# Why **Nearly Zero Energy Buildings** are the Right Choice

Experiences, expectations, and co-benefits of living in NZEBs

CoNZ€BS
Solution sets for the Cost reduction of new Nearly Zero-Energy Buildings


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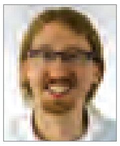
**Authors:**

Marjana Šijanec Zavrl
Marko Jaćimović
Miha Tomšič
Henrik Gjerkeš
Neva Jejčič
www.gi-zrmk.si/en

Mojca Štritof Brus
Damjana Varšek
www.ssrs.si/eng/

Hans Erhorn
Heike Erhorn-Kluttig
Micha Illner
www.ibp.fraunhofer.de

Bernd Utesch
www.abg-fh.com

Kim Wittchen
Kirsten Engelund Thomsen
www.sbi.aau.dk

Ove Mørck
Ole Balslev-Olesen
Miriam Sánchez-Mayoral
www.kubenman.dk

Mikkel Jungshoved
www.bl.dk/in-english

Michele Zinzi
Benedetta Mattoni
www.enea.it/en

Marco Corradi
Simone Gabrielli
Elisa Artioli
www.acer.re.it

# Introduction

The current EU building stock is old and energy inefficient. The latest studies show that buildings are responsible for approximately 40% of the energy consumption and 36% of the $CO_2$ emissions of the EU. Currently, about 35% of the EU buildings are over 50 years old and almost 75% of the building stock is energy inefficient [1]. As such, the building sector has been recognized as the sector that could drastically help in achieving the EU climate and energy targets (20/20/20 by 2020) [2]. In the long term, by increasing building energy efficiency and with a growing share of renewable energy sources (RES) buildings shall also significantly contribute to EU 2050 decarbonisation targets.

Besides the intensive efforts put into energy renovation of existing buildings, the EU is also concentrating on the implementation of advanced energy efficiency requirements for all new buildings. Moreover, Directive 2010/31/EU on the energy performance of buildings (EPBD) requires that by the end of 2020 all new buildings are nearly zero-energy buildings (NZEBs). (By the end of 2018 all new public buildings must be NZEBs) [1].

NZEBs are buildings with a very high energy performance. The low amount of energy that these buildings require comes mostly from renewable sources. In combination, existing technologies related to energy savings, energy efficiency and renewable energies are sufficient to reach the NZEB target. The slightly higher technology costs of early NZEBs are likely to be reduced by 2020 in reaction to more mature markets and larger volumes [3].

Even though in recent years there has been great progress in the field of energy efficient buildings, people still tend to have different views and various concerns regarding NZEBs, very often connected to the investment and maintenance costs. In addition to that, early NZEBs are often associated with a lack of trust among end-users, due to the complexity of systems and end-users' beliefs about various constraints regarding living in NZEBs. Understanding the doubts and fears as well as the benefits for the end-users living in NZEBs may substantially contribute to a better acceptance of high-energy performance buildings before the 2020 deadline and beyond.

The EU Project CoNZEBs (2017-2019) aims at the reduction of the NZEB market penetration barriers by studying in detail the cost-reduction opportunities and by addressing the most common end-users' beliefs and fears about living in NZEBs. The focus of the project is on multi-family houses. Cooperation with research partners with national housing funds enabled good insight into technology solution sets for reducing NZEB costs and into the attitude of current and future end-users to living in NZEBs.

This booklet is based on the survey concerning end-users experiences and expectations regarding NZEBs, which was completed in 2018 in the participating countries of the CoNZEBs project (Germany, Italy, Denmark and Slovenia). It is intended for potential end-users, for those who are already living in multi-family NZEBs and for housing associations to provide information to their tenants regarding the benefits and co-benefits of living in such buildings. Also, the aim of the guide is to contribute to the public acceptance of the importance of reducing the energy use in buildings.

CoNZ€Bs
Solution sets for the Cost reduction of new Nearly Zero-Energy Buildings

[1] https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings
[2] Directive 2010/31/EU of the European Parliament and of the council of 19 May 2010 on the energy performance of buildings
[3] Towards nearly zero-energy buildings – Definition on common principles under the EPBD – https://ec.europa.eu/energy/sites/ener/files/documents/nzeb_full_report.pdf

# **WHAT IS** a Nearly Zero Energy Building (NZEB)

## Key NZEB advantages:

- low energy demand for heating (and cooling),
- high share of renewable energy sources,
- low energy costs,
- low $CO_2$ emissions,
- good thermal comfort and indoor air quality.

The building sector is one of the key sectors to achieve the EU's ambitious climate and energy targets. New buildings will have to comply with high energy performance standards to contribute adequately. Commitment to high energy performance buildings (such as nearly zero energy buildings) is an effective way to foster innovation in energy efficiency and the use of renewable energy sources and therefore achieving a significant reduction of greenhouse gas emissions and energy use, as well as contributing to reduce EU energy import dependency.

According to the Energy Performance of Building Directive (EPBD), EU Member States are to ensure that by 31 December 2020, all new buildings are nearly zero-energy buildings and after 31 December 2018, new buildings occupied and owned by public authorities are to be nearly zero-energy buildings.

A Nearly Zero Energy Building (NZEB) means a building that has a very high energy performance and that consumes very little energy, as determined in accordance with the Energy Performance of Building Directive (EPBD). The nearly zero or very low amount of energy required should be covered to a great extent by energy from renewable sources, including energy from renewable sources generated on-site or nearby [2].

In practice, there are some common technical features and some frequently used technologies applied to NZEBs. The very high energy performance of the NZEB is based on a well-insulated thermal envelope, built without any thermal bridges and ensuring a high level of airtightness. Windows have thermally insulated frames and high quality glazing. Shading is important to reduce and/or prevent cooling needs, especially in warm climates. In many cases NZEBs have a mechanical ventilation system with heat recovery. However, the concrete characteristics of the building components and the technical systems installed in an NZEB are the subject of optimised design, undertaken by skilled architects and engineers, with consideration of the users' needs, location, climatic conditions and the renewable energy available on-site or nearby. Often NZEBs use heat pumps or biomass boilers, solar thermal collectors or they generate electricity by photovoltaic power panels - for their own use and/or for feeding the grid. The use of fossil fuels in NZEBs should be minimized and replaced by renewable energy available in the area. District heating systems either with a significant share of renewables or with high energy performance characteristics are a promising solution for NZEBs in urban areas.

For almost a decade now European countries have studied the technically optimized and economically viable NZEBs. A number of so called "early NZEBs" were built in different climates and following various building traditions; the experiences with these buildings were very useful for end-users, architects, engineers, contractors, technology producers, investors and policy makers. The EU Member States developed detailed national NZEB definitions and integrated them into their national building codes.

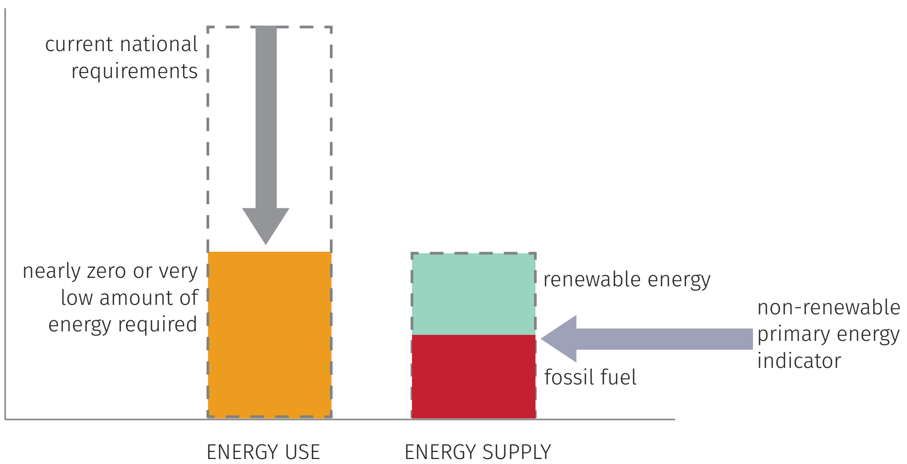



*Figure 1: Graphical interpretation of the NZEB definition according to Articles 2 and 9 of the EPBD [4]*

[4] H. Erhorn, H. Erhorn-Kluttig, Overview of national applications of the Nearly Zero-Energy Building (NZEB) definition, CA EPBD III, 2015

# **ADVANTAGES** of multi-family NZEBs

With better energy efficiency, reduction of energy consumption and the growing use of energy from renewable energy sources (RES), NZEBs bring multiple benefits – for building owners, tenants, the local community, economy and the environment.

Due to low energy needs and the use of renewable energy sources NZEBs help to avoid the risks of irreversible climate change. Alongside climate impact, the newly created NZEB market also has an influence on the transformation of the construction sector and the development of advanced energy efficient and RES technologies, with considerable employment potential across Europe.

Apart from the above benefits, living in NZEBs will have a direct positive impact on flat users due to energy and money savings, good indoor comfort and the eco-image of the end-user.

The list of advantages of living in "NZEBs as rented flats" is even longer in case of NZEBs as owner-occupied flats, as NZEBs can also be considered as a profitable long-term investment, illustrating the building owner's attitude to sustainable living.

Despite the numerous advantages proven in early NZEBs, some end-users are slowly accepting its innovations. This generates a number of common beliefs about NZEBs, sometimes almost myths.

### Advantages for tenants of NZEBs flats:

- low energy/operational costs
- less dependency on increasing energy prices
- improved indoor comfort (thermal/air quality/lower risk of mould)
- less negative environmental impact
- learning about NZEBs and trends
- role model for others, e.g. guests

### Advantages for owners living in NZEBs flats:

- low energy/operational costs
- additional investment quickly pays off
- savings generated over the entire life cycle
- less dependency on increasing energy prices
- higher property value (also in the coming years) including better energy rating performance certificate
- improved indoor comfort (thermal/air quality/lower risk of mould)
- less negative environmental impact
- role model for others, e.g. guests
- possibility to benefit from self-generated RES electricity
- comparable maintenance costs in respect to regular buildings

Pressfoto / Freepik

# Users' **EXPECTATIONS** of their homes

Meeting users' expectations about their homes is an essential success factor in good building design. NZEB is not just about energy and costs, NZEB is also about the quality of life.

Within the CoNZEBs project, a survey of current and potential future NZEB users was performed in order to gain a better insight into home owners' and tenants' opinions and their doubts, fears, preferences and priorities regarding their homes. Altogether the interviews in four participating countries (performed via housing organisations in Germany, Italy, Denmark and Slovenia) covered 293 end-users of which 112 are currently living in an NZEB and 181 are potential future users of NZEBs.

The survey contained a number of common questions intended for residents in multi-family buildings, but with respect to the specifics of the multi-family building sector in these countries, the share of tenants- and owners-used flats and the general experiences with early NZEBs. The participating countries also partially adapted their methodology in collecting this information.

## End-users' knowledge about NZEBs

Despite different terms and definitions of the NZEB in the countries concerned, one can conclude that respondents of CoNZEB's survey from Germany, Italy and Slovenia believe they have reasonable knowledge about NZEBs, meanwhile tenants in Danish social housing showed slightly less interest in the special energy features in this kind of buildings.

## End-users' preferences about their home

The results of the survey indicate that the cost and comfort related benefits (i.e. low energy costs, low energy consumption, good thermal comfort...) are the most important parameters when the end-users evaluate the level of satisfaction with the flat. The expressed preferences about their home are more or less the same for both groups of respondents, i.e. for current users of NZEBs and for potential future NZEB users (Figure 2).

WHAT IS IMPORTANT FOR YOU AS A FLAT USER – CURRENT NZEB USERS

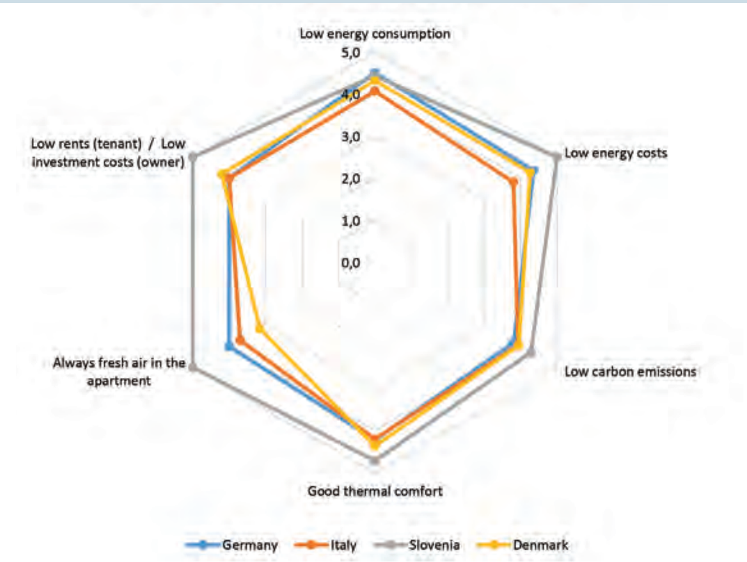



*Figure 2: Parameters that indicate current NZEB users' preferences regarding their flat*

## Concerns and doubts about living in NZEBs

One of the most important parts of the questionnaire addressed respondents' concerns and doubts about living in NZEBs, which are in general connected to:

- the indoor air quality,
- the longevity of technical building systems in NZEBs,
- the user friendliness of control systems and ICT appliances,
- the cost benefit of numerous technologies and their actual usefulness.

The survey proved that some general beliefs and even myths about living NZEBs exist among end-users. In the following pages the CoNZEB project experts dispel common concerns and doubts about NZEBs.

## Decision triggers for moving into an NZEB

In Germany, Slovenia and Italy, the most common decision triggers for moving into an NZEB are connected to comfort and cost related parameters, to incentives (subsidies) for buying an NZEB flat (available in some countries) and comparable prices/rents of flats in NZEBs with those of regular buildings. This indicates that the reduction of NZEB construction costs (also studied in the CoNZEBs project) and consequently reasonable prices and rents can encourage the future growth of interest in NZEBs.

According to the CoNZEBs survey (Figure 3) the most significant motivations for moving into an NZEB in Germany and Italy were "nice, new, modern flat building" and "good thermal comfort", which means that the most important aspects are related to the psycho-physical well-being of a person. In Slovenia, respondents chose »low energy costs« and »good thermal comfort« as the two most important reasons, however, also very important are obviously »good indoor air quality«, »location of the building« and »comparable rents/prices to other flats«.

DECISION TRIGGERS FOR MOVING INTO AN NZEB

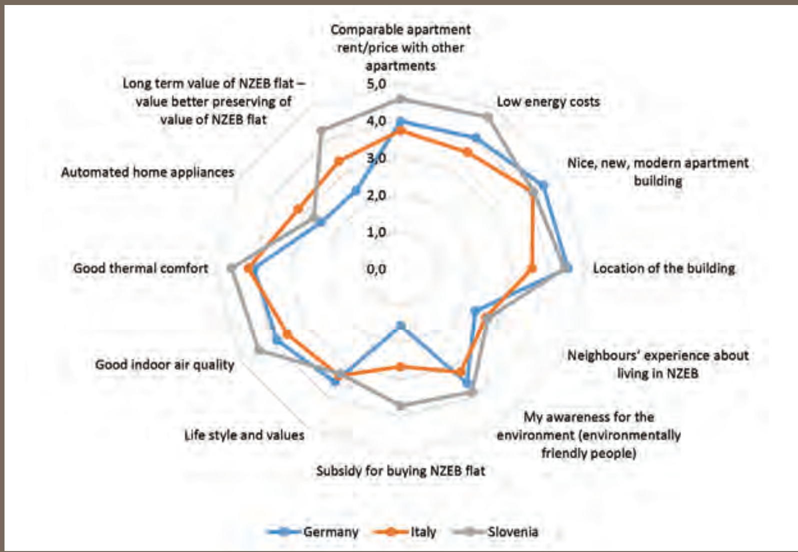



*Figure 3: Comparison of decision triggers for moving into an NZEBs – current users*

## Independent source of information about NZEBs

Most of the respondents rated the quality of the available information about NZEBs quite low, regardless of the source of information. Therefore, reliable and commercially independent information platforms should be established and widely promoted in future, as well as free information events being hosted by independent organizers in order to spread this information, to break the stereotypes regarding NZEBs and to enable further education of the potential future NZEB users.

photo prostooleh / Freepik

## Users' satisfaction with living in NZEBs

The survey shows that the potential future NZEB users are enthusiastic and have great expectations regarding good indoor comfort-related parameters and low energy costs in NZEBs. The attitude and enthusiasm of potential future NZEB users for living in NZEBs can probably be attributed to their current accommodation and perceived imperfections with it. An important conclusion from the Danish answers is that the current NZEB users are happy with living in NZEBs and 84% of them would prefer moving into an NZEB again.

# **INTERESTING FACTS** from CoNZEBs countries

## SLOVENIA

In Slovenia the interesting fact is that respondents mainly chose good airtightness as the technology that defines NZEBs best. This can probably be attributed to the fact that in recent years many end-users changed windows in their apartments and have been informed about the importance of airtightness. It can also be noted that respondents considered, more or less, that all of the technologies listed as important for NZEBs. As a rule, Slovenian end-users associate NZEBs with the use of renewable energy sources. It is frequently understood that NZEBs need photovoltaics (PV) power plants, and not just the other more common RES technologies like heat pumps, biomass boilers and/or solar thermal collectors.

TECHNOLOGIES THAT CHARACTERIZE NZEBS
(5-the most important to 1-the least important)

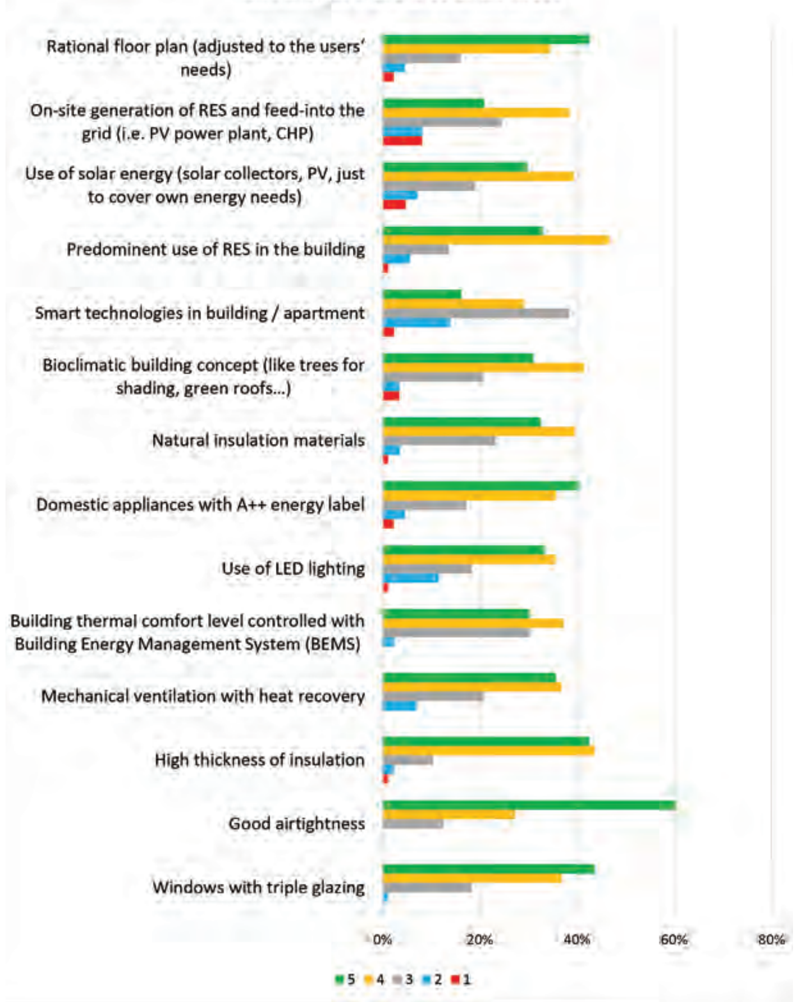



*Figure 4: Technologies characterizing NZEBs – end-user opinions in Slovenia*

## GERMANY

The three most important factors for German apartment users are healthy building materials, low energy consumption and good access to daylight. It has to be mentioned that in the German version of the end-user questionnaire "healthy materials" was translated as "non-hazardous material" which might be the reason why this factor was voted higher in Germany than in the other countries.

WHAT IS IMPORTANT FOR YOU AS AN APARTMENT USER?
(5-the most important to 1-the least important)

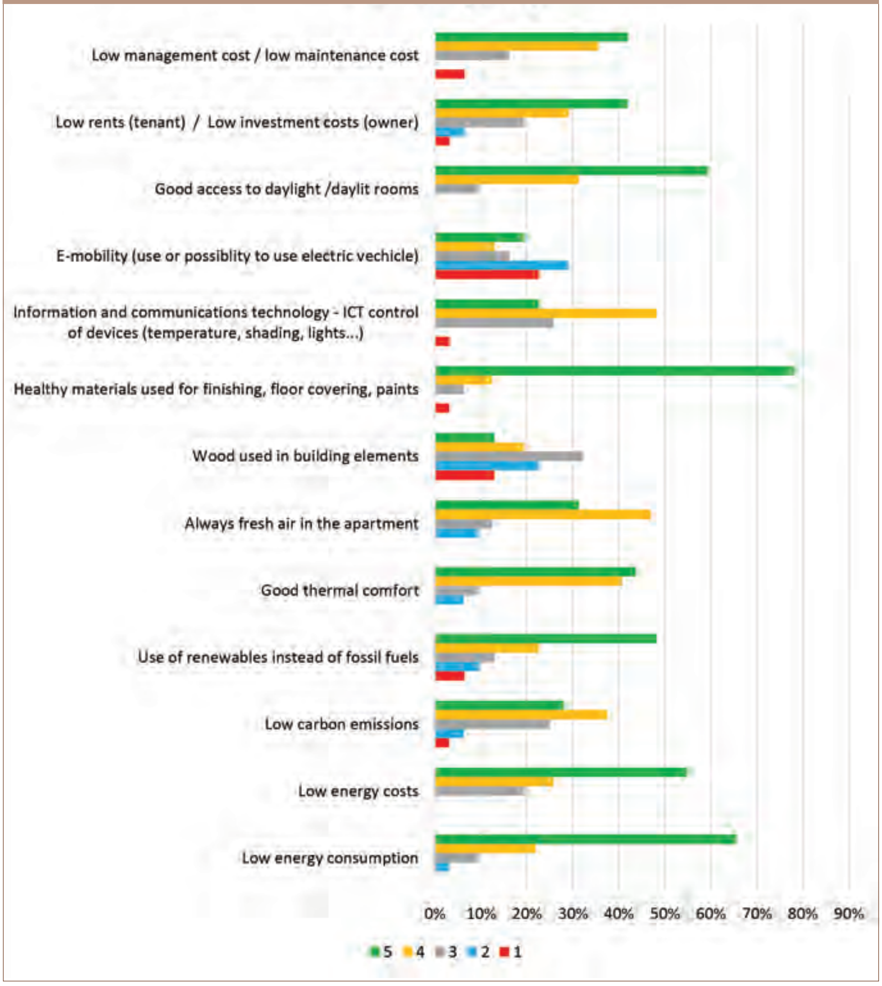



*Figure 5: Importance of NZEB features for current NZEB users in Germany*

## DENMARK

The Danish survey brought a surprising result about users' habits. Namely, all multi-family NZEBs in Denmark are mechanically ventilated due to a requirement of the Danish Building regulations. Despite that, 37% of the residents claim that they open their windows several times each week to ensure fresh air in their flats. And most of the residents (70%) who open the windows leave them open for more than 10 minutes at a time.

HOW OFTEN DO YOU OPEN THE WINDOWS

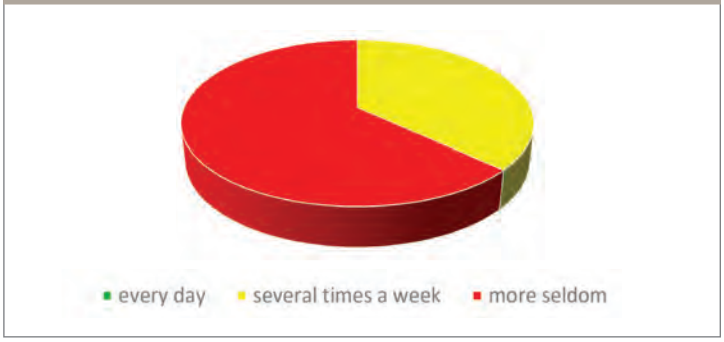



*Figure 6: Residents opening windows in mechanically ventilated multifamily houses (Denmark)*

FOR HOW LONG DO YOU LEAVE THE WINDOWS OPEN

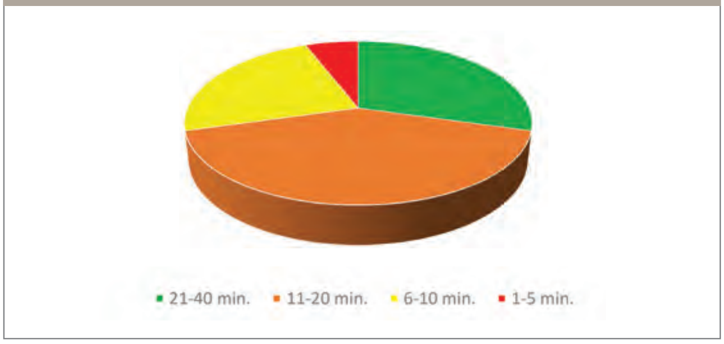



*Figure 7: Duration of residents opening the windows (Denmark)*

## ITALY

In Italy respondents living in NZEBs evaluated technological skills they felt were necessary when using buildings offering high energy performance. Most respondents believe that technological expertise in the optimal use of NZEB buildings is useful, if not necessary. To be specific, one third of NZEB end-users recommend at least a basic knowledge of any technologies installed, while others believe that NZEB buildings can be used without any technological knowledge, however a well-informed user can improve a building's performance.

IS PREVIOUS TECHNICAL KNOWLEDGE NEEDED TO LIVE IN AN NZEB

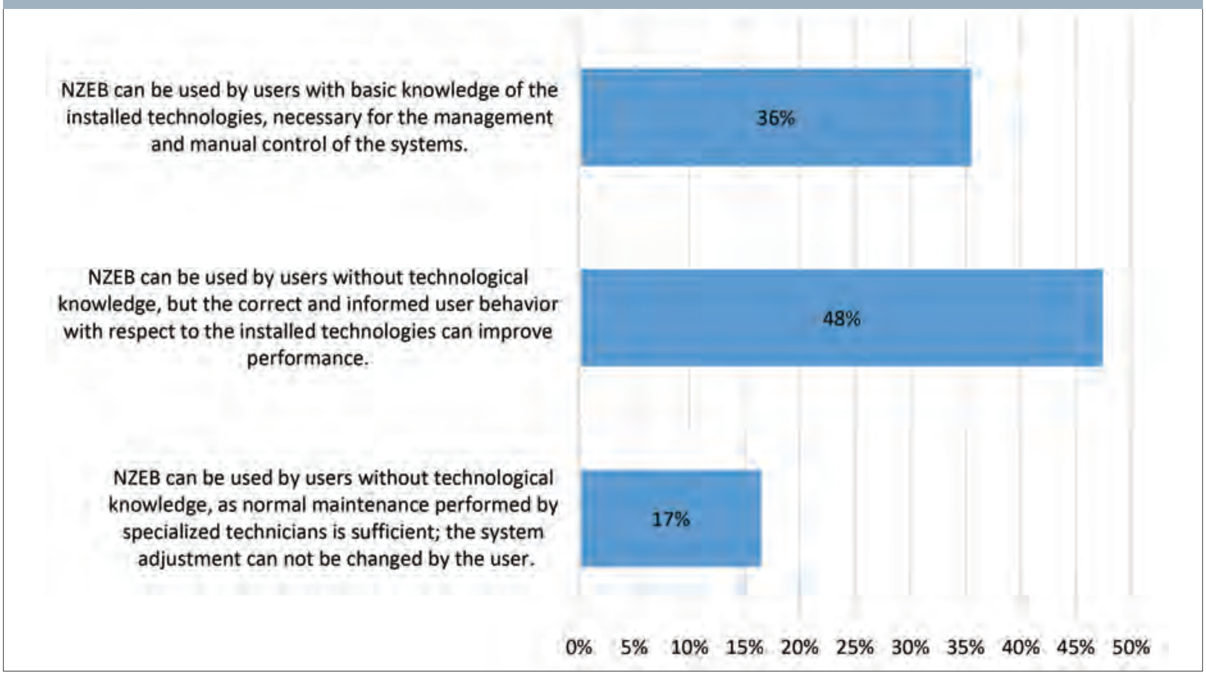



*Figure 8: How vital is previous technical knowledge required to live in an NZEB (Italy)*

# **DISPELLING THE MYTHS** about NZEBs

Woman, 60 years old, living in a conventional 70s apartment building:

*"I am worried about these new airtight buildings. Breathing in stale air is not what I want."*

## An excessively high level of building airtightness may cause a lack of fresh air

There is no such thing as too high level of building airtightness if a building is designed and constructed in such a way that it enables its users to ventilate it according to actual needs – either naturally or mechanically. This should be one of the essential features of any building, not only of NZEBs. Of course, the user must be adequately acquainted with these elements and be aware that a large share of responsibility for comfortable and healthy indoor microclimate lies on him or her. Appropriate airtightness is needed not only to reduce heat losses but also to ensure that systems like mechanical ventilation or air conditioning function with maximum efficiency. Technical regulations, which prescribe minimum levels of ventilation (air change rate in buildings) – also for NZEB compliant design and construction, however, are simply not enough to assure indoor air quality if buildings are used incorrectly.

A building declared as airtight is not literally fully sealed. No matter how carefully we construct it or how advanced materials and products we use for this purpose are, there will always be some uncontrolled air exchange between indoors and outdoors. This, of course, is not enough to guarantee fresh air in a room. However, lack of fresh air can occur in any building if we forget about the basic rules of healthy living. The real issue is air quality – inadequate humidity, odours, VOC, dust particles and even radon. Fact: in a highly airtight NZEB, the air quality can be several times better than in a standard building, if it is ventilated properly and the other one not. All it takes is to remember that windows have handles to open them, and mechanical ventilation systems have switches and programming buttons to operate them.

## High energy efficient buildings have less daylight

To start with, an NZEB is not only about energy indicators. It should among other things, exhibit suitable and balanced health and comfort related features as any building should. Technical regulations and recommendations define the minimum area of transparent envelope elements (windows, glass doors, skylights, etc.), minimum daylight factor values and other parameters to tackle the risk of low daylight levels. The still popular belief that for a building to achieve excellent energy features one must reduce window sizes, as they are the most obvious source of heat losses, is all wrong. In NZEBs we use glazing with multiple layers, inert gas fillings and special low-emissivity coatings. They all reduce heat losses noticeably and improve thermal comfort, but at the same time slightly lower the visible transmittance of such glazing compared to the basic single or double one. This should not be seen as a problem. If daylight levels are to become inadequate, the designer shall compensate this by enlarging the transparent areas accordingly. Visual comfort must not be compromised, whether a building is an NZEB or not. If the analysis then shows that NZEB energy indicators become less favourable, then there are many corrective options at hand to choose from – probably the simplest being to slightly increase the thickness of the thermal insulation of certain opaque elements.

Woman, 45 years old, living in a conventional 70s building:

*"Triple glazing and windows hidden deep in thick walls will reduce the daylight in the house."*

*Icons designed by Freepik*

## With time, will the airtightness performance of the building be compromised due to a deterioration of materials (like sealants, foils, etc.)

Man, 47 years old, living in a conventional 70s apartement building:

*"I am worried about ageing of advanced materials used in NZEB, how durable the sealants can be?"*

For good energy performance of NZEB airtightness is indeed a very important feature, especially in case of mechanical ventilation systems with heat recovery. To seal the joints of building components and windows, contractors use a combination of compatible products that prevent excessive transport of air, heat and moisture through the joints in the envelope. Several studies across the EU addressed the building's energy performance during the operation phase, among them also a German study that compared the measured airtightness of 31 passive houses in Stuttgart and revealed that their airtightness has only slightly changed in 2 years between 2000 and 2002. Despite that, the compliance with German regulation was not compromised.

## A building needs numerous advanced energy efficiency and RES technologies to meet NZEB requirements

To achieve the NZEB energy level there is no need for numerous different technologies. More important than having many different technologies, is to optimize and combine them appropriately into a building system adopted for each building. That is why an integrated design process is important, because each building is specific and we can meet NZEB requirements by using different technology combinations such as heat pumps, mechanical ventilation (with heat recovery), photovoltaics and solar thermal panels. Within the CoNZEBs project various NZEB solution sets, using various technologies, were analysed and presented in a report.

## NZEBs are too hot in summer

This is not true. No matter what type of the building it is, if it is not designed correctly then it can get too hot in the summer. There are several architectural and design concepts to avoid overheating in NZEBs during summer, even without an air-conditioning system. One of the most efficient and financially optimal concepts is without doubt passive/natural cooling during night time or so-called "night flushing". By opening the windows at night, cool air simply circulates the building and reduces indoor air temperature and the temperatures of the structure (building mass). Consequently, less accumulated heat, and at lower temperature, is emitted by the building structure during the daytime.

The other very efficient way for reducing overheating is by designing the exterior shading system appropriately. This has to be designed according to building and window orientation. By using natural shadings, e.g. deciduous trees, this can also be an energy and cost efficient solution. They help to prevent overheating in the summer period, but yet in winter they allow good daylight distribution within the building.

## The PV system is not useful in the event of power outages

This is actually true. However, in case of power outage, no other electrical system or appliance in a building can operate either, and it is true for all types of buildings, not just for an NZEB. A photovoltaic (PV) power plant used for domestic energy self-supply uses the public electricity network for storing energy and a source to overcome unfavourable periodic characteristics of power generation. The solar power plant is connected to the national grid with key components (i.e. inverter) powered by electricity from the grid to create stable operation. So, an NZEB is not an “off-grid” building. The only way to achieve this, would be to have a large enough battery or an auxiliary power supply.

## NZEBs offer transparency and good control over personal energy consumption

Often, NZEBs have implemented a Building (Energy) Management System (BMS). By using BMS, the user can monitor and control the operation of mechanical and electrical systems within the building. It allows the appropriate use of mechanical and electrical building equipment and consequently improves energy efficiency by analysing and monitoring how energy is consumed and the impact of end-users actions.

Woman, 50 years old, living in a 40s apartement building:

*"I am concerned about very dry air in new buildings."*

## Dry air in NZEBs during winter period

The term »nearly zero-energy« does not imply »nearly zero-humidity«. If we know that increased airtightness is one of the important features of a NZEB, then the direct opposite situation would be expected: higher air humidity due to the reduced uncontrolled air exchange through untight joints and elements.

The relative air humidity is what interests us most here, and this is simply a proportion of water vapour in the total air volume. The higher the air temperature, the larger the maximum moisture content can be. Outside air has a low temperature in winter, and consequently a reduced ability to contain water vapour. Its absolute humidity (the amount of water vapour expressed in grams) is therefore low despite its high relative humidity. Ventilating a building means exchanging moist and stale indoor air with the fresh outdoor air. This outside air warms up in a building very quickly – its temperature rises while its initial water vapour content is very low, thus having a significant “reserve” to absorb indoor humidity produced by the occupants and other sources.

Ventilating in winter really does mean reducing the relative humidity of the indoor air. Note: this happens in the same way in a “standard” building as in an NZEB if the same ventilation rate is achieved. If the air becomes too dry then the solution lies in the humidification of internal air in the building to bring the relative humidity into the comfort zone. Of course, this must be done carefully and with a feeling. A general piece of advice: if a building is not equipped with any automatic conditioning system then place some common household humidity meters (even better, combined humidity/temperature gadgets showing the “safe” range of both parameters) into spaces where you feel discomfort, and take action accordingly and in a timely manner.

Young woman, 27 years old, postgraduate student:

*"I live in a 70s block of flats with my boyfriend. The heating costs are high. Although we keep the radiators closed, it is often too warm and we must have windows open during most of the day. We open the windows that much also due to ventilation, because the flat is a bit humid and we want to prevent bad air. The floors in the rooms connected to external walls are cold. Being aware of the problems in our rental flat we expect the very opposite from nearly zero-energy buildings. The indoor temperature should be adequate for the user's needs and we wish to have a floor heating and we'd like to have room ventilation and not loose so much heat; and also to have pleasently cool spaces during the summertime. It is difficult for us to control temperature in rooms manually, therefore we would appreciate if the building could do that for us, so that we could experience good living comfort and low energy consumption."*


## NZEBs always provide very good thermal comfort and indoor climate

Flats and buildings in general are designed to provide comfortable habitats. NZEBs are promoted in having good, healthy indoor environment and in general they actually offer this. Two key advantages of NZEBs in comparison to regular buildings, regarding thermal comfort and indoor climate are:

- Normally, more insulation and better windows, therefore higher indoor surface temperatures within the building envelope and better thermal comfort.
- Frequently, use of mechanical ventilation (with heat recovery) and assuring appropriate ventilation and good indoor air quality.

But why are healthy buildings such a challenge?

To design a building that needs a small amount of energy for its operation and is at the same time ensuring a high quality of thermal comfort, is a complex task. To achieve good results, an appropriate, integrated design approach is mandatory. A comprehensive design team of experts in architecture, building physics and building systems is needed. Good understanding of technologies for heating, ventilation, hot water, (prevention of) cooling, lighting and use of renewables is essential. New design techniques and simulation tools can support successful NZEB design. Quality assurance during construction and good building management is essential for meeting the targeted NZEB performance during building operation. The energy use for heating, cooling and ventilation should be optimised during building design, including as well passive measures like solar shading, geometry and building orientation as well as adaptable user profile.

ARE MAINTENANCE COSTS IN NZEBs HIGHER THAN FOR REGULAR BUILDINGS

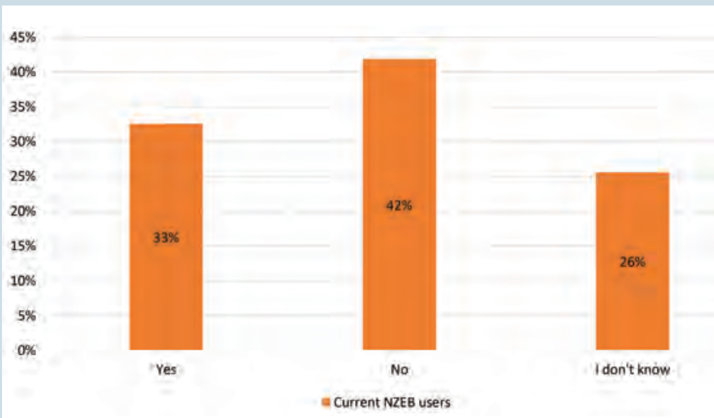



*Figure 9: Comparison of maintenance costs between NZEBs and conventional buildings (Slovenia, Germany and Italy)*

### Advanced technologies used in NZEBs may increase the maintenance and operational costs

NZEB users expect significant savings in energy and operational costs in comparison to regular buildings. On the one hand, NZEBs usually tend to have higher maintenance costs due to more advanced building technologies being installed, but on the other side, the higher maintenance costs may be compensated by lower energy costs due to high building energy performance, the use of renewable energy sources and efficient operation of energy systems. Optimized NZEB design, construction and operation lead to good performance and money savings over the lifetime of the building.

In the CoNZEBs survey about end-users' experiences and expectations regarding NZEBs, respondents were asked about the level of maintenance costs in NZEBs. 42% current NZEB users stated that they don't experience higher maintenance costs in NZEBs than in regular buildings, while 33% believed that their maintenance cost are higher and 26% of them didn't know.

# **NATIONAL EXAMPLES** of multi-family NZEBs




Even though the nearly zero energy building will become an obligatory standard for new residential buildings by the end of 2020, many "early" residential NZEBs were built voluntarily before the full implementation of EPBD requirements.

On the following pages, four national examples of multi-family buildings are shown, which have been built to the NZEB standard and taken from CoNZEBs countries (Slovenia, Germany, Denmark and Italy). Each building is presented with a technical description and statements from designers, building managers and end-users. The buildings are housing organisations investments (either private or public). They were designed and built even before the detailed national NZEB definitions were accepted and the criteria became obligatory. The presented examples of multi-family NZEBs paved the way for many followers.

National examples of multi-family NZEBs:

- Model House F3, Ljubljana (Slovenia)
- Frankfurter Klimaschutzhaus, Frankfurt (Germany)
- Apartment building on Dortheavej, Copenhagen (Denmark)
- San Giusto, Prato (Italy)

# MODEL HOUSE F3 ZELENI GAJ, LJUBLJANA

## FOUR ARCHITECTS, FOUR APPROACHES, ONE COMMON GOAL

**The Model House F3 is owned by the Housing Fund of the Republic of Slovenia. It combines visions of four different architects, and is divided into four sections or lamellas, which differ from each other in terms of function, structure, technology, and design. Above all they differ in terms of the materials used for floor finishes and types of ventilation.**

The load-bearing structure is of reinforced concrete up to the third floor, while the third floor and terrace floor have a wooden structure. The five above-ground levels of lamellas A and B are connected by external stairs and a lift, while the floors of lamellas C and D each have their own internal stairs and lift. The building has a common basement level. The roof over the garage serves as a forecourt with parking spaces and the entrances to the building.

The building as a whole is designed to be highly energy efficient, using advanced materials and building systems, i.e. some individual flats have mechanical ventilation with heat recovery, while others have humidity-sensitive ventilation.

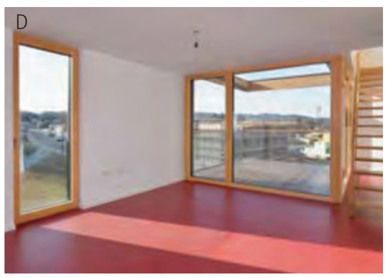
**The Model House F3 features an innovative approach to the design of the building, the flats within it, and the materials used.**

- Firstly, it was a design experiment: how to create as many single spatial solutions as possible in a single static framework.
- Secondly, it introduces a concept with an optimal ratio between innovation (use of materials, ventilation systems, combined heating systems and energy efficiency) and accessible prices.

The conceptual design of the building integrates factors of energy efficiency, architectural design, use of materials and sociological aspects. For this reason the building is part of a special project researching living comfort in a multi-family building which envisages a minimum three-year period of implementation, research and monitoring, where the involvement of users and their sense of well-being is a key, if not the most important factor.


**Building project:**
Prof. Aleš Vodopivec, architect
Assoc. prof. Tadej Glažar, architect
Prof. Janez Koželj, architect
Assoc. prof. Jurij Kobe, architect
**Outdoor areas:** Dekleva Gregorič arhitekti d.o.o. Ljubljana
**Investor:** Housing fund of the Republic of Slovenia (SSRS)
**Duration:** Construction commenced in 2014, completion of construction and outdoor areas in 2016
**Number of flats:** 52 (in 4 building sections/lamellas)
**Total net floor area:** 5,515 m$^2$
**Other premises:** 1 nursery school 207 m$^2$, 2 offices 15 m$^2$
**Parking spaces:** 110 (68 in underground garage, 42 outside)



***Mag. Črtomir Remec, director of the investor (SSRS)***

*"The Model House F3 was built to NZEB standards and is the result of domestic know-how from the University of Ljubljana's Faculty of Architecture under the guidance of four experienced professors and other participating organisations. This project was a very useful experience for SSRS regarding the design and construction process of an NZEB, as well as the use of energy efficient building technologies and renewable energy. As the F3 multi-family building was one of the first larger NZEB projects in Slovenia, we believe that it will serve as an example of good practice for future investments in residential NZEBs.*

*SSRS is planning to build around 1000 new flats for rent until 2020, so experiences gained from the Model House will be very useful, especially in the area of reducing construction costs and overall investment cost, which will allow us to offer flats at lower rents."*

## Technical description of the building

| | |
|---|---|
| Structure | Ground floor and 2 floors: reinforced concrete structure; 3rd floor and terrace: wooden structure |
| Wall | Ground floor and 2 floors: ventilated with fibre cement panels; 3rd floor and terrace: ventilated wooden facade |
| Windows, balcony doors | Combined aluminium/wooden frames with triple glazing |
| Heating | Lamella A: floor heating connected to a heat pump air/water and supported by a biomass boiler system; Lamellas B, C, D: floor heating connected to a common biomass boiler (woodchips) and solar collectors (for generating domestic hot water and as general heating support system) |
| Ventilation | Mechanical ventilation with 85% heat recovery in 30 flats, in others humidity-sensitive ventilation |
| Cooling | n.a.<br>External shading, manually operated roller blinds |
| Domestic hot water | Generated by the heating system |
| Renewable energy | Solar collectors and biomass |
| Energy performance: | Energy class A2 (calculated EPC)<br>Calculated net heating energy: 14 kWh/m²/yr<br>Calculated final energy demand: 49 kWh/m²/yr<br>Calculated primary energy: 36 kWh/m²/yr |

***Gregor Sagadin, manager of the F3 house***

*"The users are satisfied with energy efficiency of the building, especially in summer, when the flats have very pleasant temperature. During the winter period, they expected the floor to be a bit warmer, due to the floor heating, however the floor heating operates at low temperature and maintains the temperature around 22 °C. We educate the F3 flat users about usage and maintenance of the building systems in the apartment units and we plan to do that in the future. My opinion, as the building manager and as an architect, is that NZEBs are welcome and represent the progress and future of the housing construction and it is right to build NZEBs because we educate people and direct them towards the sustainable development of society. It will take time, but the generations that are at the beginning of their life course will look at this spectrum differently."*

***Maša Andoljšek, NZEB flat user***

*"I have lived in an NZEB for 1 year and so far I have to admit that I am quite satisfied. If I compare living in an NZEB and living in an older multi-family building, I can say there is a very notable difference in indoor comfort. For me it is important that now I have low energy costs and high indoor comfort, which especially means fresh air – without stuffiness, high daylight level and a nice feeling of a warm flat during winter. The latter was especially a big issue for me in the previous apartment, since the building was older, exterior walls were very cold and I had issues with stale air and moisture. The technologies implemented in the current flat are actually useful and easy to use, even though in general I am not into technologies. Overall, I am happy that I moved in an NZEB flat and I would do it again."*

# NZEB "FRANKFURTER KLIMASCHUTZHAUS"

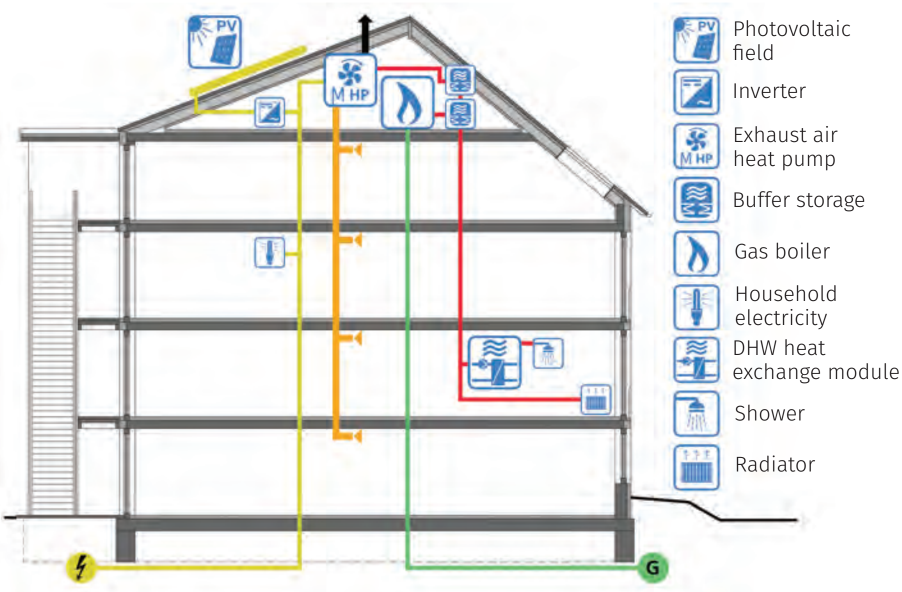
**Within the scope of a model project, ABG FRANKFURT HOLDING in Frankfurt/Main (Germany) has built 46 flats that are particularly efficient in terms of costs and energy. The project was implemented in cooperation with schneider+schumacher architects, Frankfurt and EGS-plan GmbH in Stuttgart.**

The apartment buildings are intended to play an exemplary role in terms of architecture and energy balance. To achieve this goal, conventional standards were consistently scrutinized. A building type was developed, which aims at minimizing the heated building volume and allows to significantly reduce building cost by deploying a semi-precast construction system. The architects opted for two parallel, volume-optimized blocks of flats with a double pitch roof.

The ratio of building envelope to building volume is favourable in terms of energy performance and constitutes an important design feature for an NZEB concept. Special features of the energy concept include:

- Building services centre is housed in the attic
- Central position of the flat shafts along the centre bulkhead
- Supply air via facade (window rebate)
- Heat recovered from the exhaust air system
- Photovoltaics: Electricity is being used for heat pump and ventilation and sold to the tenants
- Domestic hot water heat exchange module
- Central pipework layout (not in floor construction)
- Compact bathroom with short pipework

*Source: ABG FH and schneider+schumacher*




*Source: Fraunhofer IBP based on the energy concept of EGS-plan*

**Building project:** schneider+schumacher architects, Frankfurt
**Investor:** ABG FRANKFURT HOLDING GmbH
**Structural design:** bauart Konstruktions GmbH & Co. KG
**Energy concept:** EGS-plan Ingenieurgesellschaft für Energie-, Gebäude- und Solartechnik mbH
**Number of flats:** 46 flats (2 to 4 rooms)
**Number of buildings:** 2 residential buildings encompassing 3 or 4 full storeys
**Number of parking lots:** 20 in the basement garage and CarSharing service
**Total living area:** 2,949 m²

**Frank Junker, CEO, ABG FRANKFURT HOLDING GmbH (Investor, housing company)**

*"Our buildings are low-priced, but not cheap. ABG wants to demonstrate how new residential buildings can be high-quality, energy-efficient, and cost-effective in the present economic context. To us, it is important not to cut down on energy efficiency, in order to also keep incidental costs low for the tenants. We calculated according to market conditions: current standard land value, no funding means. In doing so, we undershoot the prices for ABG new constructions by some 20 percent. The actual prices requested on Frankfurt's privately financed housing market are undershot by one third. Construction costs could be reduced by employing 'serial construction methods'. The flats are based on standardized modules, which can be connected in line and stacked upon one another. In addition to repeating construction elements such as windows and staircases, simple construction principles, short piping, lines and ductwork and optimized building services contribute to keeping building costs as low as possible."*

**Claudia Dumitru, NZEB flat user**

*"Right after moving into our nearly zero-energy flat I immediately perceived that the flat is pleasantly quiet, although we are living in Frankfurt. During the first winter of our occupancy I noticed that the entire flat was always evenly warm though we rarely used the radiator in the living room. Besides, the floor is never cold, and I don't have cold feet, even though the flat doesn't have floor heating."*

**Benedikt Schneemann, NZEB flat user**

*"High ancillary costs, cold winters and too hot summers were our motivation to abandon our flat to move into a nearly zero-energy home. In the beginning, we opened the windows every morning – merely out of habit. Nowadays, we sometimes don't open the windows for weeks. As the flat is provided with a balanced mechanical ventilation system there is no need to open the windows. The nice side effect: street noise and fumes are kept outside. There is always fresh air in the flat, with no heating energy being lost."*

## Technical description of the building

| | |
|---|---|
| Structure | Massive construction. Load transfer via transverse reinforced concrete bulkheads and longitudinal reinforced concrete floors.<br>External walls made from monolithic hollow brick masonry.<br>The external facade does not fulfill any static functions. |
| Wall | Monolithic wall construction: 36.5 cm building bricks<br>U-value of the external wall: 0.18 W/(m²K)<br>Airtight building envelope |
| Windows, balcony doors | Triple glazing in plastic window frames |
| Heating | Gas condensing boiler, air-to-water heat pump, buffer storage tank |
| Ventilation | Air inlets in the facade, centralized exhaust air with heat recovery via heat pump into the DHW |
| Cooling | n.a. |
| Domestic hot water | Preheating by the exhaust-air heat pump, the DHW heat exchange modules (fresh water stations) in the flats allow to keep system temperatures low |
| Renewable energy | n.a. |
| Energy performance: | Calculated annual need for space heating energy: 27 kWh/m²/yr<br>Calculated delivered energy need: 27 kWh/m²/yr<br>Calculated primary energy need: 31 kWh/m²/yr |

# APARTMENT BUILDING ON DORTHEAVEJ, COPENHAGEN

**This apartment building on Dortheavej in Copenhagen is owned by the social housing company Bo-Vita. It was designed by the Danish architect company BIG. The load-bearing structure is concrete and the facades are covered with Siberian pine. The building is centrally heated from the district heating network in Copenhagen. The flats are ventilated by a central mechanical ventilation system with heat recovery.**

The building is a low-energy building built according to Building Class 2020 – defined in the Danish Building regulations. In Denmark this has been agreed to be the Danish definition of a NZEB building.

The building gently curves in the centre, creating space for a public plaza towards the street on the south side and an intimate green courtyard towards the north. The housing modules repeat along the curve and are stacked to the height of the surrounding buildings. Large floor to ceiling windows in the flats allow lots of daylight into the units. On the sunny south side, balconies retract and add depth to the facade, while on the northern side the facade is even.

In the beginning of 2018, BIG and Bo-Vita were honored by the Danish Association of Architects with the Lille Arne Award for prioritising the spatial qualities of the residences and the building strategy on a strict affordable housing budget. Furthermore, the building has been nominated for the 2019 European Union Prize for Contemporary Architecture – Mies van der Rohe Award.



***J. Laursen, NZEB flat user***
*"It's nice not to spend a lot on heating as the flat is so well insulated. We first turned on the heat here in November. It was hot indoors in the hot summer this year, but it's hard to avoid this when the temperatures outside are high. There is just such good daylight here. We are very happy to live here! The indoor climate is really nice and comfortable."*


***J. Mørk, NZEB flat user***
*"We are very happy for our flat with its split levels. The indoor climate is nice, but it became hot in the summer. Hovwever, that is not so strange as there are very large window sections from floor to ceiling. The daylight is amazing. It's nice with an energy efficient heating system, and the radiators don't run very often. The building is well insulated and you can't hear the neighbours."*

***E. Duus, NZEB flat user***
*"It is a nice building and it has also proved to be a wonderful flat with a good indoor climate. There is plenty of daylight with big window areas. This autumn there has been a little dew (condensation) outside on the windows in the morning, but it only shows that these are good windows! It was possible during the hot summer to make cross-ventilation by opening the patio door and window, although it is usually not necessary as the mechanical ventilation works well."*

**Building project:** BIG, Denmark
**Investor:** Social housing company Bo-Vita
**Number of flats:** 66 – 21 different types and sizes, from 61–115 m²
**Number of other premises:** 1 youth dwelling of 36 m²
**Total living area:** 6,800 m²

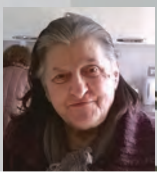
### Technical description of the building

| | |
|---|---|
| Structure | Concrete core |
| Wall | Covered by Siberian pine with approx. 250 mm insulation |
| Windows, balcony doors | Aluminium - wood, triple glazing |
| Heating | District heating with radiators and floor heating in the bathrooms |
| Ventilation | Mechanical ventilation with heat recovery |
| Cooling | n.a. |
| Domestic hot water | Prepared by the district heating system |
| Renewable energy | Photovoltaic (PV) cells on the roof – 120 pcs. polycristalline panels, each 1,666 x 999 mm with a total effect of 31,800 Wp |
| Energy performance: | Building Class 2020 (calculated)<br>Calculated net heating energy: 29.4 kWh/m²/yr<br>Calculated final energy demand: 37.8 kWh/m²/yr<br>Calculated primary energy: 20 kWh/m²/yr |

# NZEB "SAN GIUSTO" IN PRATO

The case study is located in Prato, in the centre of Italy, and was funded by the local social housing company Edilizia Pubblica Pratese. The building is located on the outskirts of the city and represents an example of urban renewal connecting two separate built areas. It is a mixed-use building with three residential floors and a public civic centre on the ground floor. Different flat sizes have been designed according to the needs of the final users. The building also has a garden and a private parking, guaranteeing a clear separation between pedestrian and vehicular traffic. A pedestrian colonnade on the ground floor visually connects the public square in front of the building with the private green area.

The façades are marked by balconies and glazed railings. Lamellar blinds are installed on staircases to prevent overheating. Low energy consumption and construction costs were achieved by the means of adequate planning from different perspectives. Firstly, the design and technological choices have been simplified as much as possible to avoid extra costs, for example, the use of continuous façades minimizes thermal bridges. Furthermore, outdoor parking spaces as opposed to underground parking lowered construction costs and rents for users. Bioclimatic criteria have been implemented, with particular attention to summer comfort. Finally, locally recycled materials have been used for the thermo-acoustic insulation.



***L. Menozzi, NZEB flat user***
*"The building is isolated, functional and also suitable for people with movement problems like me. There are sliding doors and the areas are spacious and large to facilitate movement. In addition, thanks to the large windows overlooking the playground, we enjoy beautiful natural light."*

***T. Celestino, NZEB flat user***
*"I could not ask for more. This is a home with lots of comfort and located in a quiet area away from the busy Via Emilia. Inside I hardly use any electrical lighting on sunny days thanks to the beautiful natural light that enters through the window in the living room. The accommodation, in general, is very well done and all rooms have smoke and gas detectors which is a really good thing for us.*
*As for heating costs, I am satisfied, because the house is well-insulated and located on the 2nd floor. I can save consumption during the winter and in summer I can use the air conditioner in a reasonable way."*

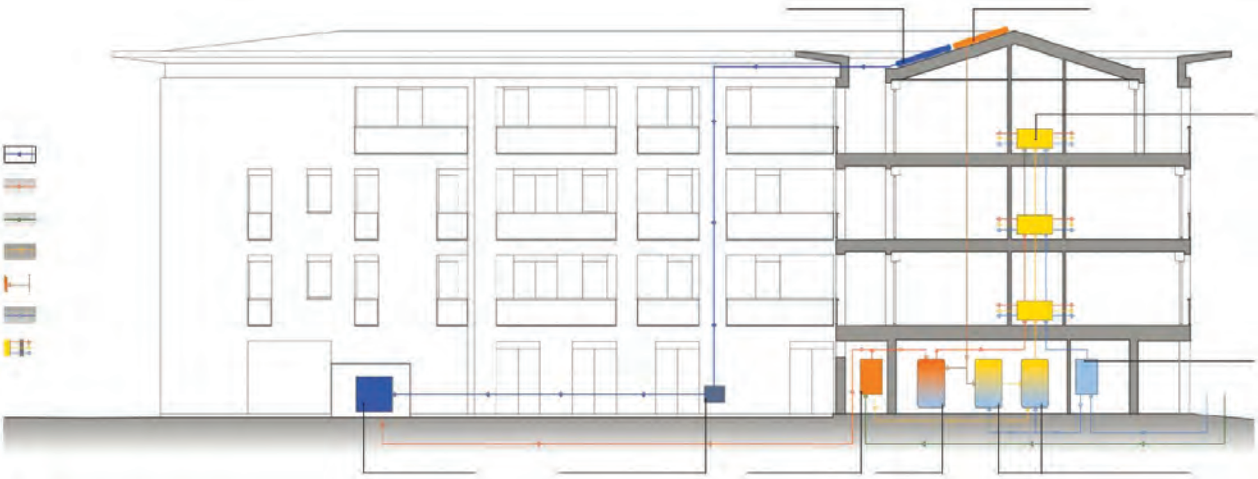
**Building project:** architect Riccardo Roda
**Investor:** Edilizia Pubblica Pratese
**Number of buildings:** 1
**Number of flats:** 29 (net floor area from 45 m² to 95 m²)
**Total net area:** 2,127 m²
**Other services:** private cellars and public civic center at the ground floor, common recreation garden, private parking

***Architect Riccardo Roda, NZEB designer and planner of the San Giusto NZEB Project***

*"The San Giusto NZEB project is a synthesis moment of a long-term experimental experience in social housing, aimed at designing innovative buildings at reduced costs, with the final objective of improving the residents' life conditions.*
*Sustainable architecture means: livability, low energy bills, low management costs.*
*The design strongly relies on the settlement quality, through flats with double exposure, large balconies facing a large garden, supporting services, a civic centre and green recreation areas.*
*The project also includes extensive use of recycled components at zero kilometers, coming from the reuse of wastage of the local textile sector."*

***Engineer Giulia Bordina, Edilizia Pubblica Pratese (Prato Social Housing Company), project manager for the San Giusto NZEB Project***

*"The mission of Edilizia Pubblica Pratese (Social Housing Company of Prato) is to build low cost social dwellings devoted to vulnerable social groups.*
*Social housing is historically the preferred means for promoting sustainable development in the territory.*
*The San Giusto NZEB pilot project aims at demonstrating the achievement of high energy performances within the economic restraints of social housing.*
*This pilot project will also be useful in increasing the energy efficiency of all the dwellings, managed by our company, aiming at reducing the energy bills for very low income families."*



## Technical description of the building

| | |
|---|---|
| Structure | Clay bricks; roof: masonry and XPS thermal coating covered by steel plate mounted on wooden planks – U-value 0.20 W/m²K |
| Wall | ETICS (external thermal insulation composite system) – U-value 0.17 W/m²K |
| Windows, balcony doors | Argon-filled double-glazed windows with aluminum frames – U-values 1.46 W/m²K |
| Heating | 171 kW water to air heat pump plus 94 kW condensing boiler as back-up |
| Ventilation | Natural by manual window opening |
| Cooling | No active systems, bioclimatic solutions to minimize overheating |
| Domestic hot water | 94 kW condensing boiler with 2000 liters storage tank |
| Renewable energy | 30 m² solar thermal collectors and 22 kWp (142 m²) poly-crystalline PV system |
| Energy performance: | Calculated heating energy: 4.15 kWh/m²/yr<br>Calculated primary energy need (non-renewable): 9.27 kWh/m²/yr |

# The CoNZEBs project

CoNZEBs is a EU Horizon 2020 project on the topic 'Cost reduction of new Nearly Zero Energy Buildings' (call H2020-EE-2016-CSA, topic EE-13-2016).

CoNZEBs identifies and assesses technology solution sets that lead to significant cost reductions in new Nearly Zero Energy Buildings (NZEBs). The focus of the project is on multi-family buildings. Close cooperation with housing associations allows for an intensive interaction with stakeholders and tenants.

The project started 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. Then the planning and construction processes were analysed to identify possible cost reductions.

The technology solution sets for cost reduction of NZEBs can include solutions for installations or generation systems, pre-fabrication and construction acceleration, systems with RES technologies (like pure electrical heating in combination with PV, PV/T in conjunction with a heat pump so that no earth coupling is required, ventilation supply through the walls to reduce the costs for ducts, larger bricks including insulation, decentral domestic hot water generation, etc.). All solution sets are assessed regarding cost savings, energy performance and applicability in multi-family buildings.

A life cycle assessment of different building levels (regular buildings, NZEBs) and NZEBs using the solution sets for long-term cost reduction provides a longer term perspective on the environmental and economic impact on alternative NZEB design solutions.

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

The project team consists of 9 organisations (national research organisations in the field of high performance buildings and housing associations) from 4 different countries (Germany, Denmark, Italy and Slovenia). The project period is from 01/06/17 to 30/11/19.

www.conzebs.eu; conzebs@ibp.fraunhofer.de

Editors: Marjana Šijanec Zavrl, Marko Jaćimović, Gradbeni inštitut ZRMK d.o.o., Ljubljana, Slovenia
Designed and prepared by: Tridesign d.o.o., Ljubljana, Barbara Železnik Bizjak
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CoNZ€Bs
Solution sets for the Cost reduction of new Nearly Zero-Energy Buildings

**Project partners:**

Coordinator
Fraunhofer Institute for Building Physics, Germany (Fraunhofer IBP)
www.ibp.fraunhofer.de

Aalborg Universitet, Denmark (AAU)
www.sbi.aau.dk

Kuben Management AS, Denmark (Kuben)
www.kubenman.dk

Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile, Italy (ENEA)
www.enea.it/en

Gradbeni Institut ZRMK d.o.o., Slovenia (GI ZRMK)
www.gi-zrmk.si/en

ABG Frankfurt Holding Wohnungsbau- und Beteiligungsgesellschaft mit beschränkter Haftung, Germany (ABG-FH)
www.abg-fh.com

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Azienda Casa Emilia Romagna della Provincia di Reggio Emilia, Italy (ACER Reggio Emilia)
www.acer.re.it

Stanovanjski Sklad Republike Slovenije, Javni Sklad, Slovenia (SSRS)
www.ssrs.si/eng/

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