mechanical ventilation system with heat recovery (system efficiency of 85%) and for an air-to-air inverter heat pump that preheats or precools the supply air. Cooling needs are negligible with the standard usage profile. The amount of renewable energy sources (RES) in both energy grids (district heating and electricity) is 100 MWh/yr as part of the total delivered energy of 612 MWh/yr. Taking the production of 33 MWh/yr. of electricity from the PV plant on the roof into account, the proportion of renewable energy sources (133 MWh/yr.) adds up to 22% in the total delivered energy. The share of RES in the primary energy (Q_P) balance is equal to 31%.

During the design and construction phase, the focus of the demonstration project was on the implementation of integrated energy design and quality assurance (QA) protocols that included on-site inspections of the thermal envelope like the air-tightness layer quality, and the installation of windows according to the RAL guidelines. The QA process for the NZEB during the construction phase covered: training of on-site working teams, video streaming of best practice applications of NZEB technologies, special coordination meetings of on-site workers, contractor, designers, investor and QA team and selected EE quality control on site.

The benefits of the implementation of QA are reflected not only in the technical aspects but also in improved processes and better skilled workforce as well as in profound understanding of barriers specific to various occupations and workers' profile. The theoretical background of NZEB planning was integrated into the construction process by defining various protocols, in which comprehensive knowledge and skills of the whole production chain (investor, designer, contractor, quality control, technology provider etc.) are essential for the success of such demonstration project.

ESH was completed in 2014 and in 2015 entered in the post-occupancy monitoring period, with the aim of monitoring the energy performance indicators, comfort parameters and users' satisfaction as well as assessing the sustainable building indicators (OPEN HOUSE assessment protocol).

Technical description

- U-values: 0.17 W/m²K (walls), 0.14 W/m²K (roof), U_w = 0.83 W/m²K; triple glazing (U_g = 0.58 W/m²K), PVC frames
- Air-tightness per sectors, n_{50}, is between 0,45 h^{-1} and 0,59 h^{-1} (measured with a blower door test)
- Energy efficient municipal district heating, with wood biomass co-burning and cogeneration
- Mechanical ventilation with heat recovery (system efficiency of 0.85) and inverter heat pump, air to air, for the inlet air
- Cooling needs are negligible
- Rainwater stored in a roof tank (60 m³)
- Green roof
- Solar power plant (34 kW_p) on the roof, and e-mobility with car sharing

Costs

There are no corresponding average energy costs (or energy consumptions) available. The building has not yet been fully occupied within the relevant monitored period. The investment costs with and without ground are not available. The investment costs for building components (BC) and service system (SS) are based on the calculative costs.

6. Cross analysis of the cost data

In this chapter the collected data on investment costs and energy costs will be analysed and the resulting average data will be discussed. Additionally a first attempt for a comparison of the international average data is performed, taking into account the different national influence factors.

6.1 Germany

The German cost data is mainly derived from three different sources:

- BKI cost catalogue [DE 14]
- Pilot projects of the research initiatives Efficiency House Plus and EnEff:Stadt
- Multi-family houses built by the CoNZEBs partner ABG Frankfurt Holding within 5 years

All data is taken from realised buildings. The available information however differs. The BKI cost catalogue only includes investment costs, no energy costs. The research projects and ABG Frankfurt Holding could provide information on investment costs and energy costs; it was however not possible to complete the table for every building.

When calculating the average investment costs for the three building levels, it was decided to do this for the sum of building components and building services systems costs only, because this is the field where most data is available and the division into the three building levels leads to more reliable results. It has to be noted though, that for calculating the average value of investment costs for the minimum energy performance level a total of 105 buildings has been taken into account, for the NZEB level 25 buildings and for the building level beyond NZEB 5 buildings. It is understandable that the higher the energy performance level is, the fewer buildings have been built and documented in this detail regarding costs. But with the lower number of buildings included in the database the reliability of the average costs is decreasing.

Chapter 5.1 describes in detail (see remarks 47 to 49) how the average investment cost data for the three building levels has been calculated. Since some of the BKI data is included twice (either as a main average for small, medium and big multi-family houses and then again subdivided into averages for buildings built in simple, medium and high building standard or as average and then as single building data) it was decided to use the higher ranked average value multiplied by the number of buildings obtained from BKI together with the additional building examples provided by ABG Frankfurt and Fraunhofer IBP in the corresponding building level. This calculation provided the following average investment costs for the building components and the building services systems:

Table 19: Calculated average investment costs for the building components and the building services systems for the three building energy performance levels in Germany

Building energy performance level	(1) Average investment costs for building components and building services systems	(2) Difference of the average investment costs of (1) to the minimum energy performance building level
	€/m² living area	€/m² living area
Minimum energy performance requirements	1,879	-
NZEB	1,923	44
Beyond NZEB	2,377	498

Figure 3 shows a graphical comparison between the investment costs for building components and building services systems of the example buildings. The different energy performance levels are indicated in colours and the calculated average investment costs for each level are represented by horizontal lines.

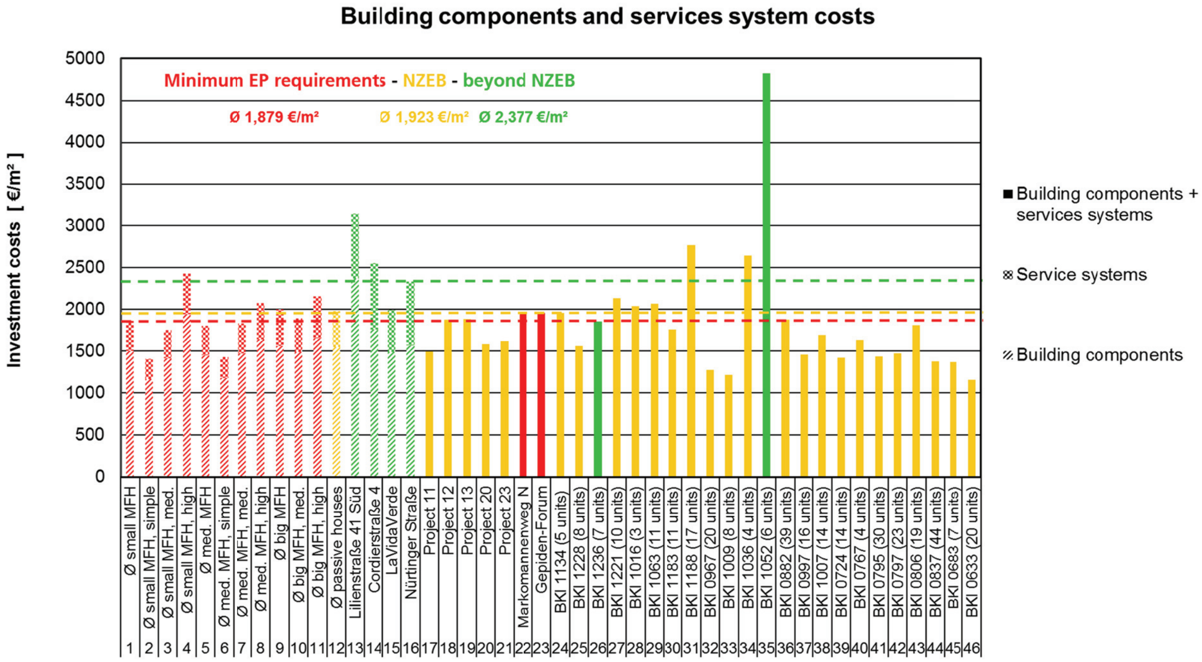

Figure 3: **Building components and services systems costs for the collected German example buildings in three different energy performance levels. The calculated average investment costs per energy level are included as horizontal dashed lines.**

Concerning the energy costs, the calculation of average data is even more problematic because less comparable data could be gathered. It was decided to calculate averages for two different types of energy cost data:

- Building-related electricity costs
- Total building related energy costs

For the detailed explanation of the cost types see chapter 4.

The average building-related electricity costs and the total building-related energy costs for buildings fulfilling the minimum EP requirements could be calculated based on two buildings, for NZEBs based on five buildings and for buildings beyond NZEBs based on three buildings. These are obviously very small numbers. In Table 14 the results of these calculations are therefore put in brackets, and should not be used as a basis for more detailed calculations. However, the general tendency of the costs seems to be right. With a higher building energy performance level more building related electricity is used, e.g. for mechanical ventilation systems, control systems and partly also due to the application of electrical heat pumps. At the same time the average building related energy costs excluding the electricity costs and the average total building related energy costs are decreasing with a higher energy performance level due to less energy use. The negative average for the average total building related energy costs (and for the average building related energy costs excluding electricity costs) is due to energy cost benefits due to electricity feed-in generated from renewable energy sources in the three efficiency house plus buildings.

Table 20: Calculated average energy costs for the three building energy performance levels in Germany

Building energy performance level	(1) Average building related electricity costs	(2) Average building related energy costs excluding electricity costs ((3) – (1))	(3) Average total building related energy costs
	€/m² living area and year	€/m² living area and year	€/m² living area and year
Minimum energy performance requirements	0.86 *	5.25 *	6.11 *
NZEB	1.56 *	4.40 *	5.96 *
Beyond NZEB	1.80 *	-3.27 *	-1.47 *

* Note: The average costs are derived from 2 to 5 building examples only. They should not be used for further calculations.

6.2 Denmark

The Danish cost data is derived from mainly three different sources:

- Four DGNB certified projects
- One Bolig+ dwelling R&D project
- General information about the allowed costs for social housing in different regions of Denmark

The two first sources therefore represent data from realised buildings and the third is used as a general guideline for the costs of social housing in Denmark.

For the Bolig+ housing project, the idea has been that the building is a net energy producer. Therefore, there are no energy costs for this project.

Since there is only one project built to meet the minimum energy performance requirements and one project beyond NZEB level the averages presented in Table 15 are just equal to the numbers of these two projects. The table also contains two theoretically calculated projects – one at minimum energy performance requirement level (Vingen) and one at NZEB level (Bolig+) – see comments DK (5) and DK (7).

From Table 15 the following average investment costs for the building components and the building services systems have been extracted:

Table 21: Calculated average investment costs for the building components and the building services systems for the three building energy performance levels in Denmark

Building energy performance level	(1) Average investment costs for building components and building services systems	(2) Difference of the average investment costs of (1) to the minimum energy performance building level
	€/m² gross building area	€/m² living area
Minimum energy performance requirements	1,182	-
NZEB	1,247	65
Beyond NZEB	n.a.	n.a.

The comparison of average costs shows the general and expected trend, that projects built according to minimum energy performance requirement cost less the NZEB projects, which again cost less that beyond NZEB projects. There is one exception: the building component costs (BC) for the minimum energy performance requirement project are higher than the average building component costs for the NZEB projects. This is probably due to the fact that the minimum energy performance requirement project, Vingen, is a one-storey building and the other buildings are multi-storey buildings. A second reason is the uncertainty that is always a part of contractor's bids for tenders – large variation may occur. Unfortunately, the building component costs are not available for the beyond NZEB project.

Figure 4 shows a graphical comparison between the investment costs for building components and building services systems of the identified example buildings in Table 15. The different energy performance levels are indicated in colours and the calculated average investment costs for each level are shown by horizontal lines.

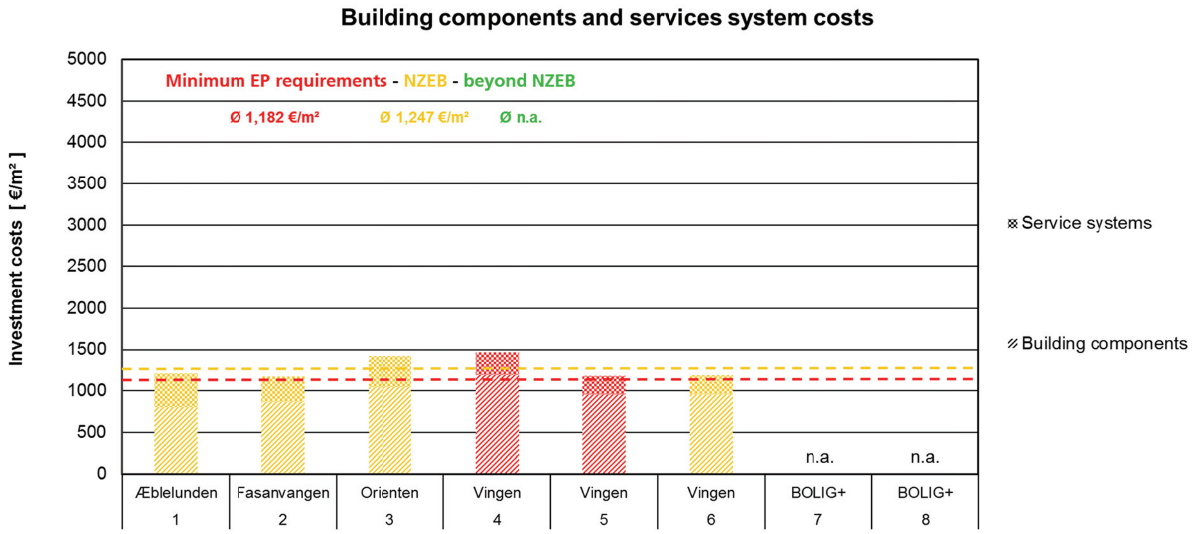

Figure 4: **Building components and services systems costs for the collected Danish example buildings in three different energy performance levels. The calculated average investment costs per energy level are included as horizontal dashed lines.**

Concerning the energy costs, the calculation of average data is even more problematic because less comparable data could be gathered. It was decided to calculate averages for two different energy cost data types:

- Building-related electricity costs
- Total building related energy costs

For the detailed explanation of the cost types see chapter 4.

The average building-related electricity costs and total building related energy costs for buildings fulfilling the minimum energy performance requirements are actually based on the example buildings, for NZEBs it is based on four building projects and for buildings beyond NZEBs there are no energy costs as explained above. The average building related energy costs excluding the electricity costs and the average total building related energy costs are decreasing with a higher energy performance level due to less energy use.

Table 22: Calculated average energy costs for the three building energy performance levels in Denmark

Building energy performance level	(1) Average building related electricity costs	(2) Average building related energy costs excluding electricity costs ((3) – (1))	(3) Average total building related energy costs
	€/m² living area and year	€/m² living area and year	€/m² living area and year
Minimum energy performance requirements	1.03 *	9.16 *	10.19 *
NZEB	0.50 *	8.09 *	8.59 *
Beyond NZEB	0.00 *	0.00 *	0.00 *

* Note: The average costs are derived from 1 to 4 building examples only. They should not be used for further calculations.

6.3 Italy

The Italian data related to multi-family houses of NZEB level and beyond NZEB level are provided directly from stakeholders involved in the process: designers, energy consultants, construction companies, social housing associations. The construction costs are fully documented, the same cannot be done for the energy costs, in fact they do not come from monitored data but from the Energy Performance Certificate or, for few buildings still in the finalisation of construction phase, from energy design calculations. Limitations of the provided data are fully explained in the remarks of Chapter 5.3. Even with these limitations, the data show the ambitious target set by stakeholders for these high performing buildings.

Concerning the buildings fulfilling the minimum energy performance requirements, few data was directly provide by the project partner ACER RE from Reggio Emilia, Italy. However for this building category it was possible to derive national average cost thanks to a publication, which provides total and disaggregated costs for typical Italian residential and non-residential buildings (see remark (14) in Chapter 5.3). The data provided in the table is the average of the five multi-family houses, identified as typical for the country and for which the useful area was determined to be the reference building surface as used in the analysis. The useful area is defined as the area of the single apartment excluding external walls but including the internal partitions. For uniformity with NZE multifamily house in the list only the reference buildings without underground construction for cellar and garage were taken into account. To be noted that, being unknown the recurrence of each typology, a simple arithmetic average is applied. Being the publication issues in 2012 and being the data presumably acquired the year before, the presented costs are actualised through the construction cost indexes, provided with three months frequency by the Italian National Institute of Statistics (www.istat.it/).

For multi-family houses beyond the nearly zero-energy level only two cases are available, built as demonstrative buildings and with very high energy standard. Moreover their building data includes also demolition and reconstruction works. It has to be noted that no nationally recognised building level beyond NZEB standard and correspondent scheme exists in Italy. For these reasons the cost difference between these buildings and the national average for buildings fulfilling the minimum energy performance requirements cannot be considered representative for the construction market.

Table 23: Calculated average investment costs for the building components and the building services systems for the three building energy performance levels in Italy

Building energy performance level	(1) Average investment costs for building components and building services systems	(2) Difference of the average investment costs of (1) to the minimum energy performance building level
	€/m² useful area	€/m² useful area
Minimum requirements	1,387	-
NZEB	1,615	229
Beyond NZEB	(4,183)	(2,834)

The relative increase of investment costs of NZEBs compared to buildings fulfilling the minimum energy performance requirements is about 16%. It has to be noted that the increase for the building component costs for NZEBs is 12%, and for the services systems costs is 21%. This is in line with earlier predictions in Italy, because it was expected that the costs for renewable energy installations would have a relevant impact on total energy systems costs.

Figure 4 shows a graphical comparison between the investment costs for building components and building services systems of the example buildings. The different energy performance levels are indicated in colours and the calculated average investment costs for each level are represented by horizontal lines.

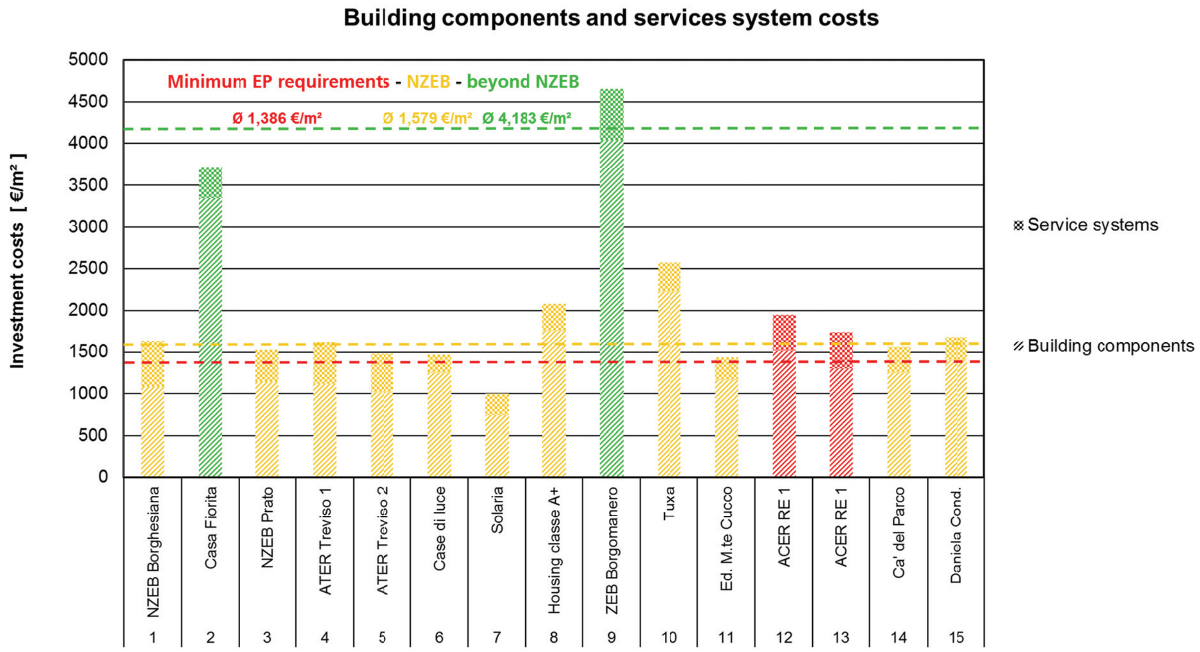

Figure 4: **Building components and services systems costs for the collected Italian example buildings in three different energy performance levels. The calculated average investment costs per energy level are included as horizontal dashed lines.**

Concerning the energy costs, which are reported in Table 17 for information purposes, it was decided to not proceed with additional analyses, due to the lack of data and the limited reliability of the available sources.

Last but not least we would like to mention the fact that by 2018, Italian buildings built according to the minimum energy performance requirements and NZEBs will have very similar energy performances, since they will have to respect the same requirements for energy system efficiencies and for the share of renewable energy, while small differences will remain in terms of insulation performances of the building envelope. This implies that from this date very small cost differences between a conventional and a nearly zero-energy building can be expected. Therefore construction costs will also get very close and this will reduce the costs of new nearly zero-energy multifamily houses in general. This trend has already started and the costs of NZEBs are slightly decreasing in relation to the year of construction.

6.4 Slovenia

The calculation of average values based on the building data in Table 18 provided the following costs for the building components and the building services systems:

Table 24: Calculated average investment costs for the building components and the building services systems for the three building energy performance levels in Slovenia

Building energy performance level	(1) Average investment costs for building components and building services systems	(2) Difference of the average investment costs of (1) to the minimum energy performance building level
	€/m² conditioned net floor area	€/m² conditioned net floor area
Minimum energy performance requirements	1,037	-
NZEB * (Costs based on one example (building #7 of Table 18)	1,141 (1,621)	104 (584)
Beyond NZEB * (Costs based on one example (building #10 of Table 18)	1,234 (1,057)	197 (20)

* Note: Average costs for NZEBs and beyond NZEBs are indications based on investors and national partners' experiences. In brackets are the average costs for NZEB and beyond NZEB buildings derived from one building example only. They should not be used for further calculations.

It must be noted that the sample for NZEB and beyond NZEB buildings in Slovenia is very small. For the time being there are only two demonstration multi-family buildings of high energy performance available for this analysis. The conclusions on price levels for NZEB and beyond NZEB buildings can hardly be representative.

Although the average price levels based on one example building each in the categories NZEB and beyond NZEB are in contrary to the expectations, the data can be justified. First of all the included NZEB building (Table 18, building #7) is of a relatively standard size, while the beyond NZEB building (Table 18, building #10) is a roughly four times bigger compact highrise building. This is reflected in a bit lower specific average investment cost for building components in comparison to the NZEB building. Additionally the NZEB has a less favourable shape factor and consequently required a better insulation resultig in higher costs. Finally the NZEB building example is subject to the national regulation on green public procurement and therefore the building has a more compley wooden envelope with ecological building materials.

Both buildings are demonstration projects: the NZEB building (Table 18, building #7) is a public investment of the housing fund SSRS with a focus on the demonstration of envelope technologies (concrete walls and prefabricated wood panels as well as various airtightness solutions), various heating and ventilation systems (heat pump, biomass boiler, district heating, mechanical and hybrid ventilation) and above all different architectural solutions (with invited architects designing individually different parts of the building). Due to the diversity of selected technologies and solutions in the pilot NZEB building one can conclude that the investment costs are definitely higher than with a single building concept for the whole multi-family house.

The beyond NZEB building (Table 18, building #10) has also served as a demonstration project of an energy efficient building (FP7 EE-HIGHRISE), but the important difference is that a private developer built the building in order to sell the apartments on the market. The costs are summarized based on design stage calculation of costs and the nominal data on actual investment costs are not available. However, as a part of the demonstration project (FP7 EE-HIGHRISE) the investor team and experts analysed the incremental costs due to the better energy standard, as follows:

- Better insulation of the envelope, triple-glazed windows instead of double-glazed ones, central ventilation with heat recovery and automated shading devices increased the investment in comparison to minimum energy performance requirements by about 8%.
- Additional measures that are considered as inevitable for beyond NZEB – smart installations, the solar power plant, charging stations for electric vehicles and the car-sharing service, the rainwater storage and the secondary rainwater supply system, some local A/C devices, biometric locks etc. increased the investment by additional 9%.
- It is also estimated, that design stage optimizations for the NZEB, better construction and quality control raised the construction costs comparing to standard buildings for about additional 2%.

Due to a small and at this stage not yet not representative sample of NZEB and beyond NZEB multi-family buildings we based the average cost levels in Table 24 and in Figure 5 upon the above summarized increase of costs, i.e.:

- 10% for NZEB building and
- 19% for beyond NZEB building, each one compared to the minimum energy performance building

Additional buildings that will be constructed and added to the database during the lifetime of this project will enable the creation of more realistic and representative average cost levels.

In Slovenia there are many buildings built better than required in the PURES 2010 Building Codes, mainly due to the policy of the housing fund or developer. However, they do not meet the NZEB standard (actually, the gap is quite small). In the Slovenian cost table such buildings (built by SSRS) were classified as minimum energy performance requirements buildings.

Figure 5 shows a graphical comparison between the investment costs for building components and building services systems of the example buildings. The different energy performance levels are indicated in colours and the calculated average investment costs for each level are represented by horizontal lines.

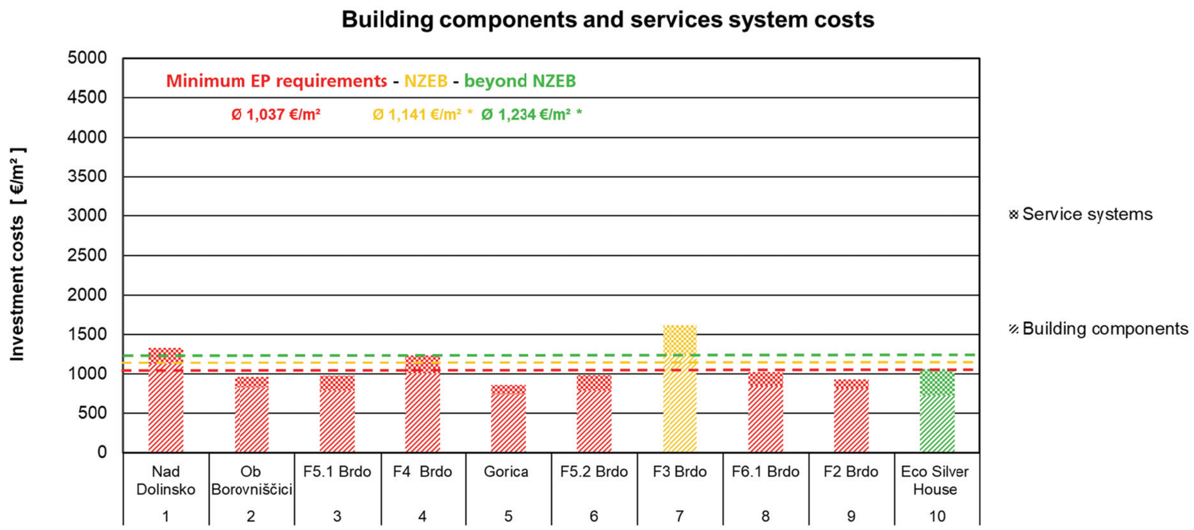

Figure 5: Building components and services systems costs for the collected Slovenian example buildings in three different energy performance levels. The average investment costs per energy level are included as horizontal dashed lines.
*** The presented average investment costs of the NZEB and beyond NZEB level are not derived from the single example buildings of each level but based on the reflections of Chapter 6.4.**

6.5 Across the four countries

As addressed before the comparison of the cost data between the four countries won't lead to useful results because of various reasons. Some of the reasons are given in the following list:

- Different costs for labour in the country
- Different costs for material and technologies based on the location of production and the market situation
- Different minimum energy performance requirements and NZEB requirements
- Different types of buildings beyond NZEB
- Different energy performance calculation methods and user profiles
- Different types of floor area to which the costs are related
- Different energy price tariffs
- Different climates
- In many cases too small numbers of buildings with available cost information

Therefore we have decided to include here only a table on the investment cost difference for building components and building services systems between NZEBs and buildings built according to the minimum energy performance requirements, see Table 25.

Table 25: Average investment cost difference for building components and building services systems between NZEBs and buildings built according 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 *
Denmark	65 €/m² gross floor area *
Italy	229 €/m² useful area *
Slovenia	104 €/m² conditioned net floor area *

* Note: When using the data, take the remarks and explanations to the calculated average cost differences in Chapters 5.1 to 5.4 and 6.1 to 6.4 into account.

Based on the unfortunately partly limited data the determined average investment cost differences between NZEBs and buildings fulfilling the current minimum energy performance requirements are between 44 €/m² living area in Germany and 229 €/m² useful area in Italy.

7. Summary and outlook

The CoNZEBs partners have collected and analysed available data of investment costs and energy costs in Germany, Denmark and Italy. Despite extensive efforts including literature research, the use of data available at the CoNZEBs housing organisations and publicly available building cost data of research and demonstration buildings the number of analysed buildings in the four countries were between 8 and 46 at the time of the completion of this report. Since the data has to be divided into three different building levels, the calculation of average cost data is difficult and statistically unfortunately not always firm. The project partners will continue the search for relevant data in order to improve the quality of the calculated averages.

The detailed cost data in Table 14, Table 15, Table 17 and Table 18 and derived from these, the calculated differences of the average investment costs for building components and building services systems of the NZEB and the minimum energy performance building level per country can give rough indications of the cost barriers for building NZEBS in the countries:

- Germany: 44 €/m² living area
- Denmark: 65 €/m² gross floor area
- Italy: 229 €/m² useful area
- Slovenia: 104 €/m² conditioned net floor area

Available data for energy costs for the different building levels was even harder to gather. However, it can be derived from them that buildings fulfilling the NZEB level result in higher building-related electricity costs but lower building-related energy costs from other sources and also lower total building-related energy costs. Most NZEBs include more electrical building services systems like ventilation systems or heat pumps but despite higher electricity costs the total building-related energy costs are still lower than for regular new buildings. The buildings beyond NZEB are in most cases energy plus or energy neutral buildings. The resulting energy costs are either zero or even negative due to electricity generated from renewable energy sources fed into the national grid.

The results of the work documented in this report will be used in the related CoNZEBs work package 5 that identifies technical solution sets to reduce the cost gap between minimum energy performance requirements and NZEBs. It is also a part of the evaluation of the determined performance indicators at the beginning of the project (CoNZEBs task 2.2).

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