IMPLEMENTING NEARLY ZERO-ENERGY BUILDINGS (nZEB) IN POLAND -

TOWARDS A DEFINITION AND ROADMAP

BPIE

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The Building Performance Institute Europe (BPIE) is an independent not-for-profit organisation dedicated to improving the energy performance of buildings across Europe, and thereby helping to reduce CO_2 emissions from the energy used by European buildings. Our main focus lays on policy analysis, implementation and dissemination of knowledge through studies, policy briefs and best practices.

BPIE acts both as European centre of expertise and as the European partner for a Global Buildings Performance Network.

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1. SETTING THE STAGE

The building stock is responsible for a large share of greenhouse gas emissions (GHG) in the European Union. Major emission reductions can be achieved through changes in this sector and the building sector is crucial to achieving the EU's reduction targets. With more than one quarter of the 2050s building stock still to be built, a large amount of GHG emissions are not yet accounted for. To meet the EU's ambitious reduction targets, the energy consumption of these future buildings needs to be close to zero, which makes finding and agreeing on an EU-wide definition or guidelines for "nearly Zero-Energy Buildings" (nZEB) essential in the effort to reduce domestic greenhouse gases to 80% of 1990 levels by 2050.

The recast of the Energy Performance of Buildings Directive (EPBD) introduced, in Article 9, "nearly Zero-Energy Buildings" (nZEB) as a future requirement to be implemented from 2019 onwards for public buildings and from 2021 onwards for all new buildings. The EPBD defines a nearly Zero-Energy Building as follows: [A nearly Zero-Energy Building is a] "building that has a very high energy performance… [ ]. The nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby".

Acknowledging the variety in building culture, climate and methodological approaches throughout the EU, the EPBD does not prescribe a uniform approach for implementing nearly Zero-Energy Buildings (nZEBs) and each EU Member State has to elaborate its own nZEB definition. The EPBD also requires EU Member States to draw up specifically designed national plans for implementing nZEBs which reflect national, regional or local conditions. The national plans will have to translate the concept of nearly Zero-Energy Buildings into practical and applicable measures and definitions to steadily increase the number of nearly Zero-Energy Buildings. EU Member States are required to present their nZEB definition and roadmaps to the European Commission by 2013.

So far the nZEB criteria, as defined in the EPBD, are of a very qualitative nature with much room left for interpretation and way of execution. Indeed, there is little guidance for Member States on how to concretely implement the Directive and on how to define and realise nearly Zero-Energy Buildings. Therefore, a more concrete and clear definition of nZEB needs to be formulated which includes common principles and methods that can be taken into account by EU Member States for elaborating effective, practical and well thought-out nearly Zero-Energy Buildings.

The aim of this study is to actively support this elaboration process in Poland by providing a technical and economic analysis for developing an ambitious yet affordable nZEB definition and implementation plan. Starting from country data on current construction practices, economic conditions and existing policies, different technological options are simulated for improving the energy performance of offices and single- and multi-family buildings. We have evaluated the economic implications of the various options and offer recommendations for an implementation plan.

2. PRINCIPLES FOR IMPLEMENTING nEARLY ZERO-ENERGY BUILDINGS IN EUROPE

In 2011, BPIE conducted a study on "Principles for nearly Zero-Energy Buildings"[1] (nZEBs) which aimed to support the public debate around this EPBD requirement by analysing the key implementation challenges and proposing a set of general principles to be taken into account for implementing a sustainable, realistic and cost-effective nZEB definition at national level. Based upon the analysis of the technical and economic implications of the proposed principles, the study makes general recommendations for moving towards nearly Zero–Energy Buildings in Europe.

The study identified 10 main challenges that should be addressed when shaping the nZEB definition at national level (Figure 1), leading to important implications in terms of the energy efficiency, renewable energy supply and associated carbon emissions of the nZEB. The proposed nZEB principles offer general indications for defining the boundaries in the building's operational energy flow and for setting thresholds for the energy demand/need, renewable energy share and associated carbon emissions of the building (Tables 1 and 2).

Figure 1: Challenges to be addressed for implementing a sustainable nZEB definition

Policy	Technical	Beyond EPBD
Meeting the EU's low-carbon 2050 goals	(nearly) zero CO_2 and zero energy building	Single building vs. groups of buildings
Convergence with EPBD cost-optimality requirement	Renewables temporal/local disparities	Household electricity for appliances
	Balance between energy efficiency and renewable energy supply	Life-cycle energy
	Transferability to varied climate and building types	
	Flexible and open nZEB definition	

[1]BPIE (2011) *Principles for nearly Zero-Energy Buildings - Paving the way for effective implementation of policy requirements*. Available at www.bpie.eu

Table 1: Principles for nearly Zero –Energy Buildings: defining the boundaries in the energy flow of the building

First nZEB Principle: **Energy demand**	**Second nZEB Principle:** **Renewable energy share**	**Third nZEB Principle:** **Primary energy and CO_2 emissions**
There should be a clearly defined boundary in the energy flow related to the operation of the building that defines the energy quality of the energy demand with clear guidance on how to assess corresponding values.	There should be a clearly defined boundary in the energy flow related to the operation of the building where the share of renewable energy is calculated or measured with clear guidance on how to assess this share.	There should be a clearly defined boundary in the energy flow related to the operation of the building where the overarching primary energy demand and CO_2 emissions are calculated with clear guidance on how to assess these values.
Implementation approach		
This boundary should include the energy need of the building, i.e. the sum of useful heat, cold and electricity needed for space heating, domestic hot water, space cooling and lighting (the latter only for non-residential buildings). It should also include distribution and storage losses within the building. **Addendum:** While it is not specifically requested by the EPBD, the electricity consumption of appliances (plug load) and of other building technical systems (i.e. lifts, fire security lighting etc.) may also be included in position within that corridor based on specific relevant national conditions.	This boundary could be the sum of energy needs and system losses, i.e. the total energy delivered into the building from active supply systems incl. auxiliary energy for pumps, fans etc. The eligible share of renewable energy represents all energy produced and delivered to the building from on-site (including the renewable share of heat pumps), nearby and offsite renewable sources. Double counting must be avoided.	This boundary should include the primary energy demand as well as the CO_2 emissions related to the total energy delivered into the building from active supply systems. Clear national rules and guidance should be provided on how to calculate the net export of the renewable energy produced on-site in the case this exceeds the building's energy needs over the balance period.

Table 2: Corollary to the nZEB principles: fixing thresholds on energy demand/need, on renewable energy share and on associated CO_2 emissions.

Corollary of First nZEB Principle: Threshold for energy demand	Corollary of Second nZEB Principle: Threshold for renewable energy share	Corollary of Third nZEB Principle: Threshold for CO_2 emissions in primary energy
A threshold for the maximum allowable energy need should be defined.	A threshold for the minimum share of renewable energy demand should be defined.	A threshold for the minimum share of renewable energy demand should be defined.
Implementation approach		
For the definition of such a threshold, it could be recommended to gradually increase the minimum requirements in a certain corridor, which could be defined in the following way: • The upper limit (least ambitious) can be defined by the energy demand/need of the building as derived through application of the cost-optimal methodology (Article 5 of the recast EPBD). • The lower limit (most ambitious) of the corridor is set by the best technology that is available and well introduced on the market. Member States might determine their individual position within that corridor based on specific relevant national conditions.	A reasonable range for renewable energy share seems to be between 50% and 90% (or 100%). The share of energy delivered to the building from renewable sources should be increased step-by-step between 2021 and 2050. The starting point should be determined based on best practice with nZEB serving as a benchmark for what can be achieved at reasonable life-cycle cost.	For meeting the EU's long term climate targets, it is recommended that the buildings' CO_2 emissions linked to energy demand is below 3 kg $CO_2/(m^2yr)$. The EPBD requires improved energy performance from buildings by imposing a minimum requirement for primary energy consumption. However, the buildings should also follow the EU's long-term decarbonisation goals (by 2050). Consequently, introducing an indicator for the CO_2 emissions of buildings (linked to the primary energy indicator for the energy demand) is the single way to ensure coherence and consistency between the long-term energy and environmental goals of the EU.

The above nZEB principles were simulated on two pre-defined reference buildings, a single-family house and an office building for three European climate zones: cold climate (Copenhagen), moderate climate (Stuttgart) and warm climate (Madrid). The simulations analysed these reference buildings and estimated the impact of several technical options for heating, cooling and domestic hot water in primary energy demand, on renewable energy share and on CO_2 emissions. Table 3 gives an overview of the general findings of the simulations as compared to the thresholds proposed in Table 2.

Table 3: Impact of different simulation options

Renewable energy share between 50% and 90%	CO_2 emissions below 3kgCO_2/(m^2yr)
Fossil fired solutions without additional renewables are already struggling to achieve a renewable share of 50%. The impact of district heating systems depends largely on its renewable share; a 50% renewable DH system is not enough in some locations. In single family buildings, heat pump solutions easily achieve a 50% renewable share. By using additional off-site green electricity or on-site renewables, the heat pump option can even secure a 100% renewable energy share. For single family homes with heat consumption, it is possible to achieve a 90% share of renewable only by using a 100% heat supply from biomass-fired systems (boiler, CHP). In office buildings, biomass and heat pump solutions reach a 50% share of renewables. Office buildings have a higher relative share of electricity than residential buildings. Therefore, green electricity is required by all considered options (except the fossil fuels options) in order to reach a 90% share, usually including even office equipment (appliances).	Without additional renewables, for the single family building all fossil fired solutions (gas boiler, micro CHP and district heating with a small renewable share) are generally clearly above the limit of 3kgCO_2/ (m^2yr). Heat pump solutions come close and bio solutions (biomass boiler, bio micro CHP) clearly stay below the threshold. For the single family building, additional on-site renewables (i.e. PV in this simulation) improve the situation. The fossil solutions are still above the threshold even with the considered additional PV system (which is however quite small, but enough to reach a high renewable energy share). For office buildings, only the biomass micro CHP is below the threshold. Using green off-site electricity significantly decreases CO_2 emissions. For the single family building, the fossil fired solutions generally fail to meet the target (with or without the consideration of appliances), except at locations with very little heating and hot water demand (in warm climate zones). In office buildings, because of the relatively high share of electricity, all related variants stay below the threshold. Consideration of the electricity demand for the appliances and office equipment does not generally change this result. For office buildings, additional on-site renewables such as CO_2 compensation is much less effective. Fossil fuel options in moderate and cold climate zones cannot meet the conditions even with additional on-site PV power.

3. AIM AND METHODOLOGY

The current study builds on the previous report "Principles for nearly Zero-Energy Buildings" and evaluates through indicative simulations whether these principles hold true for the situation in Poland.

The objective is to offer an independent and research-based opinion proactively supporting national efforts to draw up an affordable yet ambitious definition and an implementation roadmap for nearly Zero-Energy Buildings (nZEBs) in Poland.

The project started with an in-depth survey of the Polish building stock, construction practices, market prices for materials and equipment, existing legislation and support measures. We defined and evaluated new reference buildings (current practice) for the following building types:

- Detached single family houses (SFH)
- Multi-family houses (MFH)
- Office buildings (OFFICE)

Detached single family houses and multi-family blocks of flats represent around 88% of the residential building stock in Poland and 94% in terms of net floor area. The office buildings represent around 26% of the non-residential building stock.
Altogether, these three building types account for around 77% of the Polish building stock. Therefore we consider them to be representatives enough to be selected for this study as the main building typology in the country.

With these three reference buildings we undertook several simulations using variants of improved thermal insulation and equipment for heating, cooling, ventilation and hot water. To improve the CO_2 balance and the renewable energy share of the building, we considered photovoltaic compensation. These simulations were evaluated for compliance with the nZEB principles as elaborated in the BPIE study. Moreover, the economic and financial implications of each variant were analysed in order to determine the most suitable and affordable solutions under the country's specific circumstances. Finally, the selected optimal solutions were extrapolated at national level to determine the direct and indirect benefits and impacts. Besides the CO_2 saving potential, impacts on job creation and industry/technology development were also considered.

The last chapter presents key policy recommendations and an indicative roadmap for the implementation of nZEBs in Poland.

This report was conceptualised, coordinated and finalised by BPIE. The overall data aggregation and selection, simulations and analysis were executed by Ecofys Germany as a lead consultant. The provision of data concerning Polish buildings, policies and market prices, the definition and selection of reference buildings and the revision of the final study were made by BuildDesk Polska team as national consultants

The building simulations were undertaken with the TRNSYS[2] software tool. The economic analysis was performed by using the Ecofys analytical tool Built Environment Analysis Model (BEAM2)[3].

[2] TRNSYS is, a transient systems simulation program, commercially available since 1975, which has been used extensively to simulate solar energy applications, conventional buildings, and even biological processes. More details at: http://www.trnsys.com/

[3] Further information on BEAM2 model available at: http://www.ecofys.nl/com/news/pressreleases2010/documents/2pager_Ecofys_BEAM2_ENG_10_2010.pdf

4. OVERVIEW OF THE POLISH BUILDING SECTOR

The Polish building sector was analysed as follows:

- Building stock size and new building rates;
- Typical shapes of new buildings and current practice;
- Current building regulations for new buildings;
- Current market situation for investment;
- Current support schemes for new buildings;
- Current market situation for district heating;
- Current market prices for energy efficient technologies.

The main findings of this in-depth evaluation are presented in the following sub-chapters.

4.1. BUILDING STOCK SIZE AND NEW BUILDING RATES

The housing stock in Poland consists of approximately 13.7 million dwellings[4] in around 6 million buildings [5] [6]. In urban areas, the majority of dwellings (76%) are located in blocks of flats, in contrast to rural areas where the majority (90%) are in single family homes. Individual single family buildings represent around 92% of the Polish residential building stock. The blocks of flats, mainly concentrated in urban areas, represent around 8% of the building stock but account for around 56% of Polish dwellings. Some 75% of the residential dwellings are owner-occupied.

At the end of 2011, the total floor area of the Polish building stock was about 1 292 million m^2, whereas the residential floor area was about 980 million m^2 and non-residential floor area about 312 million m^2. The number of residential buildings in Poland stood at about 6 million (Table 4)[7] [8].
The most prevalent building type in the residential sector is the urban multi-family house (37%), followed by the detached rural single family house (36%) (see Figure 2). Detached single family and multi-family buildings together represent a 94% share of the total residential buildings.

The most prevalent building types in the non-residential sector are office buildings (26%) and educational facilities (26%) as you can see in Figure 3 which illustrates the distribution of the non-residential building stock in Poland according to the floor area. It can be observed that there are three major sectors that dominate: educational, office and retail, which comprise 77% of the total stock.

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[4]According to the 2011 Census in Poland. More details in table 13 and 14 at: http://www.stat.gov.pl/cps/rde/xbcr/gus/lu_nps2011_wyniki_nsp2011_22032012.pdf

[5]Based on data collection of BuildDesk Polska research

[6]P. Choromanski, R. Wnuk (March 2009). *Current state of heating and cooling markets in Poland.* A report prepared as part of the IEE project "Policy development for improving RES-H/C penetration in European Member States (RES-H Policy)". Available at: http://www.res-h-policy.eu/RES-H_Policy_Market-Report-PL_(D3)_english.pdf

[7]This is an approximation since the data availability on the total stock is limited. Our approximation is based on partial data collection and comparison with countries from the region, especially Romania, Hungary and Bulgaria. The main sources of data collection are: BuildDeesk Polska, BPIE(2011). *Europe's buildings under the microscope.* BPIE. Available at www.bpie.eu, The Polish Foundation for Energy Efficiency (FEWE) (2011). Website at: http://www.fewe.pl

[8]Idem 4

Figure 2: Distribution of residential floor area by building type

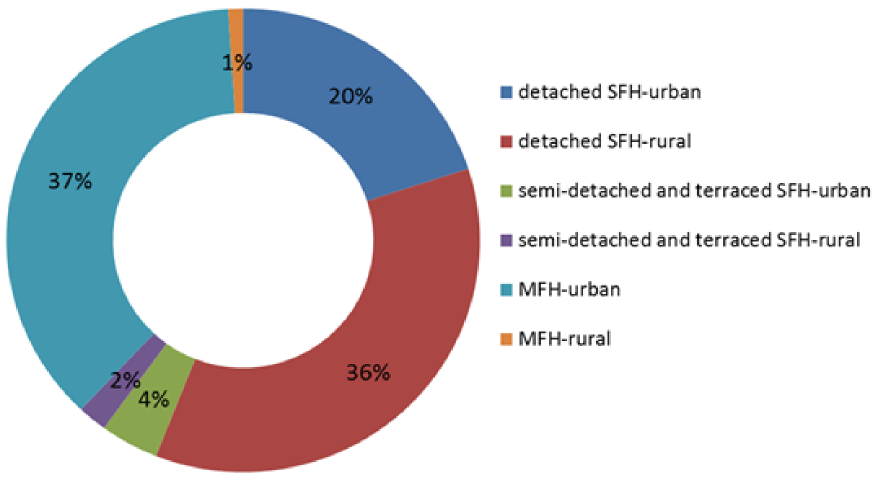
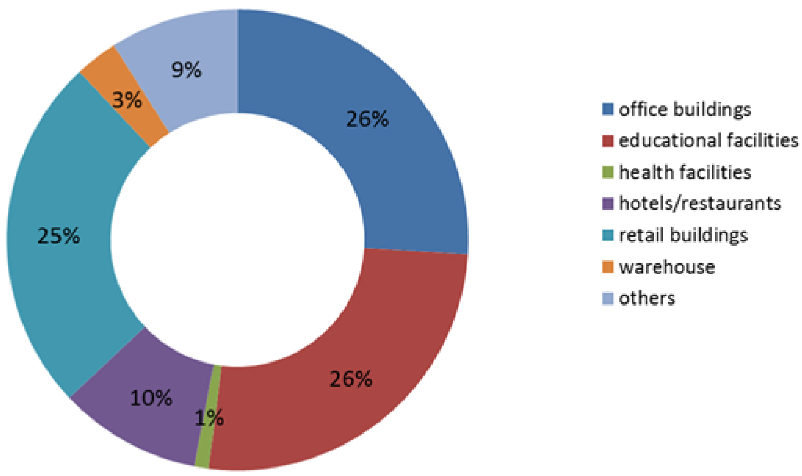


Figure 3: Distribution of non-residential floor area by building type



Approx. 50% of residential buildings are built before 1970 and around 87% before 1989[9]. The buildings built before 1990 have poor energy performance at around 250kWh/m2/yr or above.

The Polish housing sector has been one of the country's most problematic issues, particularly due to the quantitative and qualitative deficits. In 1990, the disparity between the number of households and the available dwellings was estimated around 1.5 million. This housing deficit, one of the highest in the EU, increased slightly during this period, especially in the regions registering high economic development, i.e. in the Greater Warsaw area, Poznan, the Tri-City (Gdansk, Sopot, Gdynia), Wroclaw and Krakow. In 2002 the ratio was at 113 households per 100 dwellings, compared to 111.7 households per 100 dwellings in 1988[10] .

The thermal performance of much of the building stock is poor. Often there is a lack of sophisticated controls and of metering. Heat supply is often regulated using so-called 'qualitative' methods – i.e. with a constant flow rate; the output of boiler system is often manually adjusted according to outside temperature. Building users in turn have no control over the amount of heat they receive and no incentive to use *heat* rationally[11].

In Poland, the condition of approximately 1 million homes is sufficiently poor to make them virtually uninhabitable and the majority of homes are poorly insulated and draughty. Although the minimum insulation requirements in Poland's building regulations have been tightened significantly in recent years, they still fall short of the levels required in many Western European countries. Heat losses from residential buildings in Poland have been estimated at about twice of those found in European Union countries. Polish households spend about 12% of their budget on energy, compared to an average of 4% across the European Union[12] .

Bearing in mind that heating prices remain subsidised, it is likely that the coming few years will see a series of increases in the real price of heating. The financial burden on households of purchasing energy is, therefore, likely to increase still further. Ensuring the thermal integrity of dwellings, both existing and new-build, is consequently likely to prove beneficial not only at the macro-level, but also in helping to improve the financial standing of individual households [13].

With subsidised energy prices for heating, it is often difficult to present a compelling case on purely financial grounds for insulating and draught-proofing existing homes. But, if thermal improvements are deferred until heating prices have reached economic levels, there is a risk that households will be trapped in a position of energy poverty – unable to afford energy efficiency investments because of the burden of high energy bills. The Thermo-modernisation Program (detailed in the following sub-chapters) was introduced specifically to address this problem and should provide a significant stimulus to the market for insulation materials, double and triple glazing and *draught-stripping*[14] .

New construction rates are generally higher in the non-residential sector than in the residential sector. In the residential sector the new construction rate is between 0.1% and 2.4%. In the non-residential sector, the new construction rate is between 0.0% and 6.5% (*table 4*)[15] [16] .

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[9] M. Zawislak, Ministry of Infrastructure (2005). *Housing policy in Poland.* Presentation in Tallin, May 2005. Available here: www.mkm.ee/public/Marek_Zawislak.ppt[5] Based on data collection of BuildDesk Polska research

[10]IB. Schmigotzki. The Polish Housing Market - *A Concise Description of the Current Status, Problems and Investment Perspectives.* Available at: http://www.iwoev.org

[11] Idem6

[12]Export Council for Energy Efficiency (ECEE) (2010). Web Page: *The Market for Energy Efficiency in Poland*. Available at http://www.ecee.org/pubs/poland.htm#energy

[13]Idem 4

[14]Idem 5

[15]Cushman&Wakefield Poland(2011). *Polish Real Estate Market*. Available at: http://www.cushwake.com

[16]Estimations from BuildDesk Polska

Table 4: Number of buildings in Poland and new construction rates

Building type		Region	Number of buildings (1000)	Floor area (million m^2)	New construction rate (%)
Residential Buldings	Detached single family houses	Urban	1 900	200	2.4%
		Rural	2 900	348	0.7%
	Semi-detached and terraced single family houses	urban	500	40	0.3%
		rural	220	20	0.1%
	Multi-family buildings	urban	402	362	0.4%
		rural	45	10	0.4%
	Total		**5 967**	**980**	**0.9%**
Non-residential buildings	Commercial and public office		No data	82	0.0-0.5%
	Educational facilities		No data	81	No data
	Health facilities		No data	30	No data
	Hotels & restaurants		No data	30	6.5%
	Retail buildings		No data	78	6.6%
	Warehouses		No data	11	5.3%
	Total		**No data**	**312**	**2.5%**

The driving factors behind the growth of the Polish building stock are diverse and depend on the building type. Growth will be driven by varied factors:

- *increase income mainly in the case of single family houses;*
- *stricter conditions for loans mainly in the case of multifamily buildings;*
- *increased market demand in the case of hotels and restaurants;*
- *increased demand for office spaces in the case of office buildings and mainly for low-standard and economical offices.*

In the residential sector, there is a trend for people to move from residential blocks to single family houses. This trend is also due to the fact that the cost of building a single family house on the outskirts of the cities is similar to the cost of buying an apartment in a city centre. Based on the number of issued buildings permissions, the yearly supply of new single family houses is between 60 000 and 100 000. For multi-family buildings, the trend is towards more economical buildings with smaller living areas, but with greater energy performance [17.]

In the non-residential sector, the hotel & restaurant and retail building stock had been developing fast over the recent decades. There are currently around 53 beds per 10 000 inhabitants in Polish hotels, the lowest rate in the EU, and there is therefore an ongoing need for building new accommodation capacities. The small retail sector is developing rapidly and even big commercial chains have started to invest in smaller cities.

A significant percentage of the office area is located in old buildings from the 1960s and 1970s which have been refurbished to meet low standards and are traded on the real-estate market at lower prices than brand new buildings. This market segment of old refurbished office buildings is still developing well, whereas the new office building market has subsequently stopped. In general, office buildings with a low standard are often found in refurbished buildings.

For the coming years, it is expected that the above-mentioned trends will continue. For single family houses more renovations are expected, mainly for houses in very good locations, i.e. close to city centres. In the non-residential sector, a continuous development of new hotel buildings is anticipated with a focus on middle class hotels, and in the retail sector, mainly due to the expansion of big commercial chains, the construction of shops of up to 2 000 m^2 in smaller cities.

4.2. CURRENT BUILDING REGULATIONS FOR NEW BUILDINGS

4.2.1. Energy performance and specific component requirements

Poland has performance-based requirements for new buildings and renovations. The Polish building codes also have prescriptive/ element-based criteria for thermal insulation, ventilation, efficiency for boiler/ A/C system and for lighting efficiency. Additional prescriptive requirements are for solar shading and for the window area .[18]

According to the current regulations the architect must ensure that the quality of the building components is at a certain level or that a certain primary energy demand is not exceeded. The specific component requirements are set out in Table 5.

[17]Central Statistical office of Poland (2009). *The yearly supply of SFH Central Statistical office of Poland.* Available at: http://www.stat.gov.pl/english

[18] BPIE (2011). *Europe's buildings under the microscope*. BPIE. Available at www.bpie.eu.

Table 5: Specific component requirements in Poland

Maximum U-values for:	Walls	Roof	Floor	Windows
Residential building	0.3	0.25	0.45	1.7
Non-residential buildings [19]	0.3	0.25	0.45	1.8

The maximum primary energy demand in buildings is dependent on the shape factor, A/Ve (ratio between envelope area and external volume of building) and is calculated as follows:

- The minimum energy performance requirement for heating, ventilation and domestic hot water in residential buildings(EP_{H+W})

  a) For $A/V_e \leq 0.2$: EPH+W = 73 + ΔEP [kWh/m2.yr]
  b) For $0.2 \leq A/V_e \leq 1.05$: $EP_{H+W} = 55 + 90*(A/V_e) + \Delta EP$ [kWh/m2.yr]
  c) For $A/V_e \geq 1.05$: $EP_{H+W} = 149.5 + \Delta EP$ [kWh/m2.yr]

- The minimum energy performance requirement for heating, ventilation, domestic hot water and cooling (EPHC+W) in residential buildings:

  $EP_{HC+W} = {}_{EPH+W} + (5+15*A_{w,e/}A_f)(1-0.2*A/V_e)*A_{f,c}/A_f$ [kWh/m2.yr]

- The minimum energy performance requirement heating, ventilation, domestic hot water, cooling and lighting (EPHC+W+L) in commercial and industrial buildings:

  $EP_{HC+W+L} = EP_{H+W} + (10+60*A_{w,e}/A_{f)}(1-0.2*A/V_e)*A_{f,c}/A_f$ [kWh/m2.yr]

  Where:

  ΔEP is domestic hot water (DHW) based factor, ΔEP = 7800/(300+0,1 x Af)
  Af = heated area of building
  EP = primary energy demand per unit area [kWh/(m2 year)]
  $A_{w,e}$ = area of external walls
  $A_{f,c}$ = cooled area of building
  A = envelope area of building
  Ve = external volume of the building

In addition, there are other important requirements for buildings in the section "Technical Conditions" from building codes. As an example, it is compulsory to install heat recovery with minimum 50% efficiency in mechanical ventilation systems with airflow over 2000 m3/h. There are also lighting requirements such as those presented in Table 6.

[19]Poland now has similar requirements for all building types with the same maximum U values specified. Different U values only come from different internal temperature

Table 6: Prescriptive lighting requirements in Poland

Building type	Maximum installed capacity for lighting (W/m²) Class		
	A (basic requirements)	B (extended requirements)	C (requirements with full visual communication)
Offices	15	20	25
Schools, education	15	20	25
Hospitals	15	25	35
Restaurants	10	25	35
Sport & recreation	10	20	25
Retail	15	25	35

4.2.2. Renewable energy share in new buildings

Specific requirements for using renewable energy for heating and DHW in buildings do not exist. Since January 2009 every new building with a net area over 1000 m^2 is required to analyse the economic possibility of using renewable energy (geothermal energy, wind, solar and DHP).

4.2.3. Current practice in construction

According to the estimations of experts, the prescriptive building requirements for maximum U-values for components are satisfied in Poland. However, the energy performance requirement is satisfied in less than 50% of new buildings. An issue often highlighted by different experts is that the influence of domestic hot water is too high in the formula to calculate maximum primary energy demand and this makes it almost impossible to fulfil the energy performance requirement.

4.2.4. Enforcement

In Poland, it is possible to choose one of the prescriptive or performance-based requirements and usually (almost always) architects prefer to take into account at the design stage the requirements for all building components and not the overall primary energy consumption of the building. That is why more than 50% of new buildings do not fulfil the energy performance (EP) requirements (which are visible when an energy certificate is issued, see Table 7). The General Inspector of Buildings Control has clearly declared that they control whether an energy certificate is issued. This is one of the documents that is necessary for issuing a building usage permit.

Table 7: Share of buildings that fulfil EP condition based on energy certificates database (Source: Based on more than 70 000 energy certificates from BuildDesk database)

Building type	Share of new buildings that fulfil energy performance requirements
SFH single family	55%
MFH multi-family	40%
Office	44%
Schools and education	49%
Warehouse	45%
Retail	46%
Industrial	55%
Hotels & restaurants	48%
Public	48%

However, since 27 April 2012 changes in regulations have taken and to obtain a building permit it is compulsory to assess the predicted energy performance for all building projects. Although, bad energy performance will stop the building permit, the change shows good direction and change of perspective in regulations to secure energy efficiency and a trend towards tightening the limits in future.

4.2.4.1. Penalties for non-compliance

There are no penalties for not fulfilling the maximum energy primary demand condition.

4.2.4.2. Body responsible for compliance in construction

The body responsible for compliance in construction is the General Inspector of Building Control and local offices (http://www.gunb.gov.pl).

4.2.4.3. Renewable energy and current practice for new buildings

The most popular renewable energy technology in Poland is the solar panel for domestic hot water in single family houses and biomass boilers in regions where no district gas is available or investors decide not to use coal. In 2010, around 655 742 m2 of solar-thermal panels were installed in Poland generating approx. 459 MWth [20].

[20]EurObserv'ER (2011): *The state of renewable energy in Europe*. 11th EurObserv'ER Report, available at: http://www.energies-renouvelables.org/observ-er/stat_baro/barobilan/barobilan11.pdf

In Poland, 19 320 installed heat pump units were reported in 2010, with an overall capacity of 25 7MWth and 33.5 ktoe renewable energy captured [21]; however no data is available on the splits between the building types. The Polish heat pump association has not been active since 2009.

Photovoltaic (PV) systems are mostly small off-grid installations and are mainly installed in buildings subsidized by EU funds. In 2010, around 1.4 MWp of PV systems were installed in Poland[22], equally distributed in on-grid and off-grid applications, but they are only found to a very limited extent in single family, multi-family and public buildings.

4.2.4.4. Workforce education and training for new technologies

There are, at the moment, many installers in Poland offering solar panel systems. The popularity has grown rapidly from 2010 due to the subsidies offered by the National Fund for Environmental Protection and Water Management (NFOSiGW). In addition, there are also approximately 80 heat pumps suppliers and some 250 specialised installers. Despite the total number of installations being fairly small, these figures indicate that it is already quite significant expertise in the marketplace for these two technologies.

Biomass is used mainly in single family houses and in areas without a gas network. Biomass boilers and biomass as a fuel are much cheaper solutions compared to heat pumps and electrical energy. There are, moreover, a lot of Polish manufacturers of very efficient and modern biomass boilers.

4.2.4.5. Main investors in the buildings sector

In the case of single family houses, the main investors are private Polish individuals who are building a home for themselves. In the case of multi-family and office buildings, the main investors are usually real-estate companies that often sell the apartments and rent the office space.

In the case of non-residential buildings, the main investors are foreign hotel networks or/and local investors (in franchise) and commercial chains in the case of retail buildings (such as Lidl, Aldi, Netto, Biedronka-Jeronimo Martins, Tesco, Carrefour etc).

4.2.4.6. Low-energy buildings: Additional costs of investments and payback

The additional costs for constructing a highly efficient building compared to a standard new building are partly covered by the potential energy cost savings. Constructing a highly energy efficient single family house with mechanical ventilation and secured air tightness is more expensive than constructing a standard one based on the national technical regulation [23] . Payback periods of low-energy buildings range normally from 10 to 15 years, depending on building type. Newly built hotels are usually equipped with mechanical ventilation. Upgrading to highly efficient heat recovery systems imply additional costs and a payback period of about 10 years.

New retail buildings are mainly built directly by commercial chains of investors for their own use (and not rented) and there are positive signs showing that they are starting to understand the importance of energy efficiency and are requesting more often professional advice and consultancy.

[21] Idem 20

[22] Idem 20

[23] The technical regulations for buildings in Poland are defined by the Decree of the Ministry of Infrastructure from 12th April 2002 and modified on 6 November 2008. Ministry of Infrastructure of Poland (2008). WT 2008 : Warunki Techniczne jakim powinny odpowiadać budynki i ich usytuowanie (Technical Conditions for new buildings...).

4.2.5. Current support schemes for new buildings

At the end of 2009, the Council of Ministers adopted a resolution on "Energy Policy of Poland until 2030". This document, based on the Energy Act, describes Poland's strategy to meet the most important challenges the Polish energy sector faces, both over short-term and by 2030. The main objectives of the Polish energy policy regarding energy efficiency are:

- To stop the increase in primary energy demand while economic growth continues (zero-energy economic growth);
- To significantly decrease the energy intensity of the Polish economy aiming to reach the EU-15 level in 2005.

In this context the Polish government has implemented several programmes and measures to promote energy efficiency in buildings which are described in the following paragraphs [24] [25].

The Thermo-modernisation and Renovation Fund was established in 1998 through the 'Act on Support for Thermo-Modernisation Investment in Buildings', which defines the Government's principles supporting the energy efficient refurbishment of buildings in Poland. The introduction of the Thermo-Modernisation Law and Fund in 1999 established the regulatory framework for making operational the Thermo-Modernisation Fund. To become eligible, refurbishment projects must meet certain technical and financial criteria, which have to be verified by an energy audit and a financial analysis prior to receiving the financial support from the Fund. Among other eligibility criteria, the refurbishment has to deliver at least 25% energy savings.

The Fund focuses on owners of multi-dwelling units, housing facilities and local governments. The measure provides loans for thermo-modernisation[26] and renovation investment, of which 16% can be rewarded as a grant.

To obtain the thermo-modernisation bonus, the investor should carry out an energy audit (to determine the work, the estimated cost and the expected savings), draw up a construction plan and carry out the investment accordingly (NEEAP Poland, 2012). The Fund has an annual budget of PLN 200 million (about 47 million euro) and is implemented by Bank Gospodarstwa Krajowego.

The aim of the Polish Green Investment Scheme (GIS, Part 1 and 5)[27] is to decrease energy consumption by providing grants and loans for buildings' thermo-modernisation and more energy-efficient lighting. The GIS supposes two distinct financing lines, one dedicated to public utility facilities (Part 1) and another one for selected public buildings (Part 5). For GIS Part 1 both grants (total budget of PLN 555 million, about 133 million euro) and loans (from a total budget of PLN 1,010 million, about 240 million euro) are available. For GIS Part 5 only grants are available, with a total budget of PLN 500 million (about 120 million euro). However, it is impossible to identify the financing share allocated to thermo-modernisation activities .[28]

While not officially confirmed, the administration of National Fund for Environmental Protection and Water Management (NFOSiGW) has announced the intention to introduce from 2013 a new financing line offering subsidies for investors in new low-energy residential buildings (both single- and multi-family buildings) [29].

[24] International Energy Agency (IEA) (2010). *Energy and Co2 Emissions Scenarios of Poland. International Energy Agency (IEA)*. Available at: http://www.mg.gov.pl/files/upload/10460/ENERGY_AND_CO2_MAE.pdf. International Energy Agency (IEA), Warsow, Poland.

[25] Erika de Visser, Paul Noothout, Rolph Spaas,Jan Grözinger (2011). *Energy Efficiency Working Paper.* Ecofys (Unpublished) for Ecofys.

[26] Thermo-modernisation is a collective term introduced in the first Polish NEEAP. Thermo-modernisation refers to investments that improve the energy efficiency of buildings, including: refurbishment of the main construction elements of buildings: roofs, façades, windows and doors, staircases, internal and external corridors and hallways, and entrance and its external construction, lifts; technical installation of the building; actions concerning energy savings and projects related to preparing modern, good standard social housing buildings by means of renovation and adaptation of existing buildings owned by public authorities or by non-profit entities.

[27] See http://www.nfosigw.gov.pl/en/priority-programmes/green-investment-scheme/

[28] Idem 21

[29] President of National Fund for Environmental Protection and Water Management (2012). *Seminars energy efficient SFH investors and MFH NFOŚiGW*. Date of communication: 2012-03-01

NFOSiGW has another funding line offering subsidies for renewable energy technologies in buildings. This includes financial support for purchase and installation of solar systems for domestic hot water in buildings assigned or used for residential purposes[30], for both new buildings and refurbishment. Apart from the National Fund (NFOSiGW) there are also its regional branches which support, at local level, the purchase of heat pumps, solar thermal panels, biomass boilers and thermo–modernisation of buildings. Only private persons and housing cooperatives are eligible to apply for receiving a financial support which is limited at PLN 1 million (250 000 euro). Moreover, co-financing of eligible projects can be obtained through selected commercial banks cooperating with NFOSiGW. Overall, this programme is expected to facilitate the implementation of additional 200 000 m^2 solar-thermal systems.

The current support schemes for promoting renewable energy technologies in buildings are obviously not sufficient. However, the implementation of Poland's Energy Policy Strategy 2030 foresees inter alia the introduction of additional support mechanisms for promoting the market up-scale of renewable heating and cooling[31] .

At the moment, there are no specific subsidies in Poland for green energy use or (green) district heating use. The main on-going and planned support programmes managed by NFOSiGW and targeted for enhancing the energy performance of buildings[32] are summarised in the table below:

[30]See http://www.nfosigw.gov.pl/en/priority-programmes/offer-for-an-individual-investor/

[31]Eva Teckenburg, M.R., Thomas Winkel, Ecofys,, Mario Ragwitz, S.S., Fruanhofer ISI,, Gustav Resch, C.P., Sebastian Busch, EEG,,Inga Konstantinaviciute, L.e.i. (2011). *Renewable energy policy country profiles*. Ecofys, Fraunhofer, Energy Economics Group, LEI. Available at: www.reshaping-res-policy.eu

[32]Second Polish National Energy Efficiency Action Plan 2012. Available at: http://ec.europa.eu/energy/efficiency/end-use_en.htm

Table 8: Main on-going and planned support programmes managed by NFOSiGW targeted at buildings

Support program/scheme	Duration	Responsible body	Targeted sector	Eligible measures	Budget	Achieved and expected savings
Green Investment Scheme part 1 – Energy Management in Public Buildings	2011 - 2014	National Fund for Environmental Protection and Water Management	Local communities, higher education schools, hospitals and health institutions, planned about 3 000 buildings	Complete thermo modernisation through renovation	126 million euro (subsidy) plus 227 million euro (loan from NFEPWM)	1 950 GWh by 2016
Green Investment Scheme part 5 (PLANNED - information from national plan for energy effectiveness, approved by the Cabinet 17 April 2012) - energy management in public buildings	2010 - 2015	National Fund for Environmental Protection and Water Management	Polish Academy of Sciences and national culture institutions	Complete thermo modernisation and internal lighting through renovation	114 million euro	Not estimated
“Energy Savings and Renewables Promotion” - EOG and Norwegian Finance Mechanism	2012 – 2017	National Fund for Environmental Protection and Water Management and Ministry of the Environment	Public buildings (education, health, social, local communities)	Thermo modernisation, exchange of old energy sources between 0,2MW-3,0MW, Renewable energy	75 million euro	Not estimated
Operational Program “Infrastructure and Environment”, 9.3 – Thermo modernisation of public buildings	2007 – 2015	National Fund for Environmental Protection and Water Management	Public buildings	Insulation, windows, lighting, heating and ventilation systems	76.7 million euro	320 GWh in 2016

5. SIMULATION OF nZEB OPTIONS ACCORDING TO LOCAL CONDITIONS

5.1. DEFINITION OF REFERENCE BUILDINGS

Based on the research results and information about the local building stock, the simulations highlight the specific national situation in Poland, which differs in many respects from the overall EU situation as presented in the general European study "Principles for nearly Zero-Energy Buildings".
To analyse the impact of different nZEB options, three reference buildings have been defined, based on current construction practices in Poland:

- Detached single family houses (SFH)
- Multi-family houses (MFH)
- Office buildings

The reference buildings selected should match the range of building types found in Poland (taking into account typical shapes, sizes, characteristics and usage of new buildings). The aim of the simulation is to analyse the technical and economic impact of moving towards nZEB starting from the current situation in an effective and realistic manner and by minimising transition costs.
The SFH is by far the dominant building type in Poland. Within this category, the detached SFH has the highest share. The second largest amount of floor space (m^2) was indicated for urban MFH.

As presented in the previous chapter, the share of office buildings within the non-residential buildings is among the highest. The other non-residential buildings such as the retail buildings sector are characterised by a high diversity of subtypes and the definition of many reference buildings would be necessary to produce an accurate picture. In addition, there is a very low dynamic in the construction of new educational and healthcare buildings. The existing stock, however, is well established and in need of improved renovation quality, renovation depth and rate. Overall, while the actual construction rates are very low, office buildings are more uniform and there are fewer subtypes than in the case of other non-residential building types. Public administration buildings are included in the office buildings category. The EPBD indicates that public administration buildings should play a leading role and adopt more timely and ambitious nZEB requirements. Based on this, we chose office buildings as the third relevant reference building category for this study.

5.1.1. Reference building N°1: Single family house (SFH)

The first reference building for Poland is an individual detached house on two floors, in accordance with current practice identified in construction. It is a building with a double sloped roof (North-South), with no basement and a usable attic. There is moderate shading from the surrounding and no sun protection system installed. The sketches of the reference SFH are in Annex 1 of the study.

It is a building with a comparably simple architecture with a sloped roof facing the south. The conditioned space on the ground floor and first floor is heated to 20°C. The basement (garage and boiler room) and the roof level are assumed to be not heated.

The general heating system is a central gas boiler heating system with radiators. The Domestic Hot Water (DHW) system uses a 100 litre tank and is connected to the heating boiler. There is no mechanical ventilation and no cooling systems, i.e. only natural ventilation via the windows. There is no solar thermal system and no PV system installed on the roof. The main building characteristics are summarised in the following table.

Table 9: Main characteristics of reference Polish single family house (specified equivalent U-values consider also thermal cold bridges)

Parameter	Value/Description
Number of conditioned floors	2
Net floor area	183.5 m^2
Room height	2.65 m
U-walls	0.23 W/(m^2.K)
U-roof	0.20 W/(m^2.K)
U-floor	0.59 W/(m^2.K)
Shading	None
Air tightness	Moderate
Heating system	Gas boiler (set point: 20°C); Heating efficiency: 0.9
DHW system	Same as for heating
Ventilation system	Natural/window ventilation
Cooling system	None
Internal gains[33]	16 W/m^2
Installed lighting power[34]	5 W/m^2
Automatic lighting control	No

[33]This value is to be understood as the maximum value. For persons, lighting, appliances and other internal gains schedules exist taking into consideration for example how many persons are at the moment in the respective zone.

[34]This value is to be understood as a maximum value. For the hourly demand individual schedules for every zone have been considered.

5.1.2. Reference building N°2: Multi-family house (MFH)

The second reference building is a multi-family house on six floors, in accordance with the current practice identified in construction. The roof is flat and the conditioned space over the 6 floors is heated to 20°C. The two basements (partially garage) are assumed to be not heated. The sketches of the reference MFH are included in Annex 1 of the study.

The general heating system is a central gas boiler heating system with radiators. The Domestic Hot Water (DHW) system uses a 2 400 litre tank and is connected to the heating boiler. There is no mechanical ventilation or cooling systems, i.e. only natural ventilation via the windows. As for the general cooling system, a split system exists in each apartment. There are no solar thermal systems and no PV system installed on the roof. The main building characteristics are summarised in the following table.

Table 10: Main characteristics of reference Polish single family house (specified equivalent U-values consider also thermal cold bridges)

Parameter	Value/Description
Number of conditioned floors	6
Net floor area	2870 m^2
Room height	2.73 m
U-walls	0.60 W/(m^2.K)
U-roof	0.28 W/(m^2.K)
U-floor	0.47 W/(m^2.K)
U-windows, frame fraction	1.70 W/(m^2.K), 25%
Window fraction (window/wall-ratio)	23%
Shading	None
Air tightness	Moderate
Heating system	District Heating (set point: 20°C); Heating efficiency: 0.95
DHW system	Same as for heating; DHW efficiency: 0.95
Ventilation system	Natural/window ventilation (0.5 1/h)
Cooling system	None
Internal gains [35]	21 W/m^2
Installed lighting power [36]	No

5.1.3. Reference building N°3: Office building

The third reference building is an office building on 3 floors, with a high amount of glazing area (50% window fraction), as identified in accordance with current practice in construction. The roof is flat and the conditioned space is heated to 20°C. The basement (garage) is assumed to be not heated. The sketches of the reference office building are included in Annex 1 of the study.

Heating and cooling are provided by water fed fan coil units using district heating as heating source. The Domestic Hot Water (DHW) system uses a 300 litre tank. The building has mechanical ventilation with a heat recovery rate of 80%. For cooling, the assumption is a central air cooled compression chiller system with fan coils. There are no solar thermal systems and no PV system installed on the roof. Internal blinds are installed to provide solar shading. The main building characteristics are summarised in the following table.

Table 11: Characteristics of reference Polish office building (specified equivalent U-values consider also thermal cold bridges)

Parameter	Value/Description
Number of conditioned floors	3
Net floor area	886 m^2
Room height	3.00 m
U-walls	0.30 W/(m^2.K)
U-roof	0.25 W/(m^2.K)
U-floor	0.45 W/(m^2.K)
U-windows, frame fraction	1.80 W/(m^2.K), 21%
Window fraction (window/ wall-ratio)	50%
Shading	Internal blinds

[35]This value is to be understood as a maximum value. For persons, lighting, appliances and other internal gains schedules exist which take into consideration for example how many persons are at the moment in the respective zone.

[36]These values are to be understood as the maximum value. For the hourly demand individual schedules for every zone have been considered.

Air tightness	Moderate
Heating system	District heating, hot water distribution, fan coils (set point: 20°C), Heating efficiency: 0.95
DHW system	Same as for heating, DHW efficiency: 0.95
Ventilation system	Mechanical ventilation with 80% heat recovery (0.5 ... 3.0 1/h, zone dependent)
Ventilation rates during system operating time (6 am till 6 pm)	Office spaces: 1.5 1/h
	Conference rooms: 3 1/h
	Other rooms: 0.5 1/h
Cooling system	Central chiller, fan coils, (set point: 26°C), SEER: 4
Internal gains [37]	7.4 W/m² (office area) and 3.1 W/m² (auxiliary area)*
Person density in office areas (considered as an additional internal load)	0 am - 8 am and 6 pm - 0 am: no persons
	8 am - 12 am and 2 pm - 6 pm: 1 person/15 m²
	12 am - 2 pm: 1 Person/30 m²
Installed lighting power[38]	20 W/m²
Automatic lighting control	Yes

[37]This value is to be understood as a maximum value. For persons, lighting, appliances and other internal gains schedules exist which take into consideration for example how many persons are at the moment in the respective zone.

[38]These values are to be understood as maximum values. For the hourly demand individual schedules for every zone have been considered.

5.2. DEFINITION OF NZEB OPTIONS, BASIC ASSUMPTIONS AND SIMULATION APPROACH

5.2.1. nZEB solutions for single family houses (SFH)

For all variants – for comparison reasons – the geometry of the reference buildings has not been changed, even if they are not optimum for a very low-energy building. Table 12 shows the variants considered for dynamic thermal simulations with TRNSYS[39] .

Table 12: Polish SFH, nZEB variants

Variants	U-value Opaque Shell	U-Value Window	Heat Recovery Rate	Solar Collector for DHW	Brief Description
V0	U-Wall: 0.23 W/m².K U-Roof: 0.20 W/m².K U-Floor: 0.59 W/m².K	1.4 W/m².K	0%	No	Reference
V1	U-Wall: 0.23 W/m².K U-Roof: 0.20 W/m².K U-Floor: 0.59 W/m².K	1.4 W/m².K	80%	No	+ mech. ventilation with heat recovery
V2	U-Wall: 0.12 W/m².K U-Roof: 0.10 W/m².K U-Floor: 0.15 W/m².K	0.8 W/m².K	90%	No	improved building shell + improved mech. ventilation with heat recovery
V3	U-Wall: 0.12 W/m².K U-Roof: 0.10 W/m².K U-Floor: 0.15 W/m².K	0.8 W/m².Kv	90%	No	improved building shell + improved mech. ventilation with heat recovery
V4	U-Wall: 0.12 W/m².K U-Roof: 0.10 W/m².K U-Floor: 0.15 W/m².K	0.80 W/m².K	90%	Yes	improved building shell + improved mech. ventilation with heat recovery + solar collectors

[39] TRNSYS is a transient systems simulation program, commercially available since 1975, which has been used extensively to simulate solar energy applications, conventional buildings, and even biological processes. More details at: http://www.trnsys.com/

Based on the local conditions and practices, for each of the five base variants the following four heating supply options are considered:

1. Wood pellet boiler
2. Air source heat pump[40]
3. Ground collector brine heat pump[41]
4. Gas condensing boiler

5.2.2. nZEB solutions for multi-family houses (MFH)

As for the SFH, all solutions are based on the same geometrical data of the identified reference MFH. Table 13 shows the variants simulated with TRNSYS.

Table 13: Polish MFH, nZEB variants

Variants	U-value Opaque Shell	U-Value Window	Heat Recovery Rate	Solar Collector for DHW	Brief Description
V0	U-Wall: 0.60 W/m².K U-Roof: 0.28 W/m².K U-Floor: 0.47 W/m².K	1.7 W/ m².K	0%	No	Reference
V1	U-Wall: 0.28 W/m².K U-Roof: 0.15 W/m².K U-Floor: 0.32 W/m².K	1.0 W/ m².K	0%	No	Improved building shell
V2	U-Wall: 0.60 W/m².K U-Roof: 0.28 W/m².K U-Floor: 0.47 W/m².K	1.7 W/ m².K	1.7 W/ m².K	No	Mech. ventilation with heat recovery
V3	U-Wall: 0.28 W/m².K U-Roof: 0.15 W/m².K U-Floor: 0.32 W/m².K	1.0 W/ m².K	85%	No	Improved building shell + mech. ventilation with heat recovery
V4	U-Wall: 0.28 W/m².K U-Roof: 0.15 W/m².K U-Floor: 0.32 W/m².K	1.0 W/ m².K	85%	Yes	improved bImproved building shell + mech. ventilation with heat recovery + solar collectors

[40] V1 and V2 will be considered to have a low temperature floor heating system to get a better system efficiency

[41] Idem 38

Variant V1 was created to examine the individual impact of a shell improvement. It should be mentioned that an airtight construction without controlled ventilation increases the risk for mould formation. It is, therefore, strongly recommended that an adequate ventilation concept is developed if this variant is to be considered for implementation.

Based on the local conditions and practices, for each of the five base variants the following five heating source options will be considered:

1. Wood pellet boiler
2. Air source heat pump [42]
3. Ground collector brine heat pump [43]
4. Gas condensing boiler
5. 5District heating

5.2.3. nZEB solutions for office buildings

Similarly, for office buildings simulation, the geometry of the reference was kept, even if it is not an optimal for an nZEB. Table 14 shows the variants simulated with TRNSYS.

Table 14: Polish office building, nZEB variants

Variants	U-value Opaque Shell	U-Value Window	Heat Recovery Rate	External shading	Window Share	Light system	Solar collector for DHW	Brief Description
V0	U-Wall: 0.30 W/m².K U-Roof: 0.25 W/m².K U-Floor: 0.45 W/m².K	1.8 W/ m².K	80%	None	None	Automatic controlled lighting	No	Reference
V1	U-Wall: 0.15 W/m².K U-Roof: 0.12 W/m².K U-Floor: 0.45 W/m².K	1.0 W/ m².K	80%	None	50%	Automatic controlled lighting	No	Improved building shell
V2	U-Wall: 0.15 W/m².K U-Roof: 0.12 W/m².K U-Floor: 0.45 W/m².K	1.0 W/ m².K	80%	Automatic	50%	Automatic controlled lighting	No	Improved building shell + external shading
V3	U-Wall: 0.15 W/m².K U-Roof: 0.12 W/m².K U-Floor: 0.45 W/m².K	1.0 W/ m².K	80%	Automatic	50%	Automatic controlled lighting +LEDs	No	Improved building shell + external shading + improved lighting
V4	U-Wall: 0.12 W/m².K U-Roof: 0.10 W/m².K U-Floor: 0.20 W/m².K	0.8 W/ m².K	90%	Automatic	50%	Automatic controlled lighting +LEDs	No	Close to Passive house stan-dard[44]

[42] V1 and V2 will be considered to have a low temperature floor heating system to get a better system efficiency. I

[43] Idem 38

[44] Passive house standard: Major shell improvements, no heat bridges, airtight construction, highly efficient mechanical ventilation (> 90%), useful heating and cooling demand < 15 kWh/m²a

For each of the five base variants, the following five heating options will be considered:

1. Central air/water heat pump
2. Central brine/water heat pump
3. Central wood pellet boiler
4. Central gas condensing boiler
5. District heating

5.2.4. General assumptions of the calculations

For calculating the impact of different supply options in the building's overall energy and CO_2 balances, the following general assumptions have been considered:

Table 15: Assumed CO_2 emissions, primary-energy-factors and shares of renewable energy of the considered energy carriers

Parameter	Unit	Off-site, grid electricity	District Heating [45]	Natural gas	Wood pellets	On-site electricity [46]
CO_2 factor[47]	[kg/ kWh]	0.252	0.683	0.202	0.000	-0.252
Renewable share[48]	[%]	35	21	0	100	100
Primary energy factor[49]	[-]	2.0	1.3	1.1	0.2	-2.0

For grid electricity the projected EU-27 average values (for detailed description see footnotes) have been chosen in consideration that local building sector targets should not be influenced by local power sector efficiency and, thereby, ensure consistency with the overall EU targets.

However, the thresholds that will be recommended for implementation in Poland according to the roadmap (see Chapter 8) will take into account actual Polish primary energy and CO_2 emission factors (which are at the moment 3.0 and about 0.9 $kgCO_2/kWh$ respectively). It should be noted that, due to the future decarbonisation of electricity production systems, the primary energy factors will decrease. As such, this anticipated improvement in primary energy and CO_2 factors will be reflected in tighter thresholds for CO_2 in the proposed nZEB definitions.

[45] The district heating was assumed to be supplied by 40% wood, 10% solar thermal and 50% gas. The distribution losses were assumed to be 40%.

[46] For the purpose of this simulation only photovoltaic (PV) is considered.

[48] The shares of renewable energy are calculated as "2011 to 2040"- average values, based on the renewable energy projections of the Energy Environment Agency and the ECN for the EU-27.

[49] The primary energy factor for electricity was calculated as "2011 to 2040"- average value, based on the renewable energy projections of the Energy Environment Agency and the ECN for the EU-27. The remaining primary energy factors were calculated using EPB calculation methodology (MC001-2006).

The Polish market currently does not offer 100% renewable electricity products, which could increase the number of possible nZEB solutions.

Furthermore, for the most locations only conventional district heat with a renewable share of about 20% is available at the moment.

The local specific energy production of PV systems per kWp was assumed to be 891 kWh/kWp [50] (for Warsaw). Assumed necessary heating capacities for reference buildings are in Table 16.

Table 16: Installed heating capacity of the heating systems for Poland

Variant	SFH [kW]	MFH [kW]	OFFICE [kW]
V0	14.3	183	79
V1 A	9.4	136	53
V1 B	9.4	136	53
V1 C	9.4	136	53
V1 D	9.4	136	53
V1 E	9.4	136	53
V2 A	8.0	119	53
V2 B	8.0	119	53
V2 C	8.0	119	53
V2 D	8.0	119	53
V2 E	8.0	119	53
V3 A	5.3	72	53
V3 B	5.3	72	53

[50] Joint Research Centre - European Commission (2012). Web Page: *Photovoltaic Geographical Information System* - Interactive Maps. Available at : http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php

V3 C	5.3	72	53
V3 D	5.3	72	53
V3 E	5.3	72	53
V4 A	5.3	72	45
V4 B	5.3	72	45
V4 C	5.3	72	45
V4 D	5.3	72	45
V4 E	5.3	72	45

5.2.5. Simulation Approach

The results of the simulations of the predefined solutions are analysed in comparison with the nZEB principles defined in Chapter 2.

The following parameters are considered and calculated:

- Specific final energy demand detailed by building services (i.e. heating, domestic hot water, cooling, ventilation and auxiliary energy);
- Specific primary energy demand;
- Share of renewable energies;
- Specific CO_2 emissions.

In addition to the above-mentioned assumptions, a further set of solutions with a rooftop PV system for compensating the remaining CO_2 emissions was assumed for all solutions. The available roof areas as well as the required areas for solar thermal systems have also been considered; in some cases full compensation cannot be achieved.

The sizes of the building's roof as well as the considered solar-thermal collectors introduce a limitation for the PV compensation in terms of maximum installed capacity such as in the followings: 5.8 kWp for SFH; 43.8 kWp for MFH and 30.2 kWp for office buildings.

Table 17 shows the derived sizes of the rooftop PV systems, which were necessary for reaching a high-degree or even full compensation of a building's CO_2 emissions.

Table 17: Sizes of the rooftop PV systems, necessary for a compensation of the CO_2 emissions

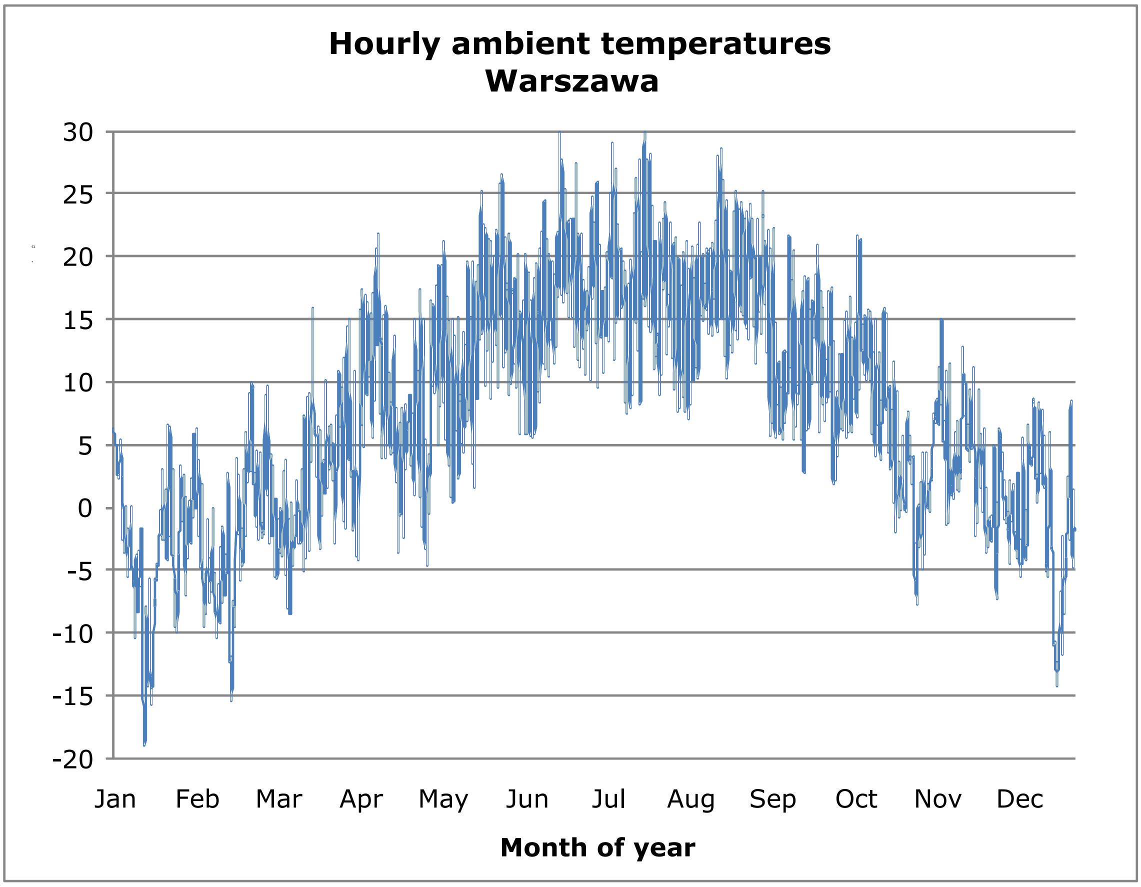
Variant	SFH [kW]	MFH [kW]	OFFICE [kW]
V1 A	5.8	43.8	30.2
V1 B	5.0	43.8	30.2
V1 C	0.8	4.3	30.2
V1 D	5.8	43.8	30.2
V1 E	-	43.8	30.2
V2 A	4.1	43.8	30.2
V2 B	3.2	43.8	30.2
V2 C	0.6	12.3	30.2
V2 D	5.8	43.8	30.2
V2 E	-	43.8	30.2
V3 A	3.3	43.8	30.2
V3 B	2.9	43.8	30.2
V3 C	0.6	11.2	30.2
V3 D	5.8	43.8	30.2
V3 E	-	43.8	30.2
V4 A	2.7	38.8	30.2
V4 B	2.1	38.8	30.2
V4 C	0.7	11.7	30.2
V4 D	5.1	38.8	30.2
V4 E	-	38.8	30.2

Remark: The electricity produced by PV was calculated as a negative contribution to the specific CO_2 emissions and the specific primary energy demand for the base nZEB system solutions, assuming the CO_2 emissions and primary energy factors of conventional grid electricity. Negative values for the CO_2 emissions and the primary energy are possible for those solutions, where the required CO_2 compensation (i.e. for the associated CO_2 emissions of the primary energy consumption of the buildings) is less than the smallest PV system (assumed to be 0.6 kWp). In cases when the rooftop PV system produces more energy than the annual demand (=> plus energy buildings) a renewable energy share above 100% is possible. On the other hand, especially for MFH and office buildings solutions, it is possible that the available roof space doesn't permit full CO_2 compensation. The existence of solar collectors in basic variant V4 leads to a further reduction of the maximum available roof space for PV.

The internationally known and well proven software tool "TRaNsient SYstems Simulation" (abbreviation: TRNSYS, version 17) has been used to perform the necessary multi-zoned dynamic simulations. Each agreed reference building was split into several zones (e.g. living room, bedroom, kitchen for SFH) to be able to take into account the differing person density or internal gains in each of the zones.

The climatic conditions forming the basis for the reference building simulations originate from Meteonorm 6.1. The following graph shows the hourly ambient temperatures for the agreed location of Warsaw.

Figure 4: Hourly ambient temperature in Warsaw



5.3. RESULTS OF SIMULATIONS AND ECONOMIC CALCULATIONS

The three predefined reference buildings for SFH, MFH and office buildings were simulated using the above-presented assumptions and by considering the defined variants for heating, cooling, ventilation and domestic hot water (DHW) supply. The purpose of this simulation is to determine the buildings' final and primary energy consumption, renewable energy share, CO_2 emissions and, therefore, to perform the economic analysis and to identify the cost-optimal nZEB solutions.

5.3.1. Final energy demand

Mainly because of its size, the reference single family house (SFH) has the highest specific energy demand for heating. With the most ambitious solutions, the specific final energy demand for SFH can be reduced even to around 10 kWh/m²*yr.

The multi-family house (MFH) has a higher specific DHW demand and less space on the roof for solar collectors than the SFH. The specific final energy demand for the most ambitious MFH solution is, hence, below 15 kWh/m²*yr higher than the final energy demand of the SFH.

As the lighting demand has to be considered for the office building and the shares for the cooling and ventilation demands are higher than for the residential buildings, the specific final energy demand for the most ambitious office solution is, at about 40 kWh/m²yr, the highest among the three examined building types.

All heat pump solutions lead to a significant reduction in the final energy demand.
A detailed breakdown of final energy consumption in the selected reference buildings is presented in Figure 5 (A-C).

5.3.2. Primary energy demand

Without CO_2 compensation, the minimal specific primary energy ranges between approximately 13 kWh/m²*yr for the most ambitious SFH solutions and more than 75 kWh/m²yr for the most ambitious office building solutions.

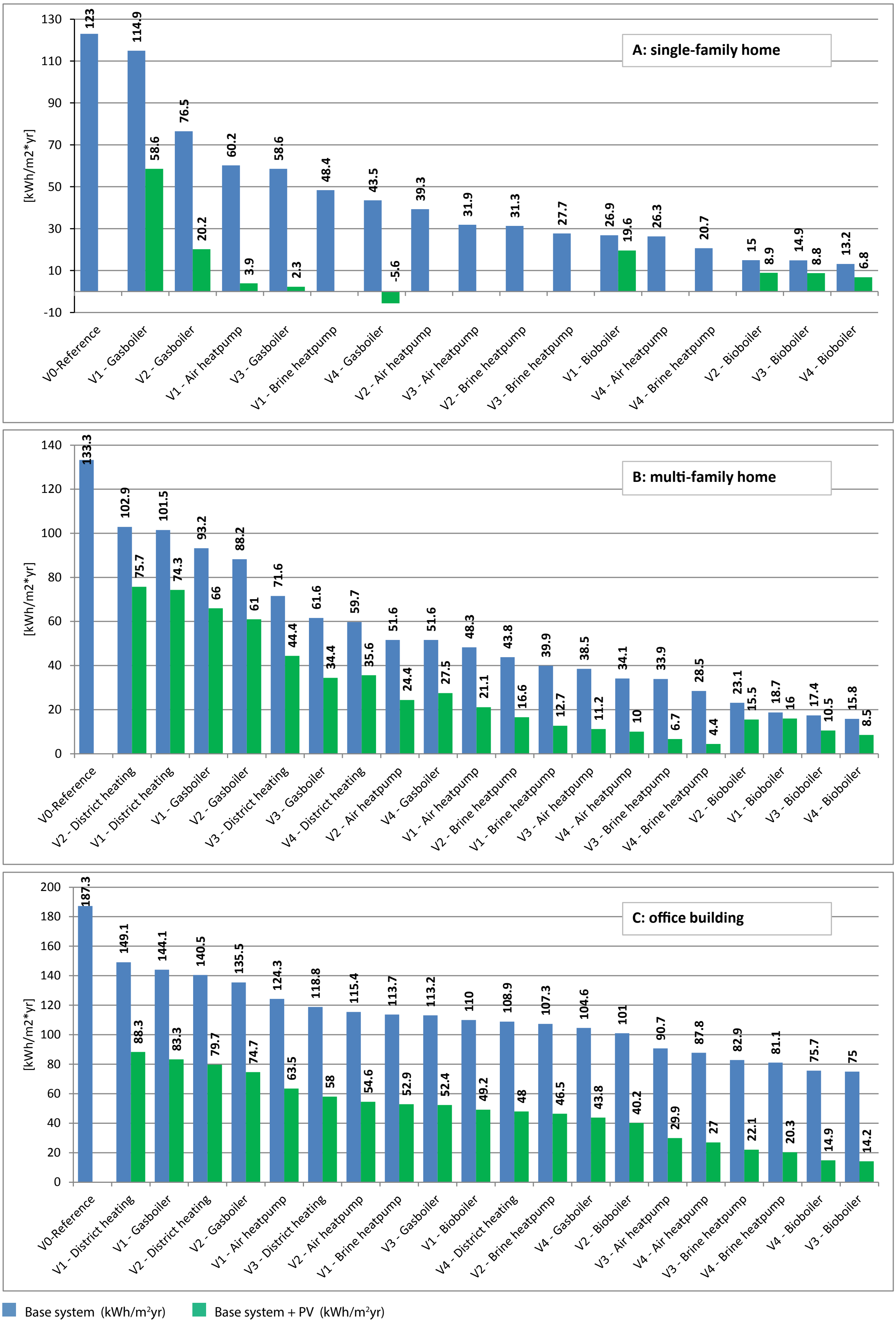
The gas boiler solution applied to the most ambitious SFH variant (V4) with CO_2 compensation leads to a theoretical negative specific primary energy demand (approx. -6 kWh/m²*yr).

For the MFH, even with maximum possible CO_2 compensation, the most ambitious district heating solution has a specific primary energy demand of more than 35 kWh/m²*yr. The least primary energy consumption for SFH is reached in the case of the most ambitious variant (V4) with a bio-boiler, i.e. below 9 kWh/m²*yr.
The reference office building has the highest specific primary energy demand. This is due to the fact that, as already mentioned, during the evaluation of final energy demand, additional lighting and ventilation demand should be considered, as well as the comparably high demand for cooling. Without CO_2 compensation, the district heating solutions indicate the highest primary energy demands of around 103 kWh/m²*yr. The least primary energy consumption for office buildings is reached in the case of the most ambitious variants (V3 and V4) with bio-boiler, i.e. approx 15 kWh/m²*yr.

Considering the CO_2 compensation, solutions below 20 kWh/m²*yr are achievable for all building types.
The primary energy consumption in the selected reference buildings and in different nZEB variants are presented in Figure 6 (A-C).

Figure 5: final energy demand for SFH, MFH and offices by building services

Figure 6: primary energy demand for SFH, MFH and offices



5.3.3. Associated CO_2 emissions

As discussed in Chapter 2, the BPIE study on Principles for nearly zero-energy buildings identified the need for having associated CO_2 emissions below 3 kg/m²yr for all new buildings. This condition has been identified by estimating the maximum allowed CO^2 emissions in the EU buildings sector in order to reach the 2050 decarbonisation target. Therefore, the analysis of the simulated nZEB solutions has been made on the basis of this assumption.

Almost all basic variants without CO_2 compensation have specific CO_2 emissions above 3 kg/m²yr.

In the case of SFH, only bio-boiler solutions reduce the building's CO_2 emissions below 3 kg/m²yr. For variants comprising higher insulation of the building shell, the heat pump solutions also reduce the building's CO^2 emissions below the threshold or slightly above it. All the variants except the gas boiler solutions and the heat pump solution in the case of the least insulated basic variant reach a full CO_2 compensation by PV rooftop systems.

In the case of MFH, the bio-boiler solutions lead to the building's CO_2 emissions being below the threshold. For MFH, all bio-boiler and heat pumps solutions with CO_2 compensation lead to overall CO_2 emissions from buildings below 3 kg/m²yr, which is not the case for district heating (with an assumed share of 21 % renewable energy) and gas boiler solutions.

In the case of office buildings, the associated CO_2 emissions of the building are below or slightly above the threshold only for bio-boiler and heat pump solutions in the two variants with highest insulation levels (V3 and V4) and with CO_2 compensation.

It is important to mention once again that in the case of heat pumps it is the CO_2 emissions of the building that are strongly dependent on the carbon content of the electricity share. However, when using the CO_2 compensation it is possible to use the electricity produced by the on-site PV system and therefore to ensure a very low CO_2 content of the heat pumps solutions.
The CO_2 emissions relating to the primary energy consumption in the selected reference buildings and in different nZEB variants are presented in Figure 7 (A-C).

5.3.4. Renewable energy share

The bio-boiler solutions without CO_2 compensation contribute to the highest renewable energy share in the three reference buildings, i.e. between 80%-140% for residential buildings and 60%-70% in case of the office building.

However, the renewable energy share for the bio-boiler (wood pellet boiler) solutions decreases for the base variants for SFH and MFH supposing a higher degree of insulation, due to the relative increase of the electricity demand – e.g. for the auxiliary energy and the ventilation - compared to the building's heating demand.

In the case of the office building, the renewable energy share is lower than in the case of residential buildings due to the significantly higher electricity demands for lighting, cooling and ventilation. By using the CO_2 compensation, all solutions achieved renewable energy share above 50%.
The renewable energy share in the selected reference buildings and in different nZEB variants are presented in Figure 8 (A-C).

Figure 7: Associated CO_2 emissions for SFH, MFH and offices

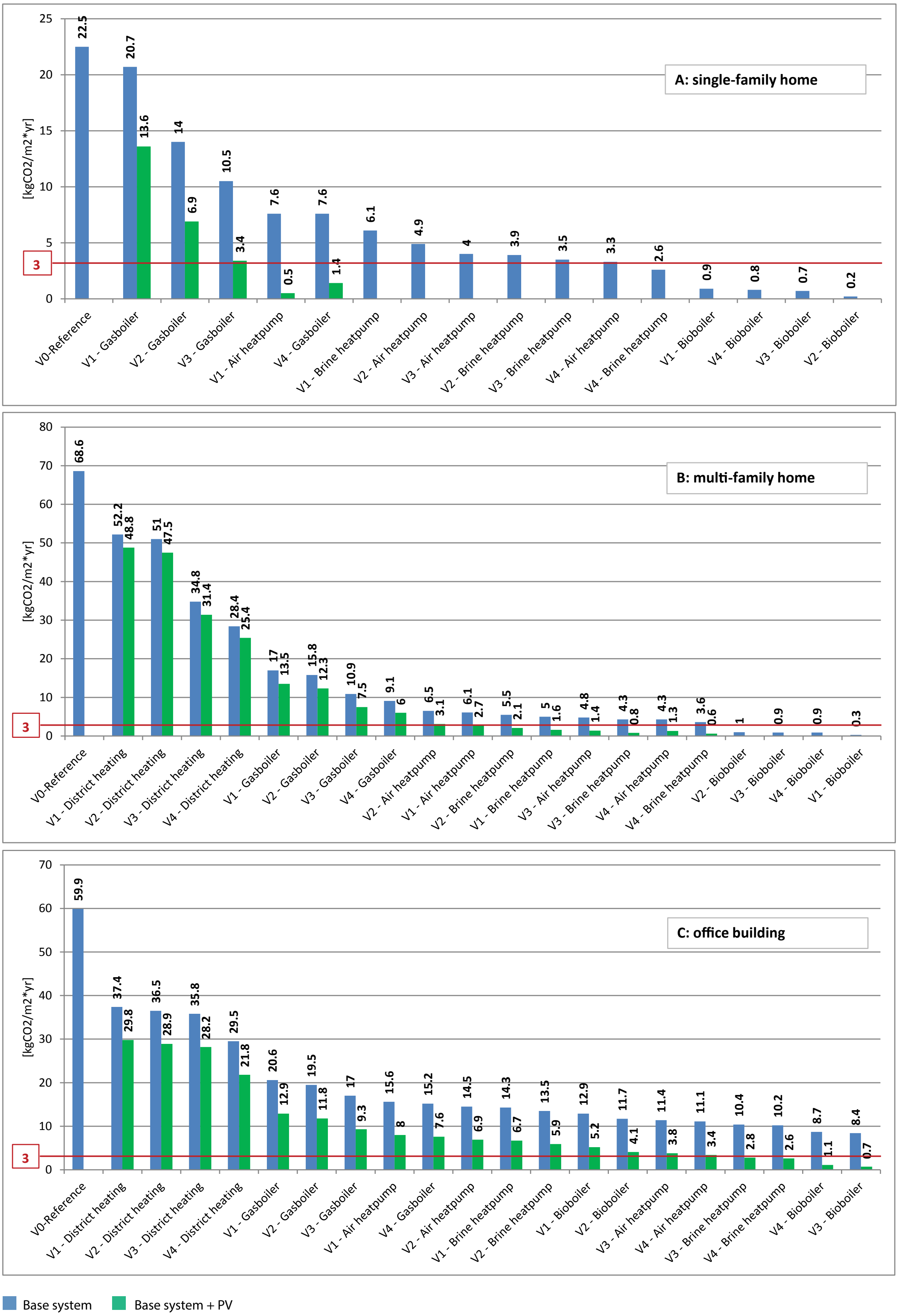
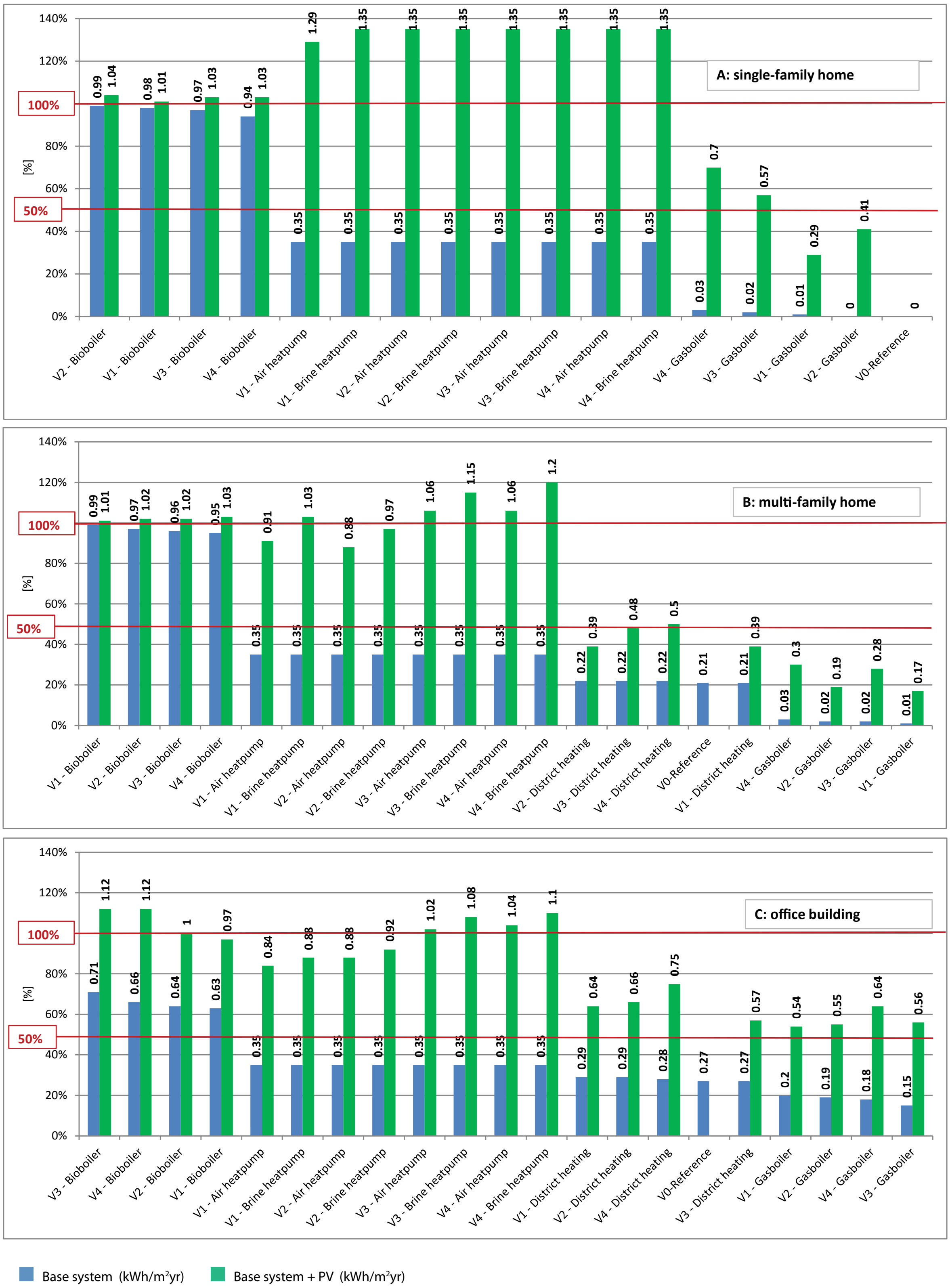


Figure 8: Renewable energy share for SFH, MFH and offices



6. FINANCIAL ANALYSIS

The financial impacts for single family, multi-family and office buildings have been calculated by assuming the extra investment costs and related cost savings (mainly reflecting energy savings) of nZEB solutions as compared to the reference buildings according to the current standard.

6.1. BASIC ASSUMPTIONS

The following tables present the assumed energy prices as the basis for estimating the financial impact for private households and offices. These prices are averages, considering a period of 30 years, with slightly differing price increase rates of the energy carriers for the two main periods considered (2011-2020 and 2021-2040). Different prices for private households (MFH and SFH) and industry (OFFICE) have been assumed.

All calculations were based on an interest rate of 5% as it currently exists in Poland.

Table 18: Assumed energy prices for private households and offices/industry (average 2011-2040)

ASSUMED ENERGY PRICES FOR PRIVATE HOUSEHOLDS (AVERAGE 2011-2040)			
	Energy price average	Yearly price increase 2011 to 2020	Yearly price increase 2021 to 2040
Gas [€/kWh]	0.082	3.0 %	3.0 %
Conventional electricity [€/kWh]	0.136	1.0 %	0.0 %
Feed-in electricity [€/kWh]	0.136	1.0 %	0.0 %
District heat (50% RES) [€/kWh]	0.053	3.0 %	3.0 %
Wood pellets [€/kWh]	0.062	3.0 %	3.0 %

Assumed energy prices for offices/industry (Average 2011-2040)			
	Energy price average	Yearly price increase 2011 to 2020	Yearly price increase 2021 to 2040
Gas [€/kWh]	0.082	3.0 %	3.0 %
Conventional electricity [€/kWh]	0.112	-1.5 %	0.0 %
Feed-in electricity [€/kWh]	0.112	-1.5 %	0.0 %
District heat (50% RES) [€/kWh]	0.053	3.0 %	3.0 %
Wood pellets [€/kWh]	0.062	3.0 %	3.0 %

The assumed investment costs as identified in the Polish market today are described in the following tables. Obviously, investment costs are dependent on specific market circumstances, contract negotiations, sales volumes etc. and might differ substantially at the level of individual projects. This study does not take into account the potential price decrease for new technologies. However, this is very probably going to happen after a certain level of market upscale. Consequently, additional costs for new technologies may decrease by 2019/2020 (when the move to nZEB is required) if proper policies are prepared and implemented.

Table 19: Assumed additional* investment costs of building components for Poland (local experts, own investigations)

Component	SFH	MFH	Office	Unit
Additional costs triple glazed windows	32	32	32	€/m2 glazing
Additional costs PH windows	57	-	57	€/m2 glazing
Additional costs automatic external shading	-	-	189	€/m2 shading
Additional costs ventilation with heat recovery	28	-	-	€/(m3/h)
Additional costs improved heat recovery	42	26	32	€/(m3/h)
Additional costs air tight construction	341	2 386	2 386	€
Additional costs LED	-	-	21	€/m2
Additional costs floor heating	8	8	-	€/m2
Additional costs 1 cm roof insulation	0.32	0.32	0.32	€/m2
Additional costs 1 cm wall insulation	0.45	0.45	0.45	€/m2
Additional costs 1 cm floor insulation	0.41	0.41	0.41	€/m2
Spec. costs PV system	2 557	1 875	1 875	€/kWp
Spec. costs solar hot water system	606	439	-	€/m^2 collector

Table 20: Assumed investment costs of heating system for Poland (local experts, own investigations)

Heating system incl. exhaust system [prices €]	SFH (4…9 kW)	MFH (80…130 kW)	OFFICE (100…170 kW)
Gas boiler	2 880	13 170…20 420	10 110…11 060
Air heat pump	3 390…6 020	40 280…76 000	25 190…29 890
Brine heat pump	4 660…8 290	55 570…104 860	34 750…41 250
Pellet boiler	6 520…6 820	27 530…43 070	19 740…22 440
District heating	-	4 550	4 550

6.2. FINANCIAL ANALYSIS OF THE NZEB SOLUTIONS

The results of cost simulations which are presented in Figures 9 and 10. Figure 9, consider only the basic options without PV compensation; Figure 10 considers the PV compensation (that reduces the building's CO_2 emissions as much possible to zero within the space limitation of the roof). The graphs show the specific annualised costs (on m2 of net floor area) over a period of 30 years, which is the usual time period over which a new building does not need major intervention and hence additional investments.

For SFH, the additional annualised costs are below € 1.5/m^2/yr for all simulated nZEB solutions. All bio-boiler and almost all heat pump solutions have negative annualised costs. Bio-boiler (pellet boiler) solution in variant V2 is the single economical solution which fulfils all nZEB principles as they were defined in the previous BPIE study (i.e. a very low energy need, a renewable energy share higher than 50% and CO_2 emissions in primary energy below 3kgCO_2/m^2/yr).

The most economical nZEB solutions for MFH are the district heat solutions. For the office building, the most economical solutions are all heating options in the less insulated variant V1.

The specific additional annualised costs compared to the reference buildings that fulfils the nZEB criteria reach a minimum of about € -1/m^2/yr for the SFH V2 and € 2/m^2/yr for the MFH V1, both using a wood pellet boiler. For the office building, the nZEB criteria are not reached by basic variants without CO_2 compensation.

The annualised costs of nZEB solution without CO_2 compensation are shown in Figure 9.

For SFH, by including the CO_2 compensation with additional rooftop PV systems, the bio-boiler and the two heat pump solutions in variant V2 are economically feasible and also fulfil the nZEB principles. Excepting the gas-boiler solution in the less insulated variant, V1, all simulated nZEB solutions for SFH fulfil the nZEB principles and have additional annualised costs below € 3.5/m2/yr. Moreover, bio-boiler and heat pump solutions in variant V2 are also economically feasible.

For MFH, the most economical solution with CO_2 compensation is the district heating solution in the least insulated variant, V1, having comparable annualised costs with the reference building.

For the office building, no economically feasible solution exists under the given circumstances.

The most economical nZEB solutions with CO_2 compensation and with CO_2 emissions below 3 kg/m^2/yr are the bio-boiler solutions, reaching -0.6 €/m^2/yr for the SFH (V2, wood pellet boiler), about 3.5 €/m^2/yr for the MFH (V2, wood pellet) and about 12 €/m^2/yr for the office building (V3, wood pellet). The highest share of the extra cost for the office building forms the automatic external shading. These costs could be reduced by a reduction of glazing area.

The annualised costs of nZEB solution without CO_2 compensation are shown in Figure 10 (see next page).

Figure 9: Annualised costs of nZEB solutions without CO_2 compensation

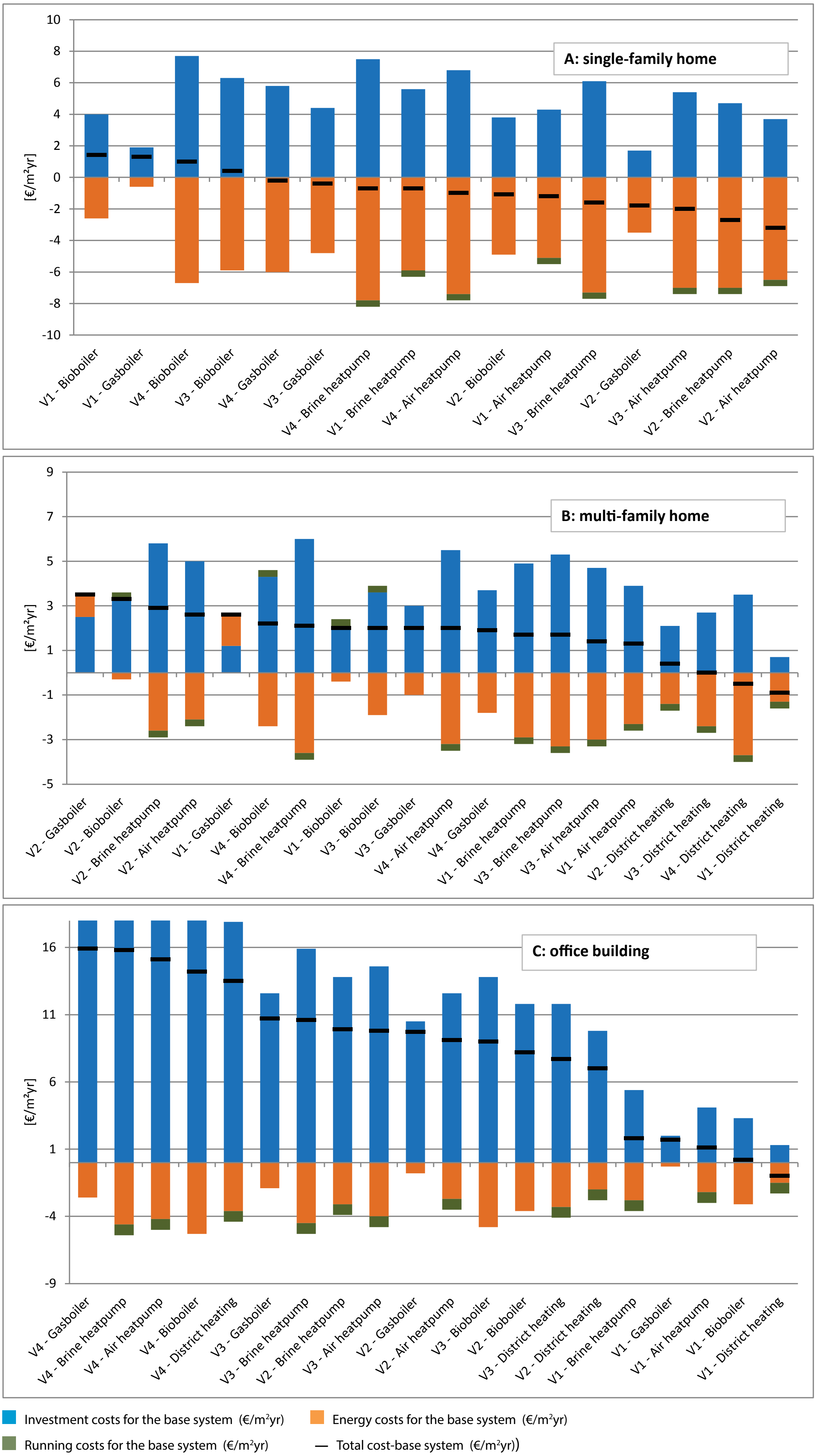
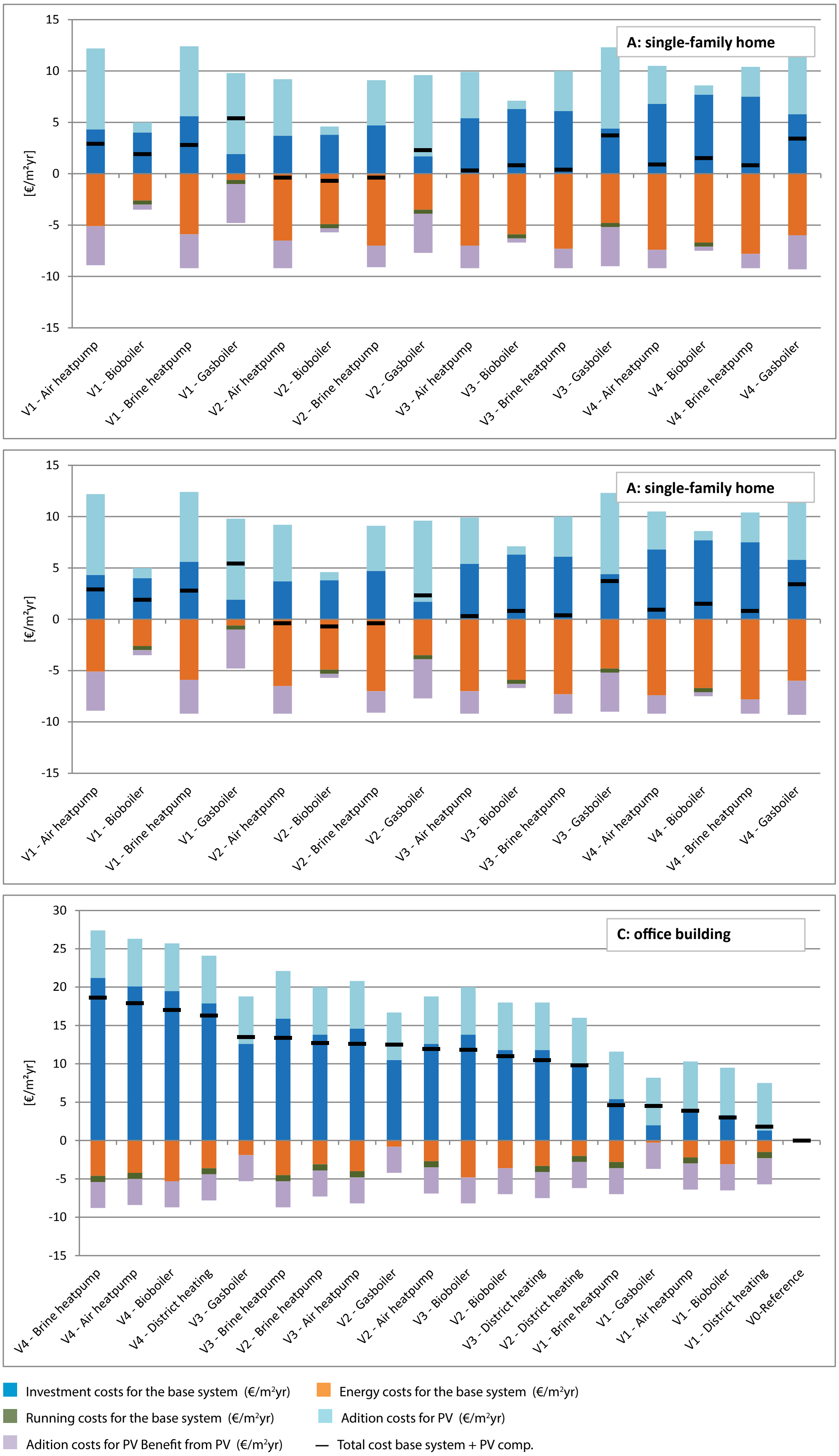


Figure 10: Annualised costs of nZEB solutions with CO_2 compensation



6.3. SUMMARY OF THE RESULTS

The simulations indicate that nZEB solutions in Poland are achievable even without major changes to the common building shapes. For a full CO_2 compensation and a high share of renewable energy, rooftop PV is sufficient for most of the SFH building solutions and for the wood pellet solution of the MFH. For the examined office building, the lighting, ventilation and cooling demand prevent the ability to reach a full CO_2 compensation. For office buildings should analyse the potential use of a central hot water system in order to allow a full CO_2 compensation. Furthermore the window fraction should be optimised to achieve, firstly, a high daylight share and secondly to minimise the solar loads. Demand side management measures, including daylight and presence control systems, may also contribute to further reduction of energy need of the building. Moreover, alternative cooling concepts like ground water cooling in combination with surface cooling systems can further drop the cooling demand of the office building. In general it can be stated that for a full CO_2 compensation by rooftop PV the number of floors needs to be limited. While at multi-family houses about six floors can be compensated, at office buildings, obviously, three floors are usually the maximum.

Without PV compensation only one of the examined solutions (SFH, V2, wood pellet boiler) fulfil the nZEB criteria and is economically feasible without considering potential subsidies. Low energy prices compared to the high investment cost prevent a return on invest for most of the energy efficiency measures.

In total three of the examined SFH solutions are economically feasible (V2, air and brine heat pump, wood pellet), but only V2 with wood pellet boiler fulfils the nZEB criteria. Two MFH solutions with district heating (V1 and V4) turned out to be more economical than the reference. Because the district heat was assumed to have a low share of renewable energy, those variants do not fulfil the nZEB criteria. For office buildings none of the solutions examined are more economical than the reference, while the most economical heating system is, in what concerns MFHs, district heating (V1).

For the considered 30 year perspective the additional annualised costs of the nZEB solutions compared to the reference variant for the SFH range from about -0.6 €/m^2/yr (V2, wood pellet with rooftop PV for CO_2-compensation) to about 3 €/m^2/yr. For the MFH the most economical solutions (V1-V4, heat pumps and wood pellet with PV compensation) indicate specific annualised extra costs between 2 and 4 €/m^{2}a. The most economical nZEB office solutions (V3-V4, brine heat pump and wood pellet) indicate extra costs between about 12 and 19 €/m^2/yr.

7. INDICATIVE nZEB DEFINITION BASED ON (COST-) OPTIMAL VARIANTS

The simulation results for each solution are shown in Tables 20-22. They reflect primary energy consumption, renewable share, associated CO_2 emissions and total annualised additional costs (investment, energy cost savings and other running costs such as maintenance). Total final and primary energy demand for residential buildings include the energy consumption within the scope of the EPBD: heating, cooling, ventilation and domestic hot water. For office buildings, this also includes lighting energy consumption. The colour code used for different nZEB options is in line with the nZEB principles defined in the previous BPIE study[51].

[51] Joint Research Centre - European Commission (2012). Web Page: *Photovoltaic Geographical Information System* - Interactive Maps. Available at : http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php

Table 21: Overview of the results for the single family building

	Final specific demand [kWh/m²/yr]	Without CO_2 compensation				With CO_2 compensation (by additional PV)			
		Primary energy demand [kWh/m2/yr]	CO_2 emissions [kgCO_2/m²/yr]	Renewable share [%]	Total additional annualised costs [Euro/m2/yr]	Primary energy demand [kWh/m2/yr]	CO_2 emissions [kgCO_2/m2/yr]	Renewable share [%]	Total additional annualised costs [Euro/m2/yr]
V0-Reference	111	123.0	22.5	0%	0	n.a	n.a.	n.a.	0.0
V1 - Air heat pump	30.1	60.2	7.6	35%	-1.2	3.9	0.5	129%	2.9
V1 - Brine heat pump	24.2	48.4	6.1	35%	-0.7	0.0	0.0	135%	2.8
V1 - Bioboiler	101.8	26.9	0.9	98%	1.4	19.6	0.0	101%	1.9
V1 - Gas boiler	101.4	114.9	20.7	1%	1.3	58.6	13.6	29%	5.3
V2 - Air heat pump	19.7	39.3	4.9	35%	-3.2	0.0	0.0	135%	-0.4
V2 - Brine heat pump	15.7	31.3	3.9	35%	-2.7	0.0	0.0	135%	-0.5
V2 - Bioboiler	68.7	15.0	0.2	99%	-1.1	8.9	0.0	104%	-0.6
V2 - Gas boiler	69	76.5	14.0	0%	-1.8	20.2	6.9	41%	2.3
V3 - Air heat pump	16	31.9	4.0	35%	-2	0.0	0.0	135%	0.3
V3 - Brine heat pump	13.9	27.7	3.5	35%	-1.6	0.0	0.0	135%	0.4
V3 - Bioboiler	50.4	14.9	0.7	97%	0.4	8.8	0.0	103%	0.9
V3 - Gas boiler	51.2	58.6	10.5	2%	-0.4	2.3	3.4	57%	3.6
V4 - Air heat pump	13.2	26.3	3.3	35%	-1	0.0	0.0	135%	0.9
V4 - Brine heat pump	10.4	20.7	2.6	35%	-0.7	0.0	0.0	135%	0.8
V4 - Bioboiler	37	13.2	0.8	94%	1	6.8	0.0	103%	1.5
V4 - Gas boiler	37	43.5	7.6	3%	-0.2	-5.6	1.4	70%	3.4
	<40	<40	<4	>50	<5	<40	<4	>50	<5
	40< x 60	40< x<70	4< >7	30>x <50	10< >5	40< x <70	4<>7	30>x <50	10< >5
	>60	>70	>7	<30	>10	>70	>7	<30	>10

Table 22: Overview of the results for the multi-family building

	Final specific demand [kWh/m²/yr]	Without CO_2 compensation				With CO_2 compensation (by additional PV)			
		Primary energy demand [kWh/m2/yr]	CO_2 emissions [$kgCO_2/m^2/yr$]	Renewable share [%]	Total additional annualised costs [Euro/m2/yr]	Primary energy demand [kWh/m2/yr]	CO_2 emissions [$kgCO_2/m2/yr$]	Renewable share [%]	Total additional annualised costs [Euro/m2/yr]
V0-Reference	101.6	133.3	68.6	21%	0	n.a	n.a.	n.a.	0.0
V1 - Air heat pump	24.1	48.3	6.1	35%	1.3	21.1	2.7	91%	2.3
V1 - Brine heat pump	19.9	39.9	5.0	35%	1.7	12.7	1.6	103%	2.7
V1 - Bioboiler	81.5	18.7	0.3	99%	2	16.0	0.0	101%	2.1
V1 - Gas boiler	83.6	93.2	17.0	1%	2.6	66.0	13.5	17%	3.5
V1 - District heating	77.3	101.5	52.2	21%	-0.9	74.3	48.8	39%	0.0
V2 - Air heat pump	25.7	51.6	6.5	35%	2.6	24.4	3.1	88%	3.6
V2 - Brine heat pump	21.8	43.8	5.5	35%	2.9	16.6	2.1	97%	3.9
V2 - Bioboiler	81.1	23.1	1.0	97%	3.3	15.5	0.0	102%	3.5
V2 - Gas boiler	77.1	88.2	15.8	2%	3.5	61.0	12.3	19%	4.5
V2 - District heating	77.1	102.9	51.0	22%	0.4	75.7	47.5	39%	1.3
V3 - Air heat pump	19.1	38.5	4.8	35%	1.4	11.2	1.4	106%	2.5
V3 - Brine heat pump	16.9	33.9	4.3	35%	1.7	6.7	0.8	115%	2.7
V3 - Bioboiler	55.8	17.4	0.9	96%	2	10.5	0.0	102%	2.2
V3 - Gas boiler	53.1	61.6	10.9	2%	2	34.4	7.5	28%	3.0
V3 - District heating	53.1	71.6	34.8	22%	0	44.4	31.4	48%	1.0
V4 - Air heat pump	17	34.1	4.3	35%	2	10.0	1.3	106%	2.8
V4 - Brine heat pump	14.2	28.5	3.6	35%	2.1	4.4	0.6	120%	3.0
V4 - Bioboiler	46.1	15.8	0.9	95%	2.2	8.5	0.0	103%	2.4
V4 - Gas boiler	43.9	51.6	9.1	3%	1.9	27.5	6.0	30%	2.8
V4 - District heating	43.9	59.7	28.4	22%	-0.5	35.6	25.4	50%	0.3
	<40	<40	<4	>50	<5	<40	<4	>50	<5
	40< x <60	40< x<70	4<>7	30>x <50	10< >5	40< x <70	4< >7	30> x <50	10< >5
	>60	>70	>7	<30	>10	>70	>7	<30	>10

Table 23: Overview of the results for the office building

	Final specific demand [kWh/m²/yr]	Without CO_2 compensation				With CO_2 compensation (by additional PV)			
		Primary energy demand [kWh/m2/yr]	CO_2 emissions [$kgCO_2$/m²/yr]	Renewable share [%]	Total additional annualised costs [Euro/m2/yr]	Primary energy demand [kWh/m2/yr]	CO_2 emissions [$kgCO_2$/m2/yr]	Renewable share [%]	Total additional annualised costs [Euro/m2/yr]
V0-Reference	118	187.3	59.9	27%	0	n.a	n.a.	n.a.	0.0
V1 - Air heat pump	62	124.3	15.6	35%	1.1	63.5	8.0	84%	3.9
V1 - Brine heat pump	56.8	113.7	14.3	35%	1.8	52.9	6.7	88%	4.6
V1 - Bioboiler	89.1	110.0	12.9	63%	0.2	49.2	5.2	97%	3.1
V1 - Gas boiler	89.1	144.1	20.6	20%	1.7	83.3	12.9	54%	4.6
V1 - District heating	87.1	149.1	37.4	29%	-1	88.3	29.8	64%	1.8
V2 - Air heat pump	57.5	115.4	14.5	35%	9.1	54.6	6.9	88%	11.9
V2 - Brine heat pump	53.6	107.3	13.5	35%	9.9	46.5	5.9	92%	12.7
V2 - Bioboiler	84.8	101.0	11.7	64%	8.2	40.2	4.1	100%	11.0
V2 - Gas boiler	84.8	135.5	19.5	19%	9.7	74.7	11.8	55%	12.6
V2 - District heating	82.8	140.5	36.5	29%	7	79.7	28.9	66%	9.8
V3 - Air heat pump	45.4	90.7	11.4	35%	9.8	29.9	3.8	102%	12.6
V3 - Brine heat pump	41.6	82.9	10.4	35%	10.6	22.1	2.8	108%	13.4
V3 - Bioboiler	75.7	75.0	8.4	71%	9	14.2	0.7	112%	11.8
V3 - Gas boiler	75.7	113.2	17.0	15%	10.7	52.4	9.3	56%	13.5
V3 - District heating	73.5	118.8	35.8	27%	7.7	58.0	28.2	57%	10.6
V4 - Air heat pump	43.8	87.8	11.1	35%	15.1	27.0	3.4	104%	17.9
V4 - Brine heat pump	40.5	81.1	10.2	35%	15.8	20.3	2.6	110%	18.6
V4 - Bioboiler	66.7	75.7	8.7	66%	14.2	14.9	1.1	112%	17.1
V4 - Gas boiler	66.7	104.6	15.2	18%	15.9	43.8	7.6	64%	18.7
V4 - District heating	65	108.9	29.5	28%	13.5	48.0	21.8	75%	16.2
	<40	<40	<4	>50	<5	<40	<4	>50	<5
	40< x <60	40< x<70	4< >7	30> x< 50	10< >5	40< x<70	4< >7	30>x <50	10<>5
	>60	>70	>7	<30	>10	>70	>7	<30	>10

**Important note: Compensation of a building's CO_2 emissions by introducing an additional onsite PV system improves significantly the primary energy demand of the building. However, the PV compensation does not necessarily supply the energy demand of the building within the EPBD scope (i.e. energy for heating, cooling, ventilation, domestic hot water and, in the case of commercial buildings, for lighting), but the overall energy demand of the building (including the electricity for household appliances). In this case, the PV compensation helps reduce the primary energy demand and associated CO_2 emissions towards or below zero, in the overall trade-off with the energy grids. Hence, the PV compensation may have a significant contribution to a nearly zero-energy demand. For simplifying the evaluation methodology in this study only a PV compensation is considered. The PV compensation may be replaced in practice by any other renewable energy system. The amount of the compensation can be reduced by, for example, improved building insulation, by improved building geometries or higher system efficiencies. However, the PV compensation has a significant direct impact in the case of office buildings, where lighting electricity consumption is within the EPBD scope and represents a significant share of the overall energy demand of the buildings.*

On the basis of the economic analysis, we selected the three most appropriated solutions for each building type (fulfilling the nZEB principles as defined in the 2011 BPIE study). The selection mainly takes into consideration the additional annualised costs of the systems. Table 24 presents these suggestions, with the right column presenting the percentage of the additional annualised costs or cost savings in relation to the construction costs (capital costs) plus user costs (running and energy costs) of the variants compared to the reference case.

Table 24: Overview of the (cost-) optimal variants

Building type	Variant	Brief Description	Heating system	Additional annualised costs (Base year 2010) [€/m²yr]	Additional annualised costs comparing with average reference actual price [52] [%]
SFH	V2b	+ mech. ventilation with heat recovery+ improved building shell	Brine heat pump	- 0.5	-0.9%
	V2c		Bio Pellet	- 0.6	-1.1%
	V3a	improved building shell+ improved mech. ventilation with heat recovery	Air heat pump	0.3	0.5%

[52] The percentage of the additional annualised costs was based on the following assumptions: turnkey costs for SFH: 825 €/m², MFH: 950 €/m² and office: 1000 €/m² (estimation by BuilDesk Poska, 2012). The lifetime of residential buildings were assumed to be 50 years for residential building and 30 years for offices.

MFH	V1c	Improved building shell	Bio Pellet	2.1	3.6%
MFH	V3c	Mech. ventilation with heat recovery	Bio Pellet	2.2	3.8%
MFH	V4b	Nearly Passive house standard	Bio Pellet	17.1	22.9%
Office	V3b	Improved building shell + external shading + improved lighting	Brine heat pump	13.4	17.9%
Office	V3c	Improved building shell + external shading + improved lighting	Bio Pellet	11.8	15.8%
Office	V4c	Nearly Passive house standard[53]	Bio Pellet	17.1	22.9%

In the residential sector in Poland, in the case of the single family house, the cost-optimal variants V2b and V2c would result in annualised cost savings of between 0.9% and 1.4%, whereas the implementation of variant V3a would increase the annualised additional costs by about 0.5%. In the case of the multi-family house, the implementation of the cost-optimal variant would result in annualised additional costs between 3.6% and 5.2%, depending on shell, heating system and type of building.

For the offices the implementation of the cost-optimal variants would result in additional annualised costs from 15.8% to 22.9%. This is also due to a shorter lifetime assumed for the office building in the calculation. In this study the district heating solutions for multi-family houses turned out to be above the CO_2 emission target of 3 kg/m^2 per year. However, it was considered that the actual Polish DH renewable energy share of about 20% and for the analysed nZEB solutions is not sufficient to bring down the CO_2 emissions to or below the required 3 kg/m^2 per year. If the renewable energy share of district heating systems in Poland will consistently increase, district heating may, therefore, be a viable and potentially cheap nZEB solution. Consequently, district heating systems with a large share of renewable energy may be a key issue for the heating strategy in Poland and fits very well in the context of increasing the energy performance of buildings towards nZEB levels.

As suggested in the BPIE study presenting nZEB principles[54], the district heating (DH) strategy has to be harmonised with building policies to better align future needs and to shape the economic instruments. Office buildings should continue to be included in the DH networks as an additional nZEB solution because they are more flexible in changing the energy carriers.

Based on the above analysis, and based on the simulation results in Tables 21-23 and taking into consideration the additional costs and results for basic variants without PV compensation, the following levels are proposed for consideration as nZEB definitions for Poland (Table 25).

[53] Major shell improvements, no heat bridges, airtight construction, highly efficient mechanical ventilation (> 90%), useful heating and cooling demand < 15 kWh/m^{2}a.

[54] BPIE (2011b). *Principles for nearly Zero-Energy Buildings - Paving the way for effective implementation of policy requirements.* Buildings Performance Institute Europe (BPIE). Available at: www.bpie.euwww.bpie.eu

Table 25: Proposed nZEB definitions for Poland

Building type	Minimum requirements	Year		
		2015/2016	2019	2020
Single family buildings	Primary energy [kWh/m2/yr]	70		30-50
	Renewable share [%]	>20		>40
	CO_2 emissions [kgCO_2/m2/yr][55]	<10		<3-6
Multi-family buildings	Primary energy [kWh/m2/yr]	90		30-50
	Renewable share [%]	>20		>40
	CO_2 emissions [kgCO_2/m2/yr][56]	<10		<3-6
Office buildings	Primary energy [kWh/m2/yr]	100		50-60
	Renewable share [%]	>20		>40
	CO_2 emissions [kgCO_2/m2/yr][57]	<15		<8-10
Public office buildings (exemplary role)	Primary energy [kWh/m2/yr]	80	40-60	
	Renewable share [%]	>20	>50	
	CO_2 emissions [kgCO_2/m2/yr] [58]	<12	<5-8	

The above-suggested thresholds for an nZEB definition in Poland are relatively ambitious but yet affordable, as several options have low additional specific annualised costs. Also several nZEB options for SFH are economically feasible.

[55]Based on emission factors specified in Table 15
[56]Based on emission factors specified in Table 15
[57]Based on emission factors specified in Table 15
[58]Based on emission factors specified in table 15

However, these thresholds are significantly less ambitious than in other Western Europe countries, which are aiming to reach climate neutral, fossil fuel free or even energy positive new buildings[59] by 2020. Thinking long term, it is necessary to ensure that the building concepts are improved to keep specific CO_2 emissions below 3 $kgCO_2/m^2yr$ (and aiming at: 0 kg/m^2yr), which is the identified EU average minimum requirement necessary for achieving the EU 2050 decarbonisation goals. The nZEB definition should therefore be gradually improved after 2020. It is likely to lead to energy and climate neutral levels by 2030. Beyond implementing an EU Directive requirement, the significant reduction of the energy consumption and related CO_2 emissions of the building sector will have a major impact on the security of energy supply, national economy and the quality of life of Polish citizens.

7.1. ARE THE PROPOSED VARIANTS AFFORDABLE?

In 2011/2012 in Poland, the monthly average income after taxation is about PLN 3649 (€873) per household, from which all living expenses have to be covered i.e. food, energy, transport etc. The net discretionary income after deducting all necessary living expenditures is on average PLN 200 (€48) per household, available for other expenditures. According to the answers of around 47,000 participants to an online questionnaire, the average net discretionary income seems to be even slightly higher[60] .

In the case of the single family house, the calculated cost-optimal variants (V2b and V2c) result in monthly savings per household ranging between €7 and €10 and additional monthly costs of €5 for variant V3a. In the case of the multifamily house, additional monthly costs are between €10 – 15 per household living in a dwelling. Comparing the monthly additional costs to the average household's monthly net discretionary income; all variants seem to be affordable.

In case additional costs for nZEB solutions are not affordable for average Polish households, there are two alternatives possible.

One alternative would be to allow for a higher benchmark regarding the CO_2 emissions for nZEB in Poland. At the EU level and for meeting the long term decarbonisation goals, the consequence would be that other countries would have to equilibrate this by constructing buildings with standards significantly below 3 kg CO_2. This is a political discussion about justice regarding the general EU emission reduction targets. Another consequence will be the potential negative impact on the local economy in the context of market transformation at the EU and global level. Without keeping pace with other economies, there is a risk of losing opportunities for developing the buildings market and supply chain industry, of preserving or even increasing energy imports, of losing potential new jobs, of putting future energy price pressure on the citizens and, last but not the least, of failing to provide a better quality of life throughout the country.

Another alternative would be to provide financial support policies and schemes by the Polish government and/or use EU and international dedicated finance to allow implementation of the standards required to fulfil the nZEB criteria.

Moreover, if the future price of energy efficient and renewable technology and materials decreased, the results would become more economically feasible. However, at the moment it is difficult to predict the future price evolution in Poland. Also country specific circumstances for new technology would have an impact on prices and the introduction of early ambitious regulations and support policies may contribute to a decrease in technology prices.

[59] For more details on the strategies of other EU countries for implementing nZEB by 2020, please see Table 3 from BPIE (2011) *Principles for nearly Zero-Energy Buildings - Paving the way for effective implementation of policy requirements*. Available at www.bpie.eu

[60] PRACA (2012). *Web Page:* Ile-z-wyplaty-zostaje-na-zycie. Available at: http://praca.wp.pl/title,Ile-z-wyplaty-zostaje-na-zycie,wid,13458100,wiadomosc.htmlhttp://praca.wp.pl/title,Ile-z-wyplaty-zostaje-na-zycie,wid,13458100,wiadomosc.html

7.2. DIRECT AND INDIRECT BENEFITS OF IDENTIFIED NZEB SOLUTIONS

Investing in more sustainable, energy efficient buildings contributes substantially to increased energy security, environmental protection, job creation and improved quality of life. It also contributes to the sustainable development of the construction sector and supply chain industry. While the upfront investment is relatively high and the return on investment usually longer than for other economic activities, there are multiple benefits that are shared among building users and owners, the construction industry, the public sector and society as a whole.

The benefits of implementing nZEBs are wider than simply energy and CO_2 savings. They can be summarised as follows:

- The quality of life in a nearly Zero-Energy Building is better than in a building constructed according to current practice. An adequate design of the building and a high quality construction include cost-saving possibilities that cover the additional costs of an energy-efficient building envelope almost entirely. Higher quality of life through better (thermal) comfort. The nearly Zero-Energy Building provides good indoor air quality. Fresh filtered air continuously delivered by the ventilation system. It is more independent of outdoor conditions (climate, air pollution). Concerning the noise protection, the thick and well-insulated structures provide effective sound insulation;
- Ambient benefits arise through reduced energy demand that reduces wider environmental impacts of energy extraction, production and supply;
- There are environmental benefits from improving local air quality;
- Social benefits arise through the alleviation of fuel poverty;
- Health benefits are possible through improved indoor air quality and reducing risks of cold homes, particularly for those on low-incomes or for elderly householders;
- Macro-economic benefits arise through the promotion of innovative technologies and creating market opportunities for new or more efficient technologies and through the provision of certain incentives for pilot projects and market transformation;
- Private economic benefits: higher investment costs may be outweighed by the energy savings over the lifetime of the building (the building offers less sensitivity to energy prices and political disturbances. When a building is sold, the high standard can be rewarded through a re-sale price up to 30% higher in comparison to standard buildings;
- Job creation can arise through the manufacturing and installation of energy efficiency measures and of renewable energy technologies;
- There will be decreased energy dependence on fossil fuels and therefore on the future energy prices[61].

In this study, the approach to quantifying some of the benefits is done in an approximate way by extrapolating results from the reference buildings to a national level, e.g. (average energy and CO_2 savings per m^2) x (m^2 built new per year) x 30 years (2020-2050). In Table 26, we present the estimated macro-economic impact by 2050 in terms of additional investments, new jobs (only direct impact in the construction industry), CO_2 and energy savings[61].

[61] Paroc (2012). Web Page: *Benefits of passive house*. Available at: http://www.energiaviisastalo.fi/energywise/en/index.php?cat=Benefits+of+Passive+Househttp://www.energiaviisastalo.fi/energywise/en/index.php?cat=Benefits+of+Passive+House

However, this is a conservative approach without considering additional important factors that may positively influence the macro-economic benefits. As an example, the job creation impact is based on the job intensity of the construction industry and reflects only the additional work places that may be created at the execution level and doesn't include the jobs in the supply chain industry induced by up-scaling the market and the indirect jobs in the administration of the processes (e.g. additional auditors and control bodies for new tech). Moreover, moving towards very efficient buildings and increasing the need for new technology will mainly have an impact on new job profiles such as renewable systems and heat pumps installers. There will be, therefore, an increased need for these new activities all over the country, driven not only by additional investment as we considered in this study, but also by the local needs for such new job profiles[62].Consequently, it is very likely to have a much higher job creation potential than is estimated in this study.

Table 26: Effect of the implementation of nZEB after 2020 in 2050

Indicator	Effect
CO_2 emissions savings in 2050	31 M t CO_2
Cumulative energy savings in 2050	92 TWh
Additional annual investments[63]	€ 242-364 million
Additional new jobs	4 106- 6 185 Full time employees

Table 27: Effect of the implementation of nZEB after 2020 in 2050

Indicator	Residential sector						Non residential sector		
	SFH			MFH					
	V2b	V2c	V3a	V1c	V3c	V4b	V3b	V3c	V4c
Annual CO_2 emissions savings [$kgCO_2/m^2yr$]	22	22	22	69	69	68	57	59	59
CO_2 emissions savings in 2050 [Mio t CO_2]	5.0	5.0	5.0	9.4	9.4	9.3	17	17	17
Annual energy savings [kWh/m^2yr]	123	114	123	117	123	129	165	173	172
Cumulative energy savings in 2050 [TWh]	27	25	27	17	16	17	48	51	51
Additional annualized investment costs per m^2 [$€/m^2yr$]	9.1	4.6	9.9	2.4	4.3	8.5	22.1	20.1	25.8
Annual additional investments [Mio €]	67	34	73	11	19	39	216	196	252
Job effects [no of new jobs]	1145	585	1244	187	331	655	3679	3335	4285

[63]As an example, additional investments in a very well established construction sector already having all necessary job profiles and spread all over the considered country or region, then the job impact is determined with a fair approximation by using the job intensity of the sector. However, if the additional invested capital supposed to expand new qualifications, as is the case for nZEB, it is necessary to create all over the given country or region a critical mass of specialists for these new qualifications able to provide the requested services. In this case, the job creation potential is much higher than in the first case (even a few times higher).

[64]This is the estimated job effect in the construction sector only and without considering the additional impact in the supply chain industry and other related sectors. It was considered that every €1 million invested will generate around 17 new jobs, as identified in several previous studies such as BPIE (2011) '*Europe's buildings under the microscope*', available at www.bpie.eu

8. A 2020 ROADMAP FOR IMPLEMENTING nZEBS IN POLAND AND POLICY RECOMMENDATIONS

Based on the analysis of the specific national situation, the previous BPIE study on nZEB principles and on related studies; there are some key recommendations that can be made when designing an nZEB implementation roadmap:

1. Different instruments should be part of a wider holistic policy package, which should include regulatory, facilitation and communication aspects. The German investment bank KfW is a strong example of good communication. They managed to raise awareness about their financial products to such extent that commercial banks and construction companies on their side advertise their offers. Targeted communication campaigns are key to a scheme's success.
2. In addition, wide public consultation with relevant stakeholders is necessary at all implementation stages of buildings policies.
3. Impact assessment (ex-ante, interim and ex-post) of the planned policies is needed together with a simple but effective monitoring and control mechanism.
4. Higher energy performance of buildings should be rewarded by better financial support, i.e. higher grant or lower interest for dedicated loans. This is again another best practice from other countries, including the above mentioned KfW example.
5. Policy-makers should combine long-term programmes to provide stable frameworks and facilitate long-term planning for all stakeholders.
6. The buildings strategy should be synchronised with national energy and climate strategy as well as with EU strategy.
7. Different policy instruments need to be aligned to ensure success. One example is the Carbon Emissions Reduction Target (CERT) in the UK which is closely coordinated with other instruments[64]. Overlapping with supporting financial instruments should be avoided .

8.1. BUILDING CODES

The first condition for implementing nZEB is the reinforcement of current building codes by a gradual increase in the energy performance requirements, as well as their systematic enforcement and compliance controls.

In Poland, most architects follow the component-based requirements for maximum U-values and not the energy performance requirement. This is why more than 50% of new buildings do not fulfil energy performance (EP) requirements. Therefore, while an energy performance certificate is necessary to issue a building usage permit, the General Inspector of Buildings Control do not analyse the energy performance nor check if the energy performance value is in referential limits.

The upcoming legislation transposing the EPBD at national level will make sure that energy performance requirements become introduced in building codes. It is also required by the EPBD to relate energy performance requirements to primary energy consumption, in order to have a more accurate picture of the energy quality and of the related CO_2 emissions. This also means that the first measure to be implemented is to reduce, as much as possible, the energy demand/need of buildings..

[64] EuroACE (2010). *Making money work for buildings: Financial and fiscal instruments for energy efficiency in buildings.* Available at: http://www.euroace.org/PublicDocumentDownload.aspx?Command=Core_Download&EntryId=133

In addition, EPBD requires supplying the remaining energy demand/need of the building by onsite and nearly renewable energy, likely to be generated onsite or nearby. This is in line with the actual practices in implementing very low-energy buildings such as the Passive House standard which imposes a limit of 15kWh/m2/yr for the energy demand for heating, mainly because this is the maximum energy need that can be covered by a heat pump.

Nearly Zero-Energy Buildings cannot be evaluated and implemented as a sum of their building components and equipment. Very low-energy buildings should be designed based on a holistic approach in order to minimise the gap between estimated and real energy performance and the overall investments and operation costs of the building. It is recommended to introduce a renewable energy share requirement in the building codes. This is in line with Article 13 of the RES Directive. Implementing nZEBs will positively contribute to both the implementation of buildings and renewable energy policies and, thereby, help achieve the EU's climate and energy targets.

Due to their energy consumption, buildings are responsible for a major share of CO_2 emissions. In its policies for reducing carbon emissions the, EU introduced a 20% binding target by 2020 and the ambitious goal of reducing them by 80-90% by 2050. While the carbon emissions of buildings and their respective energy demand will be reduced and the renewable energy use increased, it is recommended to introduce an additional requirement in building codes (even indicative at the beginning) concerning related CO_2 emissions. For instance in Ireland minimum requirements have been established for both energy consumption and CO_2 emissions. In the UK, buildings performance requirements only refer to CO_2 emissions. According to the EU's EPBD, energy performance certificates have to indicate both the energy demand and CO_2 emissions of a building. Therefore, introducing a CO_2 threshold for CO_2 emissions of buildings will ensure not only coherence and integration of climate, energy and buildings requirements, but will also secure the sustainable development of the building sector.

The following table shows the actual status of regulations on building codes for new buildings in Poland and the necessary steps towards the nearly Zero-Energy Buildings levels.

Table 28: Further steps for improving building codes in Poland

State of art	1. Poland has building code requirements and performance based requirements for new buildings and renovations. Poland has prescriptive/ element based criteria for thermal insulation, ventilation, efficiency for boiler/ A/C system, for lighting efficiency and other requirements prescribe solar shading and window area. 2. According to the current regulations, an architect must either fulfil the quality of building components or secure that a certain primary demand is not exceeded. In general, the building requirements for maximum U values are followed and, at the moment, in less than 50% of the cases the architects opt for fulfilling the maximum energy performance benchmark.
Gaps in the implementation	1. Building envelope quality requirements actually allow the bypassing of the primary energy demand requirements and vice versa. The current regulation does not oblige requirements for both, building envelope quality and primary energy demand. 2. There is no obligation to meet certain primary energy demand and/ or CO_2 emissions. 3. Specific requirements for using renewable energy and for DHW in buildings do not exist. However, since January 2009 every new building with a net area over 1000 m² is required to analyse the economic possibility of using renewable energy (geothermal energy, wind, solar and DHP).
What can be improved to achieve the implementation of nZEBs?	1. In order to secure a proper implementation of nZEB, the building regulations should be improved. The improvements should address both the structure of regulations and the ambition level. 2. The structure of the regulation should be adapted, including obligations regarding the building envelope quality, primary energy use, CO_2 emissions and the use of renewable energy. The actual bypassing possibility should be removed. 3. The ambition level of the obligations should be tightened and it is recommended to introduce appropriate thresholds for primary energy consumption, CO_2 emissions and minimum renewable energy use.
Intermediate steps	4. Tighten ambition level of obligations: • Tighten requirements for the building envelope • Tighten max. primary energy use 5. Change structure of regulation: • limit primary energy use and CO_2 emissions • introduce an obligation for a renewable energy share or a minimum renewable energy use

8.2. FINANCIAL SUPPORT AND INTERACTION OF POLICY INSTRUMENTS

For a successful implementation of nZEBs by 2020, the interaction of the policy instruments needs to be considered. The main issue to be considered is that there should be enough incentives and awareness to comply with the regulations. This requires a financial scheme to be embedded in a successfully working regulation framework (as for example the Energy Saving Ordinance - EnEV in Germany) and to be accompanied by broad information campaigns creating awareness amongst building owners. In that sense, these instruments should be part of a wider holistic policy package, which should include regulatory, facilitation and communication elements.

To maximise the benefits and to contribute to behavioural change of the society, policy-makers must avoid short term solutions, and concentrate on predictable long-term programmes.

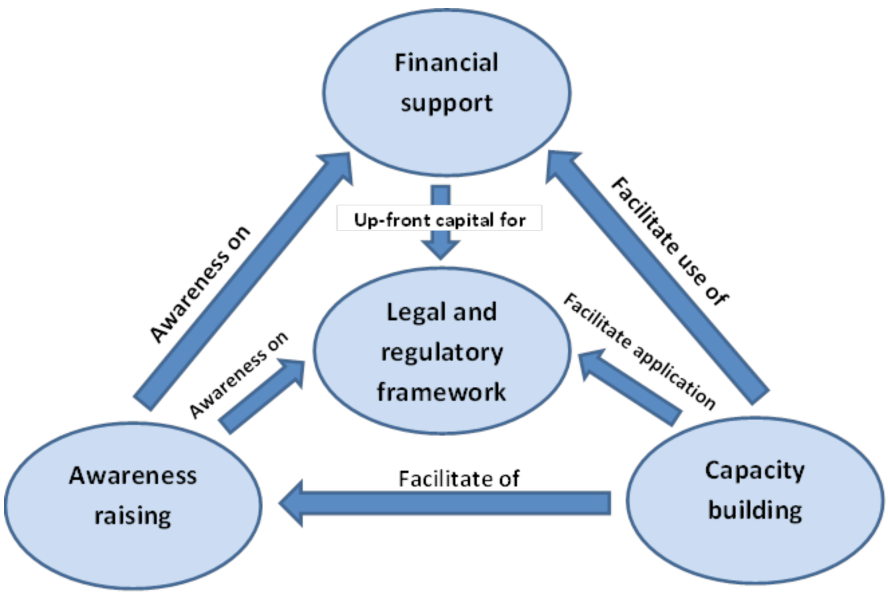
The existing market barriers for improving the energy performance of buildings should be identified and eliminated in order to allow a smooth implementation for low-energy buildings.

In the process of elaborating new policies, the first step to be made is a gap analysis addressing:

- energy efficiency and renewable energy measures and technologies to support policies;
- existing barriers to be overcome;
- effective types of economic instruments;
- the required level of economic support;
- financing and other economic support instruments that facilitate a proper uptake of the new regulations and make more attractive the investments in new technologies.

Financial schemes have the objective of fostering market development and aim to have a long term impact, beyond the lifetime of the specific support measure. To ensure the effectiveness of the different instruments to be introduced on the market (see Figure 11), a careful analysis is required to better understand their interaction.

Figure 11: Interaction of different policy instruments



Based on existing best practices, there are a few recommendations to be taken into account when introducing or expanding existing financial schemes:

1. An in-depth analysis of financial gaps should be realised to determine cost-optimal energy efficient measures and support for renewable technologies.
2. Financial schemes are key in the successful implementation of nZEBs. Grants and preferential loans are the most prevalent forms of instrument and, based on available data, are also the most successful and cost-effective ones. The financial support should be carefully assessed in order to avoid too high or too low incentive levels. They can either slow-down the market uptake (by making it strongly dependent on incentives) or not stimulate the market uptake properly by not giving the right compensation for additional costs. For loans, there appears to be a correlation between take up and interest rate levels, i.e. when the interest rates fall, the volume of applications increase. A low interest rate works as an incentive as it is perceived to be the most important factor. The Thermo Modernisation Fund in Poland[65] is a good practice that may be used for the elaboration of a financing scheme for a new nZEB.
3. In order to reduce the financing gap, all available options such as the Green Investment Schemes built by selling the surplus of CO_2 allocations under ETS schemes, the available financing schemes of International Financial Institutions, the dedicated lines from European Investment Banks should be considered, but mainly the Structural Funds.
4. The results of a study carried out by the Baltic Energy Efficiency Network (BEEN), including 26 different partners from Estonia, Latvia, Lithuania, Poland, Germany, Russia and Belarus revealed that the decisive factor for the success of a loan programme is its affordability; this depends greatly on the length of the loan's duration. To implement a successful loan programme it is important to offer long duration loans that make the (monthly) capital costs fit the net disposable income of investors/dwellers. Although the economic feasibility depends on interest rates, it has less influence on the affordability than the loan duration[66].
5. Complex application and transactional procedures can negatively affect the take up of an instrument. It is necessary to create simply accessed but effective financial instruments, avoiding unnecessary intermediate bodies in the financing chain and unjustified additional costs.

To maximise the benefits of energy efficient and renewable energy supplied buildings, it is necessary to support the development of local supply chain industries and services. Closing the economic cycle in the country itself will multiply the macro-economic benefits. The objective should be to make the biggest proportion of investments at local level. This will lead to the creation of sustainable jobs and additional tax revenues for public budgets.

A suggestion on how to improve the existing financial schemes for buildings is proposed in Table 29.

Table 29: Further steps for improving financial support schemes in Poland

National support schemes	
State of art	1. At the end 2009, the Council of Ministers adopted the resolution "Energy Policy of Poland until 2030". In this context the Polish government has implemented several programmes and measures to promote energy efficiency in buildings. Moreover, the implementation programme of Poland's Energy Policy until 2030 foresees to introduce additional support mechanisms that promote the generation of renewable heating and cooling at a larger scale. 2. The Thermo-modernisation and Repairs Fund has the main objective to offer financial aid for investors who want to improve the technical condition of an existing housing resource, and in particular of common areas of multi-dwelling units, and to reduce the consumption of energy for heating purposes.

[65] EuroACE (2010). *Making money work for buildings: Financial and fiscal instruments for energy efficiency in buildings*. Available at: http://www.euroace.org/PublicDocumentDownload.aspx?Command=Core_Download&EntryId=133

[66] Boermans, T.,Grözinger, J. (2011). *Economic effects of investing in energy efficiency in buildings - the BEAM² Model. Cohesion policy investigating in energy efficiency in buildings.* Ecofys. Available at: http://ec.europa.eu/regional_policy/conferences/energy2011nov/index_en.cfm

	3.The aim of Green Investment Scheme (Part 1 and 5)[67] is to decrease energy consumption by providing grants and loans for thermo-modernisation and energy-efficient lighting. 4.NFOiGW (National Fund for Environmental Protection and Water Management) announced plans for the elaboration of a financing instrument for supporting the energy efficient investments in residential buildings. This instrument maybe used as a main driver for supporting nZEB implementation in Poland. 5.Renewable energy technologies are subsidised from NFOSiGW. This includes support for purchase and installation of solar panels for hot water heating in buildings assigned or used for residential purposes[68]. On a local scale, the purchase of heat pumps, solar thermal panel and biomass boilers are subsidised. For instance there is a local programme (Ekogroszek), subsidising biomass boilers with strong restrictions: only boilers that use exclusively biomass are subsidised. This is important, because most of these boilers can use both, pellets and briquettes made of coal. PV technology is not subsidised. This program supports projects of individual private owners and housing cooperatives.
Gaps in the implementation of nZEBs	1. No holistic policy package for buildings 2. No long term programme for new buildings 3. No specific mechanism to promote RES-H&C, except local initiatives. The existing support schemes for energy efficiency and renewable energies technologies in buildings in Poland are obviously not sufficient 4. There are no specific subsidies for green energy use or (green) district heating use.
What can be improved to achieve the implementation of nZEBs?	1.Create financial/ fiscal instruments for EE and RE in new buildings that are embedded in a holistic policy package and which should include regulatory and communication elements. In this respect, the upgrade of the existing and planned support schemes of NFOiGW (National Fund for Environmental Protection and Water Management) may be a good solution. A mixture of loans and grants will be probably necessary in order to properly address all building owners, including those in fuel poverty 2.Make energy efficiency measures affordable and remove existing market barriers. 3.Facilitate the use of renewable technology and remove existing market barriers. 4.Support local technology and encourage the development of related supply chain industry for buildings (by offering financial support and facilitating knowledge transfer) 5.If necessary, facilitate energy efficient technology imported from other (EU) countries 6.Introduce special feed-in-tariffs for RES electricity produced in buildings

[67]See http://www.nfosigw.gov.pl/en/priority-programmes/green-investment-scheme/
[68]See http://www.nfosigw.gov.pl/en/priority-programmes/offer-for-an-individual-investor/

Intermediate steps?	Create an in-depth gap analysis to find out: • which energy efficiency measures and renewable energy technologies should receive and economic support; • which are the existing barriers for market uptake; • which type of economic instruments are more suitable for overcoming the existing barriers; • what level of economic support is needed; • which additional instruments are needed to make financing work; • how to overcome public budget limitations for support programmes and how to better address the existing EU and international financing opportunities.

8.3. MARKET UPTAKE

An important condition for achieving a liberalised energy market and the uptake of energy efficient and renewables is to gradually decrease subsidies for energy prices. At the same time it is important to elaborate support policies to ease the social burden, possibly by using the budget saved from subsidies on energy prices.

Another important condition for a successful transition to nZEB is to support the deployment of new technologies in order to cope with the anticipated increase of demand.

In Poland only around 7% of all new buildings currently have mechanical exhaust ventilation systems and 5% of all new buildings have supply and exhaust ventilation systems[69] . According to the market analysis done for this study only 0.4% of all new buildings have supply and exhaust ventilation systems with heat recovery with 80% efficiency. No data is available on mechanical ventilation exhaust and supply with heat recovery. It is assumed that almost no new building will have that, if the actual trend is maintained.

New hotels are usually equipped with mechanical ventilation. Upgrading to highly efficient heat recovery will provide additional energy savings at reasonable cost (payback time about 10 years). New retail buildings are often built by big retail chains for themselves (and not rented).

There is no data available in Poland concerning the insulation material, triple glazed windows and pellet boilers used in new buildings.

The most popular technologies used in new buildings are solar thermal systems. According to EurObserv'ER, the total installed solar-thermal area in 2010 in 2010 was 655 742 m^2.

Solar-thermal panels and biomass boilers are used in current construction practice for supplying domestic hot water in single family houses and in regions where no district gas is available and when the investor decides to not use coal. In some regions of Poland, there is a "no coal" restriction for SFH investors, obliging them to use an ecological source of energy if natural gas is not available at the location.

In Poland 19 320 heat pump installed units were reported in 2010 ; however no data is available on heat pump penetration by building types and by technology. There are major barriers for heat pump technology in Poland[71] :

[70]EurObserv'ER (2011): T*he state of renewable energy in Europe. 11th EurObserv'ER Report,* available at: http://www.energies-renouvelables.org/observ-er/stat_baro/barobilan/barobilan11.pdf

[71]Polish Organization of Development the Heat Pumps Technology (2011). *Polish experience in the heat pumps market, perspectives of development. Polish Organization of Development the Heat Pumps Technology*. Available at: http://www.ehpa.org/uploads/media/Polish_experience_in_the_heat_pumps_market__perspectives_of_development_Andrzej_Oczos.pdf

- The price of the total installation often shows negative NPV, when detailed calculation of heat pump usage is done;
- Legal obstacles (both lack of regulations or valid legal regulations)
- Information barriers;
- No guidelines, standards and norms;
- Only local subsidies for HP available;
- Quality problem (destructive to the market if released);
- No special energetic tariffs policy;
- No green certificates for RES solutions within heat pump technology.

Moreover, without imposing a condition to use green electricity, the installation of heat pumps may not reduce the associated CO_2 emissions due to the high carbon content of today's grid electricity. However, the EU power sector (including Poland) has an ambitious long term decarbonisation target by 2050, and the implementation of it will contribute to an overall reduction of the associated CO_2 content of heat pumps.

PV installations are mostly small off-grid installations and are mainly installed in buildings subsidised by EU funds. At present, the PV technology is not considered for single family, multi-family and public buildings.

As there is limited data available concerning the current energy efficient and renewable market in Poland, it is difficult to determine an exact growth factor for technologies. However; based on the present state-of-the-art and market estimations by national experts and other sources, it is possible to draw conclusions on whether the future market needs to grow and if so, by how much (qualitative estimation). Based on our analysis within this study, the nZEB implementation would require using thicker or improved insulation materials, triple-glazed windows in every building, installing mechanical ventilation with heat recovery in about 90% of the buildings, heat pumps in about 40% of the buildings, pellet boilers in about 60% of the buildings, solar thermal systems in about 15% of the buildings and PV systems in more than 75% of all new buildings (see Table 30). The exact shares correlate strongly with the distribution of variants that are built.

Table 30: Comparison of current market and demand for new technologies

	Insulation materials	Ventilation systems with heat recovery	Triple glazed windows	Heat pumps	Pellet boilers	Solar thermal systems	PV
Actual market	Existing	Very small	Small	Very small	Existing	According to demand	Very small
Demand in percentage of new nZEBs	100%	90%	100%	~40%	~60%	~15%	>75 %
Required growth of market [72]	High	Very high	Very high	Very high	High	Normal	Very high

The market analysis indicates that investments need to rise in the future to satisfy the additional demand created by new nZEBs. However, there are significant differences between the market uptake of technologies and existing barriers. We identify that for achieving a mature nZEB market, it is necessary to significantly increase the growth rates for ventilation systems with heat recovery, for triple glazed windows and for heat pumps.

[72] Own estimation

8.4. RAISING AWARENESS AND INFORMATION

In Poland, there is still a significant need for awareness-raising. It is recommended that all new regulations and market instruments that will be proposed in the future to be accompanied by awareness-raising campaigns[73] [74]. Awareness-raising campaigns are a very important and an effective instrument for overcoming many market barriers which are caused by a lack of proper information from both large public and contractors. Without proper awareness and information support, public opinion may become distorted and the future introduction of nZEB may be wrongly perceived as a threat to households, leading to greater expense and costs.

The 'Polish Energy Cities' network is probably the most important Polish organisation when dealing with municipal energy efficiency projects. Based in Krakow, the network has a mission to encourage greater use of energy efficient technologies and services in small and medium sized municipalities. Therefore, it is recommended to involve Polish Energy Cities as the main body for propagating information on nZEBs and to use the network in the implementation of this requirement.

In Poland, housing associations are emerging, from a position of relative obscurity until recently, as the most significant players in Poland's residential sector. A recent study by the UN Economic Commission for Europe noted that "Housing co-operatives could be considered as the main private-sector operator in Poland's housing sector with considerable tasks ahead, both in the existing housing stock and in new construction." The study revealed that housing co-operatives were responsible for 77% of all new housing construction in Warsaw and accounted for 2.8% of the national housing market[75] . Therefore, it is important to involve the housing associations in the nZEB implementation process and to inform them properly about regulations and their direct co-benefits deriving from improving the energy performance of households.

8.5. INTEGRATION OF BUILDING POLICIES INTO WIDER ENERGY, CLIMATE AND LOCAL POLICIES

To minimise the transition burden and costs, it is recommended to harmonise building policies with other complementary local policies, especially with district heating strategies. For instance this study shows that district heating may significantly help lower the costs of nZEB implementation if the renewable energy share is to be increased above 50%. Coherent buildings, renewable and district heating policies may significantly help to boost the development of local supply chain industries, to create additional jobs and to generally improve the living standard and welfare.

This integration of building policies in wider local and national energy policies will ensure the coherence of future energy strategy will ease implementation and will minimise the investment costs by optimising the efforts.

8.6. EDUCATION AND TRAINING OF WORKFORCE

The transition to very low energy buildings will be more difficult and costly without any measures for improving the skills of the building sector workforce. With rising requirements on building energy certification and expert capacity, problems are expected. Therefore, the basic education curricula have to be adapted for both the 'blue' and 'white' collar workers involved in the various stages of building planning, design and construction. In addition, long life training schemes should be introduced to keep pace with the new activities, processes and technologies.

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[73] TrainRebuild (2012b). *Training for Public Authority Civil Servants*. Available at: http://trainrebuild.eu/wp-content/uploads/2011/07/Draft-Toolkit-for-Local-Authorities.pdf

[74] TrainRebuild (2012a). *Guidance Document for Trainers.* Available at: http://trainrebuild.eu/wp-content/uploads/2011/07/Guidance-Document-for-Trainers.pdf

[75] Export Council for Energy Efficiency (ECEE) (2010). Web Page: *The Market for Energy Efficiency in Poland.* Available at: http://www.ecee.org/pubs/poland.htm#energyhttp://www.ecee.org/pubs/poland.htm#energy

The Polish project in the framework of IEE Build-up Skills[76] may be a very good start in the elaboration of relevant strategy for improving the skills of workforce in the construction sector.

At present there are many solar-thermal installers in Poland. The popularity of solar-thermal systems grew rapidly last year with the subsidy offered by NFOSiGW (National Fund for Environmental Protection and Water Management).

Concerning heat pumps, in Poland there are, at present, some 80 suppliers and about 250 specialised installers. However, they are currently not very experienced as the total number of installations is not very high.

In Poland there are at the moment, only two accredited passive house planners, according to the Passive House Institute Darmstadt.

To conclude, there is still a significant need for capacity building in Poland and to prepare the nZEB implementation it will be important to elaborate programmes for improving the qualification and skills of the workforce in the building sector.

8.7. RTD AND DEMONSTRATION PROJECTS

Research and innovation for energy efficient and renewable technologies should be supported. Investing into research will not only multiply economic benefits at national level, but also increase the competitiveness of national stakeholders at regional and European level.

Last but not the least, it will be necessary to conduct highly visible demonstration projects 'starring' very low energy buildings. There is a need to showcase the effectiveness of new technologies and their affordability.

8.8. A 2020 ROADMAP FOR IMPLEMENTING NEARLY ZERO-ENERGY BUILDINGS IN POLAND

The proposed policy implementation roadmap for nZEB outlines the necessary steps to be taken in order to achieve the start of the implementation after 2020.

The roadmap adds a timeline to the recommendations described in the country specific policy recommendations. New regulations should always be accompanied by financial support schemes, capacity building programmes and awareness-raising campaigns. For the adaptation of the building code there are various paths that could be chosen and this largely depends on the implementation timeline of policy processes.

Generally, for implementing an ambitious, but realistic policy implementation roadmap for nZEB in Poland, the following considerations are recommended:

1. To tighten the ambition levels of the building envelope and of the maximum primary energy use;
2. In parallel to gradually move actual subsidies on fossil energies and on energy prices to support energy efficiency measures and renewable energies in buildings;
3. To adapt the structure of the regulation, including obligations regarding the building envelope quality, primary energy use, CO_2 emissions and the use of renewable energy. The actual bypassing options should be removed.

[76] More information on this project is available here: http://eaci-projects.eu/iee/page/inc/Popup_PDF.jsp?prid=2579

In a previous chapter it has been shown that the additional financial effort for moving towards nearly Zero-Energy Buildings may be managed by introducing support schemes and for some options are even economically viable. We have also identified that by improving the thermal insulation of new buildings and by increasing the share of renewable energy use in the building's energy consumption, the implementation of nearly Zero-Energy Buildings in Poland can generate macro-economic and social benefits.

There are multiple benefits for business and society, but for ensuring a cost-effective and sustainable market transformation, concerted actions are needed. It is important to develop the appropriate policies and to increase institutional capacities. In addition, it is vital to prepare as soon as possible an implementation roadmap. This roadmap should be based on a wide public consultation involving all relevant stakeholders and an on-going information campaign. Future measures should be announced in time to allow the market to adapt their practices to future requirements.

To support the national efforts, this study proposes a 2020 roadmap for nZEB implementation (Table 31). It takes into account all necessary improvements at the level of policies, building codes, capacity building, energy certification, workforce skills, public information and research. To allow for a coherent and sustainable transition, all proposed measures should get implemented in parallel. They are interlinked and ensure an overall consistence of the proposed implementation package, trying to preserve a balance between the increase in requirements and support policies.

ANNEX 1: SKETCHES OF DEFINED REFERENCE BUILDINGS

REFERENCE BUILDING N°1: SINGLE FAMILY HOUSE (SFH)

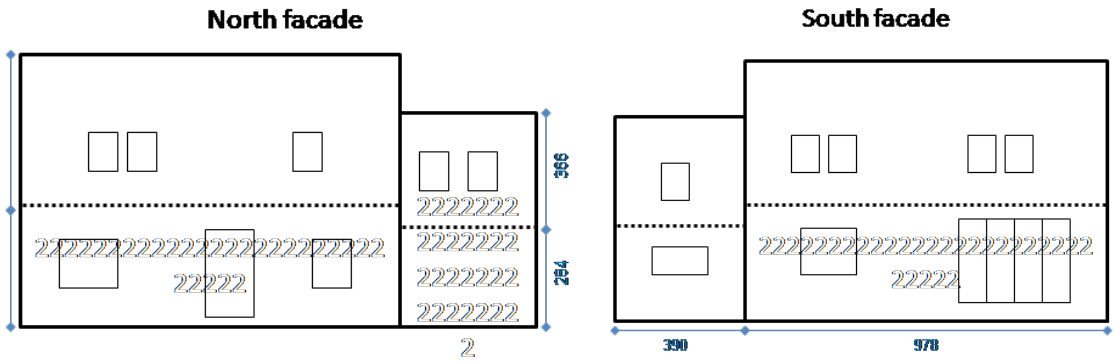

Figure A1: Facade view of North (left side) and South (right side) elevation of the single-family house

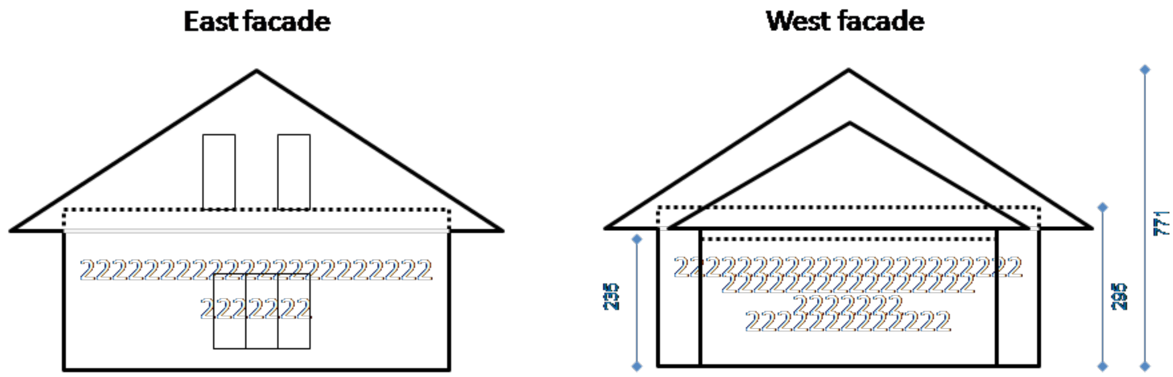

Figure A2: Facade view of East (left side) and West (right side) elevation of the single-family house

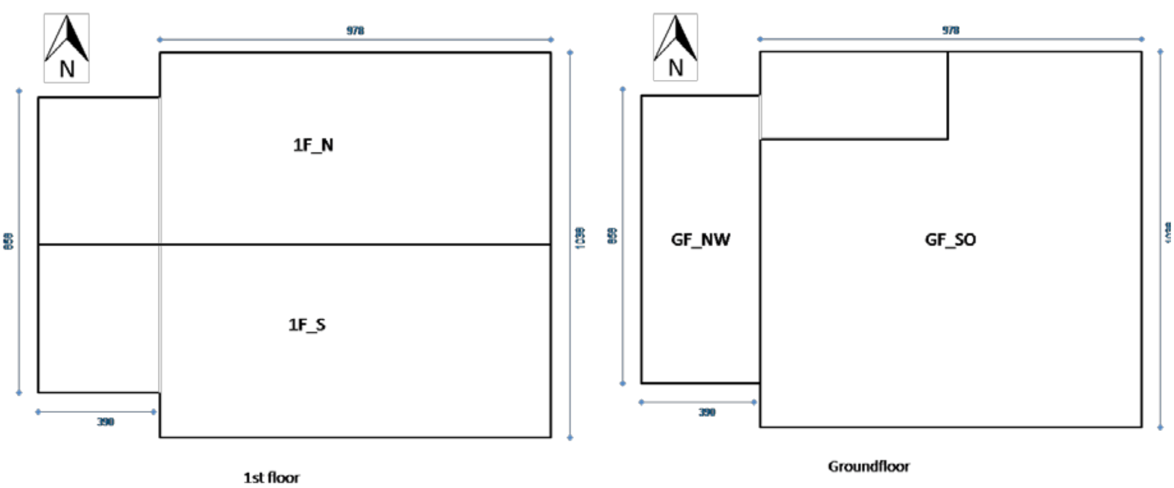

Figure A3: Floor plans (ground floor, 1st floor) with the simulated zones of the single-family house

The floor plans above show the two floors of the simulated single-family house with their zone classification. The zones are classified by orientation (North or South) and by the type of usage. The Southern ground floor zone (GF_SO) includes both the living room and the kitchen. The Northern ground floor zone (GF_NW) includes the entrance area and the garage. In the first floor the Northern and Southern zones (1F_N, 1F_S) are evenly divided by orientation as bed and bathrooms are dominant.

REFERENCE BUILDING N°2: MULTI-FAMILY HOUSE (SFH)

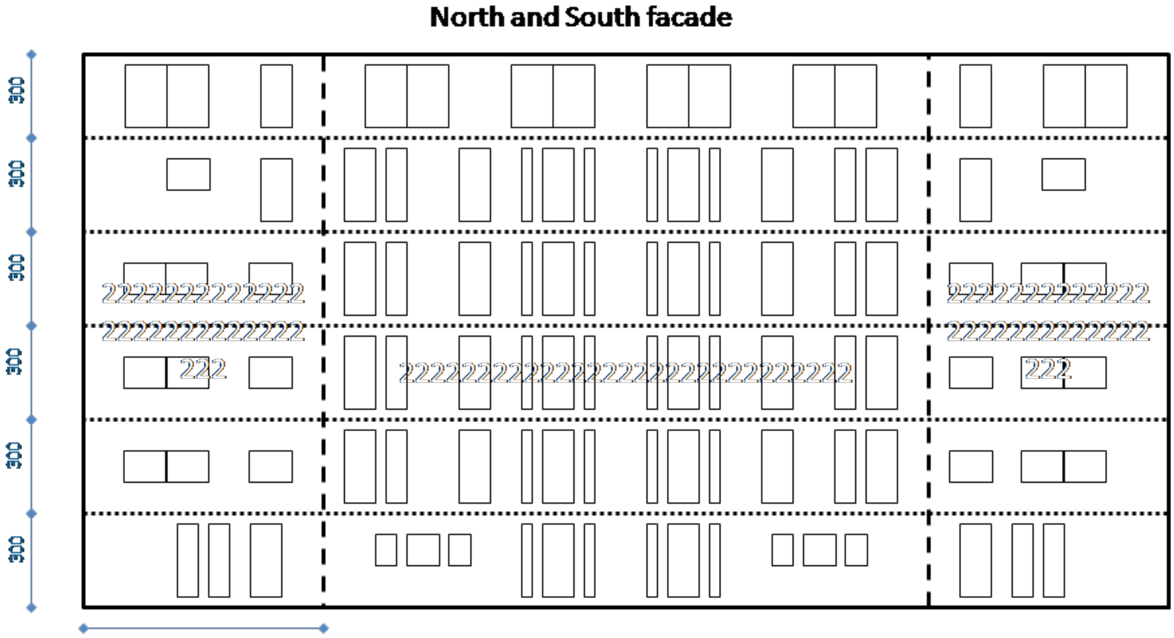

Figure A3: North and South facade view of the Polish multi-family house

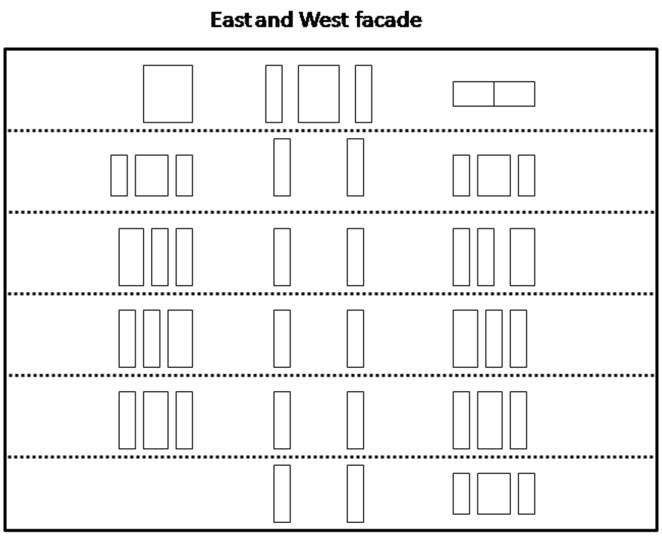

Figure A4: East and West facade view of the Polish multi-family house

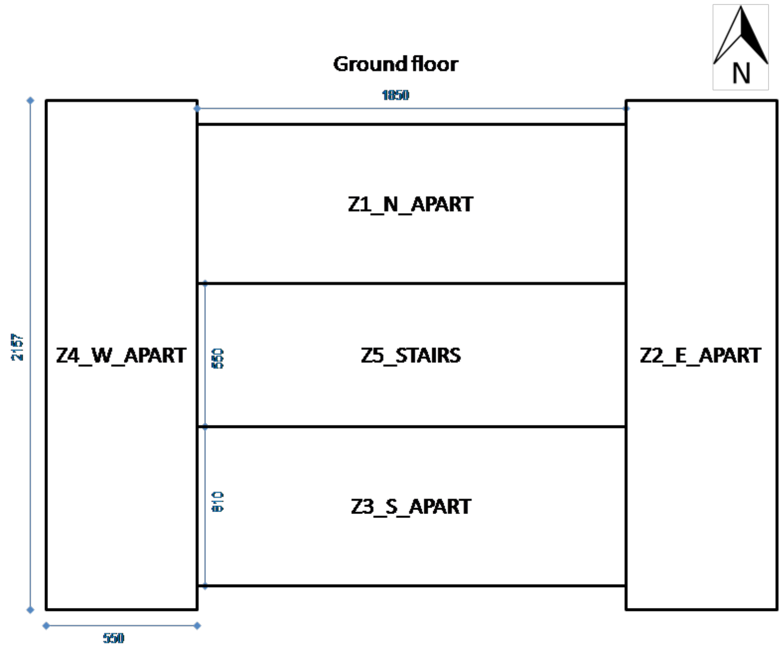

Figure A5: Floor plan standard floor) with the simulated zones of the Polish multi-family house

The floor plan above shows the five zones which have been simulated for the multi-family house. The central zone with stairs (Z5_STAIRS) and the four apartment areas either with orientation to the North, East, South and West (Z1_N_APART. Z2_E_APART. Z3_S_APART. Z4_W_APART). All zones range over the 6 floors.

REFERENCE BUILDING N°3: OFFICE BUILDING

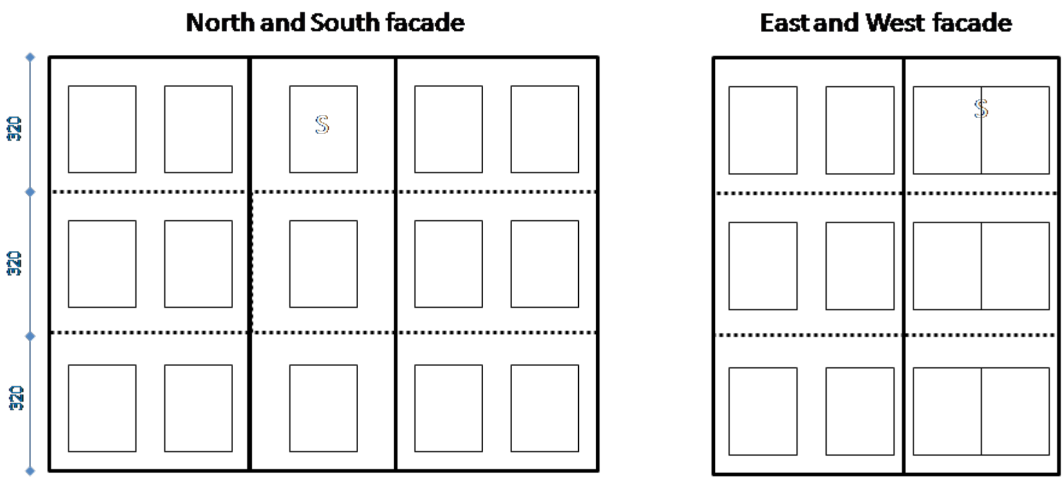

Figure A6: North, South, East and West facade view of the office building

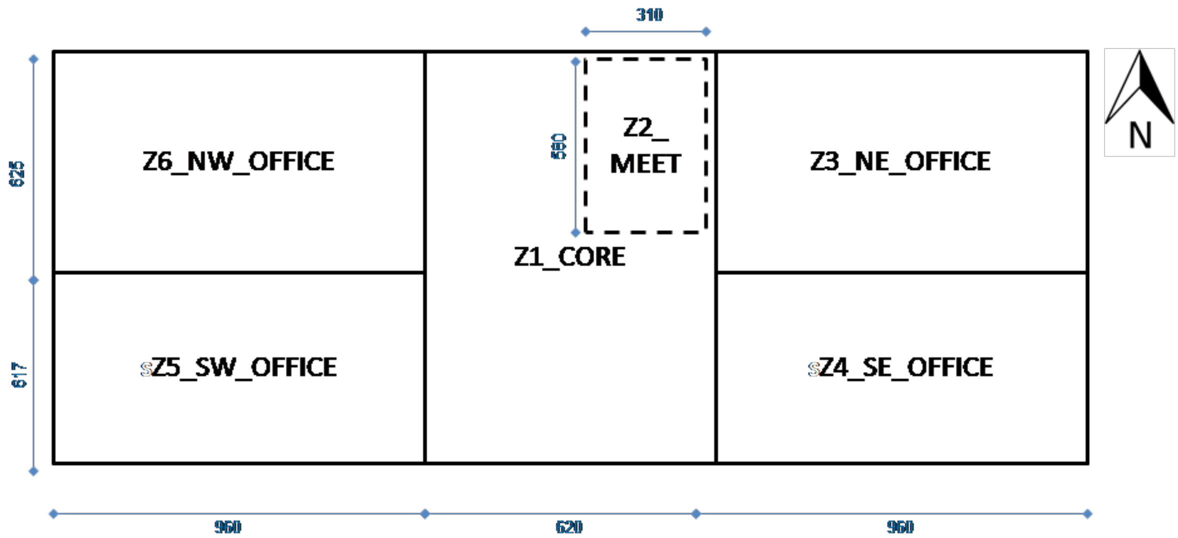

Figure A4: East and West facade view of the Polish multi-family house

The floor plan above shows the six zones, which have been considered for simulations. The central entrance zone (Z1_CORE), the conference rooms on the 2nd and 3rd floor (Z2_MEET) and the four office areas, either with orientation to the North (Z3_NE_OFFICE, Z6_NW_OFFICE) or to the South (Z4_SE_OFFICE, Z5_SW_OFFICE). Apart from the conference zone all zones enclose three floors.

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