This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 691768

Nearly zero-energy building concepts for the application of BIPV elements

Project report

BEAR-iD, NOBATEK

September 2016

Document summary

This document describes the European policy for nearly zero-energy buildings (nZEBs). It provides an overview of the state-of-the-art technical concepts and requirements in European regulation.

Different technical nZEB concepts adapted to the European climate are described. Renewable Energy Systems are a very important contribution for reaching the nZEB goals, and although this includes PV and BIPV, these are not the only possible approaches.

Acknowledgements

The work described in this publication has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 691768.

The present report was prepared by PVSITES project partners BEAR-iD and NOBATEK, with additional contributions from Film Optics and Tecnalia. It was proof-read by Project coordinator Tecnalia. The report was originally submitted to the European Commission as Project Deliverable D2.3 "NZEB building concepts for the application of BIPV building elements" in March 2016, and resubmitted in September 2016 after some small adjustments.

Disclaimer

About the PVSITES project

PVSITES is an international collaboration co-funded by the European Union under the Horizon 2020 Research and Innovation program. It originated from the realisation that although building-integrated photovoltaics (BIPV) should have a major role to play in the ongoing transition towards nearly zero energy buildings (nZEBs) in Europe, large-scale deployment of the technology in new constructions has not yet happened. The cause of this limited deployment can be summarised as a mismatch between the BIPV products on offer and prevailing market demands and regulations.

The main objective of the PVSITES project is therefore to drive BIPV technology to a large market deployment by demonstrating an ambitious portfolio of building integrated solar technologies and systems, giving a forceful, reliable answer to the market requirements identified by the industrial members of the consortium in their day-to-day activity.

Coordinated by project partner Tecnalia, the PVSITES consortium started work in January 2016 and will be active for 3.5 years, until June 2019. This document is part of a series of public reports summarising the consortium's activities and findings, available for download on the project's website at www.pvsites.eu.

The PVSITES consortium:

Tecnalia Research & Innovation	CTCV	FormatD2
Onyx Solar	Flisom	Vilogia
BEAR-iD	Cricursa	R2M Solution Research to Market
Nobatek	CEA	CADCAMation
Film Optics	Acciona Infraestructuras	WIP - Renewable Energies

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1 EXECUTIVE SUMMARY

1.1 Introduction

Subtask 2.1.2 "European climate zones and bio-climatic design" focuses on the requirements from the climate and regulation view point and will propose several NZEB building concepts with BIPV building elements.

This subtask will deliver two deliverables:

D2.2 "European climate zones and bio-climatic design requirements".

D2.3 "NZEB building concepts for the application of BIPV building elements"

Deliverable 2.3: This deliverable will deal with the design of several building concepts, considering the architectural and aesthetical requirements gathered in subtask 2.1.3. The building concepts will show the possibilities to integrate the BIPV building elements and their related energy performance. This subtask work, performed by BEAR and Nobatek, will result in a collection of concepts that reach the nearly-zero energy building (nZEB) level.

EPBD 2010

The European Directive 2010/31/EU on the energy performance of buildings (EPBD 2010), published in 2010, has a time line towards nZEB buildings. Article 9 in the Directive states that Member States shall ensure that (a) by 31 December 2020, all new buildings are nearly zero-energy buildings; and (b) after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings.

Article 2 of the Directive 2010/31/EU defines a nearly zero-energy building as a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including on-site or nearby production. According to Annex I, article 1, "The energy performance of a building shall be determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with its typical use and shall reflect the heating energy needs and cooling energy needs (energy needed to avoid overheating) to maintain the envisaged temperature conditions of the building, and domestic hot water needs."

Several studies have been done analyzing this definition and how it is applied in different European countries. An important part for this deliverable is the use of minimum levels of RES in buildings (Directive 2009/28/EU).

The latest status report is the 'Overview of national applications of the Nearly Zero-Energy Building (NZEB) definition – Detailed report' from April 2015 [12]. 16 Member States set a definition of nZEB that comprises both a numerical target for primary energy use (or final energy) and considers the share of renewables in a quantitative or qualitative way. In several countries the share of primary energy consumption, which has to be covered by renewable energy sources, is explicitly stated, while in other Member States the renewable sources are considered indirectly because the low maximum values of primary and/or final energy use cannot be met without using renewable energy sources. A few countries do not have specific renewable energy requirement included in their nZEB definition. Only five countries encourage directly BIPV system implementation.

This report gives an overview of the energy needs in buildings in Europe and the nZEB concepts that can be applied. To reach the nZEB goals, the use of Renewable Energy Systems is a very important part, although this term refers not just to PV or BIPV.

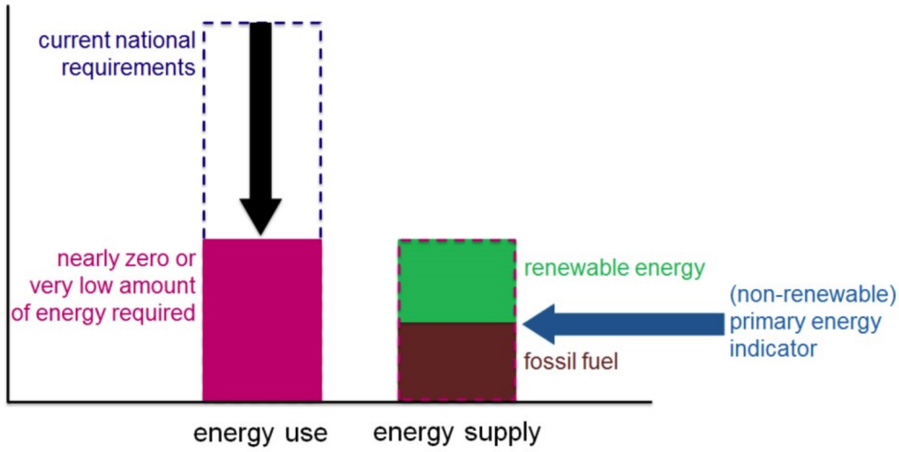

Figure 1: Graphic interpretation of the nZEB definition according to Articles 2 and 9 of the EPBD (Directive 2010/31/EU) [12]

For EU countries, we can define several nZEB concepts depending on the different European climates. The concepts are based on the "trias energetica" principles [2]. This means: Reduce energy needs, Use Renewable Energy Systems and Use Non-Renewable Energy with a high efficiency.

1.2 Reference material

Overview of national applications of the Nearly Zero- Energy Building (NZEB) definition – Detailed report, Hans Erhorn, Heike Erhorn-Kluttig, CA EPBD, April 2015.

Implementing the Energy Performance of Buildings Directive (EPBD), Directive 2010/31/EU.

PVSITES project, D2.2 "European Climate Zones and Bio-climatic Design Requirements".

1.3 Abbreviation list

BIPV: Building-integrated photovoltaics

PV: Photovoltaics

nZEB: Nearly zero energy buildings

BPIE: Buildings Performance Institute Europe

EED: Energy Efficiency Directive

EPBD: Energy Performance of Buildings Directive

2 EU COUNTRIES AND DEFINITIONS ON nZEB

In 2010, the recast of the Energy Performance of Buildings Directive [Directive 2010/31/EU] introduced the concept of and obligation for nearly zero energy buildings (nZEB), particularly for new buildings. Essentially, the Directive sets out a general framework and gives considerable latitude to Member States to define it. Therefore, nZEB is a very flexible policy requirement with no single, harmonised nZEB definition throughout the EU. Some of the expressions are intentionally vague and it is left to the Member States in their national plans to provide some rigour to the definition within the context of their own national efforts.

Article 2 of 2010 EPBD recast describes nearly zero energy buildings as buildings that have a very high energy performance with the nearly zero or very low energy use, required to a very significant extent that the energy needs are met by renewable sources including renewable energy produced onsite and nearby.

Article 9 in the Directive states that Member States shall ensure that (a) by 31 December 2020, all new buildings are nearly zero-energy buildings; and (b) after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings.

2.1 Next steps

In June 2014, Member States published their third National Energy Efficiency Action Plans (NEEAPs) that give a better indication on what progress has been made and if there are any problems in meeting the 2018 and 2020 deadlines.

2.2 National plans

'Member States shall draw up national plans for increasing the number of nearly zero-energy buildings. These national plans may include targets differentiated according to the category of building.' The national plans should include a practical application of what nZEB is supposed to consist in:

- a numerical indicator in primary energy expressed in kWh/m^2/year;

- intermediate targets for 2015;

- and policy, financial and any other type of measures that will support the implementation of nZEB and including national measures and requirements concerning the use of RES in new and existing buildings undergoing major renovation.

These plans were due to be reviewed by the Commission by the end of 2012. By the time the Commission prepared its report, only eight Member States had responded. To date, now 21 Member States have provided their plans [12].

3 ENERGY NEEDS IN BUILDINGS IN EUROPE

Buildings represent about 40% of EU final consumption and 60% of electricity consumption. Energy consumption of buildings depends on the external weather conditions, HVAC systems used and obviously on the building characteristics. In order to be able to develop and implement successful energy strategies in the buildings it is necessary to know the building energy demand.

In this part of the document, building typologies, energy demand needs and types of diffusion systems will be addressed with the common thread of defining typical characteristics for the whole of Europe. At the EU level, around two thirds of the energy consumption of buildings is for residential buildings (Figure 2). However, in some countries such as Luxembourg, Malta, the Netherlands, Italy or Portugal, non-residential buildings (i.e. services) are dominant and represent more than half of the total consumption of buildings. The share of residential buildings is above 70% in Denmark, Latvia, Poland and Austria and even reaches 80% in Romania.

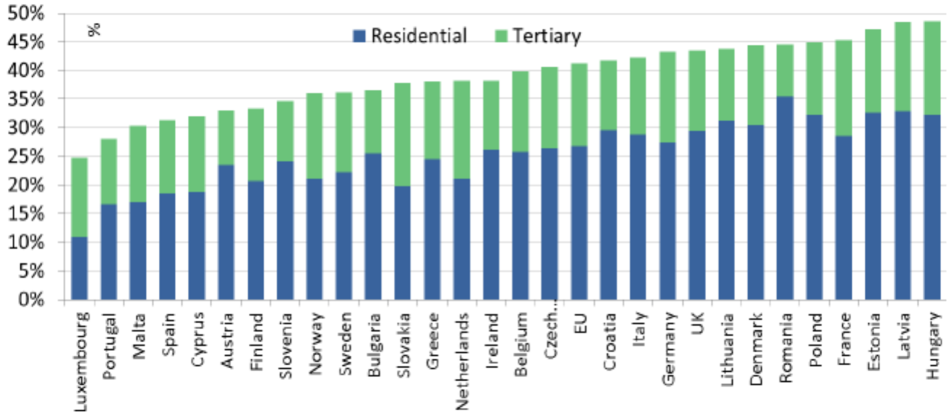

Figure 2: Share of buildings in final energy consumption [10]

The energy consumption of buildings has been decreasing since 2008 (-0.9%/year), after increasing by 0.6%/year from 2000 to 2008. This trend is not fully explained by the economic recession as the GDP contraction was lower (-0.3%/year). Electricity consumption has remained roughly stable since 2008, following a rapid increase until 2008, at the same rate as GDP (2.4%/year) (Figure 3).

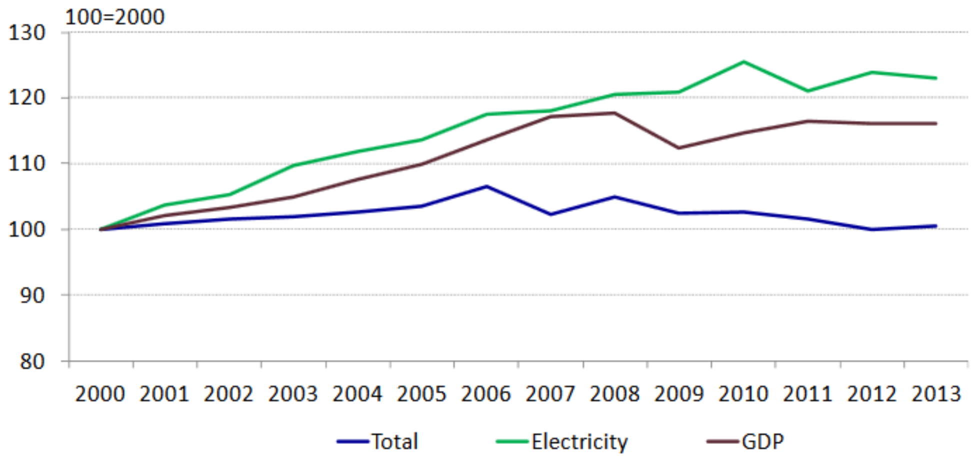

Figure 3: Energy consumption trends in buildings and GDP at EU level [10]

The specific electricity consumption per m², which can be supplied by BIPV system, varies significantly by countries (Figure 4).

It is higher in the Nordic Countries (Norway, Sweden and Finland) and France, due to the use of electricity for space heating (for instance, 32% for Finland, 25% for Sweden and 22% for France in contrast to only 9% for Denmark and 4% for the Netherlands in 2012). The high values for Greece and Spain are partly explained by space cooling.

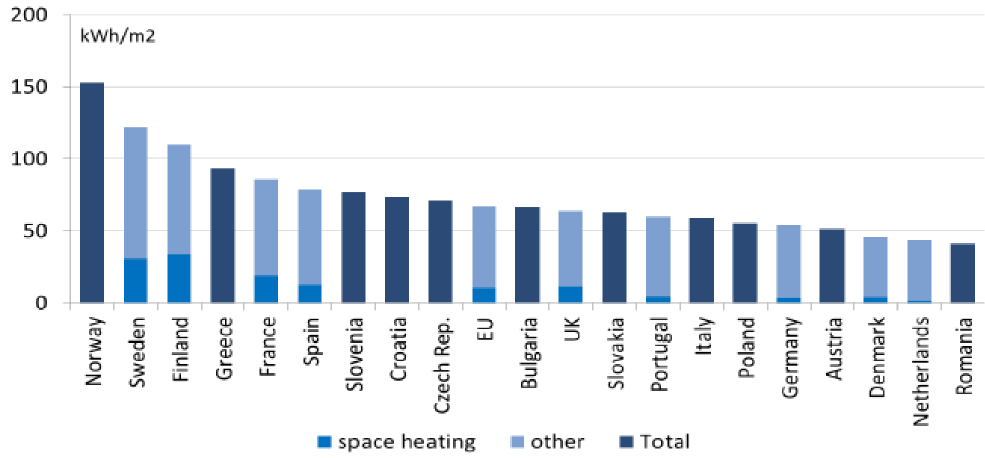

Figure 4: Specific electricity consumption in buildings (kWh/m^2) [10]

3.1 Residential buildings

Buildings account in the EU-28 for about 40% of final energy demand and about a third of greenhouse gas emissions, of which about two-thirds are attributed to residential buildings.

The fuel and amount of energy used in residential buildings varies from country to country, depending on living and comfort standards, climatic conditions, per capita income, natural resources and available energy infrastructure. Energy is mainly used for space conditioning (heating and cooling), sanitary hot water production, cooking, lighting and electrical appliances (i.e. refrigerators, washing machines and entertainment equipment).

The energy consumption by end-use in EU-28 member states is dominated by space heating (78%), followed by water heating (16%). This average masks considerable differences depending on climate (see Figure 5), the building type, thermal integrity, activity, etc. While the share of space heating is above 80% in colder climates, in warmer climates it is lower, around 50%.

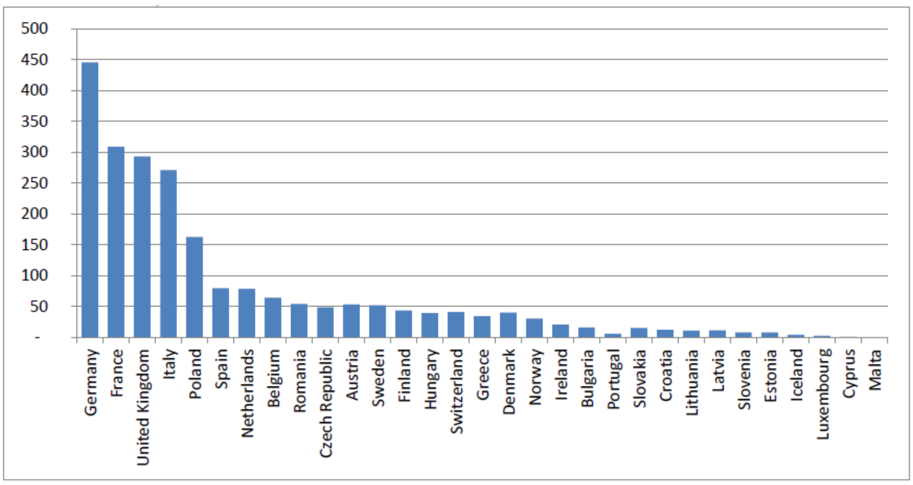

Figure 5: Space heating in the residential sector (TWh, EU28 + Norway, Iceland and Switzerland) [11]

3.1.1 Space and water heating

According to the different climatic zones in Europe, also described in D2.2, consumption for space and water heating is different. Table 1 explains the three different zones considered in this section.

Climatic zones considered	Köppen	ECOFYS
C1 - South	Csa - Hot and dry climate	Zone 1&2 - Temperate with dry, hot summer. (Mediterranean climate)
C2-Central and East	Dfb - Warm and humid climate	Zone 3 - Temperate continental climate/humid continental climate without dry season and with warm summer;
C3-North and West	Cfb - Temperate climate	Zone 4 - Temperate without dry season and warm summer
	Dfc - Cold climate	Zone 5 - Cold, without dry season and with cold summer.

Table 1: Climate zones considered in chapter 3.1.1

The total consumption for space heating in European countries grouped by climatic zones is shown in Figure 6 (left). According to this graph, Northern European countries consume similar amounts of energy for heating per dwelling compared to Central European countries. This is the result of the stricter thermal regulations and other policies that are being enforced in these countries to tackle high heating energy consumption.

Also provided in Figure 6 (right) is a pie chart showing the consumption for space heating per dwelling in million tons of oil equivalent for the three European climatic zones classified in this project. It can be observed that this consumption is considerably higher in the center of Europe, since this zone includes the most populated countries.

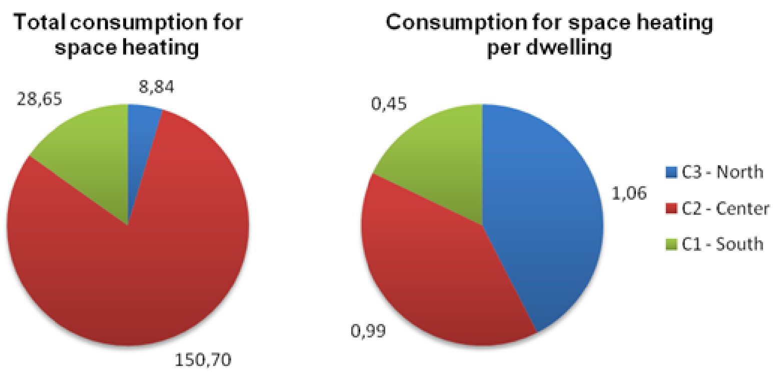

Figure 6: Consumption for space heating per dwelling in toe/dwelling/year and total consumption for space heating in Mtoe/year [6]

Similarly, Figure 7 below shows the consumption for water heating per dwelling and climatic zone (right) and the total consumption for each climatic region (left). It can be noted that this consumption is considerably higher in the Center of Europe, as it is the case for space heating, since this zone includes the most populated countries.

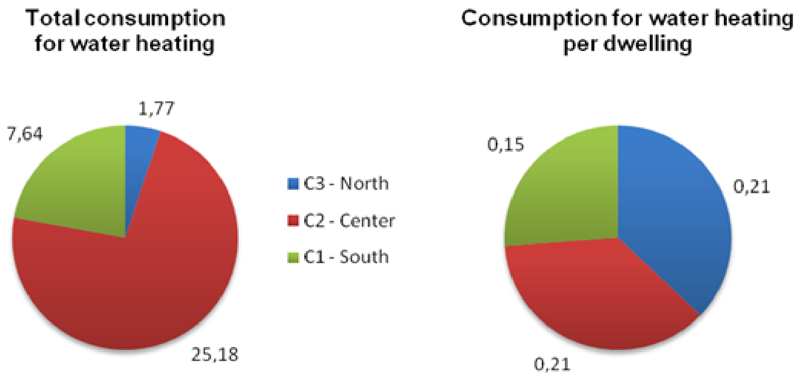

Figure 7: Consumption for water heating per dwelling and total consumption for water heating. Units: Mtoe [6]

Gas is the predominant energy source (44%) followed by oil (21%) for space heating and water heating, but differences can be observed depending on the countries and climatic zone. Table 2 shows a classification depending on the energy carrier:

- Northern Europe, district heating is predominant, followed by wood,
- Central Europe and Southern Europe, gas is predominant, followed by oil.

		Coal	Oil	Gas	District	Wood	Electricity
C3 - North	Space	0,07	0,72	0,23	4,15	2,95	1,63
	Water	0,02	0,11	0,06	0,88	0,41	0,29
C2- Center	Space	9,75	30,20	70,74	13,31	20,64	8,38
	Water	0,39	3,49	13,58	1,68	0,93	6,23
C1- South	Space	0,02	8,17	13,16	0,05	5,05	2,21
	Water	0,01	2,76	3,09	0,00	0,46	1,32

Table 2: Space and water heating consumptions by energy carrier according to defined European climatic zones. Units: Mtoe [6]

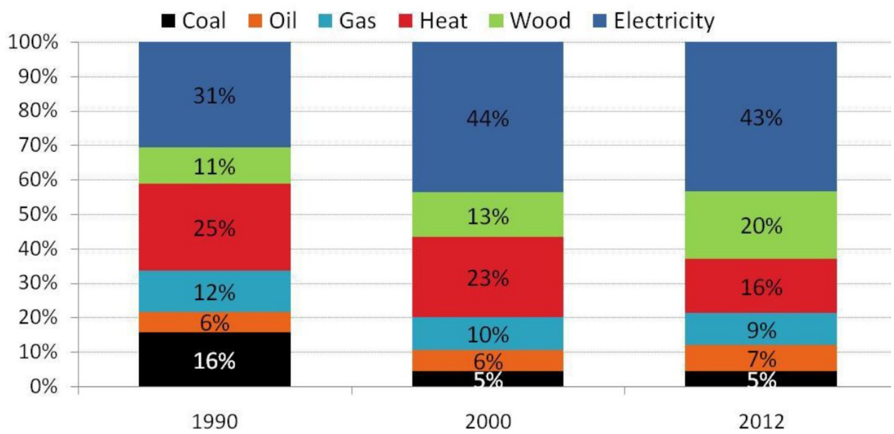

Figure 8: Household energy consumption for space heating by energy source in the EU [10]

At the EU level, coal and oil for space heating have been replaced by electricity and to a lesser extent wood. The electricity share in household energy consumption in the EU is for thermal uses but also for other applications (see section 3.1.2).

3.1.2 Electricity consumption per dwellings

Figure 9 shows the electricity consumption trends per dwelling for the different European countries.

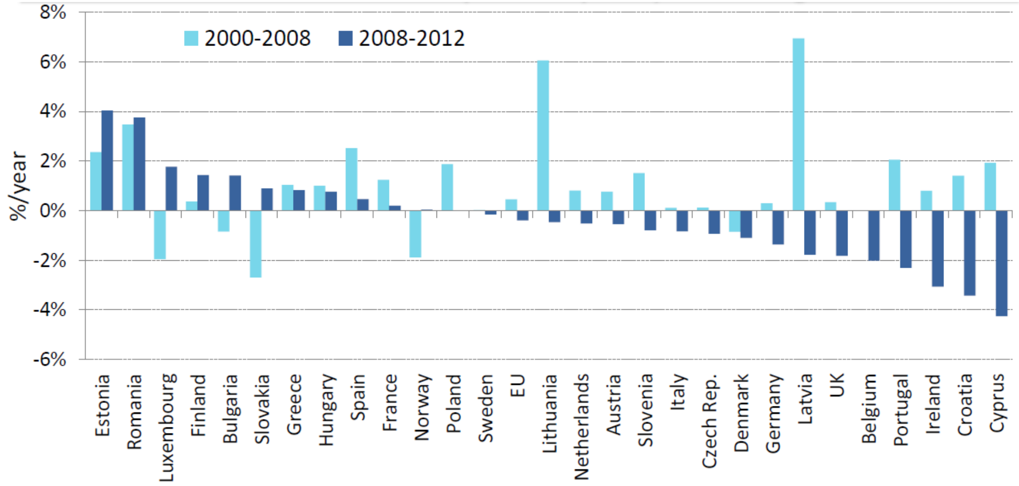

Figure 9: Trends in electricity consumption per dwellings [10]

Since 2008, a decrease of the electricity consumption per household in 19 countries and at EU level (-0.4%/year) can be observed, with a strong contraction in Cyprus, Croatia and Ireland (over 3%/year). Heterogeneity is due to thermal uses, different level of appliance ownership and energy efficiency. [22]

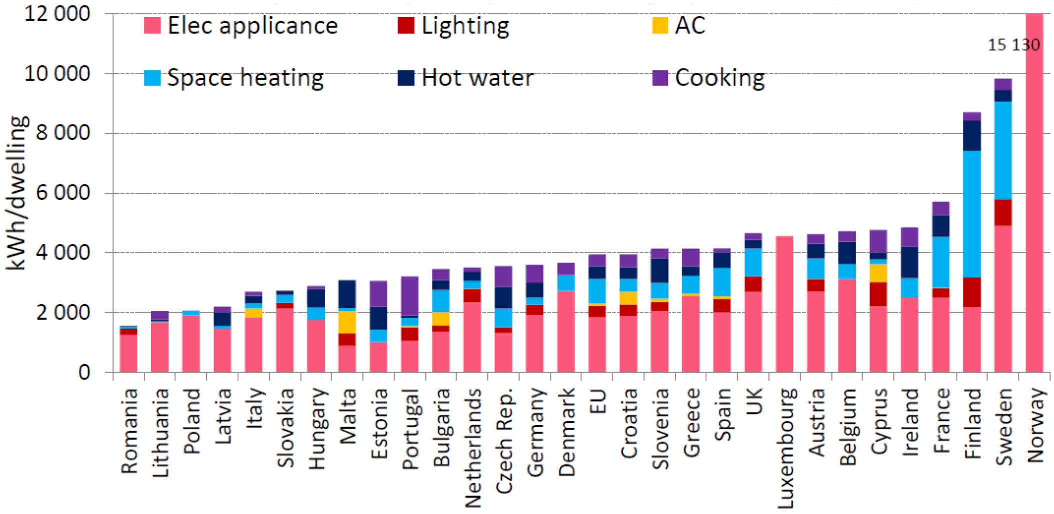

Figure 10: Electricity consumption per dwelling by end-use [10]

EU households consume on average around 4000 kWh of electricity per dwelling (Figure 10). Electricity usage is usually divided into two parts: thermal uses, where electricity compete with other fuels (space and water heating and cooking), and captive uses (electricity appliance, lighting, and air conditioning) for which only electricity is used. Thermal uses of electricity are important in Finland, Estonia and Czech Rep. (> 60%), in Portugal, France and Ireland (around 50%) and in Spain, Hungary, Slovenia and Sweden (around 40%). Even in southern countries, they are a low share of AC (Air Conditioning) (10-15%) of total electricity consumption (highest share for Malta).

Two main factors contribute to increase the household energy consumption:

- Increasing number of dwellings due to population growth and the growing number of one person households in some countries;
- Higher comfort (more household appliances and larger homes).

These effects have contributed to increase the household energy consumption at the EU level by 75 Mtoe (872.250 GWh) between 2000 and 2012. In addition, changes in heating behaviour also had an impact on the energy consumption by reducing it by 20 Mtoe (232.600 GWh) over the same period. This behavioural effect is mainly due to the combined effect of price increases and the economic recession as consumers paid more attention to their heating expenses and have also reduced their level of comfort. The use of renewable energy like BIPV can help to control energy costs.

3.2 Non-residential buildings

Non-residential buildings account for 25% of the total stock in Europe and comprise a more complex and heterogeneous sector compared to the residential sector. The retail and wholesale buildings comprise the largest portion of the non-residential stock while office buildings are the second biggest category with a floor space corresponding to one quarter of the total non-residential floor space (Figure 11). Variations in usage pattern (e.g. warehouse versus schools), energy intensity (e.g. surgery rooms in hospitals compared to storage rooms in retail), and construction techniques (e.g. supermarket versus office buildings) are some of the factors adding to the complexity of the sector [6].

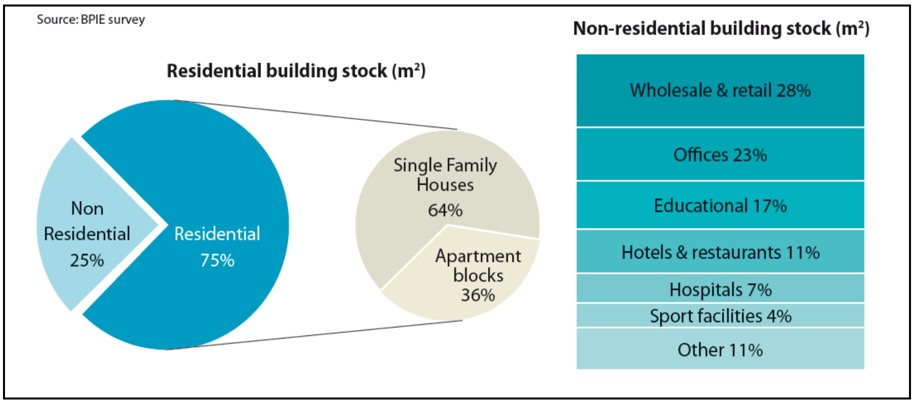

Figure 11: European buildings at a glance [11]

Understanding energy use in the non-residential sector is complex as end-uses such as lighting, ventilation, heating, cooling, refrigeration, IT equipment and appliances vary greatly from one building category to another within this sector.

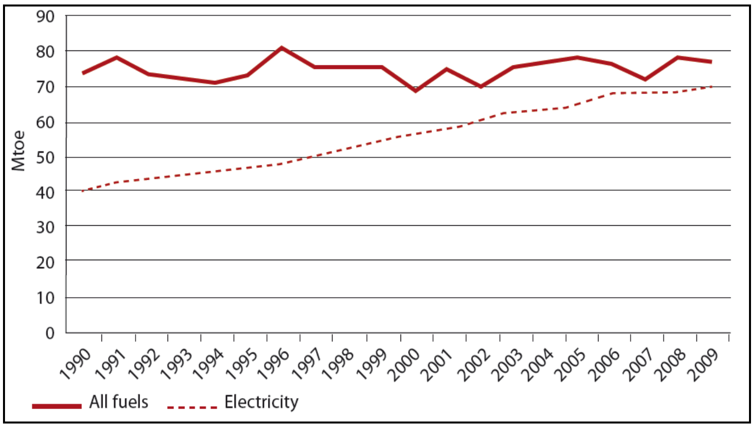

Figure 12: Historical final energy use in the non-residential sector in the EU, Norway and Switzerland [6]

Over the last 20 years in Europe, electricity consumption in European non-residential buildings has increased by a remarkable 74%. This is compatible with technological advances over the decades where an increasing penetration of IT equipment, air conditioning systems etc. implies that electricity demands within this sector are on a continuously increasing trajectory.

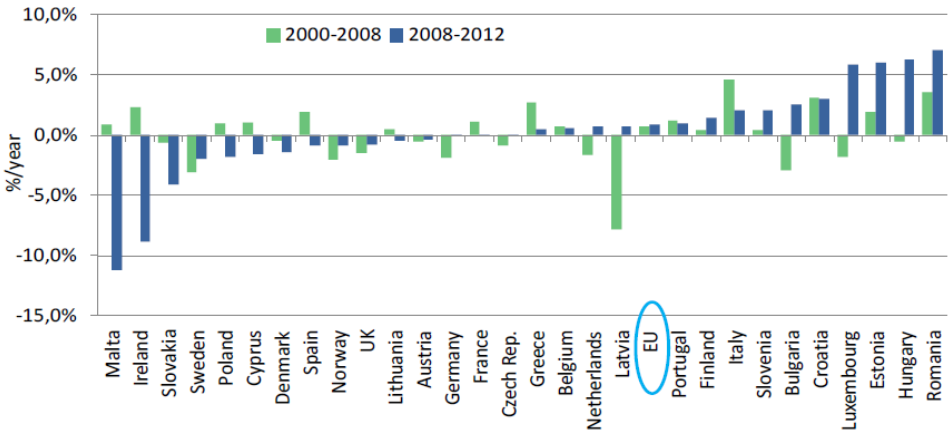

Figure 13: Electricity intensity trends in non-residential buildings [10]

At the EU level, in non-residential buildings, the electricity intensity has increased by 0.9%/year since 2008. In about 10 countries the electricity intensity is however decreasing.

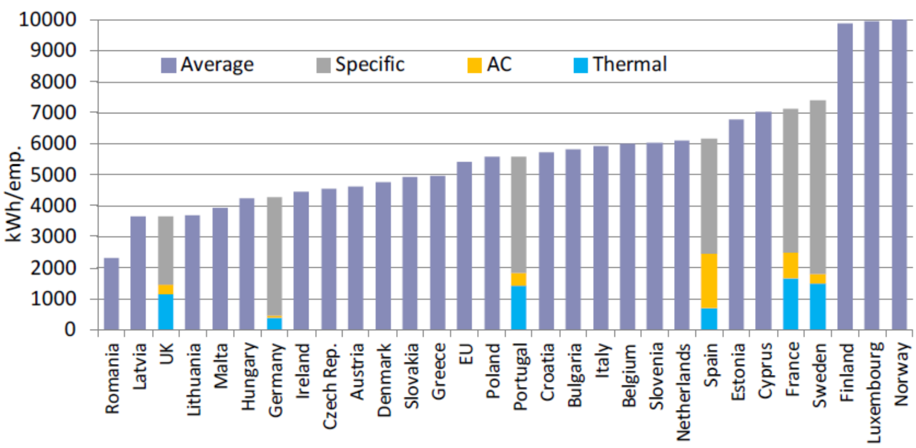

Figure 14: Electricity consumption per employee in services by end use [10]

Norway, Sweden, Finland and Luxembourg use by far the largest amount of electricity per employee (more than twice the EU average); for Norway and Finland and, to a lesser extent, Sweden, it has to do with electric heating (Figure 14). Electricity consumption per employee is increasing in most countries. Large increases can be observed for all southern countries, because of the penetration of air conditioning. The high growth for East European countries is linked to their fast economic growth, at least until the crisis. This indicator is also influenced by the number of employees available to provide services.

Within the non-residential sector, variations are expected from country to country and from one building type to another. While hospitals are, on average, at the top of the scale with continuous occupancy and high-energy intensity levels, their overall non-residential consumption is small.

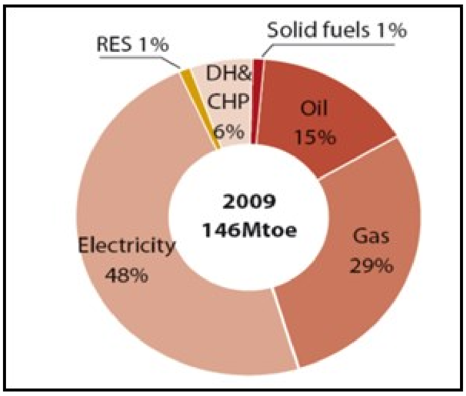

Figure 15: Energy mix in the non-residential sector in the EU [6]

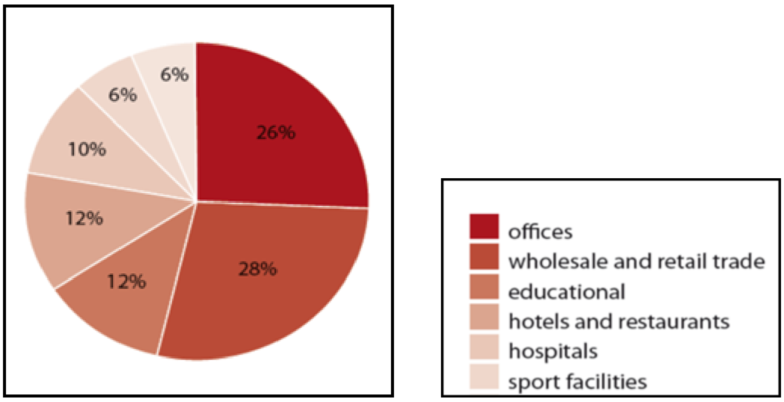

Figure 16: Share of total energy use per building type

This is also the case with hotels & restaurants, which are equally energy intensive. While these two categories represent the highest energy intensive usage type, offices, wholesale & retail trade buildings, on the other hand, represent more than 50% of energy use. Education and sports facilities account for a further 18% of the energy use while other buildings account for some 6%.

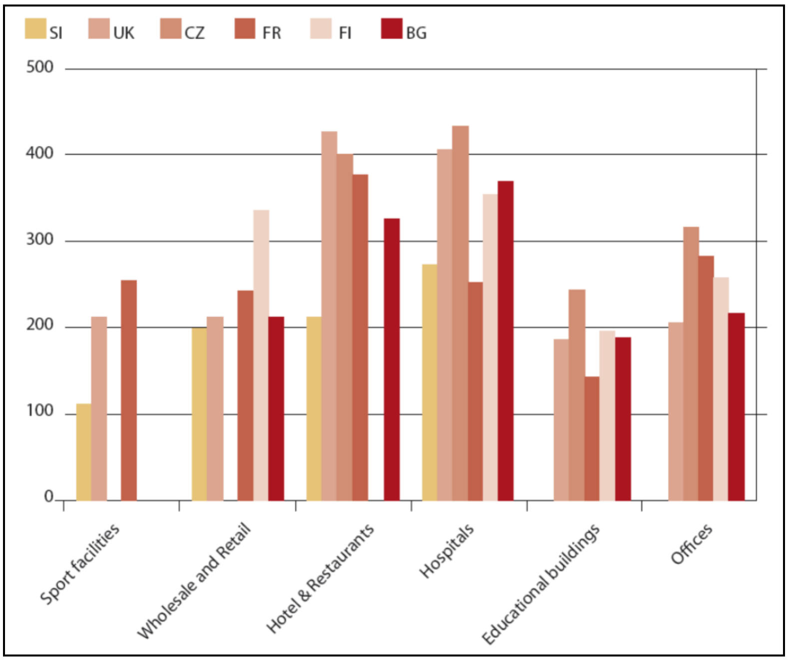

Figure 17: Specific energy use (kWh/m²a) in non-residential [6]

Construction techniques of non-residential buildings are largely similar to those in residential buildings, as the majority of data collected have shown similar performance characteristics (e.g. U values, air tightness levels) between the two types built during the same period.

While the energy performance discussion for the residential buildings above applies also to the non residential sector (hence similar renovation measures should be considered), the installation of smart energy management systems in non-residential buildings becomes more important due to their high share of electricity use (Figure 17).

As established in Europe 2020 strategy, sustainability targets are to be achieved by 2020. These targets include greenhouse gas emissions 20% lower than 1990, a share of 20% of energy from renewables and a 20% increase in energy efficiency compared to a baseline development.

Furthermore, with application of nZEB concepts in each EU country, the energy needs and electricity consumption will develop further. New approaches to improve energy performance in buildings are essential. There is a huge potential for the development of innovative new building technologies, together with innovative use concepts for buildings and urban districts, to promote the integration of renewables such as BIPV.

4 nZEB CONCEPTS IN EU COUNTRIES

4.1 Principles for sustainable nZEB in the EU

A large variety of concepts and examples exist for nearly zero-energy buildings within Europe. The definitions, descriptions or recommendations concerning low energy buildings differ largely between the different countries. There are non-governmental examples puting emphasis on different aspects (like the “zeroHaus”, “Plusenergiehaus©”, “Minergie©-A” or “Passivhaus”) as well as government-initiated programs which usually focus on the buildings’ efficiency (e.g. German KfW-building standard or Minergie© from Switzerland). Most of the countries’ definitions refer to new buildings, but there are some countries that have already established definitions for the renovation of buildings as well.

In most countries, the nZEB definitions refer to maximum primary energy as one of the main indicators. The review of available definitions shows a remarkably high variation in nZEB primary energy values being between 20 and 200 kWh/m²year. This high variation even applies within the same building type in countries with similar climate. It is partly due to different energy uses and different levels of ambition in the definitions. Some definitions ask for minimum energy requirements covering only energy for heating while others set energy requirements for all heating, cooling and water heating needs. Other definitions include electricity used for lighting and even the electricity consumption of appliances.

In a few cases (e.g. the Netherlands and the Belgian Region of Flanders), the primary energy use of the building is assessed through a non-dimensional coefficient, comparing the buildings’ primary energy use with a “reference” building with similar characteristics (e.g. building geometry). In several countries (e.g. the United Kingdom, Norway and Spain) carbon emissions are used as the main indicator, while in others (e.g. in Austria and Romania) carbon emissions are used as a complementary indicator to primary energy use. Moreover, in some definitions the specific maximum energy demand is climate dependent and even altitude dependent (e.g. in France).

Several countries wrote in their national nZEB plans that the detailed definition of the nZEB can only be prepared after the completed cost-optimal analysis of their current minimum energy performance requirements (Directive 2010/31/EU, Article 5). Regulation 244/2012 is a supplement to Directive 2010/31/EU and gives a framework for calculating cost-optimal levels of minimum energy performance requirements for buildings.

The European cost optimal methodology does not seem to be utilized in all countries – it could be speculated that existing energy calculation frames and methodologies are too different to enable easy implementation of those calculation principles. Therefore, the cost-optimal methodology can be used if the evolving factors, e.g., energy prices, primary energy factors for electricity and district heating, improved efficiency of systems and material due to research and industry innovations, building material costs, etc., are taken into account. Some countries stated that they would wait for lessons to be learned from pilot projects of high performance buildings.

It can be concluded that Member States need more guidance in order to set consistent and comparable nZEB values with equal ambition levels.

The existing low-energy buildings definitions among the EU Member States have common approaches and differences and there is a need to aggregate and improve the existing concepts in order to harmonize them to the nZEB requirements as indicated by the EPBD and also the Renewable Energy Directive.

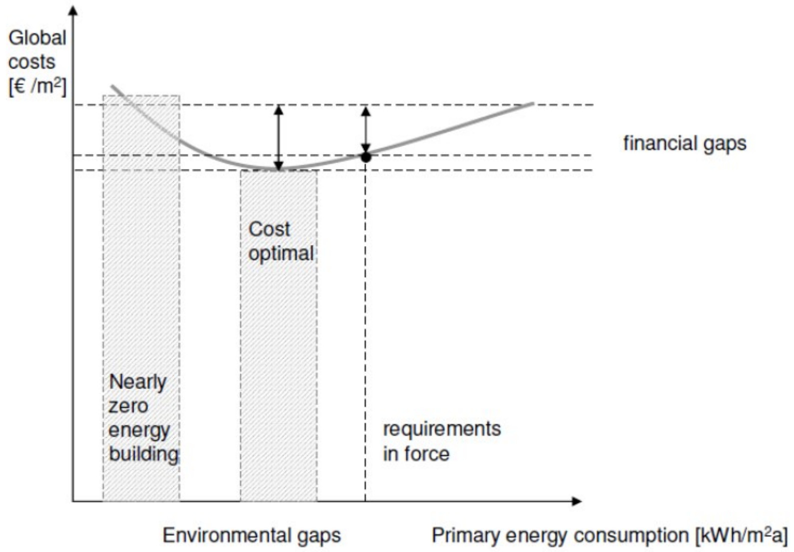

Figure 18: Financial and environmental gaps between nZEB, cost optimality and current requirements [1]

The Buildings Performance Institute Europe (BPIE) provided some early analysis on helping member states develop a nZEB definition. BPIE provides a very useful diagram to understand the principles in the broader policy context [5].

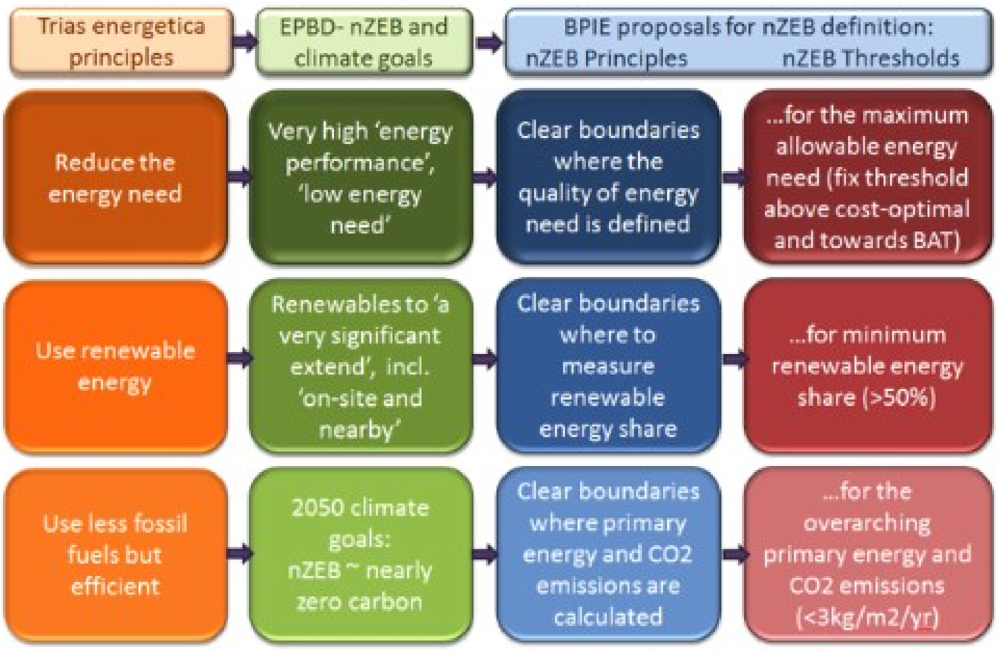

Figure 19: Principles for sustainable nZEB in the EU [2]

In relation to the three principles suggested by this study, we will start by analyzing national requirement in EU countries related to the minimum RES input and CO_2 emissions required for nZEB consideration. When possible, we identify the RES type (PV, solar thermal or biomass) that are required in order to detect if some countries have specific incentives for BIPV.

Then, technical concepts to reduce energy needs in different climate zones are listed. A specific focus is put on impact of BIPV systems and which concepts can improve BIPV yield.

4.2 Requirements in EU countries

4.2.1 CO_2 emissions requirements

The building sector has a key role to play in implementing the EU energy efficiency objectives: around 40% of the energy consumption and a third of CO_2 emissions are attributable to buildings. With the adoption of Nearly Zero Energy Buildings throughout the EU from 2020 onwards, these figures will be reduced in a perceptible and sustainable way.

Most of the energy used today is produced from fossil fuels (coal, oil, natural gas), and a direct consequence of using these fuels is that greenhouse gases are released into the atmosphere, with CO_2 being amongst the most significant ones. In response to this threat, governments across the world have committed to reducing their greenhouse gasses emissions and increasing renewable energy production.

Concerning nZEB definition, several countries (e.g. the United Kingdom, Norway and Spain) use carbon emissions as the main indicator, and others (e.g. in Austria and Romania) use it as a complementary indicator to primary energy use.

Hence, the minimum requirements for the energy performance of the building should use an energy indicator that can properly reflect both energy and CO_2 emissions of the building as the reduced energy consumption should lead to a proportional reduction of CO_2 emissions In general, the primary energy use of a building accurately reflects the depletion of fossil fuels and is sufficiently proportional to CO_2 emissions. If a single indicator is to be adopted, then the energy performance of the building should be indicated in terms of primary energy, as in line with current EPBD. However, in order to reflect the climate relevance of a building’s operation, CO_2 emissions should be added as supplementary information.

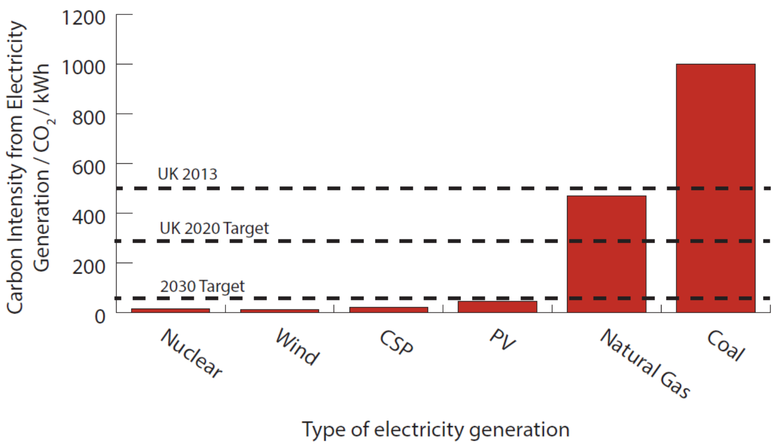

Figure 20: Carbon intensity of some key electricity generation technologies; the value for PV refers to manufacture in Europe. UK climate change committee targets for carbon intensity of electric power are shown for comparison [8]

Sustainable development projects prefer materials and systems which use up less grey energy, which is the energy spent in the extraction of the raw materials, in their transport, use and recycling. The required energy must be supplied utilizing the lowest cost and most environmentally-friendly energy sources possible. Existing fossil fuel technologies possess high carbon emission intensity through the combustion of carbon rich fuels, whilst renewable technologies such as solar produce little or no emissions during operation, but may incur emissions during manufacture.

Solar energy can thus help to mitigate carbon emissions by replacing more carbon intensive sources for heat and power. The amount of mitigated emissions depends on the amount of conventional heat or power that is displaced, the carbon content of the displaced energy sources, and the amount and type of energy that is consumed in manufacturing, installing and operating the solar energy system.

Besides the emissions associated to energy consumption during manufacturing, installation and decommissioning a BIPV system, producing electricity with BIPV emits no pollution, produces no greenhouse gases, and uses no finite fossil fuel resources.

4.2.2 Renewable energy requirements

The EPBD requests that nearby or on-site renewable energy generation (e.g. biomass, wind and solar energy) is used “to a large extent” to supply the energy needs of the building. Ventilation, heating and cooling strategies need to be planned in order to maximize the use of renewable sources and thus limit the environmental impact. Therefore, it is extremely important that these are handled correctly in the national calculation methods or requirements. Each country has specific national requirements, some of them encourage the use of renewable energy, while others do not.

The EPBD does not specify what types of renewable energy should be used but PV panels are the most common option, with nearly 70% of the NZEB examples using them. Solar thermal panels are part of the energy concept in more than half of the buildings. Other renewable energy sources used in buildings are geothermal (from ground source heat pumps), biomass and district heating with high shares of renewable energy. [21]

For PVSITES project, which aims to promote the use of BIPV systems, we analyze national requirements (Table 3) in order to see which ones encourage implementing BIPV in buildings. The table is based on an analysis of nZEB definitions in different countries. In case there is a direct requirement for RES, this question is answered with a “yes”. In case there is no direct requirement but a very low energy use that can only fulfilled with RES, it is noted as “indirect”.

Country		Description	In favor of BIPV ?
1	AT	EPBD text implemented in OIB 6 of 03/2015. Detailed definition included in national plan of 03/2014. Minimum share of the final energy dependent on the implemented RES technology. Examples: ·50% of the final heating energy covered by biomass ·10% of the final DHW energy	Yes
2	BE-B	Included in Arrêté du Gouvernement de la Région de Bruxelles-Capitale of 21 December 2007, modification of 26 March 2013.	Indirect
	BE-F	Included in Regulation of the Flemish Government of 29 November 2013 regarding the energy performance of buildings. RES: minimum share and alternative of single measure with quantitative requirements e.g., 0.02 m^2/floor area solar thermal (for single-family houses) or 10 kWh/m^2.year (for houses, apartments, schools, offices).	Yes
	BE-W	Interpretation of EPBD text in national plan, study contracted, definition will evolve. Under discussion: direct (> 50% of residual consumption of heat + cold + electricity).	Indirect
3	BG	Draft definition in national plan (BPIE study). RES: minimum share of 20% to 50% depending on building type.	Yes
4	CY	Included in decree ΚΔΠ 366/2014 (issued on 1 August 2014). RES at least 25% of primary energy.	Yes
5	CZ	Regulation No. 78/2013 Coll. has a primary energy indicator. Indirect requirements for RES.	Indirect

Country		Description	In favor of BIPV ?
6	DE	EPBD text implemented in energy saving act, detailed definition is being developed. Requirements included in current minimum energy performance. The use of renewable energies for heating in new buildings according to the Renewable Energy Heat Act may be met either by the use of solar heating, biomass, geothermal energy and environmental heat, but failing that, also by the use of waste heat, combined heat and power generation and energy conservation measures.	Yes
7	DK	EPBD definition Included in BR10, currently voluntary, to be adjusted. Indirect requirements for RES.	Indirect
8	EE	EPBD definition included in regulation VV No 68:2012 “Energiatõhususe miinimumnõuded”. No direct requirements for RES.	Indirect
9	ES	Translation of EPBD text in RD235/2013 (final approval pending). Detailed NZEB definition not yet available. No direct requirements for RES.	Indirect
10	FI	No requirements. Expected 2016.	No
11	FR	In actual thermal regulation RT2012, mandatory renewable energy requirements (for individual housing) are included: solar thermal collectors, offered renewable energy is at least 5 kWh/m² in primary energy, thermodynamic water heaters, micro-cogeneration boiler. The next thermal regulation is scheduled for 2020 and should generalize energy-plus building (BEPOS[i]).	Yes
12	GR	EPBD text implemented in Law 4122/2013 of 19 February 2013. Direct requirements included in minimum energy performance requirements.	Yes
13	HR	Definition for single-family house in the national plan. Definition for various building categories in Technical Regulation on Energy Economy and Heat Retention in Buildings (OG 130/14). Minimum share of 30% of renewable energy from annual primary energy.	Yes
14	HU	Draft EPBD definition included in Decree about Determination of Energy Efficiency of Buildings of 7/2006 (V.24), detailed definition is being developed. Direct requirements included in current minimum energy performance requirements	Yes
15	IE	Draft definition included in the national NZEB plan. Direct requirements included in current minimum energy performance requirements. RES contribution of 10 kWh/m^2.year (thermal) or 4 kWh/m^2.year (electrical)); planned to be introduced for non-residential buildings in 2015.	Yes
16	IT	EPBD text in Decree Law no. 63/90 of 2013, new energy decree includes detailed definition near completion. Planned for NZEB is 50% of primary energy (direct requirements included in current minimum energy performance.	Yes
17	LV	Included in Cabinet Regulation No. 383/2013. RES: at least partial use of RES (> 0%)	Yes
18	LT	Included in Construction Technical Regulation STR 2.01.09:2012. RES is largest part of energy consumed (> 50%)	Yes
19	LU	Interpretation of EPBD text included in national plan and in national legislation (RGD 2014), detailed definition not yet fixed. Regarding renewable energy the Grand Ducal decree of 5 May 2012 stipulates that from 1 July 2012, new buildings shall comply with the requirements of the energetic class B concerning energetic performance, which involves the need of an increased use of renewable energies.	Indirect

Country		Description	In favor of BIPV ?
20	MT	Proposed EPBD definition included in the national plan, consultation process ongoing. Indirect requirements for RES. The support schemes introduced so far strongly promote renewable energy use in buildings.	Indirect
21	NL	National plan: aim to set requirement close to energy performance coefficient = 0 by 2018/2020. No specific RES requirements are identified.	Indirect
22	PL	Translation of the EPBD text in national plan. Detailed definition included in Regulation of the Minister of Infrastructure on the technical conditions to be met by buildings and their location (Journal of Laws No 75, pos. 690), amendment in 2013. No direct RES requirements.	Indirect
23	PT	Translation of the EPBD text in Decree law 118/2013, Article 16. Detailed definition not yet available. No requirements for RES.	No
24	RO	nZEB definition included in updated national plan of July 2014. RES requirement at least 10% of primary energy	Yes
25	SE	No detailed definition is available yet. National plan states that there is currently no economic basis for further tightening. Next control planned for 2015. There are requirements in relation to electricity supply mix by RE certificates.	No
26	SK	Translation of EPBD text in Act No 555/2012, requirements in MDVRR SR 364/2012 Coll. RES at least 50% reduction of primary energy	Yes
27	SL	Translation of EPBD text in Energy Act of March 2014 (Energetski zakon, Uradni list RS, št. 17/14). National plan includes a detailed NZEB definition (approved by the Government on 22 April 2015). 50% RES as share of total delivered energy.	Yes
28	UK	National plan: no NZEB definition but target of zero carbon for new buildings through incremental changes to Building Regulations. No direct RES requirements. New homes (from 2016) and new non-domestic buildings (from 2019) to be Zero Carbon and not add extra carbon emissions to the atmosphere.	Indirect

Table 3: Renewable energy requirements in EU countries which can encourage BIPV implementation [5], [9], [12].

21 Member States set a definition of nZEB that comprises both a numerical target for primary energy use (or final energy) and consider the share of RES in a quantitative or qualitative way. [14] In several countries the share of primary energy consumption, which has to be covered by renewable energy sources, is explicitly stated, while in other Member States the renewable sources are considered indirectly because the low maximum values of primary and/or final energy use cannot be met without using renewable energy sources. A few countries do not have specific renewable energy requirement included in their nZEB definition.

In the different regulations, renewable energy is mainly used for hot water consumption and requires the use of solar thermal collectors or an equivalent system (installation allowing an energy saving at least equivalent to thermal solar collectors). Only five countries encourage directly BIPV systems implementation. When this is done in a quantitative way, some important concepts must be known in order to improve energy system production (see section 4.3).

Energy from renewable sources is not unlimited and is not available to the same extent in every localization. The available area for wind or solar powered systems is usually very limited, especially in cities. Energy from biomass is also only a reasonable and sustainable solution in some cases – if too many buildings use wood pellets for heating, the raw material required will not be able to re-grow fast enough. If building energy demand is reduced with technical concepts more suited to its environment, the situation will begin to look very differently.

4.3 Technical concepts in EU climate zones

4.3.1 Reduce energy needs

For the majority of European countries, the estimation of energy performance is an essential step during the design phase of new buildings, not only in order to ensure compliance with regulations and standards, but also to come close to an optimal design as regards the life cycle of the building. The overall design including the building envelope can affect the lighting, heating, and cooling needs of the building.

In all climate zones, to reduce energy need, the first step is the optimization of the efficiency of the building envelope. In cold regions the top priority is reduction of energy losses and control of energy gains in hot regions. Typically, low energy buildings will encompass one of the concepts below.

Technical concepts	Description
Bioclimatic architecture	Bioclimatic design capitalizes on the characteristics of the site (climate, vegetation, topography and geology of the soil) in order to minimize the energy needs of the building and to create a more comfortable environment. The positioning and orientation of the building as well as the interior distribution are calculated to profit as much as possible from the solar gain but not interfere with summer comfort.
Passive Solar Standard	The Passive Solar Standard as defined by the Passivhaus Institute in Darmstad covers most of the aspects for nZEB buildings mentioned here as well. Like high level of insulation, thermal bridge free construction, high level of airtightness, etc.
Architectural means and shadings to reduce cooling needs	Another challenge is to optimize the thermal envelope and architecture in such way that the summer cooling loads are minimized, especially for hot climate. Throughout the building, indoor temperatures remain constant and comfortable year-round. In principle the energy use for heating and cooling should be optimized during building design. Clearly passive measures like solar shading, geometry and building orientation should of course always be exploited to a maximum, but much evidence still points to severe overheating problems in well insulated buildings. Often overheating is not even limited to the hot summer months.
High level of insulation	Insulation provides resistance to heat flow, thereby reducing the amount of energy needed to keep a building warm in the winter and cool in the summer. This provides for excellent thermal protection of the building envelope and is essential to achieve high levels of energy efficiency. This principle is reversed in the summer and in warmer climatic zones: alongside external shading elements and energy efficient household appliances, thermal insulation ensures that heat remains outside, keeping the inside pleasantly cool.
Thermal bridge free construction	Heat will travel from a heated space towards the cooler outside, following the path of least resistance. Avoiding thermal bridges in building design is thus a great way to avoid unnecessary heat loss and moisture-related structural damage. Careful planning, especially for connections between building components, intermediate ceilings, and foundations, is essential.
Very energy efficient windows, doors and skylight	Windows, exterior doors, and skylights influence both the lighting and the HVAC requirements of a building. For example, during the warmer months, the sun is positioned higher in the sky so that less heat is trapped. Still, external shading is important to prevent any overheating. In addition to design considerations, materials and installation can affect the amount of energy transmitted. New materials, coatings, and designs all have contributed to the improved energy efficiency of high-performing windows, doors, and buildings. In residential buildings, using optimum window design and glazing specification is estimated to reduce energy consumption from 10 to 50 percent below accepted practice in most climates; in commercial buildings, an estimated 10 to 40 percent reduction in lighting and HVAC costs is attainable through improved fenestration.[ii]

Technical concepts	Description
Thermal mass	The concept of thermal mass regards a solid or liquid material which absorbs and store warmth and releases it when is needed. In order to let the thermal mass work correctly, it must be integrated with other passive technique, such as insulation and passive solar gain, in order to moderate the internal temperature and minimize the need for mechanical cooling as well as reducing winter heating requirements. The main properties of a thermal mass are its high density, good thermal conductivity and low reflectivity.
High level of air tightness	Adding insulation strategically will improve the efficiency of the building; however, it is only effective if the building is properly sealed. Sealing cracks and leaks prevents air flow and is crucial for effective building envelope insulation. An airtight envelope that encloses the whole interior space prevents energy loss, and draughts.
Ventilation with very efficient heat recovery	Balanced ventilation with heat recovery ensures a plentiful and consistent supply of fresh, clean, dust and pollen free air while reducing energy losses. Up to 90% of the heat from the extracted air can be recovered via heat exchange.

Table 4: Technical nZEB concepts

All these concepts have a general character. However, during the building design, the local environment as well as the intended use of the building have to be thoroughly considered. For instance, during the winter season in southern Europe there is a considerably higher level of solar radiation than in northern Europe. Like in Central Europe, in the majority of Mediterranean climates space heating is the biggest component of building energy demand, to which the strong growth of energy demand for cooling requirements is added. Concerning the cooling demand, a good thermal insulation can provide high thermal comfort during the summer period in all the Mediterranean climate zones, especially when applied in the roof in order to reduce temperature fluctuations.

Deliverable D2.2 lists the different European climates and their implications on building strategies.

Indeed, the severity of the climate has a significant impact on the thermal property requirements of building components and energy performance for new and existing buildings. The main construction features for energy efficient residential or office buildings depend on the outdoor climate and can be summarized in the following table.

Köppen	ECOFYS	NZEB typology
Csa - Hot and dry climate	Zone 1&2 - Temperate with dry, hot summer. (Mediterranean climate)	Well-insulated building envelope with limited fenestration area; glazing with very low SHGC and shading from direct sunlight in summer; reflective or cool colors exterior envelope surfaces essential (colors with low heat absorption to reduce the solar load during the summer period); solar powered AC equipment can provide day-time cooling; thermal mass and lower night-time temperatures provide comfortable indoor conditions after sunset (nocturnal ventilation).
Dfb - **Warm and humid climate**	Zone 3 - Temperate continental climate/humid continental climate without dry season and with warm summer;	Moderately insulated building envelope with limited fenestration area having low SHGC and effective shading devices; green (vegetated) roofs and/or reflective exterior envelope surfaces are beneficial; since the removal of latent heat (water vapor) matches the energy required for sensible cooling, investing in sophisticated ventilation is essential to provide healthy and comfortable indoor air conditions without wasting energy.
Cfb - **Temperate climate**	Zone 4 - Temperate without dry season and warm summer	Well-insulated building envelope with energy efficient fenestration (very low to low U-value, moderate to high SHGC- depends on glazing area); operable shading systems required to prevent summer over-heating; thermal mass and balanced ventilation with heat recovery is beneficial. Nocturnal ventilation.
Dfc - **Cold climate**	Zone 5 - Cold, without dry season and with cold summer.	Compact building design with very well- insulated building envelope components; total fenestration area should be limited with very low U-value and high SHGC (solar heat gain coefficient); thermal mass and balanced ventilation with heat recovery is essential.

Table 5: Building strategies in different climates

There is no 'best' technology. The choice of measures depends on climate conditions, micro-climate and available environmental energy, but also on saving potentials and cost-efficiency. The consideration of user's behavior and the user acceptance is essential, since the users have to understand and accept the energy saving measures; otherwise the users interact in a way which is probably not supporting the designed energy control.

4.3.2 Use Renewable Energy - Impact of BIPV systems

Roofs and walls design and materials can reduce the energy lost and the amount of air conditioning required in hot climates by increasing the amount of solar heat that is reflected, rather than absorbed. Several opportunities for installing on-site generation systems like photovoltaic system exist. BIPV can change the energy properties of an entire wall and so effect the wall design. For some integration systems it is important to know the thermal properties of the photovoltaic material/element. These are decisive when the modules have further additional functions such as thermal insulation or solar control.

Photovoltaic modules, available as flat or flexible surfaces, made with cells or laminates, can be integrated into every part of the building envelope and due to their features (size, flexibility, shape and appearance), are particularly suitable for being "designed". In fact, these photovoltaic elements can be used together with materials that are common in architecture, such as glass or metal, in opaque as well as in semitransparent surfaces. Many products specifically developed for building integration are being proposed. These simplify even more the integration work, offering architects the possibility to use BIPV as a "material" or building component in the design process.

Furthermore, their integration quality is defined as the result of a controlled and coherent integration simultaneously from all points of view, functional, constructive, and formal (aesthetic).

PV technologies have been used in building integration for 20 years, but up to recently, at a modest level. This is mainly due to conventional thinking and legislation issues. The present situation is unfolding as a dramatic push to increase the renewable part of our energy supply through maximizing BIPV use on the building skins.

Photovoltaic technologies are playing an important role in the mitigation of Global Warming producing “renewable energy” through a silent and invisible process. Moreover, Building integrated PV (BIPV) can produce energy where it is needed and without covering extra surface or green field sites.

4.3.2.1 Orientation, shading and ventilation

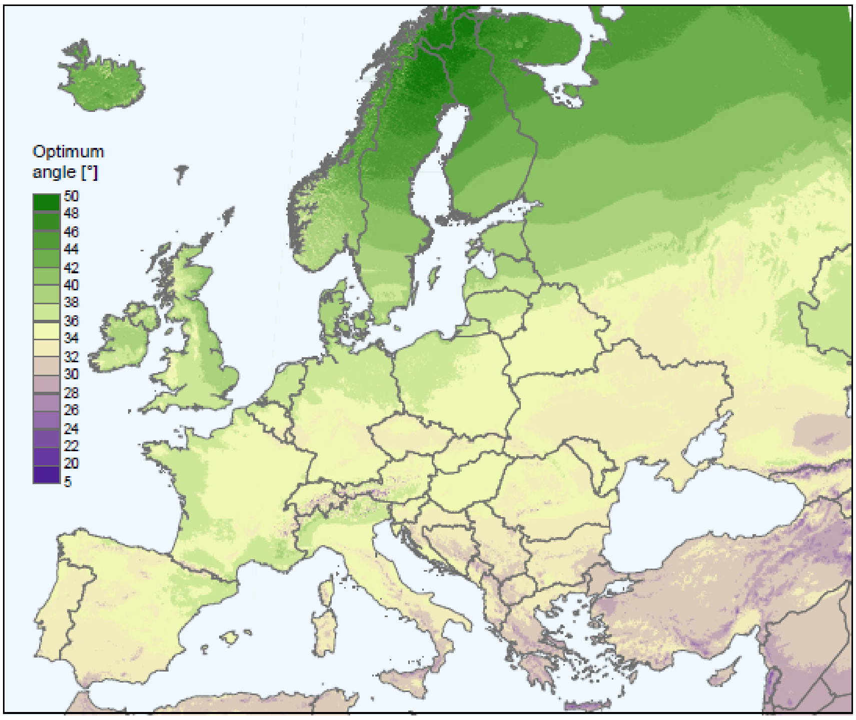

Figure 21: Optimum inclination of BIPV to maximize yearly energy yield [18]

In order to take the best advantage of the energy obtained from the BIPV systems, some simple rules must be followed for the orientation, shading and ventilation.

For each geographic situation, there are different irradiation levels associated with different orientations. The yearly sum of global irradiation (defined as the sum of irradiation coming directly from the sun and diffuse irradiation coming from the sky and that has been reflected from the surroundings) is specific to the location and can be obtained from computer programs, databases, measurements, or from irradiance maps. To limit investment costs, BIPV systems are usually oriented where the yearly solar radiation is maximized, thus minimizing the collector area needed.

The main factors determining optimum inclination angle of the BIPV systems are the geographical latitude, share of diffuse to global radiation, and in mountainous areas – shadowing by local terrain features. In general, the optimum orientation of BIPV is due South in the Northern Hemisphere. However, in some areas the optimum orientation might be slightly offset towards East or West due to shadowing by local mountains. In areas with a high partition of diffuse radiation the angle is less critical because the loss of direct radiation is compensated by diffuse radiation. Another aspect that needs to be taken into account is self-consumption, where the optimum is related to the time of the day that most of the energy is needed.

Compared to the optimum angle, BIPV mounted vertically (on facades for example) have yearly yields from about 42–33% less in Portugal, and in the Mediterranean and Black Sea zone. In Central and Northern Europe the difference diminishes to about 28%.

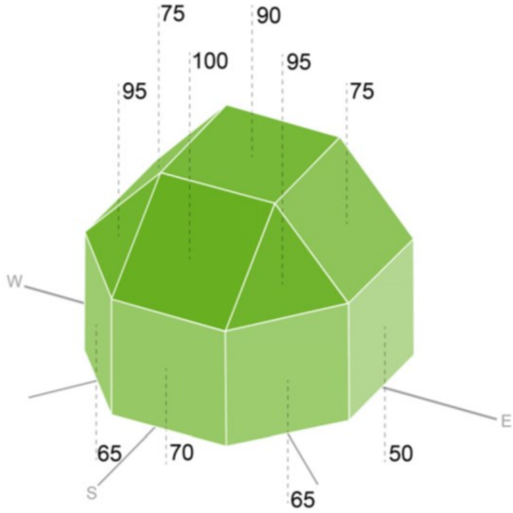

Figure 22: Example for annual irradiation vs. orientation in Central Europe [13]

Due to the abundance of sunlight, the highest yields from vertically mounted BIPV are still found in Malta, Sicily, Southern regions of Spain, France, Turkey, and Portugal (above 900 kWh/kWp per year). In the rest of the Mediterranean region and in the Black Sea the yearly yields from 1 kWp system are in the range of 650–900 kWh and similarly in France, Bulgaria and Romania, and countries of Central Europe.

The electricity yields reduce to 650 kWh/kWp in the Czech Republic, Poland Germany, Benelux, British Isles, Baltic States and Scandinavia. Although the yields for vertical BIPV installation are smaller, one advantage is a better balanced seasonal profile.

To optimize energy production, conditions at the location of the building and BIPV systems surface must be taken into account.

A correct installation is also required in order to maintain the temperature of the module as low as possible. The percentage of loss of power can be up to 10% when the module is not ventilated.

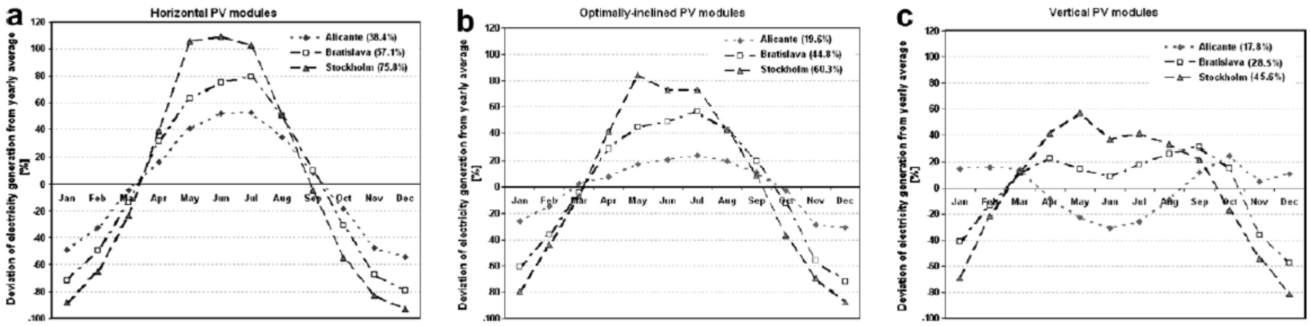

Figure 23: Seasonal variation expressed by relative deviation of monthly averages of PV electricity generation from the yearly average for Alicante (ES), Bratislava (SK) and Stockholm (SE) for BIPV mounted: (a) horizontally; (b) at optimum angle, and (c) vertically [14]

4.3.2.2 Space requirement

As the solar radiation varies with the orientation, systems with lower exposure will need a larger collector area than well exposed ones to achieve the same solar fraction. This also holds true for technology efficiency: the higher the collector efficiency the smaller the needed collector area. Understanding the crossed impact of orientation and technology on system size is fundamental for a proper system choice.

The choice of the photoactive material can be also made by considering the climatic characteristics of the site, taking into account the spectral composition of the light and the cell's conversion capacity. An example could be the choice of the thin film technology in areas with predominantly covered sky or diffuse irradiation.

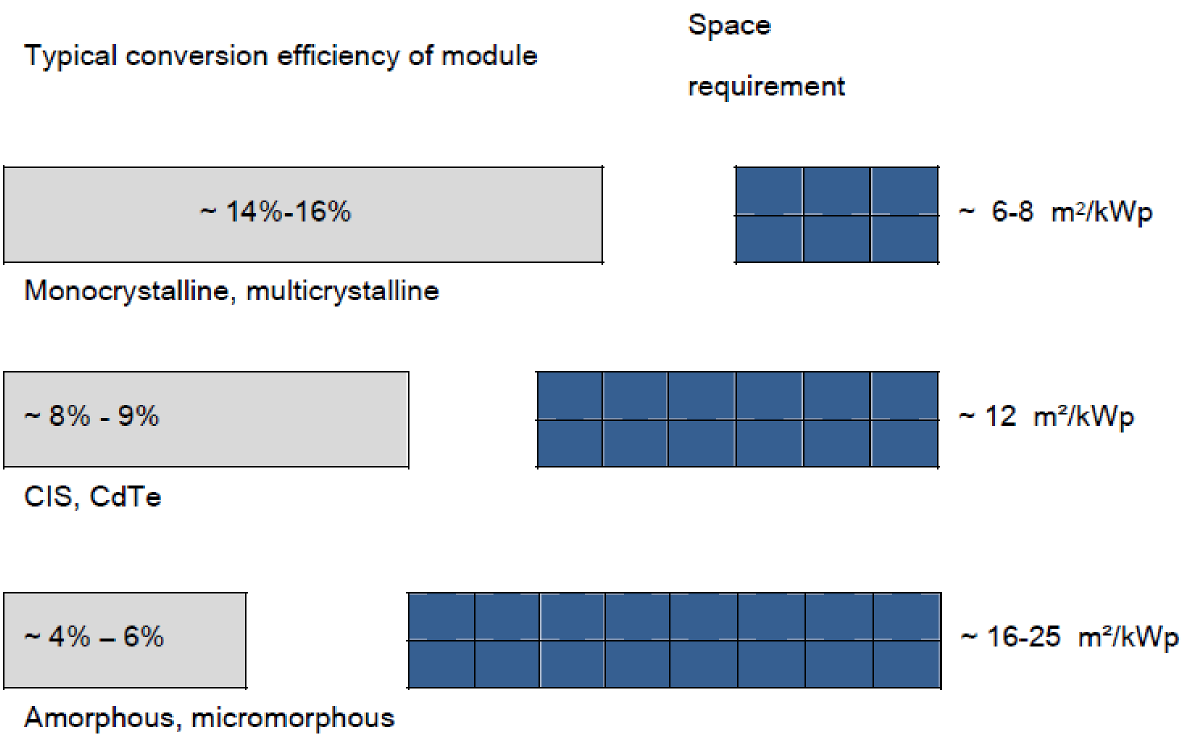

Figure 24: How the efficiency of the modules influences the space required [13]

To produce the same amount of electric energy, very different amounts of envelope surfaces are needed, depending on technology efficiencies and area orientations. As the efficiencies can range from 5% to almost 20%, the space occupied by a system, for the same orientation, can vary up to a 4 to 1 proportion.

A useful formula [13] to quickly estimate the space required (Sr) to install 1KWp of BIPV, depending on the PV efficiency (eff), follows:

Sr [m2]=1/eff

Example:
Considering a typical crystalline technology with a system efficiency of 16%: Sr = 1/0, 16 = 6,25m^2. This means that 1 kWp of crystalline modules with efficiency of 16% require a space of 6,25 m^2.

4.3.2.3 Relation between nZEB and space requirements for BIPV

The vast majority of EU countries use a primary energy indicator in kWh/m^2.year, in line with Annex I of the EPBD, either in their detailed NZEB definition, or in their current energy performance requirements for new buildings. This primary energy demand for a residential (single family house) is between 95 (Latvia) and 32 (Slovakia) and for non-residential between 110 (France) and 33 (Croatia). There is wide spread of National rules as can be seen in Table 6.

Climate zone	Country	Residential	Non-residential	Unit	Remark	RES
Zone 1-2	Cyprus	180	210	kWh/m^2.y	primary energy	25%
Zone 3	Slovakia	32-54	34-60	kWh/m^2.y	primary energy	50%
Zone 4	Belgium Flanders	30	40	kWh/m^2.y	primary energy	≥ 10 kwh/m^2.y
Zone 4	France	50	70-110	kWh/m^2.y	primary energy	-
Zone 4	Ireland	45	-	kWh/m^2.y	primary energy	-
Zone 5	Denmark	20	25	kWh/m^2.y	primary energy	> 51%
Zone 5	Estonia	50 - 100	90 - 130	kWh/m^2.y	primary energy	-
Zone 5	Latvia	95	95	kWh/m^2.y	primary energy	-

Table 6: Overview of some nZEB numerical definitions currently available [23]

Figure 25: Single family houses with large (60 m^2) PV roofs [design BEAR-iD, Tjerk Reijenga].

Example:

If we take an average primary energy figure of 50 kWh/m^2.y for a 140 m^2 residential building and we calculate with a RES of 50%, we can see what the impact on the building is. The primary energy use will be 140 x 50 = 7000 kWh primary energy. RES will be 50% of this, i.e., 3500 kWh. We take 700 kWh/kWp as PV-yield for the roof orientation of the chosen example. So for this example with the use of crystalline technology from above example, a space of 3500/700 x 6,25 = 31,25 m^2 is required. In case of CIS technology it will require a space of 3500/700 x 11,0 = 55 m^2. (Sr = 1/0,09 = 11,0 m^2).

For a single family house with a sloped roof, this is possible. Although the whole roof is needed and the maximum efficiency is also needed to get a high yield.

Another more specific example can be made for Flanders Belgium. The requirement is much lower. Primary energy is 30 50 kWh/m^2.y. The single family house has a floor surface of 190 m^2 and an available roof area of 46 m^2. When we calculate in the same way as the first example, we will need 190 x 50 x 50% = 4750 kWh from the BIPV system. With the 46 m^2 available roof we can install 46 / 6.25 = 7.36 kWp crystalline (output 5150 kWh/y) or 4.2 kWp CIS system (output 2930 kWh/y). With a minimum RES of ≥10 kwh/m2.y both systems are sufficient. In case Flanders will follow the EPBD with a requirement of > 50%, and only a system with an efficiency ≥ 14.7% will be sufficient.

Figure 26: Single family house in Belgium Flanders with 46 m^2 BIPV roof [design Format D2, Dominique Deramaix, roof elements from BFIRST FP7 project, Grant Agreement 296016].

5 BIPV MARKET FOR nZEB BUILDINGS

Directive 2010/31/EU contains requirements for member states concerning nZEBs in two different articles and also in Annex I. The main requirements of Articles 2 and 9 regarding the national application of the NZEB definition for new buildings can be summarized as follows:

The national application of the definition shall specify:

1. a very high energy performance of the building;

2. a very low amount of required energy by the building;

3. a numerical indicator of primary energy in kWh/m².year.

Furthermore, the national application of the definition should contain:

4. a very significant contribution of renewable energy to cover the remaining energy use.

The RES requirement is realized either by minimum renewable energy shares of the primary energy (x %) or by a specific minimum renewable energy contributions (x kWh/m^2.year). However, many Member States use and plan to use only indirect renewable energy requirements. They set different energy performance requirements (mostly the maximum primary energy limit), so low that they can only be fulfilled if the renewable energy contributes to the energy consumption of the building. The renewable energy requirement for nZEBs, as written in Directive 2010/31/EU Article 2, is more an aspiration rather than an obligation [12].

In terms of RES, PV panels are the most common option, with nearly 70% of the nZEB examples using them. Solar thermal panels are part of the energy concept in more than half of the buildings. Other renewable energy used in the buildings is geothermal (from ground source heat pumps), biomass and district heating with high shares of renewable energy [19].

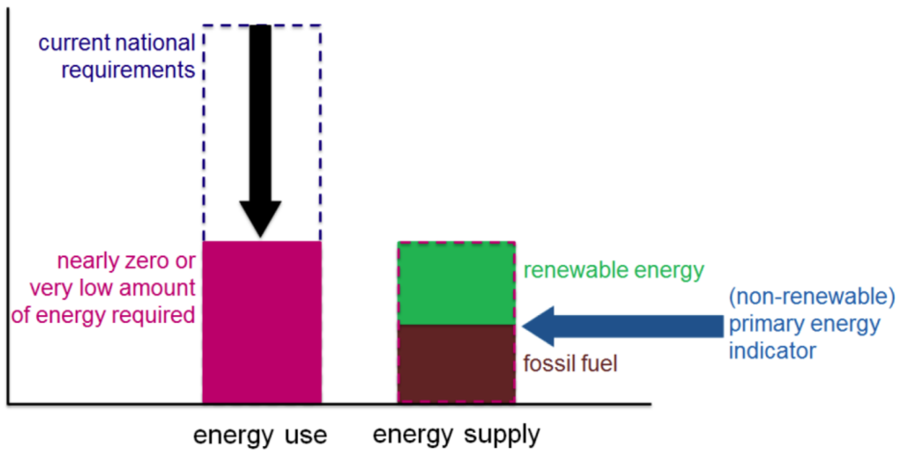

Figure 27: Graphic interpretation of the nZEB definition according to Articles 2 and 9 of the EPBD (Directive 2010/31/EU) [12]

The market for BIPV depends a lot on the regulation in the member states. Up to now not all member states have clear requirements for RES and all those member states having requirements establish different rules (see table 5 for some examples). The reality is that PV systems become more common and more affordable. For designers it is also an interesting application to add to a building (although the opinions on this topic can be very different).

Different European studies looked in detail in examples of nZEB projects [19], [22]. Different publications and on=line tools are produced. The Zebra2020 project [22] uses a web tool to show an overview of nZEB examples. The tool enables to display relevant indicators for a sample of nZEB buildings built after 2010 in selected European countries. It aims at providing information of best cases in Europe, thereby showing most recurrent technologies, materials and strategies towards the nZEB target. The tool differentiates residential and non-residential nZEB buildings and shows some of the most significant indicators regarding energy performance, passive and active solutions and production of renewable energy.

Both graphs (Figure 28 and Figure 29) show that in several countries the share of PV systems in nZEB buildings is already over 40%.

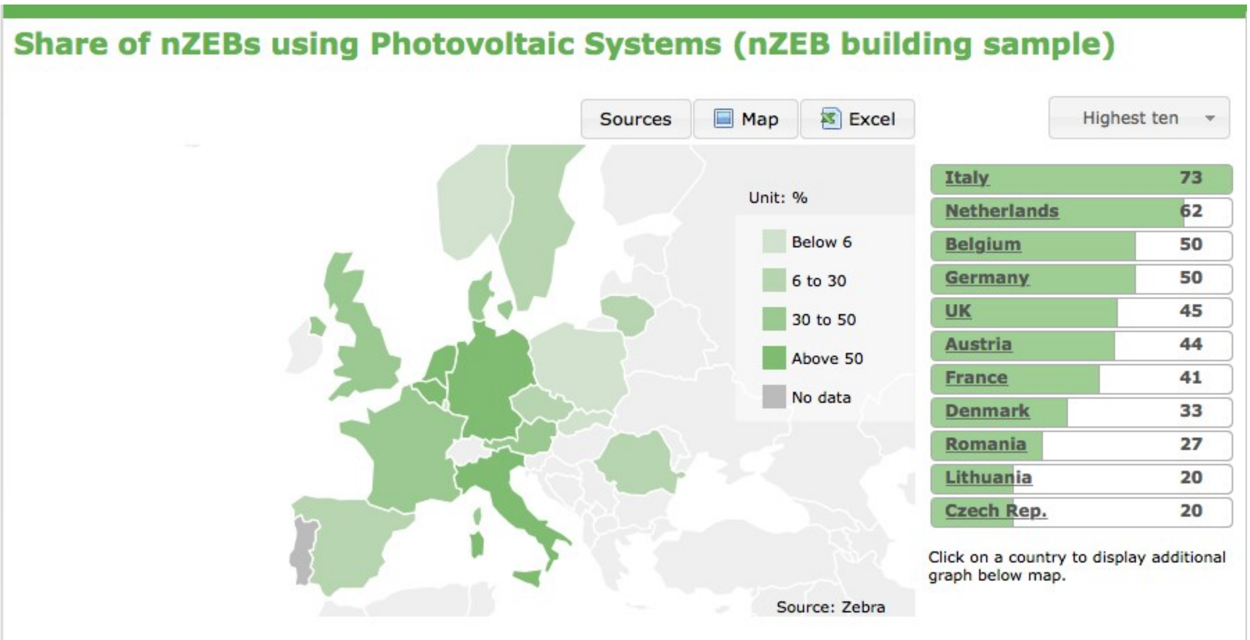

Figure 28: Output of the nZEB tool for residential buildings.

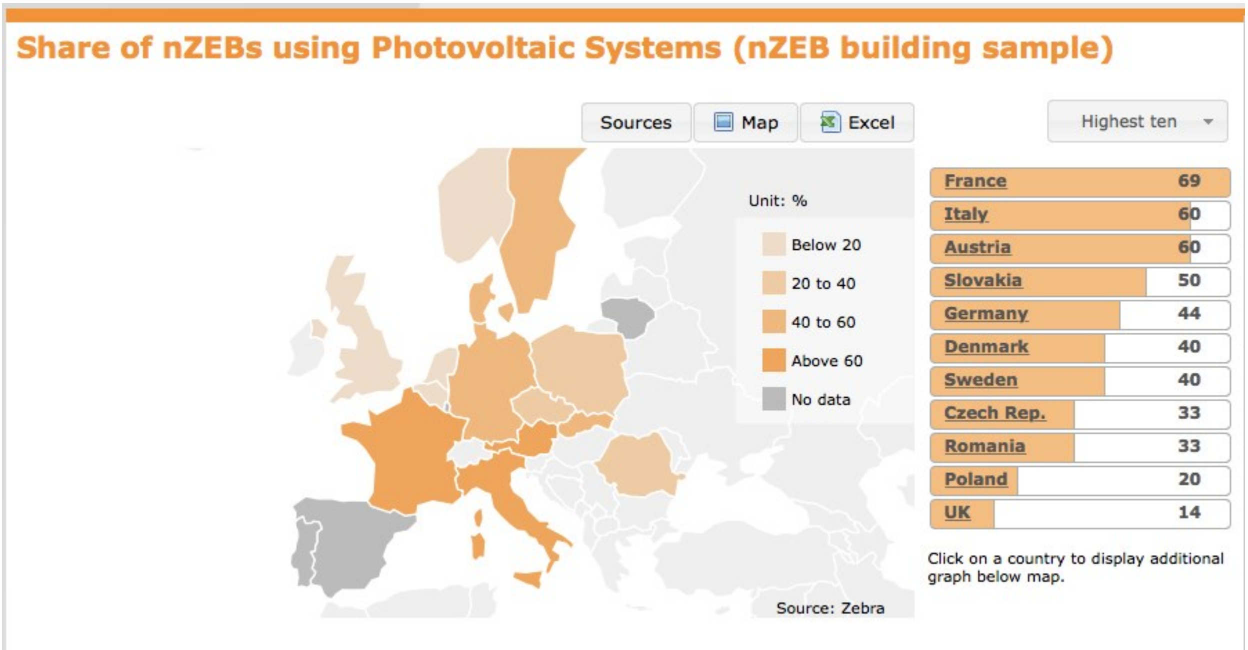

Figure 29: Output of the nZEB tool for non-residential buildings.

6 CONCLUSIONS

In order to further stimulate an increased number of energy efficient buildings, the Energy Performance of Buildings Directive (EPBD, 2010/31/EC) introduced the definition of nZEB as a building with very high energy performance where the nearly zero or very low amount of energy required should be extensively covered by renewable sources produced on-site or nearby.

Acknowledging the variety in building cultures and climate throughout the EU, the EPBD does not prescribe a uniform approach for implementing nZEB and neither does it describe a calculation methodology for the energy balance. Throughout Europe there is a large variety of concepts and voluntary standards for highly energy efficient buildings or even climate neutral buildings: passive house, zero energy, Minergie, Effinergie etc. Each country designs national plans for increasing the number of nearly Zero-Energy Buildings reflecting national, regional or local conditions. All European Member States are working on the implementation of the EPBD nZEB requirements, though with different ambition levels. The national plans have to translate the concept of nearly Zero -Energy Buildings into practical and applicable measures.

It should be in the interest of every Member State to follow a uniform, transparent approach for both reporting the national definition and national plans for increasing the number of nearly zero-energy buildings. In this report, we define several nZEB concepts depending on the different European climates and based on the “trias energetica” principles: Reduce energy needs, Use Renewable Energy Systems and Use Non-Renewable Energy with a high efficiency.

Some Member States have their own definitions that make the output a little unclear. Member States have established different parameters, both in terms of quantity and quality, in their nZEB definitions. 21 Member States set a definition that comprises both a numerical target for primary energy use (or final energy) and consider the share of RES. A few countries don’t have specific renewable energy requirement included in their nZEB definition. For instance Sweden has no strict RES requirements but it is one of the countries with a high rate of RES in buildings. In RES requirements, only five countries encourage directly BIPV system implementation.

Nowadays, buildings represent about 40% of EU final consumption and 60% of electricity consumption. Energy needs vary from country to country, depending on living and comfort standards, climatic conditions, building type, natural resources and available energy infrastructure. The electricity demand in Europe is on a continuously increasing trajectory over the last years (because of an increasing penetration of IT equipment, air conditioning systems...). Thanks to the on-site exploitation of PV technology the amount of grey energy needed for the realization of the system building is reduced. The use of non-renewable energy sources and/or fossil fuels as well as greenhouse gas emissions is also reduced. This allows the BIPV technology to be one of the sectors of the photovoltaic industry with the highest growth rate (the share of PV systems in nZEB buildings is already over 40%).

A renewable system integrated into the building, such as BIPV, represents a good practice that has many advantageous aspects, such as:

- it works as both building envelope material and energy generator,
- it saves in materials and energy costs,
- it drastically reduces CO_2 emissions,
- it can be optimally adapted on both new constructions and existing buildings,
- it actually adds architectural value to the building as well as providing a public expression of sustainable commitment.

The building and urban quality of spaces characterized by BIPV is closely related to a complex combination of functional, constructive, energetic and aesthetical aspects.

Being both a part of the building envelope/system and a power generator, BIPV systems allow a reduction in the initial investment costs, the material and the necessary labor for the set up in comparison to a traditional construction where PV systems do not replace traditional building elements.

Beside this functional/technological role, it is important to encourage project developers to take care both of technical aspect as well as of aesthetic and architectural ones, to increase the acceptation and the quality of the decentralized systems for energy production.

Europe will take an important step forward towards a sustainable future by elaborating a consistent and effective nZEB definition and by successfully implementing it. Today we have a great opportunity to define the right directions for the building sector and to exploit the requirements set by the recast Energy Performance of Buildings Directive. Currently, the development of innovative new technologies and the integration of renewables like BIPV is essential to implement nearly Zero-Energy Buildings.

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