Aalborg Universitet

AALBORG UNIVERSITY DENMARK

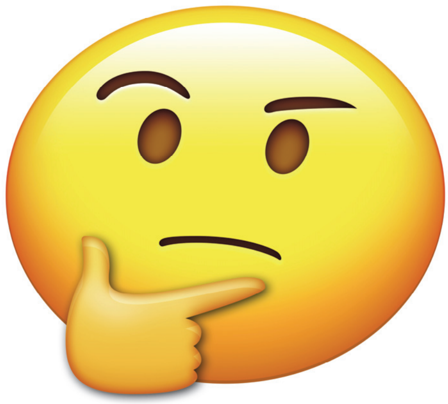
Solution sets for NZEB multifamily houses and beyond assessed for 2030 ; Deliverable D6.1

Solution sets for the Cost reduction of new Nearly ZeroEnergy Buildings – CoNZEBs

Erhorn-Kluttig, Heike; Illner, Micha; Erhorn, Hans; Thomsen, Kirsten Engelund; Wittchen, Kim B.; Mørck, Ove; Balslev-Olesen, Ole; Zinzi, Michele; Mattoni, Benedetta; Zavrl, Marjana Šijanec; Jacimovic, Marko

Publication date:
2019

Document Version
Publisher's PDF, also known as Version of record



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

EU H2020-EE-2016-CSA

Projekt ID: 754046

Solution sets for NZEB multi-family houses and beyond assessed for 2030

Deliverable D6.1

Authors:

Heike Erhorn-Kluttig, Micha Illner, Hans Erhorn (Fraunhofer Institute for Building Physics)

Kirsten Engelund Thomsen, Kim B. Wittchen (Danish Building Research Institute, Aalborg University) / Ove Mørck, Ole Balslev-Olsen (Kuben Management)

Michele Zinzi, Benedetta Mattoni (ENEA)

Marjana Šijanec Zavrl, Marko Jaćimović (GI ZRMK)

Disclaimer:

The CoNZEBs project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 754046.

The document reflects the author's view. The Commission is not responsible for any use that may be made of the information it contains.

Date: 15/10/19

Version: 2

Title page:

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

In 2018 the CoNZEBs project has identifying technical solution sets that lead to lower investment costs for nearly zero-energy buildings (NZEBs) in four countries (Germany, Denmark, Italy and Slovenia). A detailed report showing the solution sets and their investment costs savings compared to the most common national way of building an NZEB [1] was compiled and is available on the project website [2]. A solution set is a building energy concept consisting of a specified building envelope quality, partly with specific insulation or other building material, and a defined combination of building services systems.

In a follow-up task it was now analysed whether influence factors that change over time (so-called 'evolving parameters') will make the solution sets economically less or even more interesting in the next roughly 10 years. The time horizon for this is up to 2030. This was done in two steps:

1. Data collection of evolving parameters in connection with the energy performance of buildings.
2. Assessing the impact of the predicted changes on the technical solution sets by additional calculations or logical conclusions

As evolving parameters the CoNZEBs project team has identified:

- Primary energy factors
- Energy prices
- Technology costs
- Technology efficiencies
- Assessment method for the energy performance of buildings
- Climate change
- Financial support programmes

In order to assess the impact of the evolving parameters we needed to re-assess the solution sets with projected data for up to 2030. Sources (references) for the data have been collected and in some cases decisions had to be taken if several precasts were available in which the data differs. Where possible we have performed re-calculations using the data for 2030; in other cases the evaluations had to stay qualitative and are based on the expert opinion of the project participants.

2. Evolving parameters

2.1. Primary energy factors (Status August 2019)

The focus will be on the following energy sources because of the indicated changes in the energy mix that are already ongoing:

- Electricity (changes in the generation of the national electricity mix and where applicable for feed-in electricity)
- District heating (changes in the heat generation)
- Gas mix (e.g. higher ratio of biogas)

2.1.1. General assessment of national situation

Table 2: General assessment of national situation concerning evolving primary energy factors.

<table>
<tr><th>Country</th><th>General assessment: Primary energy factors</th></tr>
<tr><td>Germany</td><td>Primary energy factors for electricity (mix of Germany and feed-in electricity) have been revised in 2014 and 2016 [3]. The new DIN V 18599:2018 [4] includes updated primary energy factors for biogas and biofuel but no new values for electricity (besides the primary energy factor for feed-in electricity from PV). On the basis of the GEMIS database and calculation tool [5], [6] primary energy factors for the German electricity mix for up to 2050 can be predicted. There are no information sources for other future primary energy factors.</td></tr>
<tr><td>Denmark</td><td>Actual total primary energy factors have been changed in 2018. Information until 2050 has been analysed by SBi commissioned by the Danish Transport, Construction and Housing Authority. Note: The Danish Building Regulations [7] present the following total primary energy factors:
<table>
<tr><th></th><th>Electricity</th><th>District heating</th><th>Gas</th></tr>
<tr><td>Regular buildings up to 06/18</td><td>2.5</td><td>0.8</td><td>1.0</td></tr>
<tr><td>Regular buildings from 06/18</td><td>1.9</td><td>0.85</td><td>1.0</td></tr>
<tr><td>NZEBs up to 06/18</td><td>1.8</td><td>0.6</td><td>1.0</td></tr>
<tr><td>NZEBs from 06/18</td><td>1.9</td><td>0.85</td><td>1.0</td></tr>
<tr><td>2030</td><td>1.38[1)]</td><td>0.91[1)]</td><td>1.0</td></tr>
</table>
Danish Building Regulations 2018:
- until 30 June 2018 – Declaration BEK no. 718 of 31/05/2017
- from 1 July 2018 - Declaration BEK no. 606 of 29/05/2018
[1)] Wind scenario of the reference in Table 3/Table 4.</td></tr>
<tr><td>Italy</td><td>Primary energy factor were last modified in 2015 (national decrees). No studies exist about the time evolution of such factors.</td></tr>
</table>

Country	General assessment: Primary energy factors
Slovenia	Primary energy factors were last defined in 2010 (in the frame of Regulation for energy efficiency and listed in the annex TSG-004). In 2018 the revision of the national primary energy factors was initiated by the Ministry of infrastructure in the frame of LIFE ClimatePath 2050 project (https://www.podnebnapot2050.si/), the completion is foreseen by the end of 2019. Currently, the data for the year 2030 are drafted and reported in this study. The primary energy factor for district heating expected to be provides for specific district heating systems (RES, CHP, waste energy use).

2.1.2. Sources/references

Table 3: Sources and references for the evolving primary energy factors.

Country	Sources/references for primary energy data precast
Germany	EnEV 2014 [3] / DIN V 18599 [4] GEMIS [5]/IINAS [6] Fraunhofer IBP study [8]
Denmark	Aggerholm S. Energy factors used in energy calculations (in Danish). SBi 2017:04. Danish Building Research Institute, Aalborg University, Copenhagen, [9].
Italy	Decreto interministeriale 26 giugno 2015 - Applicazione delle metodologie di calcolo delle prestazioni energetiche e definizione delle prescrizioni e dei requisiti minimi degli edifici (Decree 26 June 2015 - Calculation methodologies for energy performances, prescriptions and minimum requirements in buildings).
Slovenia	Technical guidelines for revision of Regulation on energy efficiency of buildings (2016, Ministry of Environment and Spatial Planning, GI ZRMK and Univ of Ljubljana - Fac. of Mech. Eng.) [10] LIFE Climate Path 2050 Project (2018-2019 ongoing) [11]

2.1.3. Data

Table 4: Data for the evolving primary energy factors.

Country	Year	Non-renewable primary energy factors per energy source		
		Electricity	District heating	Gas
Germany	2018	1.8	0.7 *	1.1
	2030	0.65 (GEMIS/IINAS)	0.5 * (IBP)	1.1 (GEMIS)
Denmark	2018	0.86[1)]	0.46[1)]	1.1
	2030	0.22[1)]	0.18[1)]	1.1
Italy	2018	1.95	1.5 **	1.05
	2030	0.96 ***	-	1.05 ***

Country	Year	Non-renewable primary energy factors per energy source		
		Electricity	District heating	Gas
Slovenia	2018	2.5	1.0 – 1.2	1,1
	2030	2,2	0,95 – 1,1 (0,1 for biomass DH)	1,1

1) Depending on the scenario for future energy sources dominated by wind, biomass, hydrogen, fossil.

Sources:

- Germany: 2018: EnEV [3] / DIN V 18599 [4]
  2030: GEMIS [5] / IINAS report [6], Fraunhofer IBP assessment (study for Federal State Baden-Württemberg with focus on $CO_{2,eq.}$ emission factors) [8]
  * District heating generated by combined heat and power based on fossil fuel
- Denmark: Aggerholm S.: Energy factors used in energy calculations (in Danish). SBi 2017:04. Danish Building Research Institute, Aalborg University, Copenhagen [9].
  European Standard EN /ISO 52000-1:2017 - Energy performance of buildings – Overarching EPB assessment – Part 1: General framework and procedures [12].
- Italy: ** National value indicated in Decreto interministeriale 26 giugno 2015 - Applicazione delle metodologie di calcolo delle prestazioni energetiche e definizione delle prescrizioni e dei requisiti minimi degli edifici [Decree 26 June 2015 - Calculation methodologies for energy performances, prescriptions and minimum requirements in buildings]. In common practice the conversion factor is declared (and certified) by the company for that own and manage a specific plant.
  *** No official data exist for energy performance in buildings, the figure comes from ENEA in-house calculations according to PNIEC - Piano Nazionale Integrato per l'Energia e il Clima 2030 [Integrated National Plan for Energy and Climate 2030].
- Slovenia: 2018: Rules on efficient use of energy in buildings with a technical guideline (PURES) define non-renewable primary energy factors per energy source [13]
  2030: LIFE Climate Path 2050 Project [11] (IJS) focused on determination of non-renewable primary energy factors per particular district heating system (data collected via the national Energy agency) and this developing PEFs per specific DH types. The future PEF will be influenced by the selected national energy scenario (currently ongoing process: Energy concept of Slovenia and National energy and climate plan).

2.2. Energy prices

There are numerous studies on the energy price development available. Many of them use a linear energy price increase factor over time. The CoNZEBs partners decided to use the energy price increase factor that was/is applied in the EPBD cost-optimality procedure. This can be either the data suggested by the Commission or used by the Member States and defined in the national cost-optimal report.

2.2.1. EU EPBD cost-optimal studies

The European Commission publishes regular market analysis reports on European gas and electricity markets and energy prices and costs in Europe[1]. The quarterly reports analyse the main factors behind price and volume evolutions on the market and they analyse gas and electricity market interactions between countries

In the Guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU is stated:

The energy price development trends provided in Annex II to the Regulation[2] give information about the estimated long-term price developments for oil, gas and coal, as well as electricity. Member States must take this information into account when determining the costs for energy carriers for the purpose of their cost- optimal calculations.

The information provided in Annex II to the Regulation is taken from energy trend scenarios developed with the PRIMES model (a modelling system that simulates a market equilibrium solution for energy supply and demand in the EU 27 and its Member States). The European Commission publishes biannual updates of these trends and the latest version can be found on: http://ec.europa.eu/energy/observatory/trends_2030/index_en.htm.

The latest update[3] implies a 2.8% annual increase in gas prices, a 2.8% annual increase in oil prices and a 2% annual increase in coal prices. These trends may be extrapolated beyond 2030 until more long-term projections become available.

The full set of the 2018 cost optimal reports can be found at: https://ec.europa.eu/energy/en/content/eu-countries-2018-cost-optimal-reports. Earlier report are to be found at: https://ec.europa.eu/energy/en/content/eu-countries-2013-cost-

[1] https://ec.europa.eu/energy/en/data-analysis/market-analysis
[2] COMMISSION DELEGATED REGULATION (EU) No 244/2012 of 16 January 2012
[3] EU Energy Trends to 2030; update 2009. European Union, 2010. See: http://ec.europa.eu/energy/observatory/ trends_2030/doc/trends_to_2030_update_2009.pdf.

optimal-reports-part-1 and https://ec.europa.eu/energy/en/content/eu-countries-2013-cost-optimal-reports-part-2.

2.2.2. CO_2 pricing

Several European States have already supplemented the central element of European climate policy, the EU Emission Trading System (ETS), with CO_2 components in the energy price system. The current discussion in the Member States suggests that in the next few years an assessment of the climate relevance of the used energy sources will take place. The trend is towards cost-neutral off-setting of revenue, which means that the revenues flow into a fund that financially supports greenhouse gas reduction measures in the respective sector (household, transport, industry) under social aspects. The price discussed for the appropriate consideration of climate-damaging exhaust gases from the energy supply ranges between € 20 and € 180 per ton of $CO_{2,\ eq.}$ emission. Assuming that currently the kWh used in case of electricity emits about 600 grams of $CO_{2,\ eq.}$ and in case of natural gas about 200 grams of $CO_{2,\ eq.}$, additional energy costs of between 0.4 to 3.6 ct per kWh (natural gas) and 1.2 to 10, 8 ct per kWh (electricity) would occur. In case the $CO_{2,\ äq.}$ emission of the energy carrier will be reduced up to 2030 the energy price will be accordantly decreased.

2.2.3. Total energy price increase

For countries that have already introduced CO_2 pricing (e.g. Sweden (since 1991), Norway (1991), Denmark (1992), France (2014), Finland (1990) and Slovenia (1996)) the predicted energy price increase of the EPBD cost-optimal study includes the CO_2 pricing and its predictable development.

Germany and Italy have not yet introduced CO_2 pricing but in Germany political discussions about the introduction are going on and it can be expected that it will be introduced before 2030. Therefore the energy price increase of the German cost-optimal study will be supplemented by the proposed rate of CO_2 pricing by the Umweltbundesamt (UBA).

2.2.4. General assessment of national situation

Table 5: General assessment of national situation concerning evolving energy prices.

Country	General assessment: Energy prices
Germany	A national study [14] on the development of energy prices is available that was also used for the German analysis of the cost optimal levels for new buildings (EPBD). The $CO_{2,eq.}$ pricing was proposed by the Umweltbundesamt including data for 2030 [15].
Denmark	A national study conducted at the Danish Building Research Institute, Aalborg University in 2018 were used assessing the evolvement of energy prices.
Italy	The study on the evolution of energy costs is carried out on two energy sources: electricity and gas methane, according to the actual framework, where 90% of the national population lives in area with gas supply. The energy uses taken into account of the energy price assessment refer to usual building energy services. The price evolution is based on different national sources that were assembled to carry out the cost-optimal analysis.
Slovenia	The assessment of the evolvement of the energy prices was carried out using with the EU Reference Scenario 2016, together with national statistics, which were used in the 2018 national cost optimal study.

2.2.5. Sources/references

Table 6: Sources and references for the evolving energy prices.

Country	Sources/references for energy prices precast
Germany	Energy prices: Energiepreisentwicklung im Szenario „Bundesregierung (Prognos)“ [14] $CO_{2,eq.}$ pricing: Umweltbundesamt (UBA) [15]
Denmark	Cost-optimal levels of minimum energy performance requirements in the Danish Building Regulations, Søren Aggerholm, SBi 2018:13. Danish Building Research Institute, Aalborg University, 2018. ISBN: 978-87-563-1911-9 [16].
Italy	Italian cost optimal study (not published yet), prepared by the working group in charge on behalf of the Ministry of Economic Development.
Slovenia	Slovenian Cost optimal study (2018), [17]. https://ec.europa.eu/energy/en/content/eu-countries-2018-cost-optimal-reports EU Reference Scenario 2016, Energy, transport and GHG emissions: Trends to 2050, [18].

2.2.6. Data

Table 7: Data for the evolving energy prices.

Country	Energy price increase [unit]		
	Gas	District heating	Electricity
Germany	M: 1.1%/yr	M: 1.1%/yr[1)]	M: 0.25%/yr
Denmark		F: 1.9%/yr	F: 0.8%/yr
Italy	2.3%/yr	-	3.4%/yr
Slovenia	M: 0.69%/yr	M: -1.6%/year	M: 0.23%/year

M = Macroeconomic, F = Financial

[1)] No detailed increase rate available; rate of gas used as main energy source for district heating.

Table 8: Data for the $CO_{2,eq.}$ pricing.

Country	$CO_{2,eq.}$ pricing (2030)		
	Gas	District heating	Electricity
Germany [15]	205 €/$t_{CO2,eq.}$ * 240 g/kWh = 0.05 €/kWh	205 €/$t_{CO2,eq.}$ * 100 g/kWh = 0.02 €/kWh	205 €/$t_{CO2,eq.}$ * 390 g/kWh = 0.08 €/kWh
Denmark [17], [20]	-	41 €/$t_{CO2,eq.}$ * 0.086 g/kWh = 0.0035 €/kWh	41 €/$t_{CO2,eq.}$ * 0.1 kg/kWh = 0.004 €/kWh
Italy	-	-	-
Slovenia	-	-	-

Table 9: Data for total energy price increase.

Country	Price increase by 2030		
	Gas	District heating	Electricity
Germany	+0.06 €/kWh	+0.03 €/kWh	+0.09 €/kWh (feed-in tariff in 2030 = 0 €/kWh)
Denmark		+0.015 €/kWh	+0.032 €/kWh
Italy	+0.09 €/kWh	-	+0.29 €/kWh
Slovenia	+0.0043 €/kWh	-0.01 €/kWh	+0.004 €/kWh

2.3. Technology costs

The general development of building and building technology costs until 2030 can be estimated by using inflation rates. Yet this general price increase is not the focus of this study.

CoNZEBs looks at rather new and/or innovative technologies for which the cost development can differ from the other technologies. This is for example the case when a technology is more widely introduced into the market. The price of the technology will then become cheaper.

One example for this is the cost of photovoltaic modules. A study [21] has compared the average consumer price for roof installed PV systems over the last 12 years in Germany, see Figure 1. The price decreased by nearly 75% since 2006.

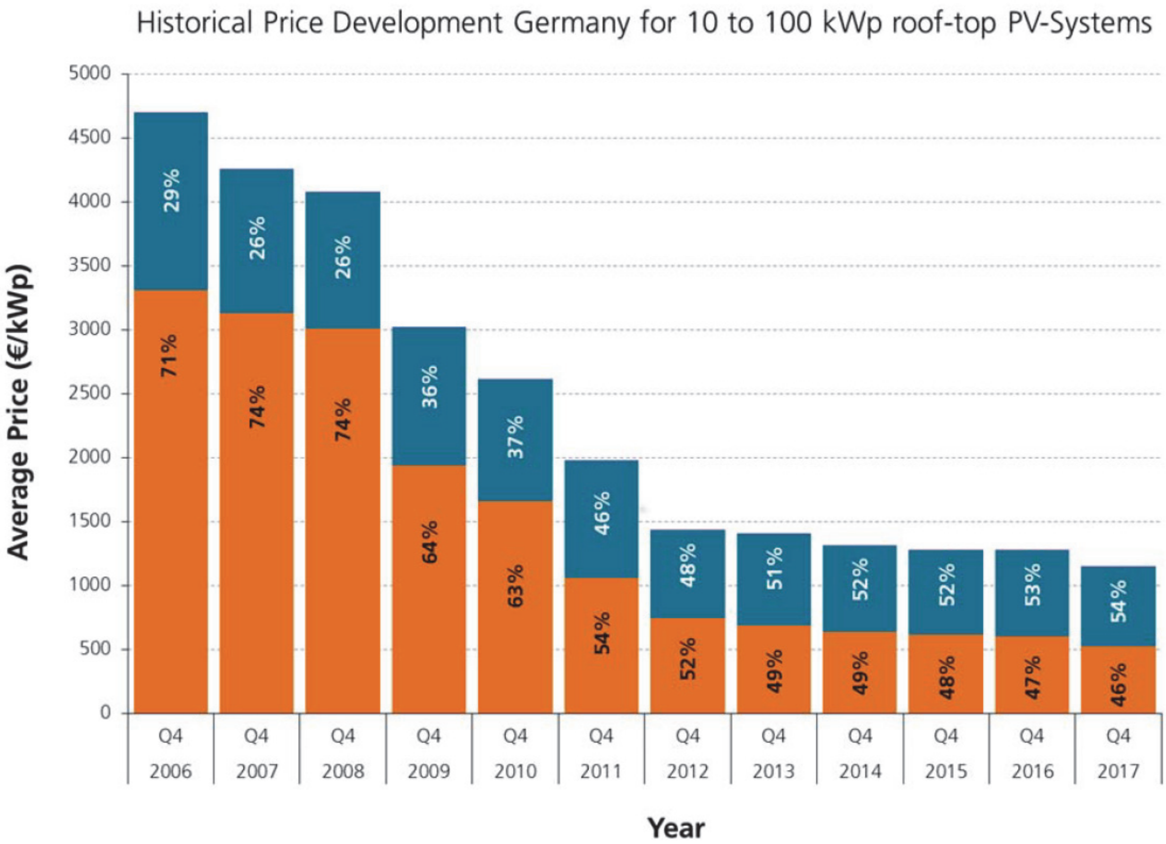


Figure 1: **Average consumer price (net system price) for installed PV systems (10 – 100 kWp) on the roof in Germany. The orange part of the columns shows the system costs, the blue part the installation costs. Data of BSW/EuPD. Diagram source PSE AG/Fraunhofer ISE [21].**

2.3.1. General assessment of national situation

Table 10: General assessment of national situation concerning evolving technology costs.

Country	General assessment: Technology costs
Germany	The price development for certain technologies is supposed to go down. Examples are: - PV - Heat pumps - Batteries (not installed in the German solution sets) - Facade PV (not mounted in the German solution sets) - ETICs with organic PV (not mounted in the German solution sets)
Denmark	Technology catalogues (in Danish) exist for evaluation of the development on the energy and environment sectors, commissioned by the Danish Energy Agency [22]. The catalogues are developed for the areas: Production of electricity, district heating and storage; Individual space heating; Renewable energies; Distribution and transmission of electricity, gas and district heating.
Italy	Costs of some technologies are expected to reduce. For the building sector, they are mainly related to the current mainstream: electrification of buildings. Hence the focus is on: heat pumps, PV (possibly integrated), storage.
Slovenia	Technology prices are expected to reduce, especially prices of heat pumps and roof PV system, since currently there is a rise in usage of them. With the latter presumably also ion lithium battery prices are supposed to go down. According to the Slovenian National Energy and Climate Plan [23], the electricity production with PV will increase up to 1.1 TWh until 2030 and up to 2.8 TWh until 2040. Besides it is also stated that in majority heat pumps will replace gas and oil heating systems.

2.3.2. Sources/references

Table 11: Sources and references for the evolving technology costs.

Country	Sources/references for technology cost developments
Germany	PV: Study of the European Photovoltaic Technology Platform [24] Heat pump: Study of ewi – Energy Research and Scenarios GmbH [25]
Denmark	https://ens.dk/service/fremskrivninger-analyser-modeller/teknologikataloger [22]
Italy	SIMTE Sistema Informativo e di Monitoraggio delle Tecnologie Energetiche (Information and monitoring system of energy technologies) developed by ENEA upon mandate of Ministry of Economic Development. Cost and efficiency of heat pumps are derived from Italian data (it is not known whether those data are based on international data). PV and batteries are derived from international data.

Country	Sources/references for technology cost developments
Slovenia	Slovenian National Energy and Climate Plan [23] GI ZRMK expert's research https://www.eks.si/ [26]

2.3.3. Data

Table 12: Data for the evolving technology costs.

Country	Technology	Cost development up to 2030
Germany	PV system	Reduction of investment costs: 45%
	Heat pumps	Reduction of investment costs: 10%
Denmark	Solar thermal collectors	2018: 755 -> 2030: 684 (2030) [€/m²] 1)
	PV	2018: 1.65 -> 2030: 1.27 (2030) [€/Wp]2)
Italy	Heat pumps	Reduction: 20-30%
	Ion lithium batteries	Reduction: 70-75%
	PV roof systems	Reduction in investment costs: 19 - 27% Reduction in operation and maintenance costs: 20 - 23%
Slovenia	Heat pumps	Reduction of investment costs: 5 - 15%
	PV roof systems	Reduction of investment costs: 20 - 30%
	Ion lithium batteries (not used in Slovenian solution sets)	Reduction of investment costs: 40 - 70%

1) 10 m² solar collector area systems, incl. piping and storage tank.

2) Full system, incl. inverter(s), cabling and installation.

2.4. Technology efficiencies

When the efficiency of technologies become higher this will result in a smaller size of the technology to be used for achieving the NZEB level and thus lead to less costs. A simple example is insulation. If the material can be produced with a lower thermal conductivity, less insulation thickness is needed. Yet, this will only lead to lower prices if the production is not more expensive and/or based on the price pressure of the market. In the case a building service system component is more efficient (e.g. a heat pump or a ventilation system with heat recovery) cost savings can be expected due to a lower thermal quality of the building envelope that is compensated by the better system efficiency.

In many cases the prices for further developed and more efficient technologies are at the beginning higher because the production facilities and the market penetration are small. It takes a few years until the new technology has succeeded on the market and the prices reach the same level as with the former technology. So within the time span of 2030 we have to look for technology developments that are more or less already available but need a higher market penetration. We should also include those that have started to have a higher market penetration but we expect this to be continued for some time.

2.4.1. General assessment of national situation

Table 13: General assessment of the national situation concerning the evolving technology efficiencies.

Country	General assessment: Technology efficiencies
Germany	The heat pump association foresees an increase of the seasonal performance of the heat pumps until 2030 [27]. Market research by Fraunhofer IBP as the main author of this report showed that the difference in performance between front runners and mainstream product of PV panels in Germany is about 10%. We believe that by 2030 the mainstream product will have an increased performance of about the same range. Fraunhofer IBP as experts in building physics expects a further development in the production of triple-glazed windows with a reduction of the average window U-value of about 0.1 W/m²K in Germany.
Denmark	Technology catalogues (in Danish) exist for evaluation of the development on the energy and environment sectors, commissioned by the Danish Energy Agency [22]. The catalogues are developed for the areas: Production of electricity, district heating and storage; individual space heating; renewable energies; distribution and transmission of electricity, gas and district heating.
Italy	Efficiencies of some technologies are expected to increase. For the building sector, they are mainly related to the current mainstream: electrification of buildings. Hence the focus is on: heat pumps, PV (possibly integrated), storage.
Slovenia	The efficiencies of technologies such as heat pumps, PV and technologies for saving solar energy (Ion lithium batteries), which are widely used and their usage is in the rise, are expected to increase. Besides, it is expected that until 2030 the energy management will improve, thus the efficiency of district system will increase as well.

2.4.2. Sources/references

Table 14: Sources and references for the evolving technology efficiencies.

Country	Sources/references for technology efficiency developments
Germany	Heat pump: Study of the heat pump association 'BWP-Branchenstudie 2015 - Szenarien und politische Handlungsempfehlungen', [27]. PV: Prediction based on market research of Fraunhofer IBP. Triple-glazed windows: Experience of Fraunhofer IBP.
Denmark	https://ens.dk/service/fremskrivninger-analyser-modeller/teknologikataloger [22]

Country	Sources/references for technology efficiency developments
Italy	SIMTE Sistema Informativo e di Monitoraggio delle Tecnologie Energetiche (Information and monitoring system of energy technologies) developed by ENEA upon mandate of Ministry of Economic Development.
Slovenia	Slovenian National Energy and Climate Plan [23] GI ZRMK expert's research https://www.eks.si [26]**Fehler! Verweisquelle konnte nicht gefunden werden.**

2.4.3. Data

Table 15: Data for the evolving technology efficiencies.

Country	Technology	Efficiency development up to 2030
Germany	Air-water hear pumps	SEER to improve by 10%
	PV systems	Performance to improve by 10%
	Triple-glazed windows	U_W to improve by 0.1 W/m²K
Denmark	Solar thermal collectors	2018: 425 -> 2030: 475 kWh/m² per year
	PV: Peak power full load hours	2018: 994 -> 2030: 1085 kWh/kWp(dc)
Italy	Heat pumps	Improvements 30 - 50%
	Ion lithium batteries	No significant improvements (peak efficiency is almost reached)
	PV roof systems	Improvements 3.5 - 6.6%
Slovenia	Heat pumps (COP)	Improvement of performance: 10%
	PV roof systems	Improvement of performance: 10 - 20%
	District heating	Improvement of performance: 20 - 30%

2.5. Other possible impact factors

2.5.1. Assessment methods for the energy performance of buildings

It can be assumed that there will be changes in the national energy performance assessment methods of buildings until 2030. Some countries might change completely to the CEN EPBD standards; other will further develop their own calculation method. This can have influence on the NZEB level. It might also allow further technologies to be used or other to be included with a higher benefit (e.g. PV-generated electricity to be included with a higher benefit).

It might also be the case that other energy uses like household electricity, external lighting, elevators and even mobility will by 2030 be part of the energy balancing method. Maybe even life cycle assessment (LCA) will by then be in the focus of the building performance methods.

2.5.2. Climate change

For many countries the climate change might lead to a reduction in heating energy use and an increase of cooling energy use. The current solution sets for all four countries (Germany, Denmark, Italy and Slovenia) do not include cooling energy for the multi-family houses. Maybe by 2030, cooling becomes more ordinary in residential buildings in some countries and thus also needs to be foreseen in NZEBs.

In order to assess the impact of the higher temperatures the country teams have calculated the difference of the heating energy use and the theoretical cooling energy demand of a 'virtual' cooling system (simple split units in living and sleeping rooms) and the resulting electricity costs between the climate data in 2018 and 2030.

2.5.3. Financial support programmes

Financial support programmes have an impact on the applied and therefore produced technologies because they reduce the costs for the building owners for a certain building energy level or certain applied technologies. For those technologies they lead to more applications on the market, which might additionally influence the market prices as consequence. In some countries (e.g. Germany, Italy) support programmes for certain technologies are more common than in others (e.g. Denmark). In Slovenia a decree for self-supply with PV power was put in place in 2019.

However predicting financial support programmes with a view to 2030 is an impossible task and therefore the impact of financial support programmes can't be calculated by the CoNZEBs team. Note, that the identified solution sets of CoNZEBs work package 5, [1] have been assessed without the impact of the available financial support programmes in 2018 as they often start, change and end quickly.

3. Impact of the evolving parameters on the cost-efficient NZEB solution sets and the building level beyond NZEB

The impact of the evolving parameters described in chapter 2 on the alternative NZEB solution set and the building level beyond NZEB is described divided into four national subchapters. All of them start with the description and the calculated energy and cost results of the identified NZEB solution sets and the building level beyond NZEB for the status of 2018 before the changes in the result due to the evolvement of each parameter towards 2030 are discussed.

The process to determine the cost-efficient NZEB solution sets was as follows: For a typical national multi-family house geometry the most common way of building an NZEB was identified - the so-called 'typical NZEB'. Then the partners have assessed alternative NZEB concepts and compared the resulting investment costs to the costs of the typical NZEB. The concepts with lower investment costs than those of the typical NZEB are presented country by country in the resulting report [1]. In addition this report contains an analysis of the transferability of the solution sets to other countries and descriptions of technologies that are part of the solution sets and innovative or at least not often used in other countries. The energy data were calculated using the currently established national calculation methods for the energy performance of buildings. The cost data were derived from national cost databases and experiences at the project partners.

Further efforts have been spent on the calculation of life-cycle costs and the life-cycle assessment of the NZEB solution sets in comparison with the typical building fulfilling the national minimum energy performance requirements and the typical NZEB building concept. The results are presented in an additional CoNZEBs report [28].

3.1. Germany

3.1.1. Typical NZEB, cost-efficient NZEB solution sets and building level beyond NZEB

Due to the missing detailed German application of the NZEB definition at the start of the project, the German CoNZEBs team defined the national NZEB requirement to be the KfW Efficiency House 55, which translates to be about 27% tighter than the legal minimum energy performance requirement for new building.

The typical NZEB energy concept for a multi-family house was chosen to consist of a condensing boiler in combination with a solar thermal collector field that generate heat and domestic hot water centrally for all residential units. The heat distribution is realised by radiators. The building includes a mechanical exhaust ventilation system. The building envelope features the following U-value qualities: 0.10 W/m²K at the external wall, 0.08 W/m²K at the roof, 0.20 W/m²K at the cellar ceiling and 0.82 W/m²K at the windows.

In comparison with this energy concept the following more cost-efficient alternative solution sets (SS) have been identified (with solution sets 1, 4, 5, 6 and 9 proving to be not cost-efficient in comparison with the typical NZEB energy concept):

- DE-SS2: Direct electrical heating and DHW
  Decentral direct electric heating and DHW system, decentral ventilation system with heat recovery, roof PV panels, heat recovery from shower waste water and reduced insulation level

- DE-SS3: Air heating system
  Central supply and exhaust ventilation and heating system with air-to-air heat pump, decentral electrical DHW heater and heat recovery from shower waste water and reduced insulation level
- DE-SS7: District heating
  Central combined heating and DHW system with district heating, radiators, central exhaust ventilation system and reduced insulation level
- DE-SS8: Exhaust air-to-water heat pump/condensing gas boiler, DHW heat exchange modules
  Central heating system with exhaust air-to-water heat pump (in central exhaust ventilation system) supported by condensing gas boiler, radiators, decentral DHW heat exchange modules, roof PV panels and reduced insulation level

The German building level beyond NZEB was chosen to be a plus energy building. The technology open definition of the plus energy level follows the on of the efficiency house plus programme of the Federal Building Ministry [29]. The specific combination to fulfil the plus energy level for the typical multi-family house geometry is:

- Central air-water heat pump for heating and DHW
- Floor heating system
- Domestic hot water heat exchangers (fresh water stations)
- Decentral ventilation system with heat recovery
- Roof PV panels
- Reduced insulation level

The mean U-values and the main results of the energy and cost calculations of the typical NZEB, the determined four cost-efficient NZEB solution sets and the beyond NZEB building level are presented in Table 16.

Table 16: Main characteristics of the typical German NZEB solution, the cost-efficient NZEB solution sets and the building level beyond NZEB with the status 2018.

Solution set results summary All specific values relate to the net floor area of the building.			German NZEB solution sets					Beyond NZEB
			Typical NZEB (base case)	DE-SS2	DE-SS3	DE-SS7	DE-SS8	
			Central combined heating + DHW system with gas condensing boiler and solar thermal collector, central exhaust ventilation system, high insulation level	Decentral direct electric heating + DHW system, decentral venti-lation system with heat recovery, roof PV panels, heat recovery from shower waste water -> reduced insulation level	Central supply and exhaust ventilation and heating system with air-to-air heat pump, decentral electrical DHW heater and heat recovery from shower waste water -> reduced insulation level	Central combined heating + DHW system with district heating, radiators, central exhaust ventilation system -> reduced insulation level	Central heating system with exhaust air-water heat pump (in central exhaust ventilation system) supp. by cond. gas boiler, radiators, decentral DHW heat exchange modules, roof PV panels -> reduced insulation level	Central air- to-water heat pump for heating and DHW, floor heating system, domestic hot water heat exchangers, decentral ventilation system with heat recovery, roof PV panels -> reduced insulation level
Building envelope	Mean U-value (incl. windows)	W/m²K	0.22	0.31	0.31	0.31	0.31	0.28
Net energy	Total	kWh/(m²yr)	35.50	35.42	36.24	41.16	49.39	28.26
Final energy	Total EPBD	kWh/(m²yr)	46.60	22.83	27.00	65.48	38.27	11.09 (-21.40)
	Total (incl. other energy uses)	kWh/(m²yr)	71.60	47.83	52.00	90.48	63.27	36.09 (-1.40) *
Primary energy	Total EPBD	kWh/(m²yr)	48.85	41.09	48.60	48.39	47.60	19.96 (-38.25)
	Total (incl. other energy uses)	kWh/(m²yr)	93.85	86.09	93.60	93.39	92.60	55.96 (-2.52) *
Energy costs	Total EPBD	€/(m²yr)	3.33	6.43	6.91	7.00	4.22	-1.93
	Total (incl. other energy uses)	€/(m²yr)	10.69	14.08	14.27	14.91	11.58	3.95 *
Investment costs	Difference to typical NZEB	€/m²	-	-84	-84	-83	-44	+107

*For the beyond NZEB level (efficiency house plus) a reduced household electricity use of 20 kWh/m²yr is applied. The value in brackets show the data incl. the electricity fed into the grid.

3.1.2. Primary energy factors

The assumed evolvement of the primary energy factors from 2018 to 2030 is described in chapter 2.1. For Germany the predicted changes are:

Table 17: Predicted changes for the German primary energy factors from 2018 to 2030

Energy source	Primary energy factor	
	2018	2030
Grid electricity	1.8	0.65
PV generated electricity fed into grid (impact on primary energy only included in the beyond NZEB level)	1.8	0.65
District heating	0.7	0.5
Gas	1.1	1.1

The impact on the calculated results for the different variants (typical NZEB, NZEB solution sets and building beyond NZEB) is as follows. For details see Table 18.

While the primary energy factors of gas are projected to be unchanged district heating and more significantly electricity primary energy factors are predicted to be lower in 2030. Consequently the solution sets with higher rates of electricity use (DE-SS2 with direct electrical heating and DHW, DE-SS3 with electrical heat pump and DE-SS8 with electrical heat pump in addition to the gas condensing boiler) result in considerably lower EPBD covered primary energy uses in 2030 compared to the results of 2018. Similarly the EPBD covered primary energy uses of the solution set with district heating (DE-SS7) shows a clear reduction. The plus energy building as beyond NZEB level can also considerably reduce the EPBD covered primary energy use in 2030, due to the use of the electrical heat pump as heating and DHW generation system.

However, according to the current German energy ordinance the lower primary energy use can not lead to a further reduced insulation level and according lower investment costs. Besides the primary energy limit, the energy ordinance contains a secondary requirement for a minimum quality of the building envelope. This is already defining the U-values of DE-SS2, DE-SS3, DE-SS7 and DE-SS8.

The total primary energy use of all presented building levels and solution sets is reduced when taking the predicted primary energy factors of 2030 into account. Here the lower factor for electricity applies to all solution sets at least on the part of the household electricity.

In the case of the plus energy (Efficiency House Plus) there is no additional mean U-value required, but the general one of the energy ordinance applies as well. This is would allow for slightly higher U-values. On the other hand the primary energy use including household electricity taking into account the feed-in of PV electricity into the grid is only slightly negative. Thus no further compensation at the building envelope is possible.

In some cases the ventilation system could be omitted in order to reduce investment costs, but they are kept for ventilation issues (internal bathrooms) and are also the supply for some of the used heat pumps.

The PV systems are necessary for DE-SS2 because of the national requirements to integrate renewable energy in the heat generation and for the beyond NZEB in order to compensate for the energy use to achieve the plus energy level. For DE-SS8 however the lower EPBD covered primary energy use allows for omitting the PV array of 10 m² on the roof and thus reducing the investment costs. This would however reduce the investment costs only slightly (-2,500 € or 2 €/m²). The marginal impact on the final energy (EPBD) would thus be +1.4 kWh/m²yr and on the primary energy (EPBD) 0.9 kWh/m²yr.

In summary the changes in the primary energy factors leads to reductions in primary energy use and gives the highest benefits to DE-SS2 (direct electrical heating and DHW), followed by DE-SS3 (air heating by electrical heat pump), DE-SS7 (district heating) and DE-SS8 (combination of electrical heat pump and gas condensing boiler). The beyond NZEB building (electrical heat pump but already very low primary energy use in 2018) and the typical NZEB (gas condensing boiler) also profit from the lower primary energy factors in 2030 but less than the other solution sets. However there is only one solution set where the lower primary energy factors can lead to slightly lower investment costs: DE-SS8 where the lower primary energy use makes it possible to omit the PV panels on the roof.

Primary beneficiaries of changes in the primary energy factors:

- All solution sets regarding primary energy results with DE-SS2 (direct electrical heating) and DE-SS3 (air heating with electrical heat pump) in the lead
- DE-SS8 (gas-condensing boiler plus electrical heat pump) regarding possible further (minor) reductions at the investment costs

Table 18: **Comparison of the German energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the primary energy factors.**

Solution set results summary All specific values relate to the net floor area of the building.			German NZEB solution sets: Typical NZEB	DE-SS2	DE-SS3	DE-SS7	DE-SS8	Beyond NZEB
			Central combined heating + DHW system with gas condensing boiler and solar thermal collector, central exhaust ventilation system, high insulation level	Decentral direct electric heating + DHW system, decentral venti-lation system with heat recovery, roof PV panels, heat recovery from shower waste water -> reduced insulation level	Central supply and exhaust ventilation and heating system with air-to-air heat pump, decentral electrical DHW heater and heat recovery from shower waste water -> reduced insulation level	Central combined heating + DHW system with district heating, central exhaust ventilation system -> reduced insulation level	Central heating system with exhaust air-water heat pump (in central exhaust ventilation system) supp. by cond. gas boiler, radiators, decentral DHW heat exchange modules, roof PV panels -> reduced insulation level	Central air- to-water heat pump for heating and DHW, floor heating system, domestic hot water heat exchangers, decentral ventilation system with heat recovery, roof PV panels -> reduced insulation level
Building envelope	Mean U-value (incl. windows)	W/m²K	0.22	0.31	0.31	0.31	0.31	0.28
Net energy	Total	kWh/(m²yr)	35.50	35.42	36.24	41.16	49.39	28.26
Final energy	Total EPBD	kWh/(m²yr)	46.60	22.83	27.00	65.48	38.27	11.09 (-21.40)
	Total (incl. other energy uses)	kWh/(m²yr)	71.60	47.83	52.00	90.48	63.27	36.09 (-1.40) *
Primary energy	Total EPBD	kWh/(m²yr)	48.85 -> 45.04	41.09 -> 14.84	48.60 -> 17.55	48.39 -> 33.09	47.60 -> 33.85	19.96 (-38.25) -> 7.21 (-13.91)
	Total (incl. other energy uses)	kWh/(m²yr)	93.85 -> 61.29	86.09 -> 31.09	93.60 -> 33.80	93.39 -> 49.34	92.60 -> 50.10	55.96 (-2.52) * -> 20.20 (-0.91)
Energy costs incl. feed-in	Total EPBD	€/(m²yr)	3.33	6.43	6.91	7.00	4.22	-1.93
	Total (incl. other energy uses)	€/(m²yr)	10.69	14.08	14.27	14.91	11.58	3.95 *
Investment costs	Difference to typical NZEB	€/m²	-	-84	-84	-83	-44	+107

*For the beyond NZEB level (efficiency house plus) a reduced household electricity use of 20 kWh/m²yr is applied. The value in brackets show the data incl. the electricity fed into the grid.

3.1.3. Energy prices

The assumed evolvement of the energy prices from 2018 to 2030 is described in chapter 2.2. For Germany the predicted changes are:

Table 19: Predicted changes for the German energy prices from 2018 to 2030

Energy source	Energy prices	
	2018	2030
Gas	0.05 €/kWh	0.11 €/kWh
District heating	0.10 €/kWh	0.13 €/kWh
Grid electricity:		
Regular	0.29 €/kWh	0.38 €/kWh
Heat pump	0.22 €/kWh	0.31 €/kWh
PV generated electricity fed into grid	0.10 €/kWh	0 €/kWh

The impact on the calculated results for the different variants (typical NZEB, NZEB solution sets and building beyond NZEB) is as follows. For details see Table 20.

Changes at the energy prices have obviously no impact on energy uses and investment costs. They influence the energy costs and therefore the payback times of the investments. While the predicted general energy price increase (as used in the EPBD cost optimal studies) results in about 1 cent/kWh for all used energy sources gas, district heating and electricity the main impact comes from the $CO_{2,eq.}$ pricing which adds 5 cents/kWh for gas, 2 cents/kWh for district heating (generated by combined heat and power based on fossil energy (gas)) and 8 cents/kWh electricity, all based on 205 €/$t_{CO2,eq.}$ Accordingly the highest increase of energy prices is predicted for the electricity uses, the lowest for district heating.

In Table 20 it becomes visible that all energy costs are significantly increasing when taking the predicted energy prices for 2030 into account. The EPBD related annual energy costs of the typical NZEB increase from 3.33 €/m²yr to 6.02 €/m²yr. The solution set with the highest energy costs in 2018, the one with the energy generation by district heating (DE-SS7) leads to energy costs of 7.00 €/m²yr in 2018 and 9.09 €/m²yr in 2030. In 2030 it is however over-taken by DE-SS3, the air heating system with the heat pump, with 9.28 €/m²yr. The cheapest annual energy costs are still (in 2018 and 2030) available for the typical NZEB and DE-SS8. In that way DE-SS8 with the combination of gas condensing boiler and electrical exhaust air heat pumps proves to be future-proof regarding changes in energy prices.

Primary beneficiary of changes in energy prices:

- DE-SS8 (gas-condensing boiler plus electrical heat pump) with still second lowest energy costs; lowest energy costs still at typical NZEB (beyond NZEB not taken into account).

Table 20: Comparison of the German energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the energy prices.

Solution set results summary			German NZEB solution sets					Beyond NZEB
			Typical NZEB	DE-SS2	DE-SS3	DE-SS7	DE-SS8	
All specific values relate to the net floor area of the building.			Central combined heating + DHW system with gas condensing boiler and solar thermal collector, central exhaust ventilation system, high insulation level	Decentral direct electric heating + DHW system, decentral venti-lation system with heat recovery, roof PV panels, heat recovery from shower waste water -> reduced insulation level	Central supply and exhaust ventilation and heating system with air-to-air heat pump, decentral electrical DHW heater and heat recovery from shower waste water -> reduced insulation level	Central combined heating + DHW system with district heating, central exhaust ventilation system -> reduced insulation level	Central heating system with exhaust air-water heat pump (in central exhaust ventilation system) supp. by cond. gas boiler, radiators, decentral DHW heat exchange modules, roof PV panels -> reduced insulation level	Central air- to-water heat pump for heating and DHW, floor heating system, domestic hot water heat exchangers, decentral ventilation system with heat recovery, roof PV panels -> reduced insulation level
Building envelope	Mean U-value (incl. windows)	W/m²K	0.22	0.31	0.31	0.31	0.31	0.28
Net energy	Total	kWh/(m²yr)	35.50	35.42	36.24	41.16	49.39	28.26
Final energy	Total EPBD	kWh/(m²yr)	46.60	22.83	27.00	65.48	38.27	11.09 (-21.40)
	Total (incl. other energy uses)	kWh/(m²yr)	71.60	47.83	52.00	90.48	63.27	36.09 (-1.40) *
Primary energy	Total EPBD	kWh/(m²yr)	48.85	41.09	48.60	48.39	47.60	19.96 (-38.25)
	Total (incl. other energy uses)	kWh/(m²yr)	93.85	86.09	93.60	93.39	92.60	55.96 (-2.52) *
Energy costs incl. feed-in	Total EPBD	€/(m²yr)	3.33 -> 6.02	6.43 -> 8.68	6.91 -> 9.28	7.00 -> 9.09	4.22 -> 6.76	-1.93 -> 0.72
	Total (incl. other energy uses)	€/(m²yr)	10.69 -> 15.52	14.08 -> 18.18	14.27 -> 18.78	14.91 -> 18.59	11.58 -> 16.28	3.95 * -> 8.32
Investment costs	Difference to typical NZEB	€/m²	-	-84	-84	-83	-44	+107

*For the beyond NZEB level (efficiency house plus) a reduced household electricity use of 20 kWh/m²yr is applied. The value in brackets show the data incl. the electricity fed into the grid.

3.1.4. Technology costs

The assumed evolvement of the technology costs from 2018 to 2030 is described in chapter 2.3. For Germany the predicted changes are:

Table 21: Predicted changes for the German technology costs from 2018 to 2030

Technologies	Technology costs	
	2018	2030
PV systems	200 €/m²	200 €/m² * 0,55 = 110 €/m²
Heat pumps	SS3: 34 kW: 26,520 € SS8: 9 kW: 12,033 € Beyond NZEB: 63 kW: 55,377 €	SS3: 34 kW: 0.9 * 26,500 € = 23,868 € SS8: 9 kW: 0.9 * 12,033 € = 10,830 € Beyond NZEB: 63 kW: 0.9 * 55,377 € = 49,839 €

It has to be mentioned that general inflation will most probably lead to higher investment costs for all technologies. This is not considered in this chapter. The approach chosen here is to identify technologies that are most likely to get cheaper in comparison with the other technologies, e.g. due to cheaper production or higher production rates and market shares. The impact on the calculated results for the different variants (typical NZEB, NZEB solution sets and building beyond NZEB) is as follows. For details see Table 22.

Since the main changes at the technology costs in 2030 are predicted for PV systems and heat pumps only combinations including one or both technologies can profit. This applies to all alternative NZEB solution sets and the beyond NZEB combination. Solution set DE-SS3 with a heat pumps but no PV and solution set DE-SS8 with a heat pump and a small PV array show only small reductions in the investment costs of 3 €/m² respectively 2 €/m² in 2030. Solution set DE-SS2 with both heat pump and considerable PV array shows higher investment cost reductions in 2030 with 12 €/m². The highest investment cost reduction due to predicted changes in technology costs in 2030 is however calculated for the beyond NZEB building with 33 €/m². On the other hand the investment costs of the beyond NZEB building level are still 74 €/m² higher than those of the typical NZEB.

Primary beneficiaries of changes in technology costs:

- Beyond NZEB (heat pump and PV array) and DE-SS2 (direct electrical heating and PV array)

Table 22: **Comparison of the German energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the technology costs.**

Solution set results summary			German NZEB solution sets					Beyond NZEB
			Typical NZEB	DE-SS2	DE-SS3	DE-SS7	DE-SS8	
All specific values relate to the net floor area of the building.			Central combined heating + DHW system with gas condensing boiler and solar thermal collector, central exhaust ventilation system, high insulation level	Decentral direct electric heating + DHW system, decentral ventilation system with heat recovery, roof PV panels, heat recovery from shower waste water -> reduced insulation level	Central supply and exhaust ventilation and heating system with air-to-air heat pump, decentral electrical DHW heater and heat recovery from shower waste water -> reduced insulation level	Central combined heating + DHW system with district heating, central exhaust ventilation system -> reduced insulation level	Central heating system with exhaust air-water heat pump (in central exhaust ventilation system) supp. by cond. gas boiler, radiators, decentral DHW heat exchange modules, roof PV panels -> reduced insulation level	Central air- to-water heat pump for heating and DHW, floor heating system, domestic hot water heat exchangers, decentral ventilation system with heat recovery, roof PV panels -> reduced insulation level
Building envelope	Mean U-value (incl. windows)	W/m²K	0.22	0.31	0.31	0.31	0.31	0.28
Net energy	Total	kWh/(m²yr)	35.50	35.42	36.24	41.16	49.39	28.26
Final energy	Total EPBD	kWh/(m²yr)	46.60	22.83	27.00	65.48	38.27	11.09 (-21.40)
	Total (incl. other energy uses)	kWh/(m²yr)	71.60	47.83	52.00	90.48	63.27	36.09 (-1.40) *
Primary energy	Total EPBD	kWh/(m²yr)	48.85	41.09	48.60	48.39	47.60	19.96 (-38.25)
	Total (incl. other energy uses)	kWh/(m²yr)	93.85	86.09	93.60	93.39	92.60	55.96 (-2.52) *
Energy costs	Total EPBD	€/(m²yr)	3.33	6.43	6.91	7.00	4.22	-1.93
	Total (incl. other energy uses)	€/(m²yr)	10.69	14.08	14.27	14.91	11.58	3.95 *
Investment costs	Difference to typical NZEB	€/m²	-	-84 -> -96	-84 -> -87	-83 -> -83	-44 -> -46	+107 -> +74

*For the beyond NZEB level (efficiency house plus) a reduced household electricity use of 20 kWh/m²yr is applied. The value in brackets show the data incl. the electricity fed into the grid

3.1.5. Technology efficiencies

The assumed evolvement of the technology efficiencies from 2018 to 2030 is described in chapter 2.4. For Germany the predicted changes are:

Table 23: Predicted changes for the German technology efficiencies from 2018 to 2030

<table>
<tr><td rowspan="2">Technologies</td><td colspan="2">Technology efficiencies</td></tr>
<tr><td>2018</td><td>2030</td></tr>
<tr><td>Air-water heat pumps: SEER</td><td>DE-SS8: heating: 3.74
DHW: 3.33
Beyond NZEB: heating: 2.95
DHW: 1.82</td><td>(= $SEER_{2018}$ * 1.1)
DE-SS8: heating: 4.11
DHW: 3.66
Beyond NZEB: heating: 3.25
DHW: 2.00</td></tr>
<tr><td>PV systems: Performance</td><td>16%</td><td>= 16 * 1.1 = 17.6%</td></tr>
<tr><td>Triple-glazed windows: U_W</td><td>0.82 W/m²K</td><td>= (0.82-0.10) W/m²K =
0.72 W/m²K</td></tr>
</table>

The impact on the calculated results for the different variants (typical NZEB, NZEB solution sets and building beyond NZEB) is as follows. For details see Table 24.

Changes in the technology efficiencies are predicted for air-water heat pumps, PV systems and triple-glazed windows. These technologies are included in the typical NZEB solution (triple-glazed windows), DE-SS2 (PV array), DE-SS8 (air-to-water heat pump and PV array) and beyond NZEB (triple-glazed windows, air-to-water heat pump and PV array). DE-SS3 and DE-SS7 show no impact of the predicted technology efficiency improvements.

The increased efficiency at the triple-glazed windows has a rather small impact as can be seen in the typical NZEB solution with reductions at the final energy and primary energy use of roughly 1.2 kWh/m²yr and at the energy costs of 0.12 €/m²yr. Since the PV array is rather small at solution set DE-SS2 the reductions at the final energy are rather small as well with about 1.34 kWh/m²yr and slightly higher at the primary energy with 2.37 kWh/m²yr. The energy costs of DE-SS2 are lowered by 0.61 €/m²yr. At DE-SS8 increased technology efficiencies at the heat pump and at a very small PV array result in 0.88 kWh/m²yr reduction at the final energy, 1.59 kWh/m²yr at the primary energy and 0.20 €/m²yr lower energy costs. The biggest impact is shown at the beyond NZEB building. Here all three technologies are included and the PV array is bigger than in DE-SS2 and DE-SS8. The final energy can be reduced by 0.34 kWh/m²yr if the feed-in electricity into the grid is not considered and by 4.89 kWh/m²yr if the feed-in electricity is considered (as it is the case for the assessment of the efficiency house plus). The impact on the total energy costs is -1.73 €/m²yr. The improved technology efficiencies could here alternatively lead to a smaller PV array and thus reduced investment costs while still meeting the efficiency house plus requirements.

Primary beneficiary of changes in technology efficiencies:

- Beyond NZEB when taking into account the feed-in electricity into the grid

Table 24: **Comparison of the German energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the technology efficiencies.**

Solution set results summary			German NZEB solution sets					Beyond NZEB
			Typical NZEB	DE-SS2	DE-SS3	DE-SS7	DE-SS8	
All specific values relate to the net floor area of the building.			Central combined heating + DHW system with gas condensing boiler and solar thermal collector, central exhaust ventilation system, high insulation level	Decentral direct electric heating + DHW system, decentral ventilation system with heat recovery, roof PV panels, heat recovery from shower waste water -> reduced insulation level	Central supply and exhaust ventilation and heating system with air-to-air heat pump, decentral electrical DHW heater and heat recovery from shower waste water -> reduced insulation level	Central combined heating + DHW system with district heating, central exhaust ventilation system -> reduced insulation level	Central heating system with exhaust air-water heat pump (in central exhaust ventilation system) supp. by cond. gas boiler, radiators, decentral DHW heat exchange modules, roof PV panels -> reduced insulation level	Central air- to-water heat pump for heating and DHW, floor heating system, domestic hot water heat exchangers, decentral ventilation system with heat recovery, roof PV panels -> reduced insulation level
Building envelope	Mean U-value (incl. windows)	W/m²K	0.22	0.31	0.31	0.31	0.31	0.28
Net energy	Total	kWh/(m²yr)	35.50	35.42	36.24	41.16	49.39	28.26
Final energy	Total EPBD	kWh/(m²yr)	46.60 -> 45.39	22.83 -> 21.49	27.00	65.48	38.27 -> 37.39	11.09 (-21.40) -> 10.43 (-26.29)
	Total (incl. other energy uses)	kWh/(m²yr)	71.60 -> 70.39	47.83 -> 46.49	52.00	90.48	63.27 -> 62.39	36.09 (-1.40) * -> 30.43 (-6.29) *
Primary energy	Total EPBD	kWh/(m²yr)	48.85 -> 47.65	41.09 -> 38.68	48.60	48.39	47.60 -> 46.01	19.96 (-38.25) -> 18.77 (-47.32)
	Total (incl. other energy uses)	kWh/(m²yr)	93.85 -> 92.65	86.09 -> 83.68	93.60	93.39	92.60 -> 91.01	55.96 (-2.52) * -> 54.77 (-11.32) *
Energy costs	Total EPBD	€/(m²yr)	3.33 -> 3.21	6.43 -> 5.92	6.91	7.00	4.22 -> 4.02	-1.93 -> -2.66
	Total (incl. other energy uses)	€/(m²yr)	10.69 -> 10.57	14.08 -> 13.57	14.27	14.91	11.58 -> 11.38	3.95 * -> 2.02
Investment costs	Difference to typical NZEB	€/m²	-	-84	-84	-83	-44	+107

*For the beyond NZEB level (efficiency house plus) a reduced household electricity use of 20 kWh/m²yr is applied. The value in brackets show the data incl. the electricity fed into the grid

3.1.6. Other possible impact factors

The CoNZEBs team has identified three other evolving factors with impact on the energy or cost figures. They are however more difficult to assess.

Assessment methods for the energy performance of buildings

Chapter 2.5.1 describes possible changes in the national assessment methods. The possibilities for changes are however too diverse to be pre-assessed in this report. A new development in political climate change activities in Germany is for example a proposal to prohibit oil boilers. Similar ideas can be developed and might even be implemented until 2030.

Climate change

The impact of the climate change is assessed by differences of the heating energy use and differences of the 'virtual' cooling energy need. The 'virtual' cooling energy is determined in this report by installing split units in all sleeping and living rooms and calculating their electricity use. This is done for two different climate data, both at the location Potsdam which is also prescribed for building energy performance certificates:

- DWD weather data (test reference year) of 2011 which was used for all earlier calculations
- DWD weather data (test reference year) predicted for the period of 2013 to 2060.

The average increase of temperature between the two test reference years is 1.3 K. The results of this temperature increase are presented in Table 25.

The final heating energy use (as the only part that is influenced by the weather data in the EPBD covered final energy) is in all NZEB solution sets reduced by about 4 to 5 kWh/m²yr. At the beyond NZEB building the reduction in heating energy is lower with 1.9 kWh/m²yr because the heating energy need was significantly lower in the year 2018 if compared to the NZEB solution sets. The 'virtual' cooling energy on the other hand increases in 2030 in all cases. The differences here are roughly between 1.5 and 1.7 kWh/m²yr for all energy concepts including the beyond NZEB building. The differences in energy costs for both heating and cooling are between -0.57 €/m²yr for DE-SS3 and +0.19 €/m²yr for the typical NZEB. Besides the typical NZEB only DE-SS8 and the beyond NZEB result in lower energy costs if both heating energy costs and 'virtual' cooling energy costs are considered.

Primary beneficiaries of climate changes:

- DE-SS3 (air-heating via heat pump) and DE-SS2 (direct electrical heating). The reason is that with these solution sets the differences in heating energy and cooling energy are both related to electricity as energy source, thus the reduced heating energy has the same cost factor as the increased 'virtual' cooling energy.

Table 25: **Comparison of the German energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on climate changes.**

Solution set results summary All specific values relate to the net floor area of the building.			German NZEB solution sets					Beyond NZEB
			Typical NZEB	DE-SS2	DE-SS3	DE-SS7	DE-SS8	
			Central combined heating + DHW system with gas condensing boiler and solar thermal collector, central exhaust ventilation system, high insulation level	Decentral direct electric heating + DHW system, decentral ventilation system with heat recovery, roof PV panels, heat recovery from shower waste water -> reduced insulation level	Central supply and exhaust ventilation and heating system with air-to-air heat pump, decentral electrical DHW heater and heat recovery from shower waste water -> reduced insulation level	Central combined heating + DHW system with district heating, central exhaust ventilation system -> reduced insulation level	Central heating system with exhaust air-water heat pump (in central exhaust ventilation system) supp. by cond. gas boiler, radiators, decentral DHW heat exchange modules, roof PV panels -> reduced insulation level	Central air- to-water heat pump for heating and DHW, floor heating system, domestic hot water heat exchangers, decentral ventilation system with heat recovery, roof PV panels -> reduced insulation level
Final energy without cooling	Total EPBD	kWh/(m²yr)	46.60 -> 41.89	22.83 -> 18.79	27.00 -> 23.40	65.48 -> 60.09	38.27 -> 33.98	11.09 (-21.40) -> 9.20 (-23.29)
	Total (incl. other energy uses)	kWh/(m²yr)	71.60 -> 66.89	47.83 -> 43.79	52.00 -> 48.40	90.48 -> 85.09	63.27 -> 58.98	36.09 (-1.40) * -> 56.09 (-3.29) *
Final 'virtual' cooling energy		kWh/(m²yr)	4.62 -> 6.17	5.20 -> 6.83	4.66 -> 6.19	4.98 -> 6.71	4.22 -> 5.89	5.81 -> 7.41
Energy costs	Total EPBD	€/(m²yr)	3.33 -> 3.06	6.43 -> 5.73	6.91 -> 5.89	7.00 -> 6.46	4.22 -> 3.84	-1.93 -> -2.33
	Total (incl. other energy uses)	€/(m²yr)	10.69 -> 10.42	14.08 -> 13.09	14.27 -> 13.25	14.91 -> 13.81	11.58 -> 11.20	3.95 * -> 3.56 *
'Virtual' cooling energy costs		€/(m²yr)	1.35 -> 1.82	1.53 -> 2.01	1.37 -> 1.82	1.47 -> 1.97	1.24 -> 1.73	1.71 -> 2.18
Investment costs	Difference to typical NZEB	€/m²	-	-84	-84	-83	-44	+107

Financial support programmes

As explained in chapter 2.5.3 national financial support programmes can't be predicted with a view to 2030 and therefore their impact on the solution sets are therefore not analysed in this report.

3.1.7. Combination of changes in the evolving factors

In addition to the individual impact assessments of chapters 3.1.2 to 3.1.5 the combination of the evolving factors

- primary energy factors,
- energy prices,
- technology costs and
- technology efficiencies

are assessed within this chapter. The individual impacts can't simply be added as some of them are interlinked and influence the same energy and cost characteristics. Note: The climate change impact is not part of this combined assessment. The results of the assessment are included in Table 26.

This assessment include multiple evolving factors, accordingly only few outcome figures are not changed in comparison with the calculations of 2018. The differences in final energy between the 2018 and the 2030 calculations are rather small for the NZEB solution sets with a maximum of 1.34 kWh/m²yr savings. Only the beyond NZEB building results in a bigger reduction of final energy with 5.66 kWh/m²yr if all energy uses (incl. household energy) are taken into account. The most impressive primary energy reductions between 2018 and 2030 are achieved by DE-SS3 and DE-SS2 which have both fully electrical energy concepts and compared to the beyond NZEBs considerably higher primary energy uses which allows for higher savings. The lowest primary energy uses are however still calculated by far for the beyond NZEB building. DE-SS2, with the direct electrical heating and DHW generation system, and DE-SS3, with the air-heating generated by the electrical air-to-air heat pump and the decentral electrical DHW heating have the lowest primary energy use among the NZEB solution sets applying the evolving factors for 2030.

Looking at the energy costs the lowest increases are calculated for DE-SS3 and DE-SS2. The cheapest energy costs in 2030 (under the combined predicted evolvements) are possible with the beyond NZEB building followed by the typical NZEB, with the gas condensing boiler with solar thermal support and DE-SS8 with the air-to-water heat pump in combination with the gas condensing boiler.

The highest reductions of investment costs are calculated for the beyond NZEB and DE-SS2, the system with direct electrical heating and DHW generation. The lowest investment costs can be achieved according to the 2030 calculations for DE-SS2 with 96 €/m² less than the typical NZEB.

A simple way to take all cost-related changes (and via the energy costs also the final energy uses) into account is to calculate a static payback by dividing the investment (differences) costs through the energy costs (differences). Due to the fact that the typical NZEB has the lowest energy costs for all NZEB solutions, while the identified alternative NZEB solution sets all lead to lower investment costs – as it was the main aim – the result of this calculation gives a rough indication of the number of years the alternative NZEB solution sets are more cost-efficient than the typical NZEB. Under the boundary conditions of 2018 the best solution set was DE-SS8 (heating and DHW by air-to-water heat pump in combination with gas condensing boiler) with 49 years. Under the predicted parameter changes for 2030 it is again DE-SS8 with now 74 years before the typical NZEB will become more cost-efficient. It has to be said that towards the end of this long time upgrades or exchanges of technologies will become necessary that are not taken into account in these calculations. The beyond NZEB building which fulfils the requirements of an efficiency house plus (= plus energy house), has compared to the typical NZEB higher investment costs of 107 €/m² in 2018 and still 74 €/m² in the calculations for 2030. The static payback is 20 years in 2018 (16 years if also the costs for household electricity is considered) and 7 years in 2030 (6 years if also the costs for household electricity are taken into account).

Primary beneficiaries of combined changes in the evolving factors:

- DE-SS2, because the direct electrical heating and DHW system in combination with the PV array benefits from the predicted lower primary energy factor for electricity, the better efficiency and lower technology costs for PV.
- DE-SS8, because the combination of air-to-water heat pump and gas condensing boiler with the small PV array keeps the comparably low energy costs and benefits from efficiency improvements at the heat pump and the PV system. It is the system that is for the longest time more cost-efficient than the typical NZEB.
- Beyond NZEB, the efficiency house plus with the air-to-water heat pump, because several impact factors such as lower primary energy factor for electricity, better efficiencies for the air-to-water heat pump, the large PV array and the triple-glazed windows and comparably lower technology costs for PV and heat pump lead to a now really short payback time of 6 to 7 years compared to the typical NZEB.

Table 26: **Comparison of the German energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the primary energy factors, energy prices, technology costs and technology efficiencies.**

Solution set results summary			German NZEB solution sets					Beyond NZEB
			Typical NZEB	DE-SS2	DE-SS3	DE-SS7	DE-SS8	
All specific values relate to the net floor area of the building.			Central combined heating + DHW system with gas condensing boiler and solar thermal collector, central exhaust ventilation system, high insulation level	Decentral direct electric heating + DHW system, decentral ventilation system with heat recovery, roof PV panels, heat recovery from shower waste water -> reduced insulation level	Central supply and exhaust ventilation and heating system with air-to-air heat pump, decentral electrical DHW heater and heat recovery from shower waste water -> reduced insulation level	Central combined heating + DHW system with district heating, central exhaust ventilation system -> reduced insulation level	Central heating system with exhaust air-water heat pump (in central exhaust ventilation system) supp. by cond. gas boiler, radiators, decentral DHW heat exchange modules, roof PV panels -> reduced insulation level	Central air- to-water heat pump for heating and DHW, floor heating system, domestic hot water heat exchangers, decentral ventilation system with heat recovery, roof PV panels -> reduced insulation level
Building envelope	Mean U-value (incl. windows)	W/m²K	0.22	0.31	0.31	0.31	0.31	0.28
Net energy	Total	kWh/(m²yr)	35.50	35.42	36.24	41.16	49.39	28.26
Final energy	Total EPBD	kWh/(m²yr)	46.60 -> 45.39	22.83 -> 21.49	27.00	65.48	38.27 -> 37.39	11.09 (-21.40) -> 10.43 (-26.29)
	Total (incl. other energy uses)	kWh/(m²yr)	71.60 -> 70.39	47.83 -> 46.49	52.00	90.48	63.27 -> 62.39	36.09 (-1.40) * -> 30.43 (-6.29) *
Primary energy	Total EPBD	kWh/(m²yr)	48.85 -> 43.71	41.09 -> 13.97	48.60 -> 17.55	48.39 -> 33.09	47.60 -> 33.28	19.96 (-38.25) -> 6.78 (-14.34)
	Total (incl. other energy uses)	kWh/(m²yr)	93.85 -> 59.96	86.09 -> 30.22	93.60 -> 33.80	93.39 -> 49.34	92.60 -> 49.53	55.96 (-2.52) * -> 19.78 (-1.34) *
Energy costs	Total EPBD	€/(m²yr)	3.33 -> 5.89	6.43 -> 8.17	6.91 -> 8.31	7.00 -> 9.09	4.22 -> 6.48	-1.93 -> 0.52
	Total (incl. other energy uses)	€/(m²yr)	10.69 -> 15.39	14.08 -> 17.67	14.27 -> 17.81	14.91 -> 18.59	11.58 -> 15.99	3.95 * -> 8.12 *
Investment costs	Difference to typical NZEB	€/m²	-	-84 -> -96	-84 -> -87	-83	-44 -> -46	+107 -> +74

*For the beyond NZEB level (efficiency house plus) a reduced household electricity use of 20 kWh/m²yr is applied. The value in brackets show the data incl. the electricity fed into the grid

3.1.8. Summary for the German situation

The analysis, which boundary conditions for the energy and cost calculations of a building in 2018 will change with a view to 2030 led to

- Primary energy factors for electricity that will considerably decrease and for district heating that will slightly decrease
- Energy prices for all used energy carriers that will considerably increase when taking into account the currently discussed CO_2 pricing
- Relatively lower technology costs for PV systems and electrical heat pumps in comparison with the other technologies
- Increased technology efficiencies for air-to-water heat pumps, PV systems and triple-glazed windows
- A warmer climate with an average temperature increase of 1.3 K.

Taking these evolving factors into account a typical multi-family house with different energy level and energy concepts was assessed with the national building energy performance assessment method and compared to the results of earlier work in the CoNZEBs project [1]. Back then a typical multi-family nearly zero-energy building (NZEB) energy concept for Germany was determined and assessed in comparison with alternative NZEB energy concepts (a.k.a. solution sets) that should result in lower investment costs. The German CoNZEBs team identified four alternative solution sets with lower investment costs. The solution sets are:

- Typical NZEB: Central combined heating and DHW system with gas condensing boiler and solar thermal collector, central exhaust ventilation system and high insulation level
- DE-SS2: Decentral direct electric heating and DHW system, decentral ventilation system with heat recovery, roof PV panels, heat recovery from shower waste water and reduced insulation level
- DE SS3: Central supply and exhaust ventilation and heating system with air-to-air heat pump, decentral electrical DHW heater and heat recovery from shower waste water and reduced insulation level
- DE-SS7: Central combined heating and DHW system with district heating, central exhaust ventilation system and reduced insulation level
- DE-SS8: Central heating system with exhaust air-water heat pump (in central exhaust ventilation system) supported by condensing gas boiler, radiators, decentral DHW heat exchange modules, roof PV panels and reduced insulation level

In addition an energy level beyond NZEB was determined to be an efficiency house plus (plus energy house):

- Beyond NZEB: Central air-to-water heat pump for heating and DHW, floor heating system, heat recovery from shower waste water, decentral ventilation system with heat recovery, roof PV panels and slightly reduced insulation level

The results of the assessment for 2030 lead to the following main conclusions:

- When looking separately at the evolving factors different solution sets are the primary beneficiaries:
  - Primary energy factors: All solution sets profit from the reduced primary energy factors with DE-SS2 (direct electrical heating) and DE-SS3 (air heating with electrical heat pump) in the lead. Due to accompanying requirements DE-SS8 (gas-condensing boiler plus electrical heat pump) is the only solution set where further (minor) reductions at the investment costs are possible
  - Energy prices: DE-SS8 (gas-condensing boiler plus electrical heat pump) has the second lowest energy costs; however the lowest energy costs are still at the typical NZEB (if beyond NZEB is not taken into account).
  - Technology costs: Beyond NZEB (heat pump and PV array) and DE-SS2 (direct electrical heating and PV array) profit the most regarding the investment costs.
  - Technology efficiencies: Beyond NZEB benefits the most when taking into account the feed-in electricity into the grid.
  - Climate change: DE-SS3 (air-heating via heat pump) and DE-SS2 (direct electrical heating), because with these solution sets the differences in heating energy and cooling energy are both related to electricity as energy source, thus the reduced heating energy has the same cost factor as the increased 'virtual' cooling energy.
- If all evolving factors (besides the climate change) are combined the following solution sets seem to be most future-proof with regard to 2030:
  - DE-SS2, because the direct electrical heating and DHW system in combination with the PV array benefits from the predicted lower primary energy factor for electricity, the better efficiency and lower technology costs for PV.
  - DE-SS8, because the combination of air-to-water heat pump and gas condensing boiler with the small PV array keeps the comparably low energy costs and benefits from efficiency improvements at the heat pump and the PV system. It is the system that is for the longest time more cost-efficient than the typical NZEB.
  - Beyond NZEB, the efficiency house plus with the air-to-water heat pump, because several impact factors such as lower primary energy factor for

electricity, better efficiencies for the air-to-water heat pump, the large PV array and the triple-glazed windows and comparably lower technology costs for PV and heat pump lead to a now really short payback time of 6 to 7 years compared to the typical NZEB.

3.2. Denmark

3.2.1. Typical NZEB, cost-efficient NZEB solution sets and building level beyond NZEB

In Denmark the typical NZEB chosen for the analysis in the CoNZEBs project was multi-family block of flats, complying with the Danish voluntary low-energy calls, as stated in the Danish Building Regulations 2018 (from 1. July 2018). A detailed description of the building, the building fabric and the technical installations, is found in [1].

The typical NZEB energy concept for a multi-family house was chosen to be a well insulated building with 3-layer windows and a mechanical ventilations system with heat recovery (90% efficiency). The heat distribution is realised by radiators. The building envelope features the following U-value qualities: 0.15 W/m²K at the external wall, 0.10 W/m²K at the roof, 0.10 W/m²K at the slab on ground and 0.85 W/m²K at the windows with a g-value of 0.53. Heating, including domestic hot water, comes from district heating. The building is ventilated with balanced mechanical ventilation with efficient heat recovery (90%).

In comparison with this typical energy concept the following more cost-efficient alternative solution sets (SS) have been identified:

- DK-SS1: More efficient insulation material in external walls – the lambda value 0.02 W/mK instead of the 0.036 W/mK used in the typical building
- DK-SS2: Solar heating for domestic hot water, resulting in reduced insulation in walls, roof and floor
- DK-SS3: 4 layer windows; natural ventilation; heat recovery on grey wastewater
- DK-SS4: Reduced insulation in walls, roof and floor; decentral mechanical ventilation with heat recovery; energy efficient taps.
- DK-SS5: PV panels; reduced insulation in walls, roof and floor; decentral mechanical ventilation with heat recovery

The Danish building level beyond NZEB was chosen to be a zero energy building (ZEB) not including the household electricity. The specific combination to fulfil the ZEB level for the typical multi-family house geometry is to use DK-SS5 as the basis and then add:

- Additional PV-panels to reach 15 Wp/m² compared to the 1.6 Wp/m² of DK-SS5
- Energy efficiency water taps (as in SS4)

The mean U-values and the main results of the energy and cost calculations of the typical NZEB, the determined four cost-efficient NZEB solution sets and the beyond NZEB building level are presented in Table 27.

Table 27: Main characteristics of the typical Danish NZEB solution, the cost-efficient NZEB solution sets and the building level beyond NZEB with the status 2018.

Solution set results summary Specific values relate to heated gross floor area[1)]			Danish NZEB solution sets						Beyond NZEB
			Typical NZEB (base case)	DK-SS1	DK-SS2	DK-SS3	DK-SS4	DK-SS5	
			3 layer windows, central mechanical ventilation with 90% heat recovery	More efficient insulation material in external walls	DHW solar heating, reduced insulation in walls, roof and floor.	4 layer windows, natural ventilation heat recovery on grey wastewater.	Reduced insulation in walls, roof and floor, Decentral mechanical ventilation, energy efficient taps.	PV panels, reduced insulation in walls, roof and floor; Decentral mechanical ventilation.	Increased area of PV, reduced insulation in walls, roof and floor; decentral mechanical ventilation, energy efficient water taps
Building envelope	Average U-value, (incl. windows)	W/m²K	0.26	Id.	0.31	0.21	0.31	0.31	0.31
Net energy	Total	kWh/(m²yr)	19.0	Id.	18.2	20.0	18.5	20.4	4.9
Final energy	Total EPBD	kWh/(m²yr)	29.0	Id.	28.2	30.0	28.5	30.4	14.9
	Total (incl. other energy uses)	kWh/(m²yr)	59.7	Id.	58.9	60.7	59.2	61.1	45.5
Primary energy	Total EPBD	kWh/(m²yr)	26.3	Id.	25.9	25.9	25.9	26.0	0.0
	Total (incl. other energy uses)	kWh/(m²yr)	84.6	Id.	84.2	84.2	84.2	84.3	58.3
Energy costs	Total (incl. other energy uses)	€/(m²yr)	11.8	Id.	11.8	11.6	11.8	11.5	7.5
	Difference to typical NZEB	€/m²	-	0.0	0.0	-0.2	-0.0	-0.3	-4.3
Investment costs	Difference to typical NZEB	€/m²	-	-2.1	-5,5	-18.1	-15.0	-12.6	8.1

Id: Idem - the same as for the base case.

3.2.2. Primary energy factors

The assumed evolvement of the primary energy factors from 2018 to 2030 is described in chapter 2.1. For Denmark the predicted changes are:

Table 28: Predicted changes for the Danish primary energy factors from 2018 to 2030

Energy source	Primary energy factor	
	2018	2030
Grid electricity	1.9	1.38
PV generated electricity fed into grid	1.9	1.38
District heating	0.85	0.91
Gas	n/a	n/a

As it appears from Table 28 the primary energy factor for district heating increases slightly, whereas it is significantly reduced for grid electricity. These changes influence primarily the two cases with PV: DK-SS5 and the beyond NZEB level. From Table 29 it can be seen that the primary energy demand increases between 0.6 and 0.9 kWh/m²yr for the typical NZEB and the first four solutions sets. For DK-SS5 it increases by 1.7 kWh/m²yr and for the beyond NZEB by 7.9 kWh/m²yr. The primary energy increases, because the electricity produced by the PV system is reducing the total primary energy. Therefore, when the primary energy factor for electricity is reduced, the weight of the PV-electricity becomes smaller.

Impacts from changing primary energy factors are

- All solution sets benefit from changing primary energy factors with DK-SS2 (additional solar heating) as the most impacted.
- For the beyond NZEB building (increased PV array) the lower primary energy factor on electricity means that the size of the PV-system needs to be increased to outbalance the heating energy consumption.

Table 29: **Comparison of the Danish energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the primary energy factors.**

Solution set results summary Specific values relate to heated gross floor area[1)]			Danish NZEB solution sets						Beyond NZEB
			Typical NZEB (base case)	DK-SS1	DK-SS2	DK-SS3	DK-SS4	DK-SS5	
			3 layer windows, central mechanical ventilation with 90% heat recovery	More efficient insulation material in external walls	DHW solar heating, reduced insulation in walls, roof and floor.	4 layer windows, natural ventilation heat recovery on grey wastewater.	Reduced insulation in walls, roof and floor, Decentral mechanical ventilation, energy efficient taps.	PV panels, reduced insulation in walls, roof and floor; Decentral mechanical ventilation.	Increased area of PV, reduced insulation in walls, roof and floor; decentral mechanical ventilation, energy efficient water taps
Building envelope	Average U-value, (incl. windows)	W/m²K	0.26	Id.	0.31	0.21	0.31	0.31	0.31
Net energy	Total	kWh/(m²yr)	19.0	Id.	18.2	20.0	18.5	20.4	4.9
Final energy	Total EPBD	kWh/(m²yr)	29.0	Id.	28.2	30.0	28.5	30.4	14.9
	Total (incl. other energy uses)	kWh/(m²yr)	59.7	Id.	58.9	60.7	59.2	61.1	45.5
Primary energy	Total EPBD	kWh/(m²yr)	26.3 -> 27.2	Id. -> 27.2	25.9 -> 26.5	25.9 -> 27.5	25.9 -> 26.7	26.0 -> 27.7	0.0 -> 7.9
	Total (incl. other energy uses)	kWh/(m²yr)	84.6 -> 69.5	Id. -> 69.5	84.2 -> 68.9	84.2 -> 69.8	84.2 -> 69.1	84.3 -> 70.1	58.3 -> 50.2
Energy costs	Total (incl. other energy uses)	€/(m²yr)	11.8	Id.	11.8	11.6	11.8	11.5	7.5
	Difference to typical NZEB	€/m²	-	0.0	0.0	-0.2	0.0	-0.3	-4.3
Investment costs	Difference to typical NZEB	€/m²	-	-2.1	-5,5	-18.1	-15.0	-12.6	8.1

Id: Idem - the same as for the base case.

3.2.3. Energy prices

The assumed evolvement of the energy prices from 2018 to 2030 is described in chapter 2.2. For Denmark the predicted changes are:

Table 30: Predicted changes for the Danish energy prices from 2018 to 2030

Energy source	Energy prices	
	2018	2030
Grid electricity	0.315 €/kWh	0.344 €/kWh
PV generated electricity fed into grid	n/a	n/a
District heating	0.059 €/kWh	0.073 €/kWh
Gas	n/a	n/a

Changes in energy prices affect the calculated results for all the different variants (typical NZEB, NZEB solution sets and building beyond NZEB) as seen in Table 31. The cost of electricity increases by about 10% and district heating by about 25% until 2030. The impact, which can be seen in Table 31, is an increase in total energy costs by approx. 15% in all cases. The differences to the typical NZEB are unchanged, except for the beyond NZEB level, where the estimated energy cost savings increases from 4.3 €/m²yr to 4.7 €/m²yr. So, the added investment in the beyond NZEB level results in an increased energy cost saving due to the increase in electricity costs.

Primary beneficiary of changes in energy prices:

- The beyond NZEB (increased PV array and energy efficient water taps). For all the NZEB solution sets the difference to the typical NZEB remains the same.

Table 31: **Comparison of the Danish energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the energy prices.**

Solution set results summary Specific values relate to heated gross floor area			Danish NZEB solution sets						Beyond NZEB
			Typical NZEB (base case)	DK-SS1	DK-SS2	DK-SS3	DK-SS4	DK-SS5	
			3 layer windows, central mechanical ventilation with 90% heat recovery	More efficient insulation material in external walls	DHW solar heating, reduced insulation in walls, roof and floor.	4 layer windows, natural ventilation heat recovery on grey wastewater.	Reduced insulation in walls, roof and floor, Decentral mechanical ventilation, energy efficient taps.	PV panels, reduced insulation in walls, roof and floor; Decentral mechanical ventilation.	Increased area of PV, reduced insulation in walls, roof and floor; decentral mechanical ventilation, energy efficient water taps
Building envelope	Average U-value, (incl. windows)	W/m²K	0.26	Id.	0.31	0.21	0.31	0.31	0.31
Net energy	Total	kWh/(m²yr)	19.0	Id.	18.2	20.0	18.5	20.4	4.9
Final energy	Total EPBD	kWh/(m²yr)	29.0	Id.	28.2	30.0	28.5	30.4	14.9
	Total (incl. other energy uses)	kWh/(m²yr)	59.7	Id.	58.9	60.7	59.2	61.1	45.5
Primary energy	Total EPBD	kWh/(m²yr)	26.3	Id.	25.9	25.9	25.9	26.0	0.0
	Total (incl. other energy uses)	kWh/(m²yr)	84.6	Id.	84.2	84.2	84.2	84.3	58.3
Energy costs	Total (incl. other energy uses)	€/(m²yr)	11.8 -> 13.2	Id. -> 13.2	11.8 -> 13.2	11.6 -> 13.0	11.8 -> 13.2	11.5 -> 12.9	7.5 -> 8.4
	Difference to typical NZEB	€/m²	-	0.0 -> 0.0	0.0 -> 0.0	-0.2 -> -0.2	0.0 -> 0.0	-0.3 -> -0.3	-4.3 -> -4.7
Investment costs	Difference to typical NZEB	€/m²	-	-2.1	-5,5	-18.1	-15.0	-12.6	8.1

Id: Idem - the same as for the base case.

3.2.4. Technology costs

The assumed evolvement of the technology costs from 2018 to 2030 is described in chapter 2.3. For Denmark the predicted changes are:

Table 32: Predicted changes for the Danish technology costs from 2018 to 2030

Technologies	Technology costs	
	2018	2030
Solar thermal collectors	755 €/m²	684 €/m²
Solar cells (PV)	1.65 €/Wp	1.27 €/Wp

Besides the predicted changes of the cost for solar heating and solar cells all other technology costs are assumed to increase following the general inflation of 1.8%. Hence, the impact of this inflation is that the difference in investments costs between DK-SS1, DK-SS3 and DK-SS5 and the typical NZEB is increased by this inflation, which amounts to almost 24% over the 12 years.

According to [22] the cost of solar heating systems is reduced by about 10% and the cost of solar cells by 23% in 2030. These changes has an impact on the calculated results only for DK-SS2 (solar heating) and DK-SS5 and the building beyond NZEB (PV) as these solution sets are the only ones where solar heating or solar cells are applied.

Most significant is the impact of the 23% decrease of PV costs on the beyond NZEB level, which becomes cheaper than the typical NZEB (0.8 €/m²) compared to the 2018 situation, where its cost was 8.1 €/m² higher than that of the typical NZEB.

The investment costs of DK-SS2 is reduced by 2.6 €/m² and DK-SS5 by 3.9 €/m².

For details, see Table 33.

Primary beneficiary of changes in technology costs:

- Beyond NZEB (increased PV array). Now cheaper than the typical NZEB.
- DK-SS2 (solar heating) and DK-SS5 (PV array and decentral MVHR).

Table 33: Comparison of the Danish energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the technology costs.

Solution set results summary Specific values relate to heated gross floor area[1)]			Danish NZEB solution sets						Beyond NZEB
			Typical NZEB (base case)	DK-SS1	DK-SS2	DK-SS3	DK-SS4	DK-SS5	
			3 layer windows, central mechanical ventilation with 90% heat recovery	More efficient insulation material in external walls	DHW solar heating, reduced insulation in walls, roof and floor.	4 layer windows, natural ventilation heat recovery on grey wastewater.	Reduced insulation in walls, roof and floor, Decentral mechanical ventilation, energy efficient taps.	PV panels, reduced insulation in walls, roof and floor; Decentral mechanical ventilation.	Increased area of PV, reduced insulation in walls, roof and floor; decentral mechanical ventilation, energy efficient water taps
Building envelope	Average U-value, (incl. windows)	W/m²K	0.26	Id.	0.31	0.21	0.31	0.31	0.31
Net energy	Total	kWh/(m²yr)	19.0	Id.	18.2	20.0	18.5	20.4	4.9
Final energy	Total EPBD	kWh/(m²yr)	29.0	Id.	28.2	30.0	28.5	30.4	14.9
	Total (incl. other energy uses)	kWh/(m²yr)	59.7	Id.	58.9	60.7	59.2	61.1	45.5
Primary energy	Total EPBD	kWh/(m²yr)	26.3	Id.	25.9	25.9	25.9	26.0	0.0
	Total (incl. other energy uses)	kWh/(m²yr)	84.6	Id.	84.2	84.2	84.2	84.3	58.3
Energy costs	Total (incl. other energy uses)	€/(m²yr)	11.8	Id.	11.8	11.6	11.8	11.5	7.5
	Difference to typical NZEB	€/m²	-	0.0	0.0	-0.2	0.0	-0.3	-4.3
Investment costs	Difference to typical NZEB	€/m²	-	-2.1 -> -2.6	-5,5 -> -8.1	-18.1 -> -22.6	-15.0 -> -18.6	-12.6 -> -16.5	8.1 -> -0.8

Id: Idem - the same as for the base case.

3.2.5. Technology efficiencies

The assumed evolvement of the technology efficiencies from 2018 to 2030 is described in chapter 2.4. For Denmark the predicted changes are:

Table 34: Predicted changes for the Danish technology efficiencies from 2018 to 2030

Technologies	Technology efficiencies	
	2018	2030
Solar thermal collectors	425 kWh/m² per year	475 kWh/m² per year
PV: Peak power full load hours	994 kWh/kWp(dc)	1085 kWh/kWp(dc)

In addition the fans and the design of mechanical ventilation systems with heat recovery might result in a reduction in electricity use for these systems. However, the electricity use of these systems are already quite low so the resulting savings are supposedly lower than the uncertainty on these calculations. Therefore, this increase in efficiency is not included in the analysis.

The improved efficiency of solar heating influences DK-SS2 and the improved efficiency of PV influences DK-SS5 and the beyond NZEB case. The other solution sets remains the same, as they do not rely on solar heating or PV electricity production.

For DE-SS2 the net, final and primary energy demands are reduced by 0.4 kWh/m²yr, but the difference is so small that it does not affect the energy costs. For DE-SS5, the difference in net and final energy is only 0.1 kWh/m²yr. As the difference is due to the electricity produced by the PV system and electricity costs are higher than the cost of district heating, there is a small impact on the energy cost, which is reduced by 0.2 €/m²yr. Due to the larger area of PV-cells the impact of the improved efficiency of the system is more significant for the building beyond NZEB, where energy costs is reduced by 0.6 €/m²yr. For details, see Table 35.

Primary beneficiaries of changes in technology efficiencies:

- ⌂ Beyond NZEB (increased PV array) and DK-SS5 (PV array and decentral MVHR)

Table 35: Comparison of the Danish energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the technology efficiencies.

Solution set results summary Specific values relate to heated gross floor area[1)]			Danish NZEB solution sets						Beyond NZEB
			Typical NZEB (base case)	DK - SS1	DK-SS2	DK-SS3	DK-SS4	DK-SS5	
			3 layer windows, central mechanical ventilation with 90% heat recovery	More efficient insulation material in external walls	DHW solar heating, reduced insulation in walls, roof and floor.	4 layer windows, natural ventilation heat recovery on grey wastewater.	Reduced insulation in walls, roof and floor, Decentral mechanical ventilation, energy efficient taps.	PV panels, reduced insulation in walls, roof and floor; Decentral mechanical ventilation.	Increased area of PV, reduced insulation in walls, roof and floor; decentral mechanical ventilation, energy efficient water taps
Building envelope	Average U-value, (incl. windows)	W/m²K	0.26	Id.	0.31	0.21	0.31	0.31	0.31
Net energy	Total	kWh/(m²yr)	19.0	Id.	18.2 -> 17.8	20.0	18.5	20.4 -> 20.3	4.9 -> 3.6
Final energy	Total EPBD	kWh/(m²yr)	29.0	Id.	28.2 -> 27.8	30.0	28.5	30.4 -> 30.3	14.9 -> 13.6
	Total (incl. other energy uses)	kWh/(m²yr)	59.7	Id.	58.9 -> 58.5	60.7	59.2	61.1 -> 60.9	45.5 -> 44.3
Primary energy	Total EPBD	kWh/(m²yr)	26.3	Id.	25.9 -> 25.5	25.9	25.9	26.0 -> 25.8	0.0 -> -2.4
	Total (incl. other energy uses)	kWh/(m²yr)	84.6	Id.	84.2 -> 83.8	84.2	84.2	84.3 -> 84.1	58.3 -> 55.9
Energy costs	Total (incl. other energy uses)	€/(m²yr)	11.8	Id.	11.8 -> 11.8	11.6	11.8	11.5 -> 11.5	7.5 -> 7.1
	Difference to typical NZEB	€/m²	-	0.0	0.0 -> 0.0	-0.2	0.0	-0.3 -> -0.3	-4.3-> -4.7
Investment costs	Difference to typical NZEB	€/m²	-	-2.1	-5.5	-18.1	-15.0	-12.6	8.1

Id: Idem - the same as for the base case.

3.2.6. Other possible impact factors

Assessment methods for the energy performance of buildings

Chapter 2.5.1 describes possible changes in the national assessment methods. The possibilities for changes are however too diverse to be pre-assessed in this report.

By June 2019, Denmark changed government and the new government have increased the focus climate change and energy efficiency. One of the suggested goals is to establish a binding climate target with a reduction of greenhouse gas emissions by 60% in 2030 compared to the 1990 level. Energy performance of buildings needs to contribute to meet this target.

Climate change

The average increase of temperature between the two test reference years 2018 and 2030 is 0.74 K. However, as seen on the plot in Figure 2 this temperature increase happens mostly in the period outside the heating season.

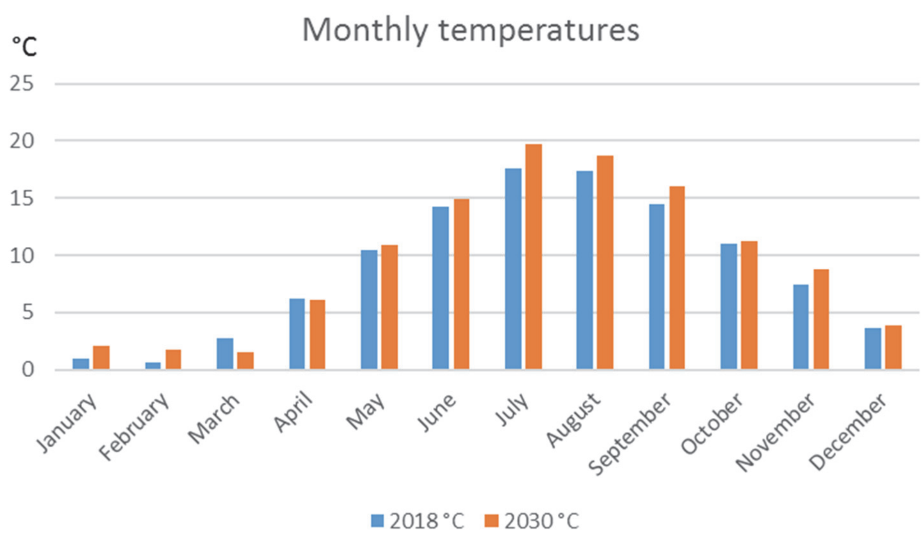


Figure 2: Monthly mean temperature of the Danish test reference years 2018 and 2030.

At the same time, the global radiation is reduced by 9.5% and this reduction is especially expected in the winter months. See Figure 3.

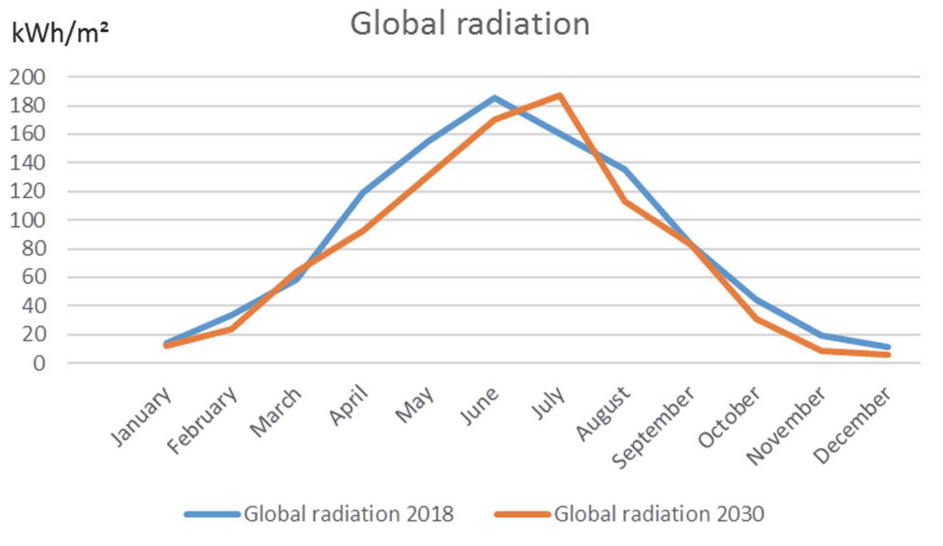


Figure 3: Monthly global radiation of the Danish test reference years 2018 and 2030.

The results of these climate changes are presented in Table 36. As can be observed from the table the total EPBD energy increases for the non-solar dependent building levels by 0.8 to 1.2 kWh/m²yr. For DK-SS2 the increase is 1.4 kWh/m²yr, for DK-SS5 1.3 kWh/m²yr and for the beyond NZEB building 2.5 kWh/m²yr. For all building solution sets, the warmer summer in 2030 induces an increased 'virtual' cooling load by approx. 4 kWh/m²yr. To show the impact on energy cost this cooling load is assumed covered by a split unit with a seasonal energy efficiency rating (SEER) of 3 and auxiliary electricity use of 0.015 kWh/kWh. In Table 36, the total energy cost including cooling is shown. The cost of cooling is approx. 55 €/year per apartment. In Denmark, however, it is not likely that a split unit heat pump will be installed in each apartment in a multi-family house – it may not be allowed. The energy cost is calculated using 2018 energy prices.

Primary beneficiary of climate changes:

- DK-SS3 (4-layer windows and natural ventilation). The cooling load is about 25% lower compared to the other solution sets and the typical NZEB - primarily due to the lower solar energy transmittance of the windows.

Table 36: Comparison of the Danish energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on climate changes.

Solution set results summary All specific values relate to the net floor area of the building.			Danish NZEB solution sets						Beyond NZEB
			Typical NZEB (base case)	DK-SS1	DK-SS2	DK-SS3	DK-SS4	DK SS5	
			3 layer windows, central mechanical ventilation with 90% heat recovery	More efficient insulation material in external walls	DHW solar heating, reduced insulation in walls, roof and floor.	4 layer windows, natural ventilation heat recovery on grey wastewater.	Reduced insulation in walls, roof and floor, Decentral mechanical ventilation, energy efficient taps.	PV panels, reduced insulation in walls, roof and floor; Decentral mechanical ventilation.	Increased area of PV, reduced insulation in walls, roof and floor; decentral mechanical ventilation, energy efficient water taps
Final energy without cooling	Total EPBD	kWh/(m²yr)	29.0 -> 29.8	Id. -> 29.8	28.2 -> 29.6	30.0 -> 31.2	28.5 -> 29.7	30.4 -> 31.7	14.9 -> 17.3
	Total (incl. other energy uses)	kWh/(m²yr)	59.7 -> 60.5	Id. -> 60.5	58.9 -> 60.3	60.7 -> 61.9	59.2 -> 60.3	61.1 -> 62.3	45.5 -> 48.0
Final 'virtual' cooling energy		kWh/(m²yr)	2.5 -> 6.4	Id. -> 6.4	2.1 -> 6.0	2.1 -> 4.3	2.1 -> 6.0	2.1 -> 6.0	2.1 -> 6.0
Energy costs	Total (incl. other energy uses and incl. 'virtual' cooling energy)	€/(m²yr)	11.8 -> 12.6	Id. -> 12.6	11.8 -> 12.6	11.6 -> 12.1	11.8 -> 12.6	11.5 -> 12.3	7.5 -> 8.7
	Difference to typical NZEB	€/(m²yr)	-	0.0 -> 0.0	0.0 -> 0.0	-0.2 -> -0.5	0.0 -> 0.0	-0.3 -> -0.3	-4.3 -> -3.9
Investment costs	Difference to typical NZEB	€/m²	-	-2.1	-5.5	-18.1	-15.0	-12.6	8.1

Financial support programmes

For the time being, Denmark has no financial support schemes for energy efficiency or renewable energy measures as it is assumed to distort the market. It is thus not expected that Denmark will have any support schemes in 2030 either.

3.2.7. Combination of changes in the evolving factors

In addition to the individual impact assessments of chapters 3.2.2 to 3.2.5 the combination of the evolving factors

- primary energy factors,
- energy prices,
- technology costs and
- technology efficiencies

are assessed within this chapter. The individual impacts can't simply be added as some of them are interlinked and influence the same energy and cost characteristics. Note: The climate change impact is not part of this combined assessment. The results of the assessment are included in Table 37.

The change in primary energy factors does not have a large impact when only energy for operating the buildings is considered. However, when the other energy (household and other electricity uses) is included the lower primary energy factor for electricity shows a considerable impact.

The most interesting result of all four factors evolvement is that the beyond NZEB building becomes a lot cheaper – actually cheaper than the typical NZEB, whereas in 2018 it was considerably more expensive. At the same time the total energy costs are further reduced by 0.9 €/m²yr compared to the typical NZEB case. Thus, designing and building a beyond NZEB building in 2030 becomes much more financially sound than in 2030. It should be added, though, that also the life cycle cost (LCC) calculations conducted in the CoNZEBs project [28] showed a positive net present value of the additional investments in the beyond NZEB building.

Primary beneficiary of combined changes in the evolving factors:

- The beyond NZEB (increased PV array and energy efficient water taps). Here the lower cost of the PV-cells shows up again and the energy costs are lower because of the increased efficiency of the PV-system

Table 37: **Comparison of the Danish energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the primary energy factors, energy prices, technology costs and technology efficiencies.**

Solution set results summary Specific values relate to heated gross floor area[1)]			Danish NZEB solution sets						Beyond NZEB
			Typical NZEB (base case)	DK - SS1	DK-SS2	DK-SS3	DK-SS4	DK-SS5	
			3 layer windows, central mechanical ventilation with 90% heat recovery	More efficient insulation material in external walls	DHW solar heating, reduced insulation in walls, roof and floor.	4 layer windows, natural ventilation heat recovery on grey wastewater.	Reduced insulation in walls, roof and floor, Decentral mechanical ventilation, energy efficient taps.	PV panels, reduced insulation in walls, roof and floor; Decentral mechanical ventilation.	Increased area of PV, reduced insulation in walls, roof and floor; decentral mechanical ventilation, energy efficient water taps
Building envelope	Average U-value, (incl. windows)	W/m²K	0.26	Id.	0.31	0.21	0.31	0.31	0.31
Net energy	Total	kWh/(m²yr)	19.0	Id.	18.2	20.0	18.5	20.4	4.9
Final energy	Total EPBD	kWh/(m²yr)	29.0 -> 29.0	Id. -> 29.0	28.2 -> 27.8	30.0 -> 30.0	28.5 -> 28.5	30.4 -> 30.3	14.9 -> 13.6
	Total (incl. other energy uses)	kWh/(m²yr)	59.7 -> 59.7	Id. -> 59.7	58.9 -> 58.9	60.7 -> 60.7	59.2 -> 59.2	61.1 -> 60.9	45.5 -> 44.3
Primary energy	Total EPBD	kWh/(m²yr)	26.3 -> 27.2	Id. -> 27.2	25.9 -> 26.1	25.9 -> 27.5	25.9 -> 26.7	26.0 -> 27.5	0.0 -> -2.4
	Total (incl. other energy uses)	kWh/(m²yr)	84.6 -> 69.4	Id. -> 69.4	84.2 -> 68.5	84.2 -> 69.8	84.2 -> 69.1	84.3 -> 69.9	58.3 -> 50.2
Energy costs	Total (incl. other energy uses)	€/(m²yr)	11.8 -> 13.2	Id. -> 13.2	11.8 -> 13.2	11.6-> 13.0	11.8 -> 13.2	11.5 -> 12.9	7.5 -> 8.0
	Difference to typical NZEB	€/m²	-	0.0 -> 0.0	0.0 -> 0.0	-0.2 -> -0.2	0.1 -> 0.0	-0.3 -> -0.3	-4.3 -> -5.2
Investment costs	Difference to typical NZEB	€/m²	-	-2.1 -> -2.6	-5,5 -> -8.1	-18.1 -> -22.6	-15.0 -> -18.6	-12.6 -> -16.5	8.1 -> -0.8

Id: Idem - the same as for the base case.

3.2.8. Summary for the Danish situation

In this chapter, the impact on the Danish NZEB and beyond NZEB solutions are analysed for the following evolving factors:

- primary energy factors,
- energy prices,
- technology costs and
- technology efficiencies.

Additionally, the predicted influence of climate change on the temperature and solar radiation from 2018 to 2030 was assessed.

The biggest impacts were observed for the changed primary energy factors. The considerably reduced primary energy factor for electricity completely changes the balance between heating energy and electric energy. The net zero primary energy of the beyond NZEB solution becomes 7.9 kWh/m²yr. This means that the size of the solar PV-systems has to be increased to outbalance the heating energy consumption.

However, the change of technology cost and technology efficiencies has the opposite effect as the solar heating systems and especially the PV-systems become less expensive and more efficient. The result is that the DK-SS2, DK-SS5 and the beyond NZEB buildings become less costly than the typical NZEB and at the same time produces more energy and therefore the energy costs for these solutions decreases.

Another impact of the changed primary energy factors and energy prices is that electrical heat pumps for heating will be more competitive, both for achieving lower primary energy demand and lower energy costs.

The assumed change of energy prices from 2018 to 2030 does hardly change the internal relationship between typical NZEB, the solution sets and the beyond NZEB building. All yearly energy costs will increase by 11 to 12%. As this percentage also influences the difference, the beyond NZEB with the lowest energy cost will become relatively cheaper.

The most visible impact of the predicted change in weather data is that all the analysed buildings will have an increased cooling load. The DK-SS3 (4-layer windows and natural ventilation) will be less influenced by the higher solar radiation in the summer month (25% lower) primarily due to the lower solar energy transmittance of the windows. If a split cooling unit is installed the cooling costs will be around 55 € per apartment (for DK-SS3 25% lower).

The overall picture of these assessments is that the PV - heat pump combination seems to have the possibility of becoming an important player in the future energy supply system.

3.3. Italy

3.3.1. Typical NZEB, cost-efficient NZEB solution sets and building level beyond NZEB

The Italian case study is an existing building located in the centre of Italy. It fulfills all the standard requirements defined in [30], [31]. The typical NZEB energy concept consists of an air-to-water heat pump for heating supply, supported by PV panels, and a condensing boiler which serves as back-up system for heat supply and provides domestic hot water for all the residential units. Production of DHW is in combination with a solar thermal collector field. Heat distribution is realized by a floor heating system.

Due to the wide variety of climate conditions in Italy, Italian simulations were performed in two representative cities: Rome and Turin. The first one is representative of zones from A to D, with milder climatic conditions, typical of central and southern zones; Turin is instead representative of climatic zone E (northern and mountain zones) and F (alpine zone). The characteristics of the case study building were thus adjusted to the requirements of the two-reference climatic zone for both minimum EP level building and typical NZEB.

According to this, the case study building located in Turin needed to be modified by increasing the insulation layers of the envelope and including a mechanical exhaust ventilation system. The building envelope in Rome featured the following U-values: 0.28 W/m²K at the external wall, 0.26 W/m²K at the roof, 0.28 W/m²K at the cellar ceiling and 1.46 W/m²K at the windows. In Turin, the U-values are the following: 0.25 W/m²K at the external wall, 0.21 W/m²K at the roof, 0.24 W/m²K at the cellar ceiling and 1.40 W/m²K at the windows.

In comparison with these two case studies, the following more cost-efficient alternative solution sets (SS) have been identified. In Rome:

- IT-R-SS1: Low-tech thermal-driven solution
  Variations in the composition of the external walls (autoclaved concrete blocks) and the technology of the windows (mono-block windows). Use of condensing boiler for both heating and DHW production. Use of radiators for heating distribution.
- IT-R-SS2: Electricity-driven solution
  Variations in the composition of the external walls (autoclaved concrete blocks) and the technology of the windows (mono-block windows). Heat pump for both heating and DHW supply. No use of solar thermal collectors. Use of low-temperature radiators for heating distribution.
- IT-R-SS3: Electricity thermal-driven solution (not complying with the Standards)
  Variations in the composition of the external walls (autoclaved concrete blocks) and the technology of the windows (mono-block windows). Elimination of the heating

system and use of electric radiators for heating supply. Condensing boiler for DHW supply.

- IT-R-SS4: Low-tech driven solution (not complying with the standards)
  Variations in the composition of the external walls (autoclaved concrete blocks) and the technology of the windows (mono-block windows). Use of condensing boiler for both heating and DHW production. Reduction of PV panels based on real needs. Use of radiators for heating distribution.

In Turin:

- IT-T-SS1: Low-tech thermal-driven solution
  Variations in the composition of the external walls (autoclaved concrete blocks) and the technology of the windows (mono-block windows). Use of condensing boiler for both heating and DHW production. Combined use of solar collectors both for heating and DHW. Use of radiators for heating distribution.
- IT-T-SS2: Low-tech thermal-driven solution (SuperNZEB)
  Variations in the composition of the external walls (autoclaved concrete blocks) and the technology of the windows (mono-block windows) plus extra insulation. Use of condensing boiler for both heating and DHW production. Combined use of solar collectors both for heating and DHW. Use of radiators for heating distribution. Mechanical exhaust ventilation system.
- IT-T-SS3: Electricity-driven solution
  Variations in the composition of the external walls (autoclaved concrete blocks) and the technology of the windows (mono-block windows). Air-water heat pump for both heating and DHW supply. No solar collectors. Low temperature radiators for heating distribution.
- IT-T-SS4: Electricity-driven solution with extra insulation (SuperNZEB)
  Variations in the composition of the external walls (autoclaved concrete blocks) and the technology of the windows (mono-block windows) plus extra insulation. Air-water heat pump for both heating and DHW supply. No solar collectors. Low temperature radiators for heating distribution. Mechanical exhaust ventilation system.
- SS5: Electricity-driven solution with extra insulation (SuperNZEB) but not complying with the Standards)
  Variations in the composition of the external walls (autoclaved concrete blocks) and the technology of the windows (mono-block windows) plus extra insulation. Elimination of the heating system and use of electric radiators for heating supply. Condensing boiler for DHW supply.

The Italian building level beyond NZEB was chosen to be as a “0” energy building without including household electricity. The specific combination to fulfil the “0” energy building level for the typical multi-family house geometry is:

- High performance thermal envelope with additional insulation
- Mono-block windows and autoclaved concrete blocks for the external walls
- Low-temperature aluminum radiators
- Heat pump supplying both heating and DHW
- Absence of solar thermal collectors
- Increased number of PV panels
- Mechanical ventilation with heat recovery (MVHR)

The mean U-values and the main results of the energy and cost calculations of the typical NZEB, the determined four cost-efficient NZEB solution sets and the beyond NZEB building level are presented in Table 38 for Rome and in Table 39 for Turin.

Table 38: Main characteristics of the typical Italian NZEB solution, the cost-efficient NZEB solution sets and the building level beyond NZEB with the status 2018 in Rome.

Solution set results summary Specific values relate to NIA of the building			Italian NZEB solution sets					Beyond NZEB
			Typical NZEB (base case)	IT-R-SS1	IT-R-SS2	IT-R-SS3	IT-R-SS4	
			Air-water heat pump for heating; condensing boiler for DHW; PV panels and solar collectors contributing to heating and DHW. Floor heating.	Low-tech thermal-driven solution: variations in composition of external walls and window technology; condensing boiler for heating and DHW.	Electricity-driven solution: variations in composition of external walls and window technology. Heat pump for heating and DHW; no solar thermal collectors.	Electricity-driven solution: Variations in composition of external walls and the window technology; electric radiators for heating. (Not legal).	Low-tech thermal-driven solution: Variations of external walls and window technology; use of condensing boiler for heating and DHW; reduction of PV panels. (Not legal).	Electricity-driven solution: Variations in composition of external walls (SuperNZEB envelope) and technology of the windows; heat pump for heating and DHW; no solar thermal collectors; increase of PV panels.
Building envelope	Average U-value (incl. windows)	W/m²K	0.34	0.34	0.34	0.34	0.34	0.25
Net energy	Total	kWh/(m²yr)	18.76	18.85	18.75	18.91	18.85	15.28
Final energy	Total EPBD	kWh/(m²yr)	11.05	11.74	8.57	12.41	11.74	7.29
Primary energy	Total EPBD (from non-renewable sources)	kWh/(m²yr)	11.03	12.33	5.91	14.66	12.43	0.25
	Total EPBD (incl. non-renewable and renewable sources)	kWh/(m²yr)	25.42	24.8	27.78	29.62	24.9	20.0
Energy costs	Total EPBD	€/(m²yr)	0.81	0.85	0.61	1.25	0.85	0.02
	Difference to typical NZEB	€/m²	-	0.04	-0.20	0.44	0.04	-0.79
Investment costs	Difference to typical NZEB	€/m²	-	-78	-67	-92	-93	-2

Table 39: **Main characteristics of the typical Italian NZEB solution, the cost-efficient NZEB solution sets and the building level beyond NZEB with the status 2018 in Turin.**

Solution set results summary Specific values relate to NIA of the building			Italian NZEB solution sets						Beyond NZEB
			Typical NZEB (base case)	IT-T-SS1	IT-T-SS2	IT-T-SS3	IT-T-SS4	IT-T-SS5	
			Air-water heat pump for heating; condensing boiler for DHW; PV panels and solar collectors contributing to heating and DHW; floor heating.	Low-tech thermal-driven solution: Variations in composition of external walls and technology of the windows. Use of condensing boiler for both heating and DHW production. Combined use of solar collectors both for heating and DHW.	Low-tech thermal-driven solution with variations in the composition of the external walls and technology of the windows and extra insulation (SuperNZEB envelope). Condensing boiler for heating and DHW; solar collectors for heating and DHW; mechanical exhaust ventilation.	Electricity-driven solution: Variations in composition of external walls and technology of windows; air-water heat pump for heating and DHW; no solar collectors.	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (SuperNZEB envelope); air-water heat pump for both heating and DHW; no solar collectors; mechanical exhaust ventilation.	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (SuperNZEB envelope); electric radiators for heating. (Not legal).	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (extra SuperNZEB envelope); Air-water heat pump for heating and DHW; no solar collectors; MVHR; Increase of PV panels.
Building envelope	Average U-value (incl. windows)	W/m²K	0.30	0.30	0.24	0.30	0.24	0.24	0.19
Net energy	Total	kWh/(m²yr)	29.37	29.37	29.63	29.37	29.63	23.33	25.8
Final energy	Total EPBD	kWh/(m²yr)	17.78	16.75	16.56	16.42	16.54	14.65	11.77
Primary energy	Total EPBD (from non-renewable sources)	kWh/(m²yr)	21.24	17.68	17.38	19.07	17.86	21.05	2.99
	Total EPBD (incl. non-renewable and renewable sources)	kWh/(m²yr)	43.32	37.64	36.53	47.39	45.4	42.72	27.34
Energy costs	Total EPBD	€/(m²yr)	1.70	1.22	1.20	1.81	1.68	1.92	0.21
	Difference to typical NZEB	€/(m²yr)	-	-0.48	-0.50	0.11	-0.02	0.21	-1.49
Investment costs	Difference to typical NZEB	€/m²	-	-63	-62	-65	-64	-56	58

3.3.2. Primary energy factors

The assumed evolvement of the primary energy factors from 2018 to 2030 is described in chapter 2.1. For Italy the predicted changes are:

Table 40: Predicted changes for the Italian primary energy factors from 2018 to 2030

Energy source	Primary energy factor	
	2018	2030
Grid electricity	1.95	0.96 *
PV generated electricity fed into grid	0	0
Gas	1.05	1.05 *

* No official data exist for energy performance in buildings, the figure comes from ENEA in-house calculations according to PNIEC - Piano Nazionale Integrato per l'Energia e il Clima 2030 (Integrated National Plan for Energy and Climate 2030)

As shown in Table 40, the only changes for 2030 are related to the evolution of grid electricity primary energy factor. The gas primary energy factor was kept as it is in 2018. The impact on the calculated results for the different variants (typical NZEB, NZEB solution sets and building beyond NZEB) is as follows. For details see Table 41 and Table 42 (for respectively Rome and Turin).

In Rome it can be noticed that the total primary energy covered by EPBD of the typical NZEB, IT-R-SS2 and IT-R-SS3 is reduced in 2030 compared to 2018 by respectively -5.5%, -47% and -23%. The highest reduction is registered for IT-TSS2: in this scenario, the electric consumption is more then 7-times higher than the gas consumption and consequently the reduction of the primary energy factor from 1.95 to 0.96 allows significant savings in terms of primary energy compared to the other scenarios. Conversely, the total primary energy covered by EPBD of the low-tech thermal-driven scenarios IT-R-SS1 and IT-R-SS4 is not affected by the variation of the electric primary energy factor since their electric consumption is zero. Similarly, also for the beyond NZEB solution, which originally presents very low gas consumption and zero electricity consumption, the total primary energy covered by EPBD in 2030 is unvaried.

The results in Turin are similar: in the two low-tech thermal-driven scenarios IT-T-SS1 and IT-T-SS2, having an electric consumption of only 79 kWh/yr, respectively 0 kWh/yr, the total primary energy covered by EPBD in 2030 is almost unvaried.

Conversely, the total primary energy covered by EPBD reduction in the other scenarios is directly proportional to the original electric consumption and to the ratio between the gas and electric consumption of each solution: the higher these values, the higher the reduction of total primary energy covered by EPBD from 2018 to 2030.

The highest percentage reduction is achieved in IT-T-SS4 (-32.7%).

Considering only the primary energy aspect and its impact on the energy performance of buildings, the assumed evolvement of the electric primary energy factor from 2018 to 2030 would thus push to realize electricity-driven solutions.

Table 41: Comparison of the Italian energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the primary energy factors in Rome.

Solution set results summary Specific values relate to NIA of the building			Italian NZEB solution sets					Beyond NZEB
			Typical NZEB (base case)	IT-R-SS1	IT-R-SS2	IT-R-SS3	IT-R-SS4	
			Air-water heat pump for heating; condensing boiler for DHW; PV panels and solar collectors contributing to heating and DHW. Floor heating.	Low-tech thermal-driven solution: variations in composition of external walls and window technology; condensing boiler for heating and DHW.	Electricity-driven solution: variations in composition of external walls and window technology. Heat pump for heating and DHW; no solar thermal collectors.	Electricity-driven solution: Variations in composition of external walls and the window technology; electric radiators for heating. (Not legal).	Low-tech thermal-driven solution: Variations of external walls and window technology; use of condensing boiler for heating and DHW; reduction of PV panels. (Not legal).	Electricity-driven solution: Variations in composition of external walls (SuperNZEB envelope) and technology of the windows; heat pump for heating and DHW; no solar thermal collectors; increase of PV panels.
Building envelope	Average U-value (incl. windows)	W/m²K	0.34	0.34	0.34	0.34	0.34	0.25
Net energy	Total	kWh/(m²yr)	18.76	18.85	18.75	18.91	18.85	15.28
Final energy	Total EPBD	kWh/(m²yr)	11.05	11.74	8.57	12.41	11.74	7.29
Primary energy	Total EPBD (from non-renewable sources)	kWh/(m²yr)	11.03 -> 10.42	12.33 -> 12.33	5.91 -> 3.11	14.66 -> 11.28	12.43 -> 12.43	0.25 -> 0.25
	Total EPBD (incl. non-renewable and renewable sources)	kWh/(m²yr)	25.42 -> 24.81	24.8 -> 24.80	27.78 -> 24.98	29.62 -> 26.24	24.90 -> 24.90	20.0 -> 20.0
Energy costs	Total EPBD	€/(m²yr)	0.81	0.85	0.61	1.25	0.87	0.02
	Difference to typical NZEB	€/m²	-	0.04	-0.20	0.44	0.06	-0.79
Investment costs	Difference to typical NZEB	€/m²	-	-78	-67	-92	-93	-2

Table 42: **Comparison of the Italian energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the primary energy factors in Turin.**

Solution set results summary Specific values relate to NIA of the building			Italian NZEB solution sets						Beyond NZEB
			Typical NZEB (base case)	IT-T-SS1	IT-T-SS2	IT-T-SS3	IT-T-SS4	IT-T-SS5	
			Air-water heat pump for heating; condensing boiler for DHW; PV panels and solar collectors contributing to heating and DHW; floor heating.	Low-tech thermal-driven solution: Variations in composition of external walls and technology of the windows. Use of condensing boiler for both heating and DHW production. Combined use of solar collectors both for heating and DHW.	Low-tech thermal-driven solution with variations in the composition of the external walls and technology of the windows and extra insulation (SuperNZEB envelope). Condensing boiler for heating and DHW; solar collectors for heating and DHW; mechanical exhaust ventilation.	Electricity-driven solution: Variations in composition of external walls and technology of windows; air-water heat pump for heating and DHW; no solar collectors.	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (SuperNZEB envelope); air-water heat pump for both heating and DHW; no solar collectors; mechanical exhaust ventilation.	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (SuperNZEB envelope); electric radiators for heating. (Not legal).	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (extra SuperNZEB envelope); Air-water heat pump for heating and DHW; no solar collectors; MVHR; Increase of PV panels.
Building envelope	Average U-value (incl. windows)	W/m²K	0.30	0.30	0.24	0.30	0.24	0.24	0.19
Net energy	Total	kWh/(m²yr)	29.37	29.37	29.63	29.37	29.63	23.33	25.8
Final energy	Total EPBD	kWh/(m²yr)	17.78	16.75	16.56	16.42	16.54	14.65	11.77
Primary energy	Total EPBD (from non-renewable sources)	kWh/(m²yr)	21.24 -> 18.94	17.68 -> 17.57	17.38 -> 17.38	19.07 -> 13.48	17.86 -> 12.02	21.05 -> 15.92	2.99 -> 2.86
	Total EPBD (incl. non-renewable and renewable sources)	kWh/(m²yr)	43.32 -> 41.02	37.64 -> 37.53	36.53 -> 36.53	47.39 -> 41.8	45.40 -> 39.66	42.72 -> 37.59	27.34 -> 27.21
Energy costs	Total EPBD	€/(m²yr)	1.70	1.22	1.20	1.81	1.68	1.92	0.21
	Difference to typical NZEB	€/(m²yr)	-	-0.48	-0.50	0.11	-0.02	0.21	-1.49
Investment costs	Difference to typical NZEB	€/m²	-	-63	-62	-65	-64	-56	58

3.3.3. Energy prices

The assumed evolvement of the energy prices from 2018 to 2030 is described in chapter 2.2. For Italy the predicted changes are:

Table 43: Predicted changes for the Italian energy prices from 2018 to 2030

Energy source	Energy prices	
	2018	2030
Grid electricity	0.20	0.49
PV generated electricity fed into grid	-	-
Gas	0.076	0.085

The impact on the calculated results for the different variants (typical NZEB, alternative NZEB solution sets and building beyond NZEB) is as follows. For details see Table 44 and Table 45 (for respectively Rome and Turin).

The variation of energy prices (cost increase for both gas and electricity) has no influence on the investment costs but causes a proportional increase of all energy costs per year. Nevertheless, the difference to the typical NZEB is not the same for all the solution sets.

In Rome, since IT-R-SS1 and the beyond NZEB do not need electricity from the grid (their energy costs are only due to gas consumption) energy cost savings in 2030 compared to the typical NZEB are higher. Furthermore, these savings are considerable since the percentage increase of electricity costs is higher than the percentage increase of gas costs (3.4% vs. 2.3%). It means that low-tech thermal-driven solutions are favoured. Energy costs of IT-R-SS1 in 2018 are indeed slightly higher than the typical NZEB (+0.04 €/(m^{2}yr)), while in 2030 they are reduced to -0.25 €/(m^{2}yr); similarly also savings between the typical NZEB and the beyond NZEB from 2018 to 2030 increase to 1.08 €/(m^{2}yr).

The same condition can be noticed in Turin, where the low-tech thermal-driven IT-T-SS2 in 2030 allows to save up to 0.70 €/(m^{2}yr) compared to the typical NZEB: in 2018 these savings were about 60% lower.

Primary beneficiaries of changes in energy prices:

- Scenarios with lower cost increase, which are both based on gas as main energy source for energy generation:
  - In Rome it is IT-R-SS1, a thermal-driven scenario with a condensing boiler supplying both heating and DHW.
  - In Turin it is IT-T-SS2 , a thermal-driven scenario with a SuperNZEB envelope with a condensing boiler and solar collectors supplying heating and DHW.

Table 44: Comparison of the Italian energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the energy prices in Rome.

Solution set results summary			Italian NZEB solution sets					Beyond NZEB
Specific values relate to NIA of the building			Typical NZEB (base case)	IT-R-SS1	IT-R-SS2	IT-R-SS3	IT-R-SS4	
			Air-water heat pump for heating; condensing boiler for DHW; PV panels and solar collectors contributing to heating and DHW. Floor heating.	Low-tech thermal-driven solution: variations in composition of external walls and window technology; condensing boiler for heating and DHW.	Electricity-driven solution: variations in composition of external walls and window technology. Heat pump for heating and DHW; no solar thermal collectors.	Electricity-driven solution: Variations in composition of external walls and the window technology; electric radiators for heating. (Not legal).	Low-tech thermal-driven solution: Variations of external walls and window technology; use of condensing boiler for heating and DHW; reduction of PV panels. (Not legal).	Electricity-driven solution: Variations in composition of external walls (SuperNZEB envelope) and technology of the windows; heat pump for heating and DHW; no solar thermal collectors; increase of PV panels.
Building envelope	Average U-value (incl. windows)	W/m²K	0.34	0.34	0.34	0.34	0.34	0.25
Net energy	Total	kWh/(m²yr)	18.76	18.85	18.75	18.91	18.85	15.28
Final energy	Total EPBD	kWh/(m²yr)	11.05	11.74	8.57	12.41	11.74	7.29
Primary energy	Total EPBD (from non-renewable sources)	kWh/(m²yr)	11.03	12.33	5.91	14.66	12.43	0.25
	Total EPBD (incl. non-renewable and renewable sources)	kWh/(m²yr)	25.42	24.8	27.78	29.62	24.90	20.00
Energy costs	Total EPBD	€/(m²yr)	0.81 -> 1.19	0.85 -> 0.94	0.61 -> 0.99	1.25 -> 1.63	0.87 -> 1.25	0.02-> 0.10
	Difference to typical NZEB	€/m²	-	0.04 -> -0.25	-0.20 -> -0.20	0.44 -> 0.44	0.06 -> 0.06	-0.79 -> - 1.08
Investment costs	Difference to typical NZEB	€/m²	-	-78	-67	-92	-93	-2

Table 45: Comparison of the Italian energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the energy prices in Turin.

Solution set results summary			Italian NZEB solution sets						Beyond NZEB
Specific values relate to NIA of the building			Typical NZEB (base case)	IT-T-SS1	IT-T-SS2	IT-T-SS3	IT-T-SS4	IT-T-SS5	
			Air-water heat pump for heating; condensing boiler for DHW; PV panels and solar collectors contributing to heating and DHW; floor heating.	Low-tech thermal-driven solution: Variations in composition of external walls and technology of the windows. Use of condensing boiler for both heating and DHW production. Combined use of solar collectors both for heating and DHW.	Low-tech thermal-driven solution with variations in the composition of the external walls and technology of the windows and extra insulation (SuperNZEB envelope). Condensing boiler for heating and DHW; solar collectors for heating and DHW; mechanical exhaust ventilation.	Electricity-driven solution: Variations in composition of external walls and technology of windows; air-water heat pump for heating and DHW; no solar collectors.	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (SuperNZEB envelope); air-water heat pump for both heating and DHW; no solar collectors; mechanical exhaust ventilation.	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (SuperNZEB envelope); electric radiators for heating. (Not legal).	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (extra SuperNZEB envelope); Air-water heat pump for heating and DHW; no solar collectors; MVHR; Increase of PV panels.
Building envelope	Average U-value (incl. windows)	W/m²K	0.30	0.30	0.24	0.30	0.24	0.24	0.19
Net energy	Total	kWh/(m²yr)	29.37	29.37	29.63	29.37	29.63	23.33	25.8
Final energy	Total EPBD	kWh/(m²yr)	17.78	16.75	16.56	16.42	16.54	14.65	11.77
Primary energy	Total EPBD (from non-renewable sources)	kWh/(m²yr)	21.24	17.68	17.38	19.07	17.86	21.05	2.99
	Total EPBD (incl. non-renewable and renewable sources)	kWh/(m²yr)	43.32	37.64	36.53	47.39	45.40	42.72	27.34
Energy costs	Total EPBD	€/(m²yr)	1.70 -> 2.10	1.22 -> 1.60	1.20 -> 1.30	1.81 -> 2.20	1.68-> 2.10	1.92 -> 2.30	0.22 -> 0.60
	Difference to typical NZEB	€/(m²yr)	-	-0.48 -> - 0.48	-0.50 -> -0.79	0.11 -> 0.11	-0.02-> -0.02	0.21 -> 0.21	-1.49 -> -1.49
Investment costs	Difference to typical NZEB	€/m²	-	-63	-62	-65	-64	-56	58

3.3.4. Technology costs

The assumed evolvement of the technology costs from 2018 to 2030 is described in chapter 2.3. For Italy the predicted changes are:

Table 46: Predicted changes for the Italian technology costs from 2018 to 2030

Technologies	Technology costs	
	2018	2030
Heat pumps	220 €/kW	165 €/kW
PV roof systems	245 €/m²	189 €/m²

The impact on the calculated results for the different variants (typical NZEB, alternative NZEB solution sets and building beyond NZEB) is as follows. For details see Table 47 and Table 48 (for respectively Rome and Turin).

The reduction of technology costs impacts only on the investment costs of the solutions. In Rome, despite the absolute costs of each solution are reduced in 2030 compared to 2018, the differences to typical NZEB do not follow the same trend. The low-tech thermal-driven solutions (IT-R-SS1 and IT-R-SS4) and the electricity-driven solution with electric radiators (IT-R-SS3) do not use a heat pump for heating supply. According to this, savings in those cases are only due to the reduction costs of PV panels. Conversely the typical NZEB has both PV panels and a heat pump and consequently in 2030 the gap in investment costs with the abovementioned alternative solutions is reduced up to 19% in IT-R-SS4. The difference in investment costs between the typical NZEB and IT-R-SS2 in 2030 is unvaried. Finally, for the beyond NZEB, savings in investment costs compared to the typical NZEB in 2030 increase from 2 €/m² to 6 €/m² due to the different amount of PV panels installed.

The same situation can be observed in Turin: savings in IT-T-SS1, IT-T-SS2 and IT-T-SS5 compared to typical NZEB are reduced by up to 23%; the differences in investment costs between the typical NZEB, IT-T-SS3 and IT-T-SS4 in 2030 is unvaried; the beyond NZEB would cost 58 €/m² more than the typical NZEB in 2018, while in 2030 this difference decreases to 46 €/m².

Primary beneficiaries of changes in technology costs, in terms of cost difference to the typical NZEB:

- In Rome it is IT-R-SS4, a thermal-driven scenario with a condensing boiler supplying both heating and DHW with a number of PV panels based on the real building needs (not complying with the Standard)
- In Turin it is IT-T-SS5, an electricity-driven scenario with a SuperNZEB envelope and electric radiators directly supplying heating service (not complying with the Standard)

Table 47: **Comparison of the Italian energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the technology costs in Rome.**

Solution set results summary Specific values relate to NIA of the building			Italian NZEB solution sets					Beyond NZEB
			Typical NZEB (base case)	IT-R-SS1	IT-R-SS2	IT-R-SS3	IT-R-SS4	
			Air-water heat pump for heating; condensing boiler for DHW; PV panels and solar collectors contributing to heating and DHW. Floor heating.	Low-tech thermal-driven solution: variations in composition of external walls and window technology; condensing boiler for heating and DHW.	Electricity-driven solution: variations in composition of external walls and window technology. Heat pump for heating and DHW; no solar thermal collectors.	Electricity-driven solution: Variations in composition of external walls and the window technology; electric radiators for heating. (Not legal).	Low-tech thermal-driven solution: Variations of external walls and window technology; use of condensing boiler for heating and DHW; reduction of PV panels. (Not legal).	Electricity-driven solution: Variations in composition of external walls (SuperNZEB envelope) and technology of the windows; heat pump for heating and DHW; no solar thermal collectors; increase of PV panels.
Building envelope	Average U-value (incl. windows)	W/m²K	0.34	0.34	0.34	0.34	0.34	0.25
Net energy	Total	kWh/(m²yr)	18.76	18.85	18.75	18.91	18.85	15.28
Final energy	Total EPBD	kWh/(m²yr)	11.05	11.74	8.57	12.41	11.74	7.29
Primary energy	Total EPBD (from non-renewable sources)	kWh/(m²yr)	11.03	12.33	5.91	14.66	12.43	0.25
	Total EPBD (incl. non-renewable and renewable sources)	kWh/(m²yr)	25.42	24.8	27.78	29.62	24.90	20.00
Energy costs	Total EPBD	€/(m²yr)	0.81	0.85	0.61	1.25	0.85	0.02
	Difference to typical NZEB	€/m²	-	0.04	-0.20	0.44	0.06	-0.79
Investment costs	Difference to typical NZEB	€/m²	-	-78 -> -65	-67 -> -67	-92 -> -79	-93 -> -76	-2 -> -6

Table 48: **Comparison of the Italian energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the energy prices in Turin.**

Solution set results summary			Italian NZEB solution sets						Beyond NZEB
Specific values relate to NIA of the building			Typical NZEB (base case)	IT-T-SS1	IT-T-SS2	IT-T-SS3	IT-T-SS4	IT-T-SS5	
			Air-water heat pump for heating; condensing boiler for DHW; PV panels and solar collectors contributing to heating and DHW; floor heating.	Low-tech thermal-driven solution: Variations in composition of external walls and technology of the windows. Use of condensing boiler for both heating and DHW production. Combined use of solar collectors both for heating and DHW.	Low-tech thermal-driven solution with variations in the composition of the external walls and technology of the windows and extra insulation (SuperNZEB envelope). Condensing boiler for heating and DHW; solar collectors for heating and DHW; mechanical exhaust ventilation.	Electricity-driven solution: Variations in composition of external walls and technology of windows; air-water heat pump for heating and DHW; no solar collectors.	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (SuperNZEB envelope); air-water heat pump for both heating and DHW; no solar collectors; mechanical exhaust ventilation.	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (SuperNZEB envelope); electric radiators for heating. (Not legal).	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (extra SuperNZEB envelope); Air-water heat pump for heating and DHW; no solar collectors; MVHR; Increase of PV panels.
Building envelope	Average U-value (incl. windows)	W/m²K	0.30	0.30	0.24	0.30	0.24	0.24	0.19
Net energy	Total	kWh/(m²yr)	29.37	29.37	29.63	29.37	29.63	23.33	25.8
Final energy	Total EPBD	kWh/(m²yr)	17.78	16.75	16.56	16.42	16.54	14.65	11.77
Primary energy	Total EPBD (from non-renewable sources)	kWh/(m²yr)	21.24	17.68	17.38	19.07	17.86	21.05	2.99
	Total EPBD (incl. non-renewable and renewable sources)	kWh/(m²yr)	43.32	37.64	36.53	47.39	45.40	42.72	27.34
Energy costs	Total EPBD	€/(m²yr)	1.70	1.22	1.20	1.81	1.68	1.92	0.21
	Difference to typical NZEB	€/(m²yr)	-	-0.48	-0.50	0.11	-0.02	0.21	-1.49
Investment costs	Difference to typical NZEB	€/m²	-	-63 -> -49	-62 -> -50	-65 -> -65	-64 -> -64	-56 -> -43	58 -> 46

3.3.5. Technology efficiencies

The assumed evolvement of the technology efficiencies from 2018 to 2030 is described in chapter 2.4. For Italy the predicted changes are:

Table 49: Predicted changes for the Italian technology efficiencies from 2018 to 2030

Technologies	Technology efficiencies	
	2018	2030
Air-water hear pumps: COP	3.28	4.23
PV systems: nominal efficiency of the module	0.15	0.20

Two technologies were considered: the air water heat pump and the PV panels. In both cases the efficiency is assumed to increase in the next years, up to 30% for the heat pump and up to 33% for the PV system.

Accordingly the impact was assessed for three variants only:

- the typical NZEB,
- one solution set including both technologies whose efficiencies were increased
- the beyond NZEB.

In Rome, IT-R-SS2 was evaluated since both the technologies (heat pump and PV panels) are used. In Turin, IT-T-SS4 was indeed analysed for two reasons: it is the most complete scenario (SuperNZEB envelope, air water heat pump for both DHW and heating, mechanical exhaust ventilation) and it was used as baseline for the design of the beyond NZEB solution. For details of the results see Table 50 and Table 51 (for respectively Rome and Turin).

The assumed evolvement of the technology efficiencies affects many aspects:

- Final energy
- Primary energy
- Energy costs

The impacts on these aspects are all positive, causing a reduction of both final and primary energy, and consequently also savings in energy costs due to the lower energy consumption.

In Rome, the primary beneficiary of changes in the technology efficiency is IT-R-SS2 with a percentage reduction of final and primary energy by 17% and by 48% respectively. The energy costs were also reduced by 50%, increasing the difference to the typical NZEB by -0.35 €/(m²yr). Regarding the beyond NZEB, the very low non-renewable primary energy covered by the EPBD obtained in 2018 (almost zero) was further improved in 2030 but the percentage difference between the two values is obviously lower than in IT-R-SS2. Conversely, only in this case, the total primary energy covered by EPBD including also the renewable energy in 2030 is slightly higher: 20 kWh/(m²yr) in 2018 and 20.7 kWh/(m²yr) in 2030. This is due to the fact that the amount of PV panels in this solution is very high; improving its efficiency led to a considerable increase of renewable electricity production, partially used for in-house heating (the renewable primary energy index for heating arises from 0.6 in 2018 to 1.35 in 2030) and partially sold to the grid. The energy costs were also so low in 2018 (almost zero) that the reduction in 2030 is not relevant in comparison to IT-R-SS2 and the typical NZEB. It is indeed demonstrated that the difference in energy costs to the typical NZEB which is -0.79 €/m² in 2018 will decrease to -0.66 €/m² in 2030.

In Turin, the primary beneficiary of changes in the technology efficiency is indeed the beyond NZEB solution. Due to the colder climate compared to Rome, it was not possible to reach almost zero consumptions in 2018 with the current technology conditions. Conversely in 2030, the increase of technology efficiency allowed to reduce by 25.5% the final energy and by 98% the non-renewable primary energy. Similarly, as in Rome, the total primary energy covered by the EPBD including the renewable sources increased from 27.34 to 28.4 kWh/(m²yr).

Talking about costs, the beyond NZEB solution also got the highest benefits reducing the annual energy costs to 0. Nevertheless, as in Rome, since the original energy costs in 2018 are very low (0.21 €/(m²yr)), the difference to the typical NZEB in 2030 become smaller: -1.49 €/m² in 2018 and -1.41 €/m² in 2030.

Primary beneficiary of changes in the technology efficiency:

- In Rome it is IT-R-SS4, a thermal-driven scenario with a condensing boiler supplying both heating and DHW with a number of PV panels based on real building needs (not complying with the Standard)
- In Turin it is the beyond NZEB, an electricity-driven scenario with a SuperNZEB envelope and a heat pump for heating and DHW.

Table 50: Comparison of the Italian energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the technology efficiencies in Rome.

Solution set results summary Specific values relate to NIA of the building			Italian NZEB solution sets: Typical NZEB (base case)	Italian NZEB solution sets: IT-R-SS1	Italian NZEB solution sets: IT-R-SS2	Italian NZEB solution sets: IT-R-SS3	Italian NZEB solution sets: IT-R-SS4	Beyond NZEB
			Air-water heat pump for heating; condensing boiler for DHW; PV panels and solar collectors contributing to heating and DHW. Floor heating.	Low-tech thermal-driven solution: variations in composition of external walls and window technology; condensing boiler for heating and DHW.	Electricity-driven solution: variations in composition of external walls and window technology. Heat pump for heating and DHW; no solar thermal collectors.	Electricity-driven solution: Variations in composition of external walls and the window technology; electric radiators for heating. (Not legal).	Low-tech thermal-driven solution: Variations of external walls and window technology; use of condensing boiler for heating and DHW; reduction of PV panels. (Not legal).	Electricity-driven solution: Variations in composition of external walls (SuperNZEB envelope) and technology of the windows; heat pump for heating and DHW; no solar thermal collectors; increase of PV panels.
Building envelope	Average U-value (incl. windows)	W/m²K	0.34	0.34	0.34	0.34	0.34	0.25
Net energy	Total	kWh/(m²yr)	18.76	18.85	18.75	18.91	18.85	15.28
Final energy	Total EPBD	kWh/(m²yr)	11.05 -> 10.27	11.74	8.57 -> 7.04	12.41	11.74	7.29 -> 6.38
Primary energy	Total EPBD (from non-renewable sources)	kWh/(m²yr)	11.03 -> 9.63	12.33	5.91 -> 3.07	14.66	12.43	0.25 -> 0.18
	Total EPBD (incl. non-renewable and renewable sources)	kWh/(m²yr)	25.42 -> 24.58	24.80	27.78 -> 25.97	29.62	24.90	20.00 -> 20.73
Energy costs	Total EPBD	€/(m²yr)	0.81 -> 0.67	0.85	0.61 -> 0.32	1.25	0.85	0.02 -> 0.01
	Difference to typical NZEB	€/m²	-	0.04	-0.20 -> -0.35	0.44	0.06	-0.79 -> -0.66
Investment costs	Difference to typical NZEB	€/m²	-	-78	-67	-92	-93	-2

Table 51: Comparison of the Italian energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the technology efficiencies in Turin.

Solution set results summary Specific values relate to NIA of the building			Italian NZEB solution sets						Beyond NZEB
			Typical NZEB (base case)	IT-T-SS1	IT-T-SS2	IT-T-SS3	IT-T-SS4	IT-T-SS5	
			Air-water heat pump for heating; condensing boiler for DHW; PV panels and solar collectors contributing to heating and DHW; floor heating.	Low-tech thermal-driven solution: Variations in composition of external walls and technology of the windows. Use of condensing boiler for both heating and DHW production. Combined use of solar collectors both for heating and DHW.	Low-tech thermal-driven solution with variations in the composition of the external walls and technology of the windows and extra insulation (SuperNZEB envelope). Condensing boiler for heating and DHW; solar collectors for heating and DHW; mechanical exhaust ventilation.	Electricity-driven solution: Variations in composition of external walls and technology of windows; air-water heat pump for heating and DHW; no solar collectors.	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (SuperNZEB envelope); air-water heat pump for both heating and DHW; no solar collectors; mechanical exhaust ventilation.	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (SuperNZEB envelope); electric radiators for heating. (Not legal).	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (extra SuperNZEB envelope); Air-water heat pump for heating and DHW; no solar collectors; MVHR; Increase of PV panels.
Building envelope	Average U-value (incl. windows)	W/m²K	0.30	0.30	0.24	0.30	0.24	0.24	0.19
Net energy	Total	kWh/(m²yr)	29.37	29.37	29.63	29.37	29.63	23.33	25.8
Final energy	Total EPBD	kWh/(m²yr)	17.78 -> 15.39	16.75	16.56	16.42	16.54 -> 14.42	14.65	11.77 -> 8.77
Primary energy	Total EPBD (from non-renewable sources)	kWh/(m²yr)	21.24 -> 17.7	17.68	17.38	19.07	17.86 -> 13.3	21.05	2.99 -> 0.07
	Total EPBD (incl. non-renewable and renewable sources)	kWh/(m²yr)	43.32 -> 42.36	37.64	36.53	47.39	45.4 -> 41.83	42.72	27.34 -> 28.40
Energy costs	Total EPBD	€/(m²yr)	1.70 -> 1.41	1.22	1.20	1.81	1.68 -> 1.25	1.92	0.21 -> 0.00
	Difference to typical NZEB	€/(m²yr)	-	-0.48	-0.50	0.11	-0.02 -> -0.16	0.21	-1.49 -> -1.41
Investment costs	Difference to typical NZEB	€/m²	-	-63	-62	-65	-64	-56	58

3.3.6. Other possible impact factors

Assessment methods for the energy performance of buildings

The Italian calculation methodologies are now under review, with the aim of implementing the 52000 standard series developed in framework of European (CEN) and global (ISO) standardisation bodies, which will be the reference technical standards within the next years. The main topic is the evolution of the calculation method from monthly quasi-steady state to hourly/dynamic, which should strongly improve the calculation reliability for cooling energy use. Many studies, in fact, showed that the monthly method lead to a significant overestimation for cooling. As an example, energy performance calculations were performed on eight dwellings of the Italian typical building, focusing on the annual energy needs for heating and cooling, to maintain the specified set-point temperatures in the building. Two methods were applied: 1) monthly quasi-steady state according to the national standards, implementing the current EN standards; 2) hourly semi-dynamic (based on Z-transform) as implemented in TRNSYS, a well known and calibrated software for thermal analyses in transient regime. The results are presented in Table 52. It can be observed that energy needs for space heating are in good agreement, with deviations of about 2 kWh/(m^2yr) in two cases, and a maximum of 0.7 kWh/(m^2y) for the other six dwellings. Conversely very high discrepancies are found for the cooling energy uses, with differences of 30 kWh/(m^2yr). It is expected that new technical standards, currently under implementation, and related legislative papers will be able to provide more realistic and reliable results for the calculation of the energy performance in buildings. No further detailed calculated data can be provided at this stage.

Table 52: Space heating and cooling energy needs according to difference calculation method

Dwellings	A1	A2	A3	A4	A5	A6	A7	A8
Net heating energy use [kWh/(m^2yr)]								
EP_monthly	12.5	17.9	10.7	6.2	9.8	2.6	13.9	7.4
EP_hourly	11.8	15.6	8.9	6.1	9.4	2.5	14.1	7.5
Net cooling energy use [kWh/(m^2yr)]								
EP_monthly	36	22	22	41	26	27	31	26
EP_hourly	11.2	7.3	8.7	11.9	8.7	10.1	10.1	12.4

Climate change

The available data [32] show a contradictory trend in terms of the evolution of air temperature. According to the data (averaged for 2029, 2030, 2031), the temperatures will be lower than the current ones during the cooling months. This implies that no critical variations for the theoretical cooling energy uses and the thermal comfort conditions can be expected in not cooled buildings.

On the other side, the increase of temperature in winter months will lead to reduced space heating uses in Turin. However, the impact on the energy performance and costs won't be significant due to the very low energy uses in future NZEBs and beyond NZEB. Temperature increases in Rome are observed during the intermediate seasons only, with no impact on cooling and heating performances.

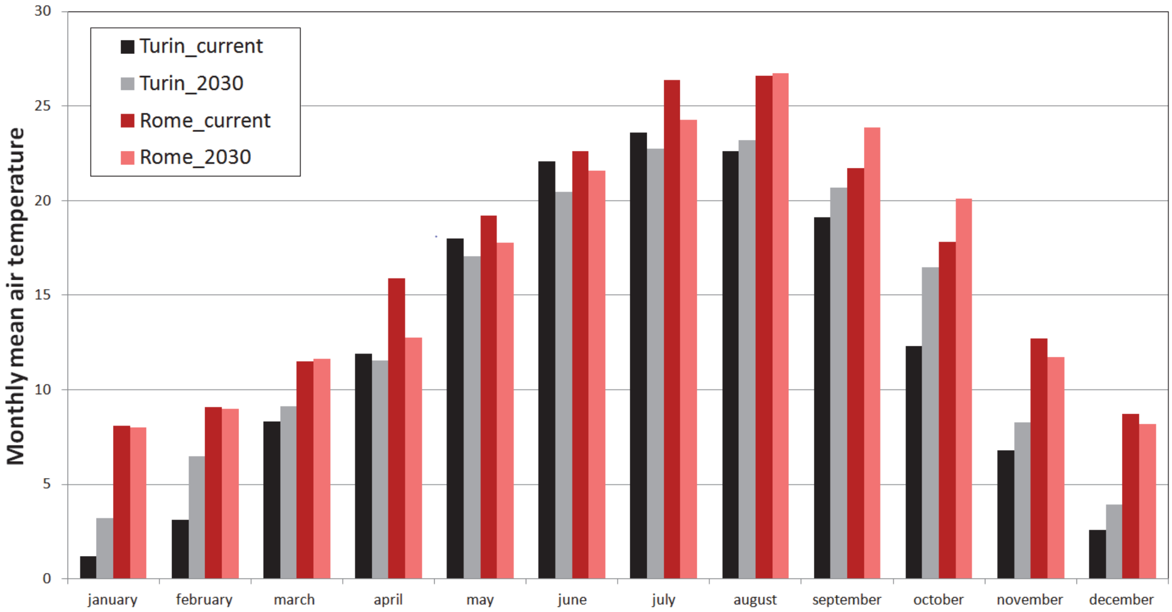


Figure 4: **Monthly mean air temperature in Turin and Rome, current reference values and predictions according to [32].**

Financial support programmes

No national financial programs supporting energy related measures in new residential buildings are established in Italy. Specific support actions might be implemented at local level, but no data are available.

3.3.7. Combination of changes in the evolving factors

In addition to the individual impact assessments of chapters 3.2.2 to 3.2.5 the combination of the evolving factors

- primary energy factors,
- energy prices,
- technology costs and
- technology efficiencies

are assessed within this chapter. The individual impacts can't simply be added as some of them are interlinked and influence the same energy and cost characteristics. Note: The climate change impact is not part of this combined assessment. The results of the assessment are included in Table 53.

The combination of these factors allows to consider all the positive/negative impacts of each aspect: the technology efficiency allowed to improve the energy performance of the building and to reduce the final energy of the solutions; starting from these values, the primary energy was calculated using the predicted lower electric primary energy factor; finally, the energy costs, thus reduced thanks to improvement of the energy performance of the building, were estimated using the increased energy prices forecasted in 2030. The investment costs are the same as described in section 3.3.4.

The results of the assessment are included in Table 53 for Rome and in Table 54 for Turin.

With the exception of the technology efficiency changes, results are available for all solution sets for each single impact factors. The results of the combined analysis are only available for three solutions (typical NZEB, one alternative NZEB solution set and the beyond NZEB) since the technology efficiency impact was assessed only for those three.

In Rome the best performance is achieved by IT-R-SS2. The final energy reduction compared to 2018 is about 18% while the non-renewable primary energy reduction is about 74%.

The energy costs, as can be expected, are increased in 2030 compared to 2018. This is particularly relevant for the beyond NZEB solution, where the energy costs increase from 0.02 €/(m²yr) to 0.39 €/(m²yr). Comparing these results with the values shown in Table 50, it can be noticed that the combination of higher technology efficiency and lower electric primary energy factors has a good impact especially on IT-R-SS2: the primary energy in Table 50, where only the technology efficiency was taken into account, is expected to reduce by 48% while the combination of the two factors would lead to a reduction of 74%.

In Turin, the best performance considering the combination of the evolving factors is the beyond NZEB solution: the final energy decreases in 2030 by 25.5% and the primary energy by 98%. In this case the effect of the future electric primary energy factor has no impact since the electric consumption is zero. Conversely, in IT-T-SS4 the primary energy is reduced by 49% thanks to the combination of the evolving factors; considering indeed the individual impact assessments of chapter 3.2.5, the reduction from 2018 to 2030 was about 25%.

Primary beneficiaries of combined changes of the evolving factors:

- In Rome it is IT-R-SS2, an electricity-driven scenario with a heat pump supplying both heating and DHW.

- In Turin it is the beyond NZEB, an electricity-driven scenario with a SuperNZEB envelope and a heat pump for heating and DHW.

Table 53: **Comparison of the Italian energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the primary energy factors, energy prices, technology costs and technology efficiencies for Rome.**

Solution set results summary Specific values relate to NIA of the building			Italian NZEB solution sets					Beyond NZEB
			Typical NZEB (base case)	IT-R-SS1	IT-R-SS2	IT-R-SS3	IT-R-SS4	
			Air-water heat pump for heating; condensing boiler for DHW; PV panels and solar collectors contributing to heating and DHW. Floor heating.	Low-tech thermal-driven solution: variations in composition of external walls and window technology; condensing boiler for heating and DHW.	Electricity-driven solution: variations in composition of external walls and window technology. Heat pump for heating and DHW; no solar thermal collectors.	Electricity-driven solution: Variations in composition of external walls and the window technology; electric radiators for heating. (Not legal).	Low-tech thermal-driven solution: Variations of external walls and window technology; use of condensing boiler for heating and DHW; reduction of PV panels. (Not legal).	Electricity-driven solution: Variations in composition of external walls (SuperNZEB envelope) and technology of the windows; heat pump for heating and DHW; no solar thermal collectors; increase of PV panels.
Building envelope	Average U-value (incl. windows)	W/m²K	0.34	0.34	0.34	0.34	0.34	0.25
Net energy	Total	kWh/(m²yr)	18.76	18.85	18.75	18.91	18.85	15.28
Final energy	Total EPBD	kWh/(m²yr)	11.05 -> 10.27	11.74	8.57 -> 7.04	12.41	11.74	7.29 -> 6.38
Primary energy	Total EPBD (from non-renewable sources)	kWh/(m²yr)	11.03 -> 9.61	12.33	5.91 -> 1.56	14.66	12.43	0.25 -> 0.13
	Total EPBD (incl. non-renewable and renewable sources)	kWh/(m²yr)	25.42 -> 24.52	24.80	27.78 -> 24.46	29.62	24.90	20.00 -> 20.68
Energy costs	Total EPBD	€/(m²yr)	0.81 -> 1.04	0.85	0.61 -> 0.70	1.25	0.87	0.02 -> 0.39
	Difference to typical NZEB	€/m²	-	0.04	-0.20 -> -0.34	0.44	0.06	-0.79 -> -0.65
Investment costs	Difference to typical NZEB	€/m²	-	-78	-67 -> -67	-92	-93	-2 -> -6

Table 54: Comparison of the Italian energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the primary energy factors, energy prices, technology costs and technology efficiencies for Turin.

Solution set results summary Specific values relate to NIA of the building			Italian NZEB solution sets						Beyond NZEB
			Typical NZEB (base case)	IT-T-SS1	IT-T-SS2	IT-T-SS3	IT-T-SS4	IT-T-SS5	
			Air-water heat pump for heating; condensing boiler for DHW; PV panels and solar collectors contributing to heating and DHW; floor heating.	Low-tech thermal-driven solution: Variations in composition of external walls and technology of the windows. Use of condensing boiler for both heating and DHW production. Combined use of solar collectors both for heating and DHW.	Low-tech thermal-driven solution with variations in the composition of the external walls and technology of the windows and extra insulation (SuperNZEB envelope). Condensing boiler for heating and DHW; solar collectors for heating and DHW; mechanical exhaust ventilation.	Electricity-driven solution: Variations in composition of external walls and technology of windows; air-water heat pump for heating and DHW; no solar collectors.	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (SuperNZEB envelope); air-water heat pump for both heating and DHW; no solar collectors; mechanical exhaust ventilation.	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (SuperNZEB envelope); electric radiators for heating. (Not legal).	Electricity-driven solution: Variations in composition of external walls and technology of windows and extra insulation (extra SuperNZEB envelope); Air-water heat pump for heating and DHW; no solar collectors; MVHR; Increase of PV panels.
Building envelope	Average U-value (incl. windows)	W/m²K	0.30	0.30	0.24	0.30	0.24	0.24	0.19
Net energy	Total	kWh/(m²yr)	29.37	29.37	29.63	29.37	29.63	23.33	25.8
Final energy	Total EPBD	kWh/(m²yr)	17.78 -> 15.39	16.75	16.56	16.42	16.54 -> 14.42	14.65	11.77 -> 8.77
Primary energy	Total EPBD (from non-renewable sources)	kWh/(m²yr)	21.24 -> 15.60	17.68	17.38	19.07	17.86 -> 9.14	21.05	2.99 -> 0.07
	Total EPBD (incl. non-renewable and renewable sources)	kWh/(m²yr)	43.32 -> 40.26	37.64	36.53	47.39	45.4 -> 37.67	42.72	27.34 -> 28.39
Energy costs	Total EPBD	€/(m²yr)	1.70 -> 1.80	1.22	1.20	1.81	1.68 -> 1.60	1.92	0.21 -> 0.10
	Difference to typical NZEB	€/(m²yr)	-	-0.48	-0.50	0.11	-0.02 -> -0.20	0.21	-1.49 -> -1.70
Investment costs	Difference to typical NZEB	€/m²	-	-63	-62	-65	-64 -> -64	-56	58 -> 46

3.3.8. Summary for the Italian situation

In this section, a brief summary of the Italian results (for Rome and Turin) is provided, highlighting which solution is the primary beneficiary of the variation for each evolving factor.

Regarding the primary energy factor, as aforementioned, the only figures available for 2030 regard the evolution of the grid electricity primary energy factor. It is expected to decrease from 1.95 to 0.96. The gas primary energy factor is indeed unvaried (1.05). According to this, the primary beneficiary of this evolution in Rome is IT-R-SS2: an electricity-driven solution where the heat pump supplies both heating and DHW. The reduction of the primary energy from 2018 to 2030 is 47%.

In Turin, the best results are achieved by IT-T-SS4, with a primary energy reduction by 33% in 2030. This is also an electricity-driven solution with extra insulation (SuperNZEB) where a heat pump supplies heating and DHW and a mechanical exhaust ventilation system is installed.

The variation of energy prices (cost increase for both gas and electricity in 2030) will cause a proportional increase of the annual energy costs for all solutions. The increase of electricity costs is higher than the increase of gas costs (3.4% vs. 2.3%); accordingly, the electricity-driven solutions are not favoured by the energy price variation. The solution whose energy costs per year increase the least is indeed IT-R-SS1, a thermal-driven solution where the condensing boiler provides both heating and DHW. In this case the increase of the energy costs from 2018 to 2030 is about 11%. The same situation can be found in Turin, where the most favoured solution is IT-T-SS2, with an energy cost increase of only 8%.

The reduction of technology costs impacts only the investment costs of the solutions. The investment costs in this report are not provided as absolute values but in terms of difference to the typical NZEB. In Rome the highest reduction compared to the typical NZEB is obtained in IT-R-SS4 (19%), while in Turin it is reached in IT-T-SS5 with a percentage difference of -23% compared to the typical NZEB.

Finally, regarding the variation of technology efficiency, the impact was assessed only for three variants: the typical NZEB, one solution set including both technologies whose efficiencies were increased and the beyond NZEB.

The primary beneficiary of changes in the technology efficiency in Rome is IT-R-SS2 with a reduction of the final and the primary energy by 17% and 48% respectively if compared to 2018. The energy costs are also reduced by 50%, increasing the difference to the typical NZEB by -0.35 €/(m^2yr).

In Turin, the best performing results are indeed achieved by the beyond NZEB solution. In 2030, the increase of technology efficiencies allowed a reduction of final energy by 25.5% and of primary energy by 98%. Talking about costs, the beyond NZEB solution also got the highest benefits reducing the annual energy costs to 0.

In addition to the results of the individual impact assessments the combination of the evolving factors (primary energy factors, energy prices, technology costs and technology efficiencies) was also assessed. In Rome the best results are achieved by IT-R-SS2 (heat pump for both heating and DHW): regarding the final energy, the reduction compared to 2018 is about 18% while concerning the primary energy the difference is about 74%. Energy costs are expected to rise in 2030, due to the increase of energy prices; nevertheless, IT-R-SS2 will have the lowest increase among the three solution sets analysed (+15% compared to 2018).

In Turin, the primary beneficiary of the combination of the evolving factors is the beyond NZEB solution: the final energy decreases in 2030 by 25.5% and the primary energy by 98%. Regarding the costs, despite the increase of energy prices, the beyond NZEB solution will guarantee a reduction of energy costs in 2030 of about 52% compared to 2018.

3.4. Slovenia

3.4.1. Typical NZEB, cost-efficient NZEB solution sets and building level beyond NZEB

For the Slovenian NZEB definition and requirements the Action Plan for Nearly Zero-Energy Buildings [33] has been used, which in comparison to buildings fulfilling the minimum energy performance requirements noticeably increases the required ratio of renewable energy sources (RES). Due to this fact, the typical Slovenian NZEB energy concept consists of solar collectors on the roof (which is the RES technology in high growth) in combination with a gas condensing boiler, since gas is an energy source commonly used in Slovenia. The heat distribution is realised by floor heating. The building envelope is composed by external walls with a U-value of 0.15 W/m^{2}K, the flat roof with a U-value of 0.12 W/m^{2}K, the cellar ceiling with a U-value of 0.16 W/m^{2}K and windows with a U-value of 1.3 W/m^{2}K. The typical NZEB has a hygro-sensitive mechanical ventilation system implemented.

In order to reduce investment costs, the following solution sets have been identified:

- SI-SS1: District heating as generation for heating and DHW; decentral mechanical ventilation system with heat recovery; better airtightness
- SI-SS2: Air heat pump as generation for heating and DHW; decentral mechanical ventilation system with heat recovery; better airtightness; triple-glazed windows with a U-value of 0.88 W/m^{2}K

- SI-SS3: Air heat pump as generation for DHW; gas condensing boiler for heating; decentral mechanical ventilation system with heat recovery; better airtightness; triple-glazed windows with a U-value of 0.88 W/m²K
- SI-SS4: Air heat pump as generation for heating and DHW; hygro-sensitive mechanical ventilation system; roof PV panels; better airtightness; triple-glazed windows with a U-value of 0.88 W/m²K

The Slovenian building level beyond NZEB was chosen to be a self-sufficient building on annual basis. The specific combination to fulfil the self-sufficient building level for the typical multi-family house geometry is:

- air heat pump as generation for heating and DHW
- decentral mechanical ventilation system with heat recovery
- better airtightness
- triple-glazed windows with a U-value of 0.88 W/m²K,
- roof PV panels

The mean U-values and the main results of the energy and cost calculations of the typical NZEB, the determined four cost-efficient NZEB solution sets and the beyond NZEB building level are presented in Table 55.

Table 55: Main characteristics of the typical Slovenian NZEB solution, the cost-efficient NZEB solution sets and the building level beyond NZEB with the status 2018.

Solution set results summary			Slovenian NZEB solution sets					Beyond NZEB
			Typical NZEB (base case)	SI - SS1	SI-SS2	SI-SS3	SI-SS4	
Specific values relate to the conditioned net floor area of the building			Heat supply: gas condensing boiler; solar collectors for DHW; use of hygro-sensitive ventilation system; double-glazed windows	District heating as generation for heating and DHW; use of mechanical ventilation with 85% heat recovery; better airtightness	Air heat pump as generation for heating and DHW; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness	Air heat pump as generation for DHW; gas condensing boiler for heating; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness	Air heat pump as generation for heating and DHW; roof PV panels; use of hygro-sensitive mechanical ventilation; triple-glazed windows; better airtightness	Air heat pump as generation for heating and DHW; roof PV panels; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness
Building envelope	Specific coefficient of trans-mission thermal losses H'_T	W/m^2K	0.413	0.413	0.333	0.333	0.333	0.333
Net energy	Total	$kWh/(m^2yr)$	40.1	31.5	27.5	27.5	35.7	27.5
Final energy	Total EPBD	$kWh/(m^2yr)$	49.0	40.8	35.0	35.6	43.0	34.6
Primary energy	Total EPBD	$kWh/(m^2yr)$	44.3	59.9	39.9	43.1	3.4	0
Energy costs	Total EPBD	€/(m^2yr)	3.19	3.42	2.39	2.43	1.10	0.94
	Difference to typical NZEB	€/(m^2yr)	-	0.23	-0.80	-0.76	-2.09	-2.25
Investment costs	Difference to typical NZEB	€/m^2	-	-65	-32	-18	-5	26

3.4.2. Primary energy factors

The assumed evolvement of the primary energy factors from 2018 to 2030 is described in chapter 2.1. For Slovenia the predicted changes are:

Table 56: Predicted changes for the Slovenian primary energy factors from 2018 to 2030

Energy source	Primary energy factor	
	2018	2030
Grid electricity	2.5	2.2
PV generated electricity fed into grid	n/a *	n/a *
District heating	1.0 – 1.2	0.95 – 1.1
Gas	1.1	1.1

* In Slovenia the feed into the grid system is not an option anymore; the green electricity prices are defined by individual contracts, at a building level the principle of regulations on self-supply of electricity from renewable energy sources is used.

The impact on the calculated results for the different variants (typical NZEB, NZEB solution sets and building beyond NZEB) is as follows. For details see Table 57.

In Slovenia the changes in primary energy factors in 2030 are not that significant, since the electricity primary energy factor reduces from 2.5 to 2.2 and the district heating primary energy factors reduce from 1.0 - 1.2 to 0.95 - 1.1 (or more, i.e. to 0.1 in case of biomass district heating), depending on whether it is based on cogeneration systems or not.

Consequently the solution sets with electricity as their main energy source have the highest changes in the primary energy. The predicted changes of the primary energy factor has the highest impact on SI-SS1, which uses district heating for the generation of DHW and heating, leading to a reduction of the primary energy of 5.77 kWh/m^{2}yr. A similar change of primary energy use occurs for SI-SS2, where an air heat pump takes care of heating and DHW, and results in a reduction of 4.8 kWh/m^{2}yr primary energy use. A slightly lower decrease can be noted in the SI-SS3, where a heat pump is used for DHW, while a gas condensing boiler is used for heating. Consequently for SI-SS3 there is a reduction of 3.9 kWh/m^{2}yr of primary energy use. SI-SS4 and the beyond NZEB have very low primary energy, thus also the change is very low. The typical NZEB uses a gas condensing boiler for heating and as secondary DHW generation, since DHW is mainly covered by solar collectors. Therefore the changes at the primary energy use at the typical NZEB occur only due to the reduction of the electricity primary energy factor, resulting in 2.26 kWh/m^{2}yr reduced primary energy use.

Primary beneficiary of changes in the primary energy factors:

- SI-SS1, which uses district heating for heating and DHW.
- SI-SS2 and SI-SS3, that use heat pumps for heating and/or DHW.

Table 57: **Comparison of the Slovenian energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the primary energy factors.**

Solution set results summary Specific values relate to the conditioned net floor area of the building			Slovenian NZEB solution sets					Beyond NZEB
			Typical NZEB (base case)	SI - SS1	SI-SS2	SI-SS3	SI-SS4	
			Heat supply: gas condensing boiler; solar collectors for DHW; use of hygro-sensitive ventilation system; double-glazed windows	District heating as generation for heating and DHW; use of mechanical ventilation with 85% heat recovery; better airtightness	Air heat pump as generation for heating and DHW; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness	Air heat pump as generation for DHW; gas condensing boiler for heating; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness	Air heat pump as generation for heating and DHW; roof PV panels; use of hygro-sensitive mechanical ventilation; triple-glazed windows; better airtightness	Air heat pump as generation for heating and DHW; roof PV panels; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness
Building envelope	Specific coefficient of trans-mission thermal losses H'$_T$	W/m²K	0.413	0.413	0.333	0.333	0.333	0.333
Net energy	Total	kWh/(m²yr)	40.1	31.5	27.5	27.5	35.7	27.5
Final energy	Total EPBD	kWh/(m²yr)	49.0	40.8	35.0	35.6	43.0	34.6
Primary energy	Total EPBD	kWh/(m²yr)	44.3 -> 42.0	59.9 -> 54.1	39.9 -> 35.1	43.1 -> 39.2	3.4 -> 3.0	0.2 -> 0.2
Energy costs	Total EPBD	€/(m²yr)	3.19	3.42	2.39	2.43	1.10	0.94
	Difference to typical NZEB	€/(m²yr)	-	0.23	-0.80	-0.76	-2.09	-2.25
Investment costs	Difference to typical NZEB	€/m²	-	-65	-32	-18	-5	26

3.4.3. Energy prices

The assumed evolvement of the energy prices from 2018 to 2030 is described in chapter 2.2. For Slovenia the predicted changes are:

Table 58: Predicted changes for the Slovenian energy prices from 2018 to 2030

Energy source	Energy prices	
	2018	2030
Grid electricity	0.15	0.154
PV generated electricity fed into grid	n/a *	n/a *
District heating	0.065	0.053
Gas	0.05	0.054

* In Slovenia the feed into the grid system is not an option anymore; the green electricity prices are defined by individual contracts, at a building level the principle of regulations on self-supply of electricity from renewable energy sources is used.

The impact on the calculated results for the different variants (typical NZEB, NZEB solution sets and building beyond NZEB) is as follows. For details see Table 59.

Changes at the energy prices do not affect energy uses and investment costs, however they have obviously significant impact on the energy costs and therefore the payback times of the investments. Taking into account the predicted general energy price increase for each energy source, the highest energy price change in 2030 applies for district heating, whose price will be reduced by 1.15 cents/kWh. On the other hand, gas and electricity both increase by approximately 0.42 cents/kWh.

The above mentioned price changes for the different energy sources can be seen in Table 58. The solution with the highest energy costs change is SI-SS1, which uses district heating as generation for heating and DHW, namely the energy costs are reduced by 0.68 €/m^{2}yr. In comparison to the typical NZEB the SI-SS1 switches from having higher energy costs to having lower energy costs. This result was expected, since district heating has the highest predicted energy price change. The lowest energy costs increase has SI-SS2, where energy costs increase only for 0.06 €/m^{2}yr. In case of SI-SS4 and beyond NZEB, which both use the combination of air heat pump and PV system, the energy costs are reduced by a similar amount, approximately 0.20 €/m^{2}yr. SI-SS3 uses the same energy sources as the typical NZEB, however the energy costs increase is lower, since SI-SS3 has a better thermal envelope and a lower energy use. Looking at the Table 59, it can be concluded, that with the predicted changes in energy prices the solution sets SI-SS1, SI-SS2 and SI-SS3 increase their savings in comparison to the typical NZEB, while SI-SS4 and the beyond NZEB become slightly less cost-efficient.

Primary beneficiary of changes in energy prices:

- SI-SS1: use of district heating

Table 59: Comparison of the Slovenian energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the energy prices.

Solution set results summary Specific values relate to the conditioned net floor area of the building			Slovenian NZEB solution sets					Beyond NZEB
			Typical NZEB (base case)	SI - SS1	SI-SS2	SI-SS3	SI-SS4	
			Heat supply: gas condensing boiler; solar collectors for DHW; use of hygro-sensitive ventilation system; double-glazed windows	District heating as generation for heating and DHW; use of mechanical ventilation with 85% heat recovery; better airtightness	Air heat pump as generation for heating and DHW; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness	Air heat pump as generation for DHW; gas condensing boiler for heating; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness	Air heat pump as generation for heating and DHW; roof PV panels; use of hygro-sensitive mechanical ventilation; triple-glazed windows; better airtightness	Air heat pump as generation for heating and DHW; roof PV panels; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness
Building envelope	Specific coefficient of trans-mission thermal losses H'_T	W/m²K	0.413	0.413	0.333	0.333	0.333	0.333
Net energy	Total	kWh/(m²yr)	40.1	31.5	27.5	27.5	35.7	27.5
Final energy	Total EPBD	kWh/(m²yr)	49.0	40.8	35.0	35.6	43.0	34.6
Primary energy	Total EPBD	kWh/(m²yr)	44.3	59.9	39.9	43.1	3.4	0.2
Energy costs	Total EPBD	€/(m²yr)	3.19 -> 3.32	3.42 -> 2.73	2.39 -> 2.45	2.43 -> 2.53	1.10 -> 1.28	0.94 -> 1.15
	Difference to typical NZEB	€/(m²yr)	-	0.23 -> -0.58	-0.80 -> -0.86	-0.76 -> -0.79	-2.09 -> -2.04	-2.25 -> -2.16
Investment costs	Difference to typical NZEB	€/m²	-	-65	-32	-18	-5	26

3.4.4. Technology costs

The assumed evolvement of the technology costs from 2018 to 2030 is described in chapter 2.3. For Slovenia the predicted changes are:

Table 60: Predicted changes for the Slovenian technology costs from 2018 to 2030

Technologies	Technology costs	
	2018	2030
PV systems	250 €/m²	250 €/m² * 0.75 = 187.5 €/m²
Heat Pumps	SI-SS2, SI-SS4, beyond NZEB: 50 kW: 33,500 € SI-SS3: 30 kW: 27,500 €	 33,500 € * 0.9 = 30,150 € 27,500 € * 0.9 = 24,750 €

The impact on the calculated results for the different variants (typical NZEB, NZEB solution sets and building beyond NZEB) is as follows. For details see Table 61.

The presumed main reductions at the technology costs in 2030 are predicted for PV systems and heat pumps, thus only solution sets including one or both technologies can profit. Since SI-SS2 and SI-SS3 use heat pump for DHW and/or heating but no PV, they show a small reduction in the investment costs of approximately 2 €/m² in 2030. Solution sets SI-SS4 and beyond NZEB use heat pumps and a larger area of PV, which results in a higher reduction of investment costs of 10 €/m² in 2030, mainly due to the predicted noticeable reduction of PV investment costs. However, the investment costs of the beyond NZEB are still 16 €/m² higher than those of the typical NZEB.

Primary beneficiary of changes in technology costs:

- SI-SS4 and beyond NZEB (heat pump and PV system)

Table 61: **Comparison of the Slovenian energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the technology costs.**

Solution set results summary Specific values relate to the conditioned net floor area of the building			Slovenian NZEB solution sets					Beyond NZEB
			Typical NZEB (base case)	SI - SS1	SI-SS2	SI-SS3	SI-SS4	
			Heat supply: gas condensing boiler; solar collectors for DHW; use of hygro-sensitive ventilation system; double-glazed windows	District heating as generation for heating and DHW; use of mechanical ventilation with 85% heat recovery; better airtightness	Air heat pump as generation for heating and DHW; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness	Air heat pump as generation for DHW; gas condensing boiler for heating; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness	Air heat pump as generation for heating and DHW; roof PV panels; use of hygro-sensitive mechanical ventilation; triple-glazed windows; better airtightness	Air heat pump as generation for heating and DHW; roof PV panels; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness
Building envelope	Specific coefficient of trans-mission thermal losses H'_T	W/m²K	0.413	0.413	0.333	0.333	0.333	0.333
Net energy	Total	kWh/(m²yr)	40.1	31.5	27.5	27.5	35.7	27.5
Final energy	Total EPBD	kWh/(m²yr)	49.0	40.8	35.0	35.6	43.0	34.6
Primary energy	Total EPBD	kWh/(m²yr)	44.3	59.9	39.9	43.1	3.4	0.2
Energy costs	Total EPBD	€/(m²yr)	3.19	3.42	2.39	2.43	1.10	0.94
	Difference to typical NZEB	€/(m²yr)	-	0.23	-0.80	-0.76	-2.09	-2.25
Investment costs	Difference to typical NZEB	€/m²	-	-65 -> -65	-32 -> -34	-18 -> -20	-5 -> -15	26 -> 16

3.4.5. Technology efficiencies

The assumed evolvement of the technology efficiencies from 2018 to 2030 is described in chapter 2.4. For Slovenia the predicted changes are:

Table 62: Predicted changes for the Slovenian technology efficiencies from 2018 to 2030

Technologies	Technology efficiencies	
	2018	2030
Heat pumps (COP)	3.4	3.74
PV roof systems (efficiency)	η = 12 %	η = 14 %
District heating (efficiency)	η = 80 %	η = 95 %

The impact on the calculated results for the different variants (typical NZEB, NZEB solution sets and building beyond NZEB) is as follows. For details see Table 63.

The highest increase of technology efficiency in 2030 is predicted for district heating, thus in SI-SS1 the highest decrease of final and primary energy use can be noted. To be specific the final energy use is reduced by 6.52 kWh/m^{2}yr, while the primary energy use is reduced by 7.17 kWh/m^{2}yr. Consequently, energy cost are lower by 0.42 €/m^{2}yr in comparison with 2018. The lowest difference in energy costs and in final and primary energy use have SI-SS2 and SI-SS3, since they use heat pumps, for which the lowest increase of efficiency in 2030 is predicted. The final energy for these two solution sets reduces between 0.42 and 0.67 kWh/m^{2}yr, while the primary energy use is reduced by between 1 and 1.67 kWh/m^{2}yr. The energy costs also don't change significantly, they are reduced by between 0.06 and 0.1 €/m^{2}yr. SI-SS4 and beyond NZEB use the combination of heat pump and PV system, which also leads to a significant decrease in primary energy and as well in energy costs. The primary energy of SI-SS4 is predicted to be reduced to 0 kWh/m^2, while the beyond NZEB has already been self-sufficient. In both cases, energy costs are reduced by approximately 0.6 €/m^2, mainly due to the higher efficiency of the PV system.

Primary beneficiary of changes in technology efficiencies:

- SI-SS1 (district heating)

Table 63: **Comparison of the Slovenian energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the technology efficiencies.**

Solution set results summary Specific values relate to the conditioned net floor area of the building			Slovenian NZEB solution sets					Beyond NZEB
			Typical NZEB (base case)	SI - SS1	SI-SS2	SI-SS3	SI-SS4	
			Heat supply: gas condensing boiler; solar collectors for DHW; use of hygro-sensitive ventilation system; double-glazed windows	District heating as generation for heating and DHW; use of mechanical ventilation with 85% heat recovery; better airtightness	Air heat pump as generation for heating and DHW; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness	Air heat pump as generation for DHW; gas condensing boiler for heating; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness	Air heat pump as generation for heating and DHW; roof PV panels; use of hygro-sensitive mechanical ventilation; triple-glazed windows; better airtightness	Air heat pump as generation for heating and DHW; roof PV panels; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness
Building envelope	Specific coefficient of trans-mission thermal losses H'_T	W/m²K	0.413	0.413	0.333	0.333	0.333	0.333
Net energy	Total	kWh/(m²yr)	40.1	31.5	27.5	27.5	35.7	27.5
Final energy	Total EPBD	kWh/(m²yr)	49.0 -> 49.0	40.8 -> 34.3	35.0 -> 34.3	35.6 -> 35.2	43.0 -> 38.8	34.6 -> 30.7
Primary energy	Total EPBD	kWh/(m²yr)	44.3 -> 44.3	59.9 -> 52.7	39.9 -> 38.2	43.1 -> 42.0	3.4 -> 0	0.2 -> 0
Energy costs	Total EPBD	€/(m²yr)	3.19 -> 3.19	3.42 -> 3.00	2.39 -> 2.28	2.43 -> 2.36	1.10 -> 0.48	0.94 -> 0.35
	Difference to typical NZEB	€/(m²yr)	-	0.23 -> -0.18	-0.80 -> -0.90	-0.76 -> -0.82	-2.09 -> -2.22	-2.25 -> -2.35
Investment costs	Difference to typical NZEB	€/m²	-	-65	-32	-18	-5	26

3.4.6. Other possible impact factors

Assessment methods for the energy performance of buildings

It can be presumed that there will be changes in the national assessment methods as it is described in chapter 2.5.1. In Slovenia changes in the current Rules on efficient use of energy in buildings with a technical guideline [13] will presumably be made, which will probably also have influence on the NZEB level and technologies currently used. Besides, a technical study in collaboration with the Ministry of Infrastructure has been made, where influences of different factors on achieving the NZEB level have been analysed. However, currently it is not possible to pre-assess these changes more detailed in this report.

Climate change

In Figure 5, the comparison between the monthly mean air temperatures in Ljubljana is presented for 2018 and 2030. The weather data for 2030 is taken from [32]. It can be seen that the temperatures in the autumn and winter periods will presumably rise, while in spring and early summer months they will be lower. Consequently, it can be assumed that no additional cooling energy and thermal comfort conditions can be expected. In contrast, the predicted increase of the temperatures in the autumn and winter months will lead to the reduced heating energy. The mentioned changes of temperatures in the heating season can have a noticeable impact on the energy performance and heating costs. However the impact can't be assessed in detail for this report.

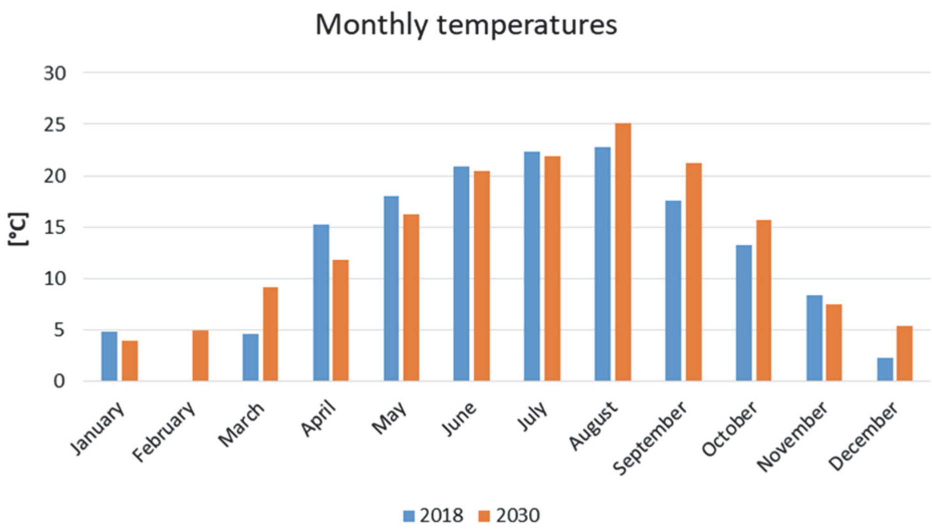


Figure 5: Monthly mean air temperatures in Ljubljana for 2018 and 2030.

Financial support programmes

In Slovenia, there are currently financial support programmes, but as explained in chapter 2.5.3, it is impossible to predict financial support programmes for 2030. Therefore their impact on the solution sets are not analysed in this report.

3.4.7. Combination of changes in the evolving factors

In addition to the individual impact assessments of chapters 3.2.2 to 3.2.5 the combination of the evolving factors

- primary energy factors,
- energy prices,
- technology costs and
- technology efficiencies

are assessed within this chapter. The individual impacts can't simply be added as some of them are interlinked and influence the same energy and cost characteristics. Note: The climate change impact is not part of this combined assessment. The results of the assessment are included in Table 64.

The combination of changes in the evolving factors allows have a look at all impacts and to evaluate them. The predicted improvements of the technology efficiencies helped to reduce the final and the primary energy use and to change the energy costs. The primary energy use of all solution sets was calculated using the predicted lower electric and district heating primary energy factors. Together with the predicted improvements of the technology efficiencies, the reduced primary energy factors lead to lower primary energy uses in all solution sets. Despite the rise of the electrical energy and district heating prices, due to the combination of better technology efficiencies, all solutions sets have lower energy costs. The highest change in energy costs is noted for SI-SS1, where district heating is used, for which a quite high decrease of the energy price is predicted and on the other hand the highest technology efficiency increase. Thus the energy costs in SI-SS1 switch from being 0.23 €/m^{2}yr higher to being 0.99 €/m^{2}yr lower in comparison to the typical NZEB. This indicates how important technology efficiency improvements for the building performance are, besides lower energy prices. The predicted lower technology costs helped to reduce the investment costs, which is described in chapter 3.4.4.

The beyond NZEB, SI-SS4 (both with air heat pump and PV panels) and SI-SS1 (district heating) are the primary beneficiaries of the combined changes in the evolving factors. Namely, the final energy use at the beyond NZEB is reduced by 12%, while the primary energy doesn't change, since it is already 0 kWh/m^{2}yr in 2018. It is similar for SI-SS1, where the final energy drops by about 16%; but here the primary energy is also approximately 22% lower. In all cases energy costs reduce significantly, approximately 33% for SI-SS1, and 40% for the beyond NZEB. However, the difference is in the investment costs where for SI-SS1 no reductions are predicted, while the investment cost of the beyond NZEB are reduced by approximately 60% compared to the typical NZEB. For SI-SS4 the situation is very similar to the beyond NZEB level; it also uses the combination of the heat pump and PV system.

Primary beneficiary of the combined changes in the evolving factors:

- beyond NZEB, SI-SS4 (both with air heat pump and PV panels) and SI-SS1 (district heating)

Table 64: **Comparison of the Slovenian energy and cost results of the different building energy concepts calculated for 2018 and 2030 (marked in green) based on changes at the primary energy factors, energy prices, technology costs and technology efficiencies.**

Solution set results summary Specific values relate to the conditioned net floor area of the building			Slovenian NZEB solution sets					Beyond NZEB
			Typical NZEB (base case)	SI - SS1	SI-SS2	SI-SS3	SI-SS4	
			Heat supply: gas condensing boiler; solar collectors for DHW; use of hygro-sensitive ventilation system; double-glazed windows	District heating as generation for heating and DHW; use of mechanical ventilation with 85% heat recovery; better airtightness	Air heat pump as generation for heating and DHW; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness	Air heat pump as generation for DHW; gas condensing boiler for heating; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness	Air heat pump as generation for heating and DHW; roof PV panels; use of hygro-sensitive mechanical ventilation; triple-glazed windows; better airtightness	Air heat pump as generation for heating and DHW; roof PV panels; use of mechanical ventilation with 85% heat recovery; triple-glazed windows; better airtightness
Building envelope	Specific coefficient of trans-mission thermal losses H'_T	W/m²K	0.413	0.413	0.333	0.333	0.333	0.333
Net energy	Total	kWh/(m²yr)	40.1	31.5	27.5	27.5	35.7	27.5
Final energy	Total EPBD	kWh/(m²yr)	49.0 -> 49.0	40.8 -> 34.3	35.0 -> 34.3	35.6 -> 35.2	43.0 -> 38.8	34.6 -> 30.7
Primary energy	Total EPBD	kWh/(m²yr)	44.3 -> 42.0	59.9 -> 46.9	39.9 -> 33.4	43.1 -> 38.1	3.4 -> 0	0 -> 0
Energy costs	Total EPBD	€/(m²yr)	3.19 -> 3.32	3.42 -> 2.31	2.39 -> 2.34	2.43 -> 2.46	1.10 -> 0.66	0.94 -> 0.56
	Difference to typical NZEB	€/(m²yr)	-	0.23 -> -0.99	-0.80 -> -0.96	-0.76 -> -0.85	-2.09 -> -2.17	-2.25 -> -2.26
Investment costs	Difference to typical NZEB	€/m²	-	-65 -> -65	-32 -> -34	-18 -> -20	-5 -> -15	26 -> 16

3.4.8. Summary for the Slovenian situation

In this chapter, the summary of the impact on Slovenian solution sets for the following evolving factors is presented:

- primary energy factors,
- energy prices,
- technology costs and
- technology efficiencies.

It is expected and predicted that the primary energy factors for electricity and district heating will decrease. Presumably, the electricity primary energy factor in 2030 will be 2.2, while the district heating will decrease from 1.0 - 1.2 to 0.95 - 1.1 (or more, i.e. to 0.1 in case of biomass district heating), depending on whether it is based on a cogeneration system or not. The primary energy in the solution sets using district heating besides electricity, reduces significantly.

The predicted energy price increase of gas and electricity in 2030 will cause an increase of the annual energy costs for solutions that use these two energy sources. On the other hand, the district heating price is predicted to be lower in 2030, which leads to lower energy costs in solution set SI-SS1 that uses district heating for DHW and heating, which is also the solution whose energy costs per year decrease the most (about 20%).

However, energy prices aren't the only factor that have an impact on the energy costs. A very important role has also the improvement of the technology efficiency. The predicted improvement of the technology efficiency significantly reduces the energy costs as well as the final and primary energy use. The improvement of the technology efficiency has the biggest impact on SI-SS1, where a 15% better efficiency of the district heating is predicted. Besides SI-SS1, also SI-SS4 and the beyond NZEB (both with air heat pump and PV panels) result in significant reductions in the mentioned result characteristics, due to improved technology efficiency.

The reduction of technology costs impacts only the investment costs of the solutions. Since it is expected that the costs of air heat pumps and PV systems will reduce in 2030, SI-SS2 (air heat pump for heating and DHW), SI-SS3 (air heat pump for DHW, gas condensing boiler for heating), SI-SS4 (air heat pump for heating and DHW and PV) and beyond NZEB (also air heat pump for heating and DHW and PV) will have lower investment costs. The listed solution sets all use air heat pumps, while the SI-SS4 and beyond NZEB also include PV systems, which is the reason for the highest investment costs decrease in these two solution sets.

The primary beneficiaries of combined changes in the evolving factors are the beyond NZEB (air heat pump for heating and DHW, decentral ventilation system with 85% heat recovery and PV) SI-SS4 (air heat pump for heating and DHW, hygro-sensitive ventilation and PV) and

SI-SS1 (district heating for DHW and heating, decentral ventilation system with 85% heat recovery), mostly due to the improvement of the technology efficiencies and the reduction of technology costs, which in the case of SI-SS4 and beyond NZEB is reduced by approximately 60% compared to the typical NZEB.

4. Executive Summary

The main goal of the EU Horizon 2020 project CoNZEBs was to identify technology combinations for multi-family houses that fulfil the Nearly Zero-Energy Building (NZEB) requirements but result in lower investment costs if compared to the typical (mainstream) NZEB technology combinations. The national CoNZEBs teams from Germany, Denmark, Italy and Slovenia were successful in finding at least four alternative technology combinations (aka alternative NZEB solution sets) per country. These solution sets and many of the contained innovative technologies are described in detail in a report [1] available on the project website. In a second step the NZEB solution sets and a technology combination achieving a building energy level beyond NZEB (zero energy building or plus energy building) have been assessed in comparison to the typical NZEB and a building fulfilling the national minimum energy performance requirements regarding life-cycle costs and life-cycle impact [28].

This report now seeks to look ahead into future developments of certain factors that have an impact on the energy performance, investment costs or energy costs of the determined solution sets. The relevant impact factors are primary energy factors, energy prices, technology costs and technology efficiencies. For each of these impact factors the developments by the year 2030 were predicted, based on available national studies or where not available based on the personal evaluation of the project partners. With the updated impact factors new energy and cost results were calculated and compared to the original results with the status 2018. This allowed for a basic identification of the “future-proof” alternative solution sets that will stay or become more financially attractive in the next approximately 10 years.

In addition, the impact of climate change, further developments in the national building energy performance assessment methods and possible financial support programmes were discussed.

The typical multi-family houses, the mainstream NZEB technology combinations and based on that also the alternative NZEB solution set as well as the beyond NZEB level differ among the four countries due to different building culture, different energy performance requirements, different climate, different technology costs, etc. Therefore the gained national results and insights of one country can't be directly transferred to the three other countries. One example for the differences is that the typical NZEB technology combination, the starting point to the assessments, is for:

- Germany: Central combined heating and DHW system with a gas condensing boiler and solar thermal collectors, central exhaust ventilation system, high building envelope insulation level
- Denmark: Central combined heating and DHW system by district heating, balanced mechanical ventilation system with 90% heat recovery, high building envelope insulation level.
- Italy: Air-to-water heat pump for heating, gas condensing boiler for DHW, PV panels and solar collectors, natural ventilation and different building envelope insulation levels for Rome and Turin
- Slovenia: Central combined heating and DHW system with a gas condensing boiler and solar thermal collectors, hygro-sensitive ventilation system

Some of the national alternative solution sets are based on singular changes (e.g. different insulation material) while others contain combinations of different heating and ventilation systems with accordingly adapted insulation levels of the building envelope. This includes solution sets with electrical heat pumps or direct electrical heating, both in combination with a PV system. Therefore it is challenging to identify the "most future-proof" solution set across all the involved four countries.

However there are two conclusions valid for all four countries:

- The building energy performance level beyond NZEB becomes financially more attractive when taking the changes at the impact factors in 2030 into account. Payback times for the additional investment costs in comparison to the typical NZEB get smaller, due to comparably lower technology costs for mainly heat pumps and PV systems and still rising technology efficiencies.
- Alternative NZEB solution sets with electrical heat pumps or (where allowed) direct electrical heating systems, both in combination with PV arrays, benefit from the changes at the considered impact parameters in the year 2030 if compared to the typical NZEB solutions.

In addition the following main national conclusions can be drawn:

- The German alternative NZEB solution set with a combination of an exhaust air-to-water heat pump and a gas condensing boiler plus small PV array keeps in 2030 the comparably low energy costs and benefits from efficiency improvements at the heat pump and the PV system.

- In Denmark, with district heating as typical heating and DHW generation system, the PV - heat pump combination seems to have the possibility of becoming an important player in the future energy supply system
- The Italian analysis resulted in slightly different conclusions for the two climate zones:
  - Rome: The best results are achieved by the NZEB solution set with a heat pump for both heating and DHW.
  - Turin: The primary beneficiary of the combination of the evolving factors is the beyond NZEB solution featuring a heat pump, PV, mechanical ventilation with heat recovery and high performance building envelope.
- For Slovenia, due to predicted reduced energy costs and increased efficiency for district heating by 2030, the alternative NZEB solution set with district heating as generation system for heating and DHW becomes more attractive.

5. References

[1] Wittchen, K. B.; Engelund Thomsen, K. et al: Solution sets and technologies for NZEBs. Report of the EU Horizon 2020 project CoNZEBs (GA-No. 754046), deliverable D5.1, 2018/2019. Available at https://www.conzebs.eu/images/D5.1_Solution%20sets%20and%20Technologies%20in%20NZEBs%20-%20FinalVersion.pdf.

[2] CoNZEBs: Solution sets for the cost reduction of new Nearly Zero-Energy Buildings. Website of the EU Horizon 2020 project CoNZEBs (GA-No. 754046). www.conzebs.eu

[3] Bundesinstitut für Bau-, Stadt- und Raumforschung: Verordnung über energiesparenden Wärmeschutz und energiesparende Anlagentechnik bei Gebäuden (Energieeinsparverordnung – EnEV), nichtamtliche Lesefassung, Stand 28. Oktober 2015 (in German). Available at https://www.bbsr-energieeinsparung.de/EnEVPortal/DE/EnEV/EnEV2013/Download/Lesefassung_EnEV2013.pdf?__blob=publicationFile&v=11.

[4] Beuth Verlag: DIN V 18599-1:2018-09. Energetische Bewertung von Gebäuden - Berechnung des Nutz-, End- und Primärenergiebedarfs für Heizung, Kühlung, Lüftung, Trinkwarmwasser und Beleuchtung - Teil 1: Allgemeine Bilanzierungsverfahren, Begriffe, Zonierung und Bewertung der Energieträger. 2018 (in German and English). Available at https://www.beuth.de/de/vornorm/din-v-18599-1/293515783.

[5] IINAS: GEMIS – Globales Emissins-Modell integrierter Systeme. GEMIS Berichte & Dokumente (in German). Available at http://iinas.org/gemis-dokumente.html.

[6] Fritsche, U., Greß, H.: Der nichterneuerbare kumulierte Energieverbrauch und THG-Emissionen des deutschen Strommix im Jahr 2016 sowie Ausblicke auf 2020 bis 2050.

[The non-renewable cumulated energy use and greenhouse gas emission of the German electricity mix in the year 2016 and prospects to 2020 up to 2050]. IINAS Kurzstudie. 2018 (in German). Available at http://iinas.org/tl_files/iinas/downloads/GEMIS/2014_KEV-Strom-2013_HEA.pdf

[7] Danish Building Regulations 2018. Executive Order No. 1615 of 13 Dec. 2017 (in force). Ministry of Transport, Building and Housing, Transport, Building and Housing Agency, http://bygningsreglementet.dk/

[8] Schrade, J.; Erhorn, H.: Energie- und Klimaschutzkonzept des Landes Baden-Württemberg für landeseigene Gebäude. Report of the Fraunhofer Institute for Building Physics WB 207/2018. Stuttgart, 2018 (in German).

[9] Aggerholm S.: Energy factors used in energy calculations (in Danish). SBi 2017:04. Danish Building Research Institute, Aalborg University, Copenhagen.

[10] Ministry of Environment and Spatial Planning, GI ZRMK and Univ of Ljubljana - Fac. of Mech. Eng.: Technical guidelines for revision of Regulation on energy efficiency of buildings. 2016.

[11] LIFE Climate Path 2050 Project (2018-2019 ongoing). Information available at http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=6308 and https://www.podnebnapot2050.si.

[12] European Standard EN /ISO 52000-1:2017 - Energy performance of buildings – Overarching EPB assessment – Part 1: General framework and procedures.

[13] PURES: Pravilnik o učinkoviti rabi energije v stavbah [Rules on efficient use of energy in buildings with a technical guideline]. Available at http://www.pisrs.si/Pis.web/pregledPredpisa?id=PRAV10043

[14] Schlesinger, M. et al.: Energieszenarien für ein Energiekonzept der Bundesregierung. Report of ewi, gws and prognos. 2010 (in German). Available at https://www.prognos.com/uploads/tx_atwpubdb/100827_Prognos_Studie__Energieszenarien_fuer_ein_energiekonzept_der_Bundesregierung.pdf

[15] Umweltbundesamt: Methodenkonvention 3.0 zur Ermittlung von Umweltkosten. 2018 (in German). Available at https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-02-11_methodenkonvention-3-0_kostensaetze_korr.pdf

[16] Cost-optimal levels of minimum energy performance requirements in the Danish Building Regulations, Søren Aggerholm, SBi 2018:13. Danish Building Research Institute, Aalborg University · 2018. ISBN: 978-87-563-1911-9.

[17] Slovenian cost optimal study. Available at https://ec.europa.eu/energy/en/content/eu-countries-2018-cost-optimal-reports

[18] Capros, P. et al.: EU Reference Scenario 2016, Energy, transport and GHG emissions: Trends to 2050. Report of the European Commission, 2016. Available at https://ec.europa.eu/energy/sites/ener/files/documents/20160713%20draft_publication_REF2016_v13.pdf

[19] Forudsætninger for samfundsøkonomiske analyser på energiområdet (In Danish) [Assumptions for socio-economic analyses in the energy sector]. Danish Energy Agency, September, 2017.

[20] Nye emissionsfaktorer for el og fjernvarme (In Danish) [New emission factors for electricity and district heating]. COWI consulting engineers for Danish Transport and Construction Agency, 2016.

[21] Wirth, H.: Aktuelle Fakten zur Photovoltaik in Deutschland [Latest facts about photovoltaics in Germany]. Report of Fraunhofer ISE, 2018 (in German). Available at https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/aktuelle-fakten-zur-photovoltaik-in-deutschland.pdf.

[22] Technology catalogues (in Danish). https://ens.dk/service/fremskrivninger-analyser-modeller/teknologikataloger

[23] Slovenian National Energy and Climate Plan (in Slovenian). Available at https://www.energetika-portal.si/fileadmin/dokumenti/publikacije/nepn/dokumenti/nepn_osnutek_avg_2019.pdf

[24] Vartiainen, E., Masson, G., Breyer, C.: PV LCOE in Europe 2014-2030. Technical report of the European PV Technology Platform. July 2015. Available at https://www.researchgate.net/publication/279866989_PV_LCOE_in_Europe_2014-30.

[25] Hecking, H.; Hintermeyer, M., Lencz, D.; Wagner, J.: Energiemarkt 2030 und 2050 – Der Beitrag von Gas- und Wärmeinfrastruktur zu einer effizienten CO_2-Minderung. Final report of ewi Energy Research & Scenarios gGmbH. November 2017 (in German). Available at www.ewi.research-scenarios.de/cms/wp-content/uploads/2017/11/ewi_ERS_Energiemarkt_2030_2050.pdf.

[26] Elektronický kontraktačný systém: Koncept trajnostne, zanesljive in konkurenčne oskrbe z energijo v prihodnosti. [The concept of a sustainable, reliable and competitive energy supply in the future]. Website available at https://www.eks.si

[27] Koch, M. et al.: BWP-Branchenstudie 2015. Szenarien und politische Handlungs-empfehlungen. Daten zum Wärmepumpenmarkt bis 2015 und Prognosen bis 2030. 2016 (in German). Available at www.waermepumpe.de/fileadmin/user_upload/waermepumpe/07_Publikationen/2016-04-08_Branchenprognose_2015_web.pdf.

[28] Sanchez Mayoral Gutierrez, M. et al.: Life cycle assessment of typical multi-family houses with different energy performance levels. Report of the EU Horizon 2020 project CoNZEBs GA-No. 754046), deliverable D7.1. 2019. Available at https://www.conzebs.eu/index.php/life-cycle-assessment.

[29] Erhorn, H.; Bergmann, A.: What makes an Efficiency House Plus? Brochure of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). Available at

https://www.forschungsinitiative.de/fileadmin/user_upload/Forschung/Effizienzhaus_Plus/Forschung/Broschuere_Wege-zum-EHP_engl_Auflage_3_2018-08.pdf

[30] DM 26 giugno 2015: Application of calculation methodologies for energy performance and definition of prescription and minimum requirements of buildings. 2015.

[31] Dlsg 28/2011: Implementation of Directive 2009/28/CE on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, 2011.

[32] Jacob, D; Kotova, L.: High-resolution datasets for the different IPCC scenarios for selected Case Study areas as input data for hygrothermal building simulation and complete high resolution dataset over entire Europe. Report of EU 7FP Climate for Culture (GA-No.: 226973). December 2013.

[33] Republika Slovenija, Ministrstvo za Infrastrukturo: Akcijski načrt za skoraj nič-energijske stavbe za obdobje do leta 2020 (AN sNES). [Action Plan for Nearly Zero-Energy Buildings]. Available at https://ec.europa.eu/energy/sites/ener/files/documents/slovenia_adopted_2015.pdf