MODULE #1

1 NZEB DEFINITION

1.1 INTRODUCTION

Residential and public buildings are the largest energy consumers (see the previous chapter), so actions are needed to be taken. The European Union is addressing the issue of poor energy performance of public and residential buildings by the directives of Energy Efficiency (EED) and the Energy Performance of Building (EPBD). The universal goal is to create a more sustainable, carbon-free and healthy built environment for the whole European community. The EPBD requires Member States to establish minimum requirements for the energy performance of newly constructed buildings and existing buildings undergoing major renovations. Set by EPBD, every EU member state should ensure that by 31 December 2020, all new buildings will be nearly zero energy buildings; and after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings.

This chapter will go through the concept of nearly zero-energy buildings (nZEB), how the EU defines it and how the member states implement the concept into their national laws and regulations. (NB: NZEB refers to net zero energy buildings. Net zero-energy buildings have zero primary energy consumption, while nearly zero-energy buildings are using more than zero primary energy.)

There are many advantages of nearly zero-energy buildings:

- A positive contribution towards climate protection for generations to come.
- Low maintenance and operating costs.
- The building’s value increases in the long-term, as well as its resale value.
- Higher level of comfort
  - ✓ pleasant warmth in the winter
  - ✓ overheating of the building is prevented
  - ✓ a sufficient supply of fresh air
  - ✓ brighter rooms due to extensive use of daylight

1.2 NZEB CONCEPTS

There are several concepts of energy efficient buildings: nearly zero-energy buildings (nZEB), net zero energy buildings (NZEB), passive houses etc. These are similar concepts, all focusing on low energy demand but each have its own definition.

Different similar definitions and names are available for measuring a building's energy performance as well: autonomous zero-energy building, net-zero site energy building, net-zero source energy buildings, net-zero energy cost building, and net-zero energy emission building. For example, autonomous zero energy buildings are not grid-connected, they operate completely independently of any external energy infrastructure. A zero-energy building (ZEB) defined by the United States' Department of Energy produces enough renewable energy to meet its own annual energy consumption requirements. Passive houses have their own criteria to meet defined by the German Passivhaus Institut, see Figure 1.

Space Heating Demand	not to exceed 15kWh annually OR 10W (peak demand) per square metre of usable living space
Space Cooling Demand	roughly matches the heat demand with an additional, climate-dependent allowance for dehumidification
Primary Energy Demand	not to exceed 120kWh annually for all domestic applications (heating, cooling, hot water and domestic electricity) per square meter of usable living space
Airtightness	maximum of 0.6 air changes per hour at 50 Pascals pressure (as verified with an onsite pressure test in both pressurised and depressurised states)
Thermal Comfort	Thermal comfort must be met for all living areas year-round with not more than 10% of the hours in any given year over 25°C*

Figure 1.: Required criteria of passive houses (source: https://passivehouse-international.org/)

1.3 NZEB BY THE EPBD

Whilst the above concepts are voluntary, the nZEB concept is described by the EPBD setting as an obligation to member states. However the definition is rather general as follows: :

"Nearly zero energy building means a building that has a **very high energy performance**, and the **nearly zero or very low amount of energy** required should be covered to a very significant extent by **energy from renewable sources**, including energy from renewable sources **produced on-site or nearby**."

The EPBD defines nZEB buildings by their high energy performance, while the other part of the definition adds directions to cover the low need of energy to a very significant extent by energy from renewable sources. With these unmeasurable categories, the definition leaves a lot of latitude to member states to create their own national nZEB regulations. The national regulations should consider

- The local climate: heating and cooling needs or the intensity of solar radiation,
- Economic factors: energy prices, GDP and national/transnational incentives,
- Structural/Intellectual factors: state of the existing building infrastructure, the available industrial and engineering knowledge, workforce.

Minimum requirements must take account of general indoor climate conditions in order to avoid possible negative effects such as inadequate ventilation.

The implementation of nearly zero energy building definitions has already been executed in European Union member states: every country has its own threshold values and requirements. Basically, the definitions are divided into residential and non-residential buildings, as well as for new or existing ones. Some countries use direct requirements on renewable energy amount or share, others like the Czech Republic and Germany define indirect indicators based on the maximum primary energy demand of a reference building.

1.4 VERY HIGH ENERGY PERFORMANCE?

The energy performance is defined in the EPBD as "the amount of energy needed to meet the energy demand associated with a typical use of the building which includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting". Under Annex I (3) of the Regulation, the calculation of energy performance starts with the calculation of final energy needs for heating and cooling, and ends with the calculation of the net primary energy. The "direction" of the calculation goes from the building's needs to the source (i.e. to primary energy). The primary energy use must be calculated using primary energy factors specific to each energy carrier (e.g. electricity, heating oil, biomass, district heating and cooling). The building's net primary energy use can include the produced renewables as well.

The calculation should be classified into categories such as residential buildings; offices; educational buildings; hospitals; sports facilities; etc. Positive influence of local solar exposure conditions, active solar systems and other heating and electricity systems based on energy from renewable sources; electricity produced by cogeneration; district or block heating and cooling systems and natural lighting should be taken into account.

The end objective of the energy performance calculation is to determine the overall annual energy use in net primary energy, which corresponds to energy use for heating, cooling, ventilation, hot water and lighting. However, the current directive does not provide numerical requirement of the primary energy consumption, which needs to be measured in kWh/m^2*year. In addition, Member States often include other parameters such as U-values of building envelope components, net and final energy for heating and cooling and CO_2 emissions. For example, Hungary uses specific heat loss coefficient of the building envelope and primary energy, while Slovakia uses U-value requirements of building envelope components as well.

Member States also have to define primary energy factors per energy carrier. These primary energy factors can be based on national or regional average values, or on specific values. These factors should take into account the renewable energy content of the energy supplied to the building, including from nearby sources, in order to place on-site and off-site renewable energy sources on equal footing.

Countries where a numerical indicator has been set, the requirements range rather widely from 0 kWh/(m^2*y) to 270 kWh/(m^2*y). For residential buildings, most Member States aim to have a primary energy use not higher than 50 kWh/m^2/year. The maximal primary energy use ranges between 20 kWh/(m^2*y) in Denmark or 33 kWh/(m^2*y) in Croatia (Littoral) and 95 kWh/(m^2*y) in Latvia. Several countries (Belgium (Brussels), Estonia, France, Ireland, Slovakia, United Kingdom, Bulgaria, Denmark, Croatia (Continental), Malta, Slovenia) aim at 45 or 50 kWh/(m^2*y).[1]

The European Commission also set benchmarks for the high energy performance by analyzing prices and technologies for member states' climate zones.

	NZEB level of energy performance	**Mediterranean** Zone 1: Catania (others: Athens, Larnaca, Luga, Seville, Palermo)	**Oceanic** Zone 4: Paris (others: Amsterdam, Berlin, Brussels, Copenhagen, Dublin, London, Macon, Nancy, Prague, Warszawa)	**Continental** Zone 3: Budapest (others: Bratislava, Ljubljana, Milan, Vienna)	**Nordic** Zone 5: Stockholm (Helsinki, Riga, Stockholm, Gdansk, Tovarene)
		Offices kWh/(m2/y)			
Appliances not included in offices	**net primary energy**	**20-30**	**40-55**	**40-55**	**55-70**
	primary energy use	80-90	85-100	85-100	85-100
	on-site RES sources	60	45	45	30
		New single family house kWh/(m2/y)			
Appliances and lighting not included in single-family	**net primary energy**	**0-15**	**15-30**	**20-40**	**40-65**
	primary energy use	50-65	50-65	50-70	65-90
	on-site RES sources	50	35	30	25

Figure 2. – Recommendations by the EC

1 https://ec.europa.eu/energy/sites/default/files/documents/Updated%20progress%20report%20NZEB.pdf

Source: https://www.rehva.eu/fileadmin/user_upload/1_Kurnitski_EPBD_2nd_recast.pdf

Briefly, high energy performance means that by the end, a 'nearly zero' or 'very low amount' of energy will be required.

1.5 RENEWABLE SOURCES?

Nearly zero energy demand is not enough to meet nZEB goals, the needed energy 'should be covered to a very significant extent by energy from renewable sources'. National nZEB regulations also had to define what is 'a very significant extent': only a few countries defined a specific minimum percentage for renewable energy share of the primary energy or a minimum renewable energy contribution in kWh/m^2*y, the majority set up qualitative statements or indirect requirements such as a low non-renewable primary energy use that can only be met if renewable energy is part of the building concept. This flexibility allows adaptation to national circumstances and local conditions (building type, climate, costs for comparable renewable technologies and accessibility, optimal combination with demand side measures, building density, etc.).

Large differences exist across countries regarding those RES solutions which can be included in their energy performance calculations, and those which can be used to fulfil direct nZEB RES requirements. Some technologies (e.g., solar thermal panels for domestic hot water generation and for heating, PV for self-use, as well as biomass boilers and heat pumps coupled to external air/exhaust air/ground or ground water) can in general be taken into account in the energy performance calculation in all 24 countries that took part in the evaluation. Other RES technologies (e.g., PV for feed-in, RES as part of district cooling, micro-wind turbines (self-use or feed-in) and local hydro power for self-use) can taken into account in the energy performance calculation in about half of the countries that took part. The RES technologies that can most rarely be accounted for in energy performance calculations are RES electricity via the grid (with a specific contract) and local hydro power for feed-in (see Figure 3.).

Solution \ Country	BE-BR	BE-FL	BE-WA	BG	CY	DE	DK	EE	GR	ES	FI	FR	HR	HU	IT	LT	LV	MT	NL	NO	PL	PT	SE	SK	SL	UK
RES as part of district heating	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y		Y	N	Y	Y	Y
RES as part of district cooling	N	N	N	Y	Y	Y	N	Y	Y	N	Y	Y		N	Y	N	N	N	Y	Y	N	Y	N	N	Y	N
Solar thermal panels for DHW	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Solar thermal panels for heating support	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
PV for self-use	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
PV for feed-in	Y	Y	Y	Y	Y	N	N	Y	Y	N	N	Y	Y	Y	N	Y	Y	Y	Y	Y	N	N	N	Y	Y	N
PV for heating (input to heat storage)	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
PV/T hybrid solar collectors for self-use	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
PV/T: PV for feed-in, T for self-use	Y	Y	Y	N	Y	Y	Y	Y	N	N	N	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N
Micro wind-turbine for self-use	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
Micro wind-turbine for feed-in	N	N		N	Y	Y	N	Y	Y	N	N		N	N	N	Y	Y	Y	Y	Y	N	N	N	Y	N	N
Local hydro for self-use	N	N	N	N	N	N	Y	Y	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
Local hydro for feed-in	N	N	N	N	N	N	N	Y		N	N	N	N	N	N	Y	Y	N	Y	Y	N	N	N	N	Y	N
Biomass boiler	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
Biomass CHP	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y/N	Y/N	Y	Y	Y	Y/N	N	Y	Y	Y	Y		Y	N	Y	Y	Y
HP coupled to external or exhaust air	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
HP coupled to ground / ground-water	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Direct geothermal	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Direct ground water cooling	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
RES electricity via grid (specific contract)	N	N	N	Y	N	N	N	N	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	N	N	N
Alternative: higher insulation level	Y	Y	N	Y	N	Y	N	Y	Y/N	Y/N	N	N	N	N	Y	N	N	N	Y	Y	Y	N	Y/N	N	Y	N

Figure 3: RES solutions in the MSs' nZEB calculations

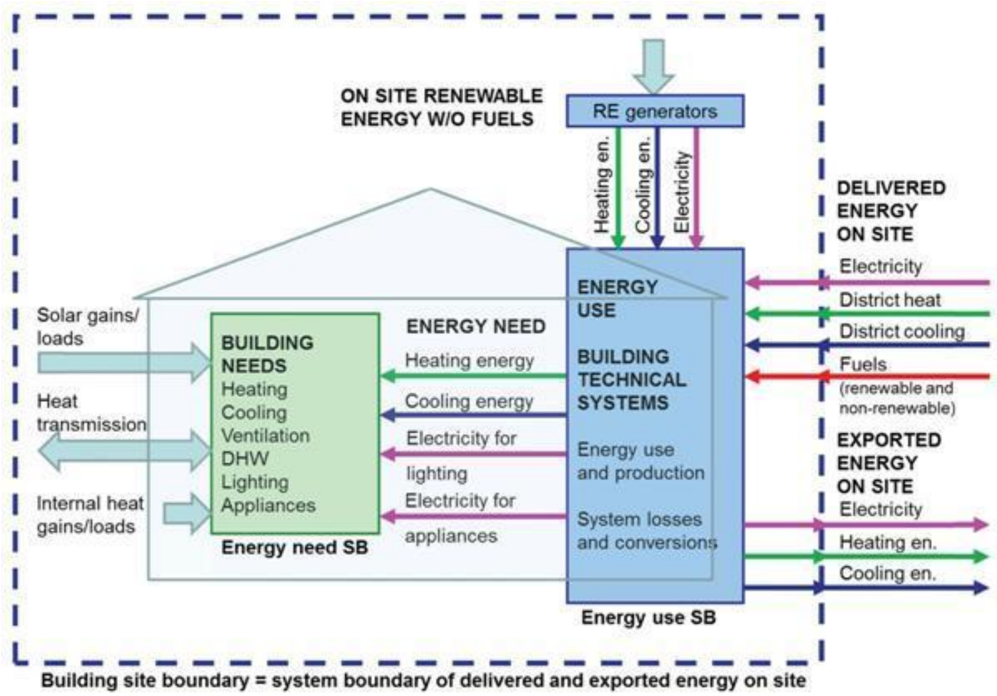
Source: https://epbd-ca.eu/ca-outcomes/outcomes-2015-2018/book-2018/ct/new-buildings-nzebs-update

In addition, the RES and the EPBD required the Member States to update the national building codes in order to promote the renewable energy in the building industry.

1.6 ON-SITE OR NEARBY PRODUCTION?

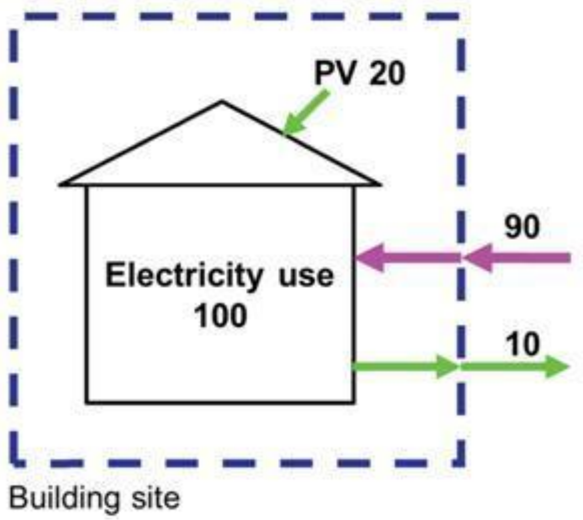
The nZEB definition in the EPBD emphasizes that used renewable energy can include energy from renewable sources produced on-site or nearby. Although 'nearby' and 'on-site' can also be equivocal. The definition is based on the system boundaries which can be:

1) at the building envelope (i.e. PVs on the roof included but PVs in the garden are not)
2) at the property lines
3) even broader, eg. pipe-systems connected to the building (i.e. district heating) can be 'part' of the nZEB building if it's using renewable sources.



4. figure – A schematic system of an nZEB building with on-site and nearby energy (SB stands for System Boundary) / Source: https://www.rehva.eu/rehva-journal/chapter/technical-definition-for-nearly-zero-energy-buildings

Energy produced on-site (used on-site or exported) reduces the primary energy needs associated with delivered energy. According to the actual EPBD, the positive influence of renewable energy produced on site is taken into account, so that it reduces the amount of delivered energy needed and may be exported if cannot be used in the building (i.e. on site production is not considered as part of delivered energy on site).



5. figure – Source: https://www.rehva.eu/rehva-journal/chapter/technical-definition-for-nearly-zero-energy-buildings

1.7 COST-EFFICIENCY

The European nZEB concept created a cost-optimal building requirement system for the member states which was needed to be implemented into the national regulations. These regulations served as the hall of nZEB regulation and should affect existing and new buildings as well. The national cost-optimal regulations should define an optimal mix of insulation or other energy efficiency measures, inclusion of highly-efficient technical building systems and use of on-site renewable energy sources and need to be monitored every 5 years.

A building's cost-efficiency is the level of energy efficiency where the building's whole life cycle shows the lowest cost. The lowest cost should include the cost of the original investment, cost of maintenance, cost of overhead (including energy costs and energy surpluses generated by renewable energy) and the cost of disposition. The level of optimal cost should be between the levels of performance where the whole economic life cycle analysis' cost-benefits are positive.

1.8 NATIONAL NZEB PLANS

According to the EPBD all member states should draft national plans for increasing the number of nearly zero-energy buildings with differentiated targets according to the category of building.

The national plans should include the following elements:

- detailed application in practice of the definition of nearly zero-energy buildings, reflecting their national, regional or local conditions, and including a numerical indicator of primary energy use expressed in kWh/m^2 per year. Primary energy factors used for the determination of the primary energy use may be based on national or regional yearly average values and may take into account relevant European standards,
- information on the policies and financial or other measures adopted for the promotion of nearly zero-energy buildings, including details of national requirements and measures concerning the use of energy from renewable sources in new buildings and existing buildings undergoing major renovation.

1.9 REFERENCES

http://www.egt.bme.hu/BSE1/Smart_and_nZEB_buildings.pdf

https://www.intechopen.com/online-first/net-zero-energy-buildings-principles-and-applications

https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016H1318&from=RO

https://ec.europa.eu/energy/sites/ener/files/documents/nzeb_executive_summary.pdf

https://www.rosenberg.hu/sites/default/files/01%20-%20Magyar_Grundfos-Rosenberg_1.pdf

https://www.rehva.eu/rehva-journal/chapter/technical-definition-for-nearly-zero-energy-buildings

http://bpie.eu/documents/BPIE/publications/LR_nZEB%20study.pdf

http://www.epbd-ca.eu/wp-content/uploads/2016/01/Overview_of_NZEB_definitions.pdf

https://www.ea-stmk.at/documents/20181/25550/NZEB_Broschuere_englisch_WEB.pdf/78737a82-4b16-4e24-a8c8-36d0501befd6