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European climate zones and bio-climatic design requirements

Project report

BEAR-iD, NOBATEK

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www.pvsites.eu

Document summary

Climate and the environment where the building is located, will affect the conditions to which the building is exposed to, and therefore will determine its thermal behaviour and final energy consumption. The thermal behaviour of the building at the same time, will condition the final selection of technologies, materials, concepts or refurbishment techniques to be used in facades in order to guarantee their energy efficiency.

When the energy consumption of buildings is analysed, it is convenient to analyse whether the specific energy use of the building is climate dependant or not. The climate dependant variables are those that affect the specific energy consumption of the building, which is increased when climate becomes more severe. Energy uses that are affected by climate are space heating and space cooling.

Among the different parameters that will affect the building space heating and cooling, climate, local environment, type of building and its use- or its internal indoor activity – may be mentioned.

This deliverable is focused in analysing the climate conditions that mainly affect the specific energy consumption, which can be shorted out as:

- external air temperature;
- wind velocity and direction ;
- solar radiation;
- Infrared radiation.

Climatic zones with similar characteristics (outside temperature, solar radiation) will be established in order to determine the most appropriate technologies for each of different European regions.

In order to reach this objective we have combined the Köppen-Geiger classification with the European Heat Index, the European Cooling Index and the nZEB zoning. This actually gives a new nZEB zoning map. Climate borders are different from political borders. So in several countries, there will be different climate zones for nZEB and this could lead to an update of the local rules.

Regulation in the EU is not the same everywhere yet. Although the nZEB regulation is on its way, there are still a lot of different rules. A state of the art is therefore given.

Acknowledgements

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The present report was mainly prepared by PVSITES project partner BEAR-iD, with additional contributions from NOBATEK. Project coordinator Tecnalia proof-read the document before publication. The report was originally submitted to the European Commission as Project Deliverable D2.2 in August 2016.

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

CONTENTS

TABLES

FIGURES

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 side 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 D2.2: Design requirements are formulated for the different climates within the EU, taking the European Bioclimatic map as a starting point. These requirements consider comfort, indoor climate, heating, cooling and daylight in relation to the different climate zones. The regulatory framework including local standards is used as input as well.

Climate and the environment where the building is located, will affect the conditions to which the buildings are subject or exposed to, and therefore will determine their thermal behaviour and final energy consumption. The thermal behaviour of the building will at the same time condition the final selection of technologies, materials, concepts or refurbishment techniques to be used in facades in order to guarantee their energy efficiency.

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Regulation in the EU is not the same everywhere yet. Although the nZEB regulation is on its way, there are a lot of different rules. A state of the art is given.

Reader guidance:

This deliverable starts with an overview of the European climate and several classification methods (chapter 2). The main climate aspects that influence the energy consumption are heating, cooling and lighting. In the overview of different climate systems we make combinations to reduce the differences and come to the main climates. These main climates are the starting point for the nZEB concepts (D2.3).

The regulatory framework is based on research done by BPIE (Buildings Performance Institute Europe) in the field of indoor air quality, thermal comfort and daylight and the nZEB regulation in different European countries. From this overview we get some insight in the possibilities for BIPV in nZEB buildings.

1.2. Reference material

Not applicable.

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 regions and bioclimatic classification

One of the main criticisms when developing climatic zones is that there can never be enough because there is in reality infinite variety in climatic conditions that buildings may bear and thus affect energy and environmental performance of systems.

2.1. Köppen-Geiger classification

The most widely used general climate classification is the Köppen-Geiger system. This system was originally developed by Wladimir Köppen around 1900. Early versions were based on previous maps of vegetation growth, but it has subsequently been revised as more comprehensive monitored data became available. As Peel et al (Peel, Finlayson et al. 2007) note, the classification still bears criticism, but it remains the benchmark against which others are assessed.

Csa:	Temperate with dry, hot summer. (Mediterranean climate)
Cfb:	Temperate without dry season and warm summer
Dfb:	Temperate continental climate/humid continental climate without dry season and with warm summer;
Dfc:	Cold, without dry season and with cold summer.

Figure 2.1 According to Köppen – Geiger climate classification, there are four prevailing climatic zones in Europe

Countries may have more than one climatic zone and it is sometimes difficult to establish the prevailing climate classification of Köppen.

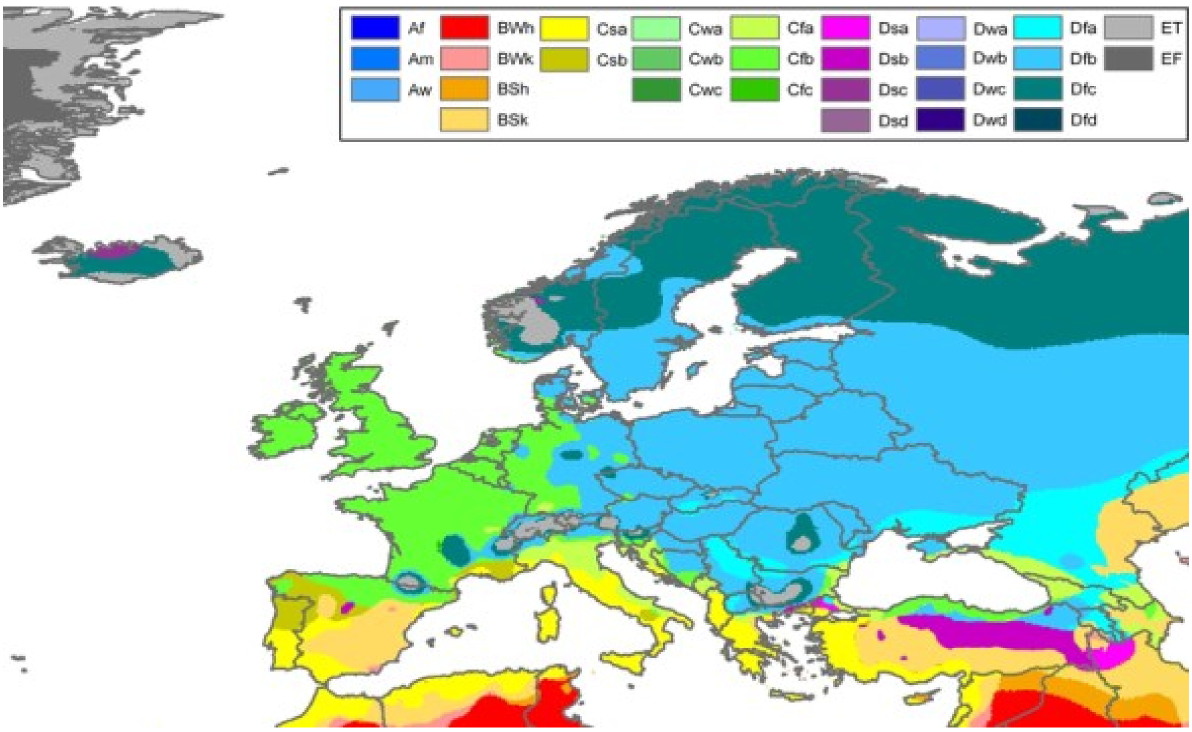

Figure 2.2 Koppen-Geiger climatic zones [Kottek et Al, 2006]

2.2. Heating and cooling degree days

The degree-day method dates back to the early 19th century when it was developed in the USA. In 1927 it was introduced at Bewag in Berlin (S. Werner, Heat load in district heating systems, 1984).

The heating and cooling degree method is a very traditional method that has been in use for decades. It provides an indication of severity of the climate in different locations by documenting when during a given year the external air temperature falls below or rises above a specified temperature, requiring thus heating or cooling. The specific temperature is called base temperature and represents the temperature at which no heating nor cooling loads are required in buildings for that climate. The degree day concept assumes, therefore, that the heat loss factor is constant and is proportional to the temperature difference between indoors and outdoors.

Heating degree days express the severity of the cold over a specific time period taking into consideration outdoor temperature and room temperature. For calculating heating degree days of European cities, weather data where taken from METEONORM and calculated to heating degree days (HDD) using the methodology applied by EUROSTAT, which form a common and comparable basis. External and internal building conditions may require additional energy for cooling and ventilation in order to meet a defined comfort level. This comfort level may be defined in building regulations or be given as user specifications. In order to meet the comfort conditions quantification of the energy for cooling is either based on the number of corresponding Cooling Degrees (similar to the number of Heating Degrees) or resulting from a iterative numeric calculation (as done in this study with the calculation program TRNSys) driven by maintaining the comfort level in the building at a given comfort temperature. (EURIMA study “U-Values for better energy performance of buildings” by Ecofys)

UROSTAT is working on a methodology to calculate cooling degree days. Because this is not finalized, the ASHRAE methodology is shown here.

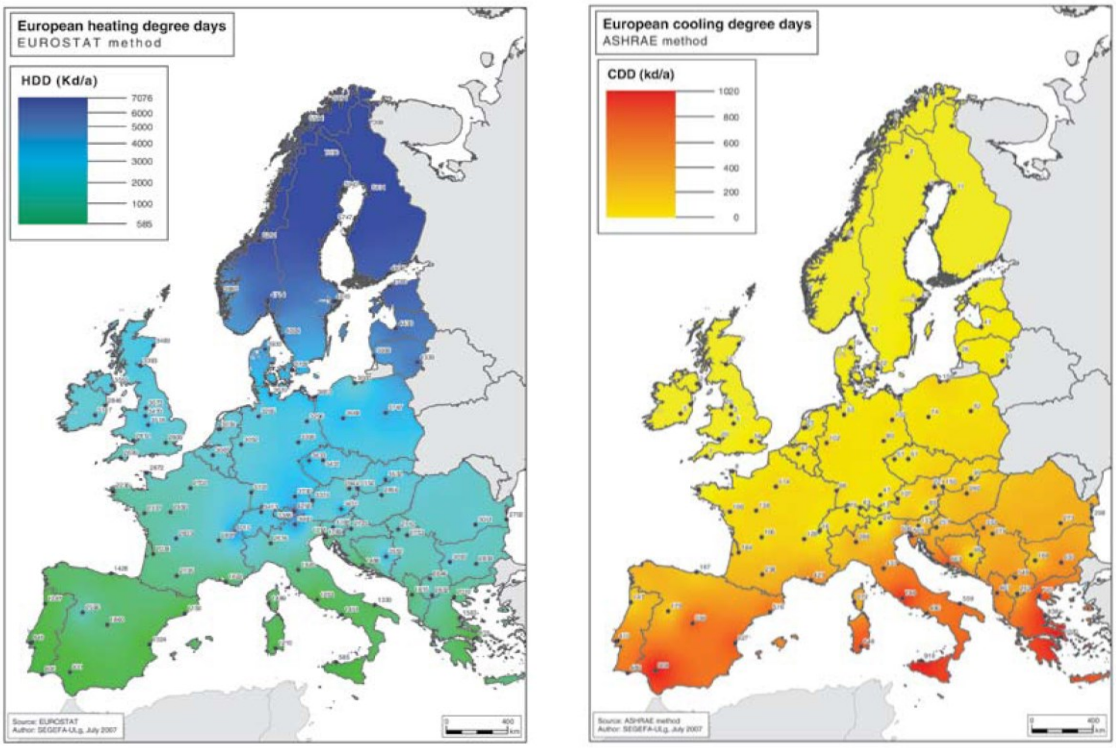

Figure 2.3 (Left) European heating degree days (Eurostat) [3] (right) European cooling degree days (ASHRAE) [3]

2.3. European Heating Index (EHI) & European Cooling Index (ECI)

The new European Heating Index (EHI) is developed to make a more consistent system for Europe. The degree-day method shows that there are 10 times more degree-days in Kiruna (North of Sweden) than in Palermo. But the heat demand in Kiruna is not ten times higher due to the different insulation of the buildings. So the EHI has been developed with this in mind.

The index is normalized, where 100 is equal to an average European condition. Using a reference degree-day number of 2600, corresponding to an annual average outdoor temperature just above 10°C, fulfills this normalization. Strasbourg in France is the typical space heating city in Europe, with a heating index of 100.

The Ecoheatcool project used 80 cities in Europe to develop the EHI and the ECI. The map is not representative for all locations in each country, since the existing data grid consists of only 80 locations.

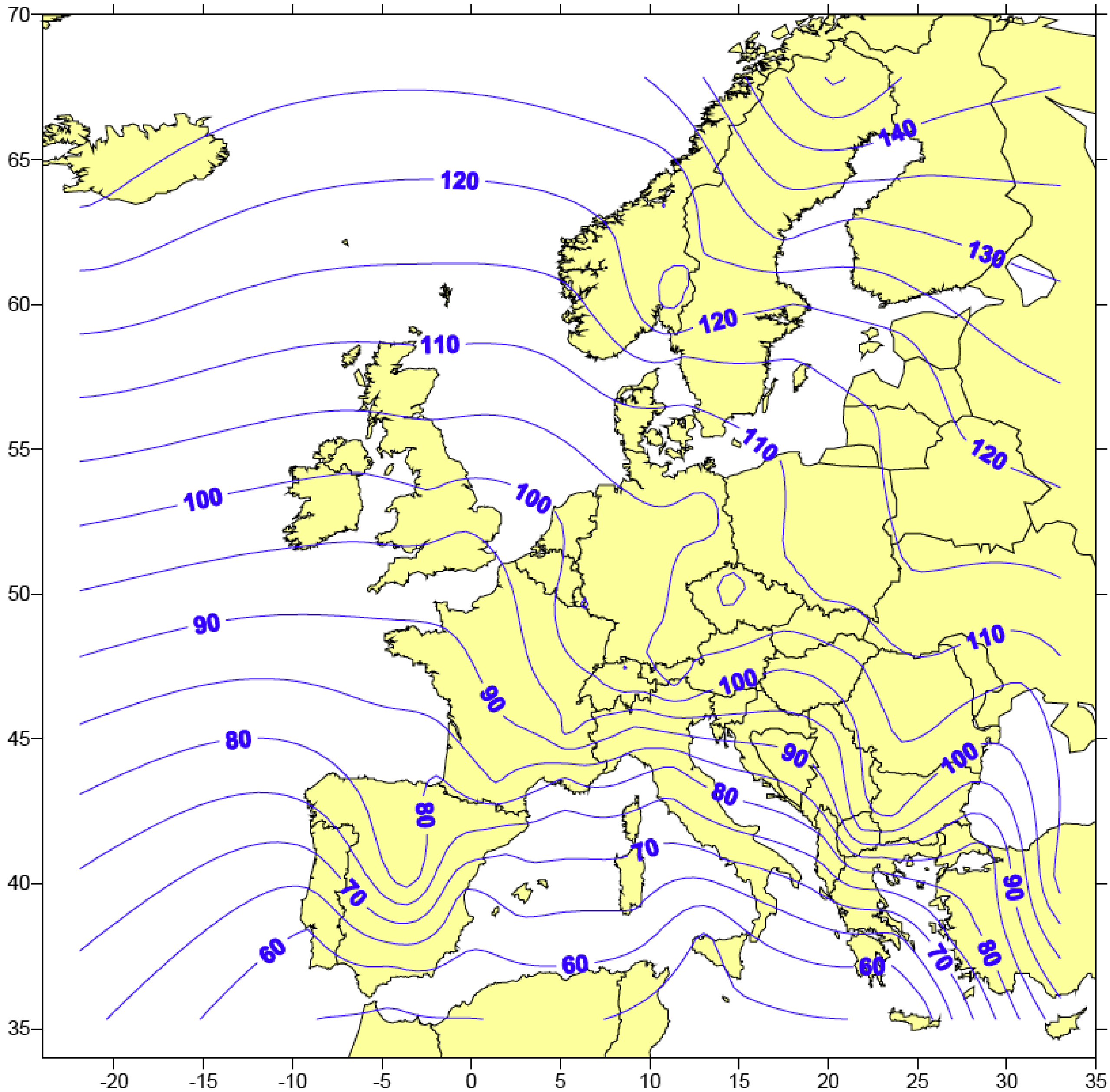

Figure 2.4 European heating index (EHI) [1]

In the same way as for the new European heating index (EHI), a new European cooling index has been constructed based on the same principles. (ECOHEATCOOL, WP1 2005) First, it is assumed that the outdoor temperature is the predominating factor for the heating and cooling demand. Furthermore, it is assumed that the heating demand (and not the cooling demand) is the predominating factor for building insulation. Therefore the same approach as for the EHI has been used. The optimal insulation thickness is proportional to the square root of the heating degree-day number, by assuming a certain heat cost and certain insulation cost. Also recovery of heat from ventilation systems would follow the same relationship. Hence, the cooling use depends on both the cooling degree-day number and the heating degree-day number, since the overall building heat resistance should be proportional to the square root of the heating degree-day number.

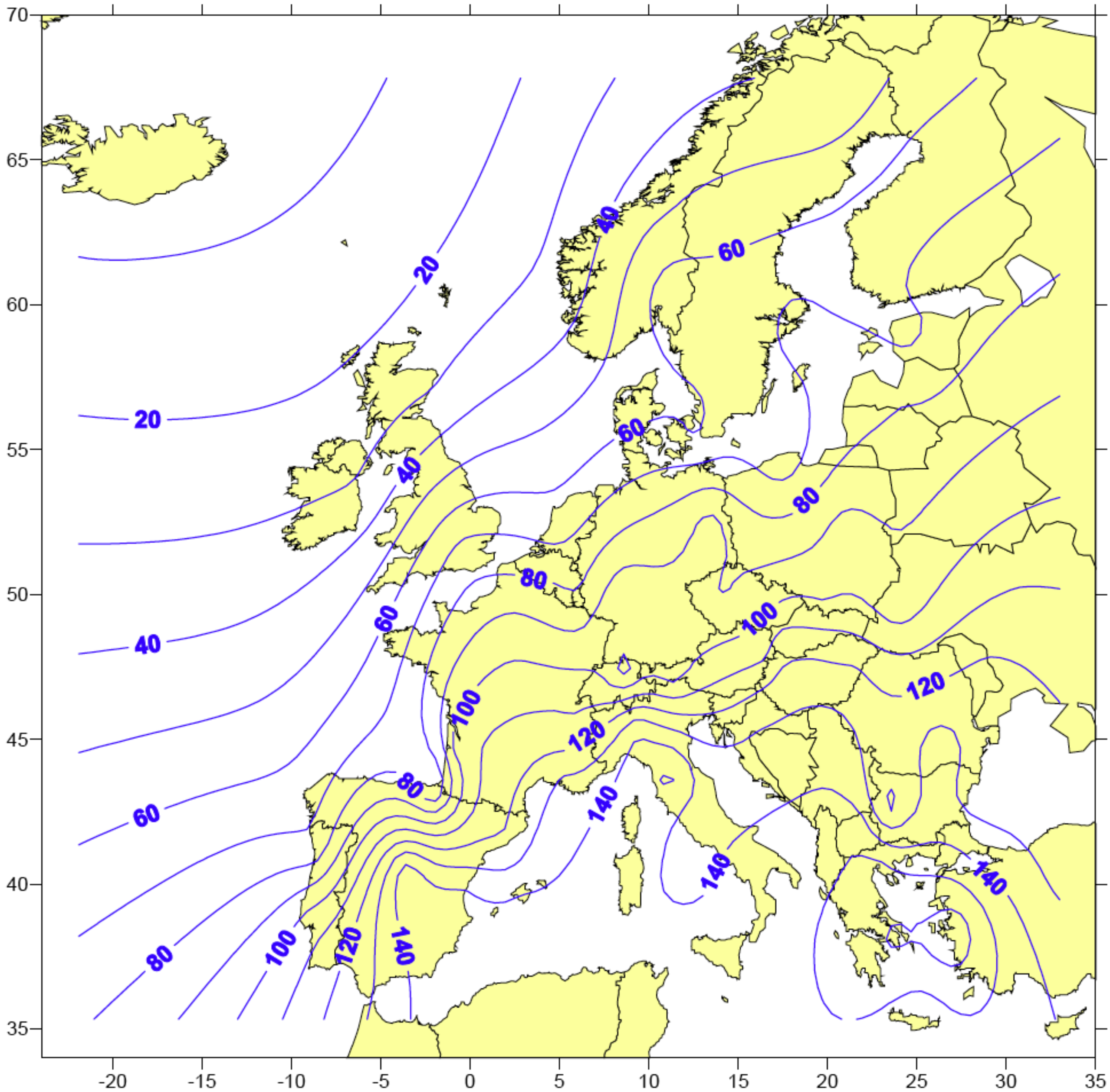

Figure 2.5 European cooling index (ECI) [2]

The ECI has been constructed according to the analysis above and is presented in Figure 2.6. The index is normalised, where 100 is equal to an average European condition, which occurs in for example Strasbourg and Frankfurt, where the average outdoor temperature is just above 10ºC (Figure 2.5). The solar and internal gains are also adjusted by the square root of the heating degree-day number, since these gains are more valuable in temperature addition, when a building is well insulated.

In the construction of the ECI it is also assumed that the cooling systems are designed to maintain an indoor temperature of 22°C only when the outdoor temperature is below 29°C. When the outdoor temperature exceeds this limit, the indoor temperature will start to slide at a constant difference of 7°C below the outdoor temperature.

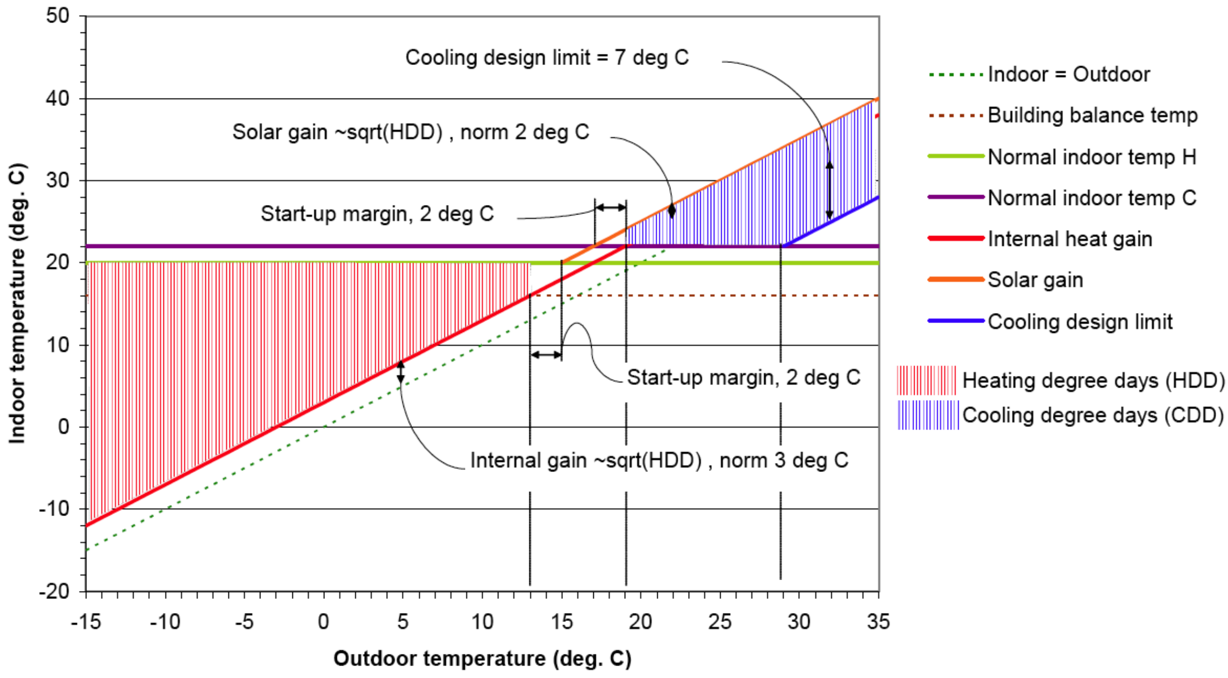

Figure 2.6 Construction of European heating and cooling index. [2]

2.4. Climate chart for NZEB

As climate charts are independent from political borders, there is another level above the climate classification. That is the political level where borders divide climates and national regulation makes the difference.

In the report ‘Towards nearly zero-energy Buildings’, Ecofys divided European countries in 5 European climate zones based on global radiation, heatings degree-days, cooling degree-days and cooling potential by night ventilation. This overview result in the following European Climate Chart that can be used for different definitions of NZEBs.

Zone	Cities	Köppen
Zone 1	Athens - Larnaca - Luga - Catania - Seville - Palermo	Csa
Zone 2	Lisbon - Madrid - Marseille - Rome	Csa Cfb
Zone 3	Bratislava - Budapest - Ljubljana - Milan - Venice	Dfb
Zone 4	Amsterdam - Berlin - Brussels - Copenhagen - Dublin - London - Macon - Nancy - Paris - Prague - Waszawa	Cfb/Dfb
Zone 5	Helsinki - Riga - Stockholm - Gdansk - Tovarene	Dfc

Table 2.1 Cities in NZEB climate zones [3]

When we compare the Köppen-Geiger Classification with the Zoning by ECOFYS, we can see that most countries get more or less the same classification. A few countries however are divided between two areas according to Köppen-Geiger.

The north of Italy and the north of Spain have Cfb climate and belong to the climate of zone 4. The same happens in Germany where West Germany belongs to Cfb climate (zone 4) and the east part to Dfb (zone 3). The south of Sweden is much warmer and belongs to Dfb while the middle and north of Sweden belongs to Dfc. In the NZEB zones there is no difference between these two classifications. Overall we can conclude that the NZEB climates zones are very useful as long as we keep local circumstances in mind.

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 2.2 Building strategies in different climates

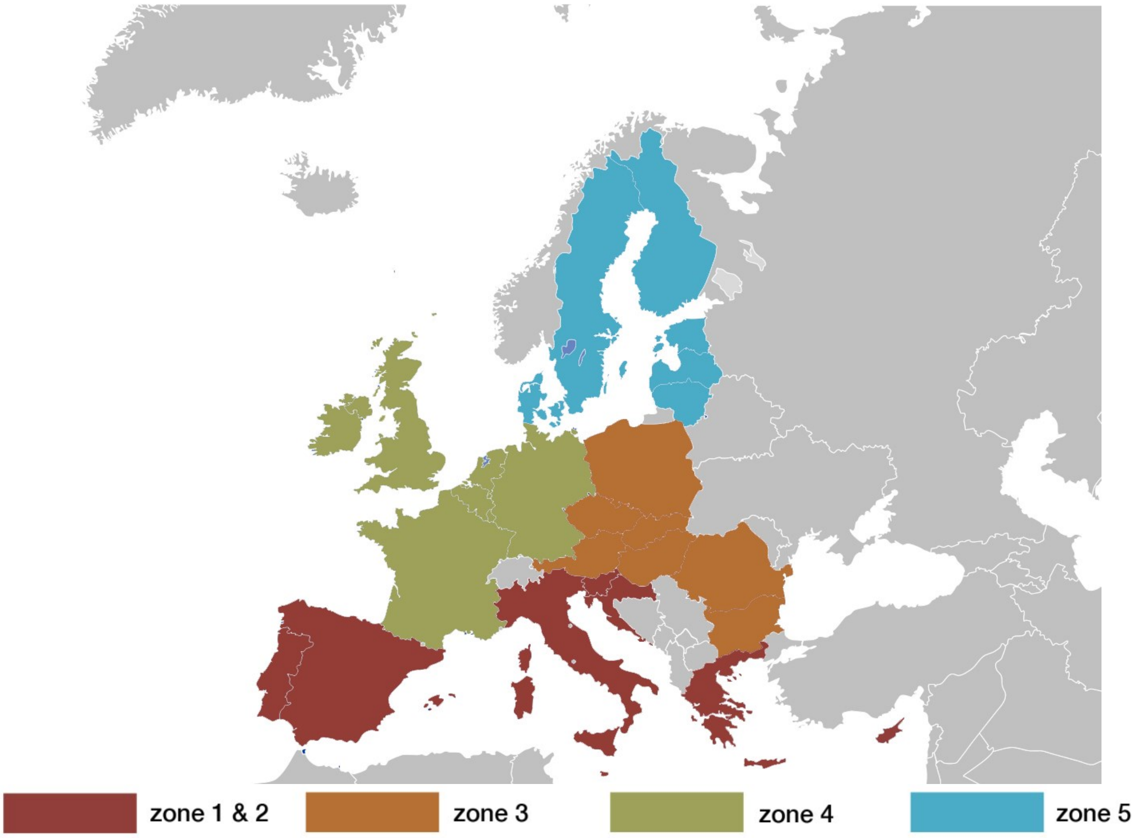

Figure 2.7 NZEB climate zones [Map is redrawn from 3]

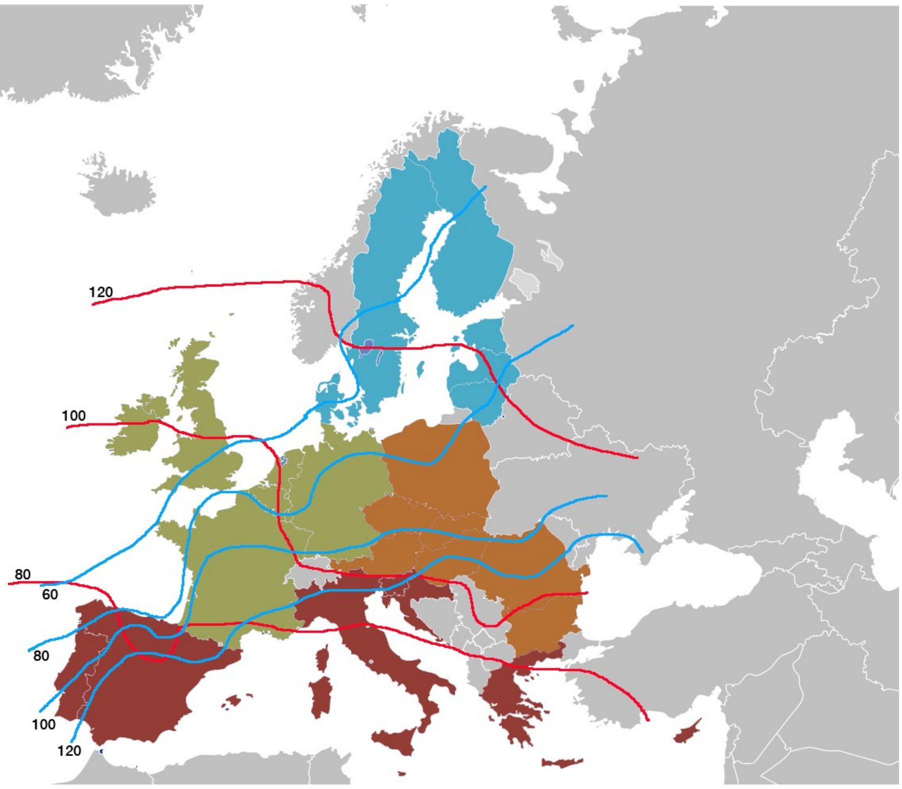

Figure 2.8 NZEB climate zones combined with EHI and ECI

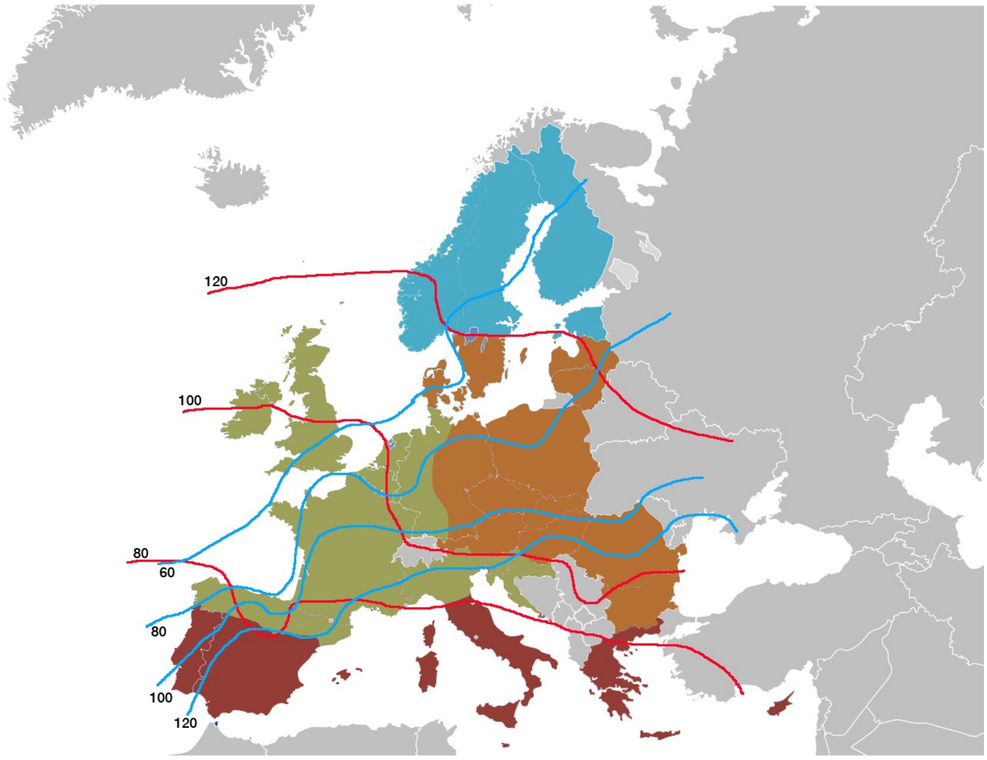

Figure 2.9 Alternative NZEB climate zones based on Köppen-Geiger and the EHI and ECI

3. Photovoltaic solar electricity potential in EU countries

The generation of solar electricity from photovoltaics (PV) is beginning to penetrate the energy market in those countries, where clear and stable policy commitments have been made in Europe. This will improve by the introduction of nZEB buildings. To reach this goal, more BIPV systems are expected to be installed [3].

The geographical analysis of the availability of the primary solar energy resource can improve our understanding of the potential PV contribution to the future energy and economic structures and thus contribute to setting up effective policies.

The map below represents the yearly sum of global irradiation on horizontal and optimally inclined surface. Over most of the region, the data represent the average of the period 1998-2011, however, north of 58° N, the data represent the 10-years average of the period 1981-1990. All data values are given as kWh/m^2. The same color legend represents also potential solar electricity [kWh/kWp] generated by a 1 kWp system per year with photovoltaic modules mounted at an optimum inclination and assuming system performance ratio 0.75.

The yearly sum of the electricity generated for each kWp of PV with horizontal modules in EU countries ranges from about 470 up to 1390 kWh.

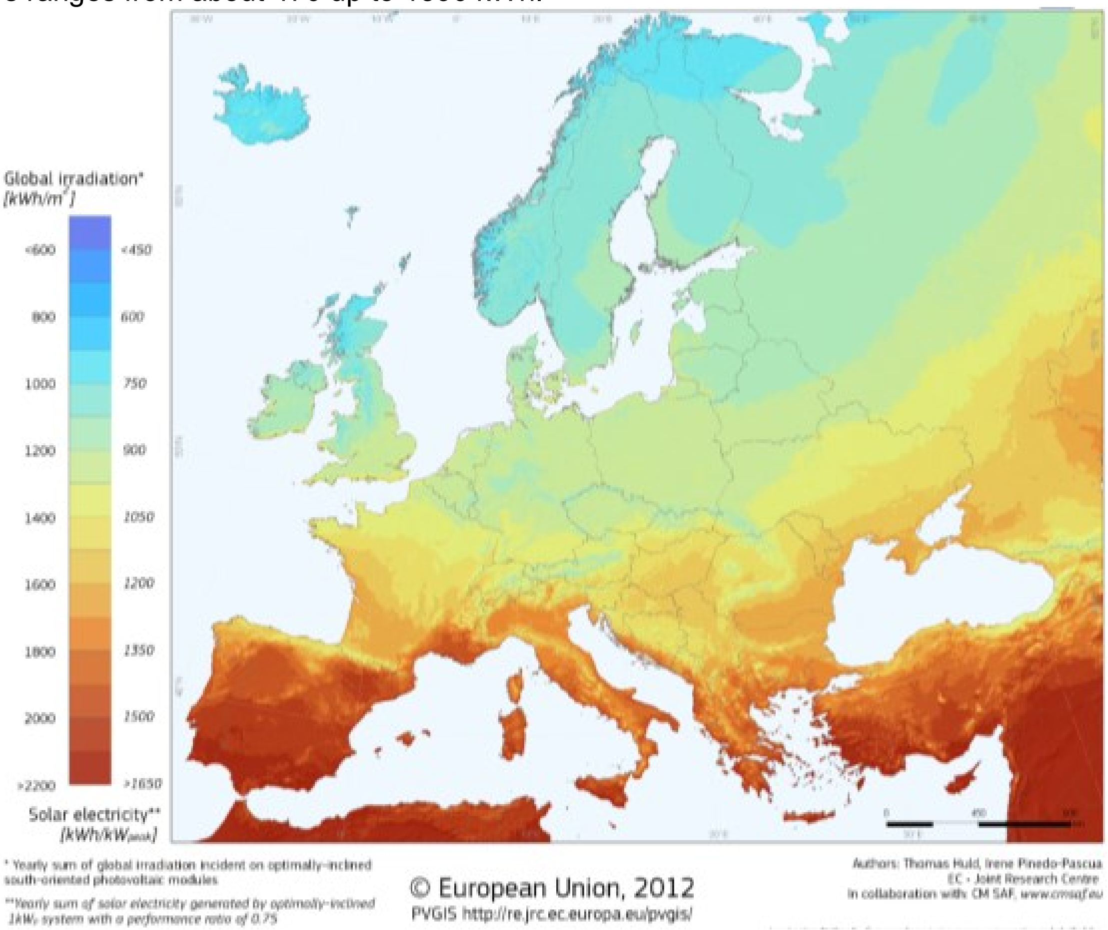

Figure 3.1 European solar irradiation map [13]

4. Regulatory framework

The European Commission's "Roadmap for moving to a competitive low carbon economy in 2050" states an overall reduction in the CO_2-emission levels for the building sector of 88%-91%, compared to 1990 levels, by 2050. Buildings account for nearly 40% of the EU's final energy consumption and 36% of its CO_2 emissions (Renovation Tracks for Europe up to 2050: Building renovation in Europe – what are the choices?" Ecofys 2012). The built environment is widely recognized as being the single sector with the highest potential for mitigation of CO2 emissions in a cost-effective way. In addition, the Energy Efficiency Directive requires EU Member States to establish long-term strategies for the renovation of their national stock of public and private residential and commercial buildings. The existing building stock in European countries accounts for over 40% of final energy consumption in the European Union (EU) member states, of which residential use represents 63% of total energy consumption in the buildings sector (Europe's buildings under the microscope. A country-by-country review of the energy performance of buildings. Buildings Performance Institute Europe (BPIE) 2012).

The Energy Efficiency Directive (EED, 2012/27/EU) adopted in October 2012 includes a requirement for Member States to develop long-term renovation strategies for their national building stocks.

EED replaces two previous directives on energy services and cogeneration. It seeks to promote energy efficiency across the European Union and was developed in order to help deliver the EU's 20% headline target on energy efficiency by 2020, as well as to pave the way for further improvements thereafter.

Alongside EED, the Energy Performance of Buildings Directive (EPBD, 2010/31/EU), recast in 2010, sets out numerous requirements including energy performance certification of buildings, inspection regimes for boilers and air conditioning plants, and requirements for new buildings to be nearly zero energy. EPBD sets minimum energy performance standards for buildings undergoing renovation. (Buildings Performance Institute Europe (BPIE).

4.1. Thermal comfort requirements in EU standards & national regulations

The energy consumption of buildings depends significantly on the criteria used for the indoor environment, which also affect the health, productivity and comfort of the occupants. The indoor environment is mentioned several times in the EPBD, aspects of thermal comfort related to low temperature or draught are often improved through measures that are primarily addressed at improving the energy performance of a building. Today still, between 50 and 125 million Europeans suffer from cold in winter (bpie.eu/fuel_poverty.html).

The European Standard specifies the indoor environmental parameters that have an impact on the energy performance of buildings. The standard specifies how to establish indoor environmental input parameters for building system design and energy performance calculations, methods for long-term evaluation of the indoor environment, displaying the indoor environment in existing buildings and criteria for measurements and monitoring. (Olesen 2010; Bopp 2006). The standard is applicable mainly in non-industrial buildings where the criteria for indoor environment concern human occupancy and where the production or process does not have a major impact on the indoor environment. The standard is thus applicable to the following building types: single family houses, apartment buildings, offices, educational buildings, hospitals, hotels and restaurants, sports facilities, wholesale and retail trade service buildings. An example of recommended design values of the indoor temperature is presented in Table 4.1.

Type of building/ space	Category	Operative temperature C	
		Heating (winter season), ~ 1,0 clo	Cooling (summer season), ~ 0,5 clo
Residential buildings: living spaces (bedrooms, drawing rooms, kitchen etc) Sedentary ~ 1,2 met	I	21,0	25,5
	II	20,0	26,0
	III	18,0	27,0
Residential buildings: other spaces: boxrooms, halls, etc) Standing-walking ~ 1,6 met	I	18,0	
	II	16,0	
	III	14,0	
Single and Landscaped offices, conference rooms, Auditoriums Sedentary ~ 1,2 met	I	21,0	25,5
	II	20,0	26,0
	III	19,0	27,0
Cafeterias/Restaurants Sedentary ~ 1,2 met	I	21,0	25,5
	II	20,0	26,0
	III	19,0	27,0
Classrooms Sedentary ~ 1,2 met	I	21,0	25,0
	II	20,0	26,0
	III	19,0	27,0

Table 4.1 Recommended design values of the indoor temperature (EN 15251)

Indoor air temperature is an indicator of thermal comfort in all surveyed countries and there are requirements and recommendations in place for lower and upper limits during winter and summer respectively. In a few countries such as France and the UK, operative temperature is also used to assess thermal comfort. Five out of eight countries require minimal temperatures in dwellings in winter (i.e. France, Germany, Poland, Sweden and the UK). Only Italy demands a lower limit in summer (max. cooling) and upper limit in winter (max. heating).

Five countries within this survey (Brussels-Capital Region-Belgium, Denmark, France, Germany and the UK) have overheating limitations (either mandatory or recommended), where overheating indicators differ by temperature and time limit. The extremes are found in Brussels-Capital Region (> 25°C for 5%/yr.) and the UK (> 28°C for 1%/yr.), but only as a recommendation in the latter case.

Passive systems to avoid overheating are common in southern climates, but minimum requirements are mainly limited to solar shades while others such as fans cooling, the use of building mass, natural ventilation and night time ventilation are rarely considered. In Sweden, the building codes explicitly ask for consideration of some passive solutions and, in Brussels-Capital Region, a minimum share of 50% for passive systems is recommended for new buildings (Kunke et al. 2015).

Leading examples in Europe are the French indicator “TIC” (Indoor Conventional Temperature) and the German “Sonneneintragskennwert” (Solar Transmittance Value) which take several (passive) aspects into account; Denmark is the only country requiring minimal solar gains in winter in case of new buildings and major refurbishment;

The requirements on indoor temperature in EU standards and national regulations were found very inconsistent. Indoor air temperature in summer range from 25 to 28°C and 15 to 21°C in winter as shown in the Figure 4.1. Summer limit of 28°C seems to be too high from that point of view since considerably reduces performance (Brelih 2013).

Finland, which is a country with coldest climate among included countries, has the highest limit of the winter minimum temperature and the lowest summer design temperature, thus making it the country with the set temperature limits which are the closest match of the optimum values. One can notice that the minimum air temperature limit is prescribed more countries than maximum air temperature limit. The recommended values in EN15251:2007 are 20°C and 26°C for winter and summer, respectively for the living space in residential building (Category II) (Olesen 2010).

A comparison with the values from the national regulations shows that seven countries have at least one temperature limit set under out of the recommended range by the EN standard. Winter minimum temperatures are more problematic since there are 6 out of 16 countries that have minimum temperature requirement below 20°C.

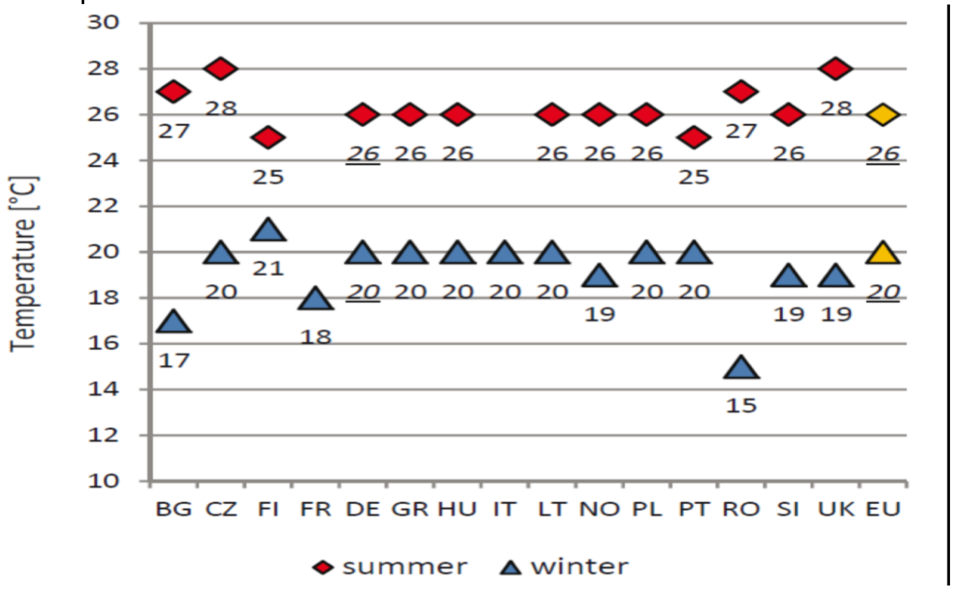

Figure 4.1 Comparison of requirements for indoor temperature (left) and relative air velocity (right). Markers in yellow [7]

4.2. Thermal comfort requirements in some EU countries

Denmark

Functional requirements and methods of specification, verification and monitoring of the thermal indoor climate are described in the DS 474 Danish Code for Indoor Thermal Climate, as well as in the International DS/EN ISO 7730. According to DS 474, indoor temperature not have to be more than 100 hours above 26°C; and not more than 25 hours above 27°C.

The planning of buildings and the choice of materials, window areas, cooling options, orientation and solar screening must ensure that satisfactory temperature conditions are achieved, even in summertime. Therefore, minimum insulation requirements are not only a response to the requirement for energy savings, but also a means to provide comfort and avoid the risk of condensation.

France

The French energy regulation for building RT 2012 (depending on the climatic region) requires certain comfort temperatures which have to be guaranteed by heating or cooling system. Heating equipment in all housing must maintain a minimum of 18°C. The indicator TIC (Indoor Conventional Temperature) is the maximum operative temperature ensuring comfort during the hot season while avoiding recourse to air conditioning systems. The value of the maximum comfort temperature is the same throughout the year when a mechanical system is used (28°C), while in the case of natural ventilation, different limit values are established according to the type of building and external temperature.

Germany

In summertime, the EnEV requires a building to be in line with an indicator for maximum solar gains ("Sonneneintragskennwert") calculated according to DIN 4108 -2.

Maximum solar gains to avoid overheating for more than 10% of the time have to be checked for each room, depending on the climatic region (A,B,C), the thermal capacity of the building (light, middle, heavy), the use of night ventilation, the window tilt, and more. Therefore, the recommended indoor air temperature is limited at 25°C, 26°C and 27°C for climatic regions A, B and C respectively.

Figure 4.2 Indoor Temperature requirements in Europe [8]

Italy

In Italy, minimal and maximal temperatures are required in order to limit the waste of energy for cooling and heating. Cooling systems have to be limited to 26°C (with -2°C of tolerance) in summer, the temperature provided by heating systems during winter needs to be limited in each building unit to 20°C (with +2°C of tolerance). Other temperature requirements for the sake of thermal comfort do not exist. External shades are mandatory for new buildings and deep refurbishments.

Poland

In Poland, the indoor temperature cannot be lower than 16°C (for rooms with a temperature of 20°C and above, as specified in the legislation). Additionally, buildings should be designed and constructed in such a way that they reduce the risk of overheating in the summer. The legalization defines also the minimal surface area of windows and other transparent surfaces.

Sweden

According to the Swedish Building Code, buildings and their installations must be designed to guarantee a satisfactory thermal comfort. Rules on thermal comfort are also issued by the Public Health Agency and by the Work Environment Authority. The recommended minimal operative temperature for the average dwellings is 18°C, and 20°C for dwellings inhabited by older people. Furthermore, among the different rooms of a dwelling, the operative temperature difference should not exceed 5°C. Additionally, surface temperatures (floor) should not be less than 16°C (in sanitary premises, a minimum of 18°C and in premises for children, min 20°C) and should be limited to a maximum of 26°C. Nevertheless, in order to maintain energy efficiency and thermal comfort, devices for the automatic control of heating systems should be provided in each room.

UK (England & Wales)

Based on the binding Building Regulations 2010, reasonable provisions shall be made for the conservation of fuel and power in buildings by limiting heat gains and losses through thermal elements and from pipes, ducts and vessels used for space heating, space cooling and hot water services;
Providing fixed building services which are energy efficient; have effective controls; and are commissioned by testing and adjusting.

Furthermore, the Government's Standard Assessment Procedure for Energy Rating of Dwellings (SAP 2012) contains a procedure that should be followed by designers to assess whether a house has high internal temperature in hot weather or not. This assessment is related to the factors contributing to the internal temperature: solar gain, ventilation, thermal capacity and medium summer temperature for the dwelling location.

Brussels capital region

Starting from January 2015, overheating (defined as temperatures of more than 25 °C) has to be limited to 5% of the time during the year. For an optimum level of comfort Bruxelles Environnement recommends the stricter value of 3%. Until end of 2014, each unit has to meet the requirement to limit the risk of overheating described in Chapter 8 of Annex II.
Additional recommendations from Bruxelles Environnement are: the level of comfort provided shouldn't be higher than the one requested by regulation and the maximum difference between internal and external temperature should be between 5°C and 7°C (in summer). An optimum level of comfort should also be guaranteed introducing devices on which you can select different temperatures per areas and time.
For new buildings, the PEB (Building Energy Performance) regulation takes into account systems such as solar protection. Active cooling is only required if the overheating indicator is higher than 6500 Kh (Kelvin-hour). On the contrary, if the overheating indicator is less than 1000 Kh, active cooling is not needed.

Air velocity & Humidity

Air velocity is an important factor in thermal comfort because people are sensitive to it. Small air movement in cool environments may be perceived as draught. If the air temperature is less than the skin temperature, it will significantly increase the convective heat loss. Very low levels of air movement can also cause a feeling of discomfort and stuffiness in a room.

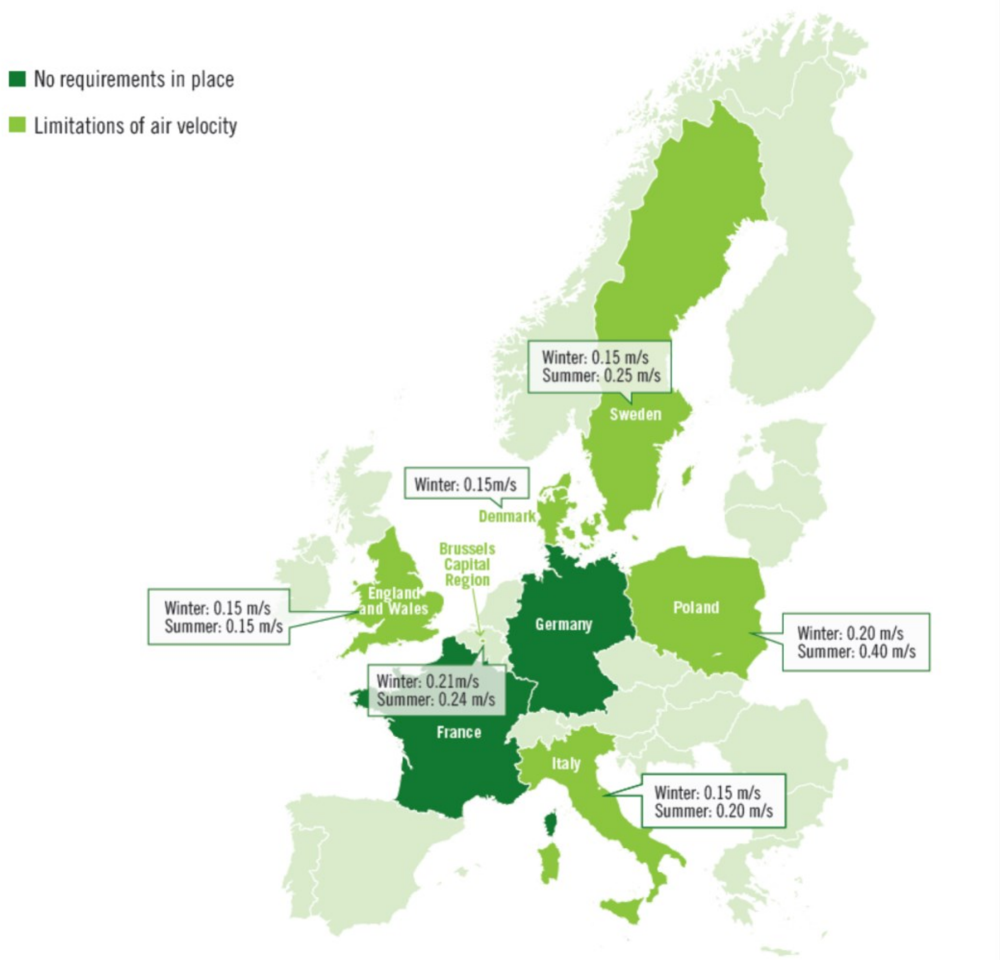

Figure 4.3 Maximal allowed air velocities in Europe [8]

4.3. Daylight in legislation in some EU countries

Using daylight is an important element to achieve a good indoor comfort in buildings, with a major impact on the inhabitant's health. Moreover, using a daylight in buildings offsets electric lighting and has a consistent energy saving potential.

Acknowledging the importance of daylight use in buildings, all surveyed countries include at least a basic reference for it in their building codes. Daylight requirements or recommendations in MS legislation mainly specify a minimum share of window/glazing area per floor area, indicate minimum levels for daylight or simply stipulate the need for sunlight access in buildings and a view to the outside.

A good level of daylight is also an integral part of a proper indoor environment. The benefits of daylight are highlighted in numerous studies with one of the most recent ones summarizing them as:

Economic and ecological, due to reduced energy consumption and CO_2 emissions;

Psychological, as daylight effectively stimulates the human visual and circadian systems;

Well-being, as it enables occupants to fulfill two very basic human requirements: to be able to focus on tasks and to perceive well the space, as well as experience some environmental stimulation.

As good practice, the Danish building codes are the only ones requiring minimal solar gains in winter while the Swedish regulations recommend the use of daylight management systems for permanently installed luminaries. Additionally, in France solar gains are part of the Building Code since 2012 (RT 2012), through the required bioclimatic indicator (Bbio). Only some building codes within the surveyed ones (i.e. Brussels-Capital Region, Denmark, Germany) highlight the importance of having a view to the outside as part of visual comfort (Kunke et al. 2015).

Denmark

According to BR 10, Article 6.1, there should be an appropriate connection between window sizes, room proportions and surface properties, taking into account the influence of outdoor obstructions. Moreover, according to Article 6.5, habitable rooms must have sufficient daylight for the rooms to be well lit and, in general, they must have satisfactory lighting without causing unnecessary heat loads.

The instructions to assess if a residential room has adequate daylight are described in BR10 and consist of two methods. The first method is to assess the minimum ratio between the glazed area of all windows and the floor area of the room, while the second method is based on the calculation of Daylight Factors (DF).

According to BR 10, for side-lit windows, the daylight level can usually be accepted as sufficient if the window glazed area corresponds to a minimum of 10% of the floor area. For roof lights, the windows should correspond to no less than 7% of the floor area. In both cases, the light transmittance of the glazing should be no less than 0.75.

The above-mentioned 10% and 7% guidelines assume a normal location of the building, normal room layout and furnishing. If the window type is not known at the design stage, the glazed area can be estimated by multiplying the outer area of the frame by the factor 0.7. The glazed area must be increased proportionally to any reduction in light transmittance (for example solar control glazing) or reduced light access from the windows (for example nearby buildings).

France

In France, the windowed surface must not be less than 1/6 of the dwelling floor area. In addition to natural lighting, the Bbio indicator, required by RT2012, includes the needs for electrical lighting. Energy needs for lighting are given a higher weighting coefficient than heating and cooling.

At the same time, electrical consumption for lighting is also taken into account in the second energy indicator Cep (Consumption in primary energy) which has to remain below a maximum value Cepmax.

In the HQE environmental voluntary label, workplaces have to have a Daylight Factor higher than 2.5%.

For existing dwellings, no daylight requirements for single element installations or replacements apply in France.

Germany

Natural or artificial lighting is not included in the energy saving requirements for residential buildings. Guidance is provided by DIN 5034-1:2011-07 referring to a specific daylight factor, which is the ratio of the internal light level to the external light level. Based on DIN 5034-1, the living areas' brightness produced by daylight is considered as sufficient for the well-being of occupants if the daylight factor is: on average 0.9%, horizontal, 0.85 m above the floor and in 1m distance to walls in the middle of the room and at least 0.75%, at the most unfavorable place.

Alternatively, to avoid complex calculations, a minimal share of a window's useful area can be applied based on a specific table from DIN 5034-1:2011-07, the indicated values fulfilling both daylight and view requirements. This may vary between 10% and 12.5% depending on the regional legislation of the federal states (Landesbauordnung-LBO).

Moreover, the Standard includes recommendations for the minimum duration of exposure to sunlight in buildings. Specifically, it recommends that in at least one habitable room of a dwelling the exposure to sunlight should be at least 4 hours at equinox (vernal or autumnal). Moreover, in the winter period, at least one room per building unit needs to have 1 hour of sun on the 17th of January.

Germany has no specific requirements for the use of daylight in existing buildings. Indirect consequences might occur through the general requirement that the energy performance of existing buildings must not be changed for worse.

Italy

In Italy, the daylight factor shall be no lower than 2% for each window and the total window surface area which can be opened shall be no lower than 12.5% of the total floor area. The designers have to take into account the exploitation of daylight and its integration with artificial light while guaranteeing an appropriate level of visual comfort.

There are no daylight requirements for the building stock at national level.

Poland

The Polish legislation specifies the conditions for exposure to sunlight. Daylight requirements depend to a large extent on the room's function. In permanently occupied rooms, the insulation time should be at least 3 hours during equinox days (21st of March and 21st of September) between 7am and 5pm. For multi-family apartments, the limit of insulation time in at least one room is set at 1.5 hours, while in one-room apartments, no insulation time is required.

In addition, in permanently occupied rooms, the ratio window area to the floor area should be at least 1:8, and in any other room, where daylight is required, the ratio should be at least 1:12. The legislation foresees the exemption from the above-mentioned requirements, when:

The daylight is not necessary or is not desirable due to applied technology

There is a need for functional spaces in the underground facility or part of a building with no access to daylight.

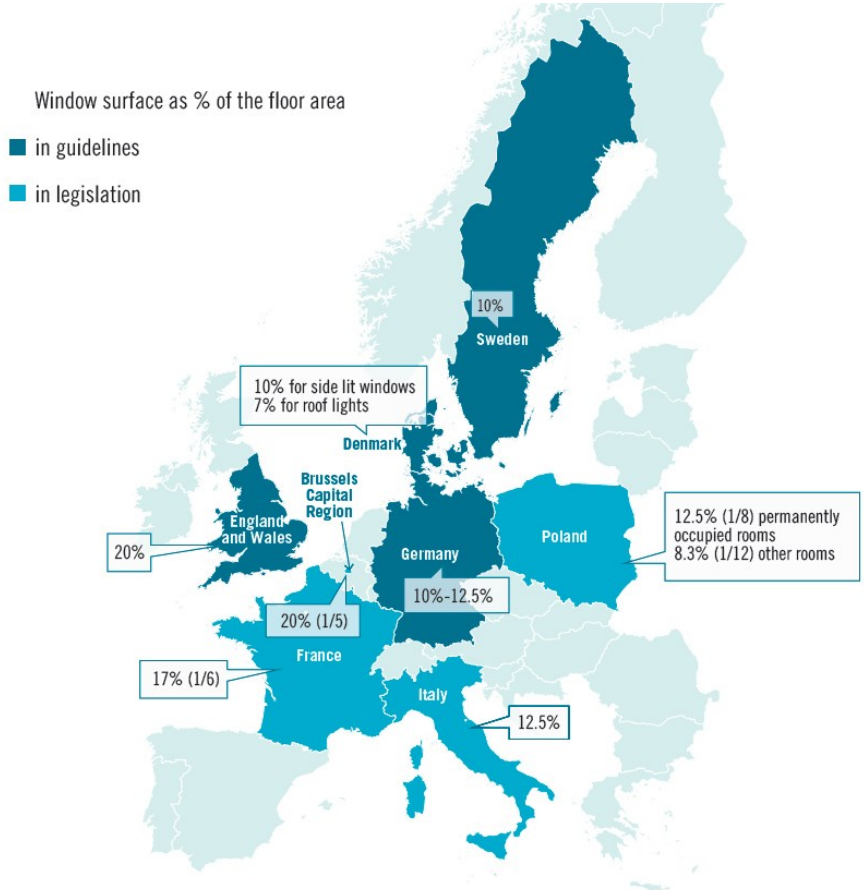

Figure 4.4 Daylight in legislation in Europe [8]

<u>Sweden</u>

In Sweden, new buildings and modifications to existing buildings shall be designed in order to achieve satisfactory lighting conditions without the risk of injury or damage to human health. When sufficient levels of brightness and lightness (luminance) are achieved and no glare and distracting reflections occur, we can assume that the lighting conditions are satisfactory.

In new buildings, in rooms where people spend time, there should be at least one window with outside view giving the opportunity to monitor seasonal and daily variations209. Nevertheless, skylights cannot be the sole source of natural light in these rooms. Additionally, these crowded rooms should be designed and oriented so as to allow direct access to daylight and to sunlight.

According to the Swedish Standard SS 91 42 01, the glazed area in a room should be 10% of the floor area. That means a daylight factor of about 1%209. For rooms with conditions other than those specified in the Standard, the glazed area is calculated for a daylight factor of 10%.

The above-mentioned conditions for new buildings should also be followed for modifications to existing buildings, unless the implementation of the necessary measures damages the building’s cultural, architectural or aesthetic value. On the contrary, for student residences (<35m2) direct sunlight is not needed210 and indirect daylight is only needed in the kitchen and in the common areas (living room, dining room).

UK (England & Wales)

In UK, the Building Regulations do not specify minimum daylight requirements. Reducing the window area has conflicting impacts on the building's energy efficiency: reduced solar gains, but increased use of electric lighting. However, as a general guideline, if the area of glazing is much less that 20% of the total floor area, some parts of the dwelling may experience poor levels of daylight, resulting in increased use of electrical lighting.

The British Standard "Lighting for buildings. Code of practice for daylighting" (BS 8206-2:2008), provides recommendations for minimum daylight factors: 1% for bedrooms, 1.5% for living rooms and 2% for kitchens. 80% of the working plane in each kitchen, living room, dining room and study must receive direct natural light.

Furthermore, BS 8206-2:2008 requires that interiors should receive at least 25% of the annual probable sunlight hours (APSH), with at least 5% of these being received between the 12th of September and 21st of March. The degree of satisfaction is related to the expectation of sunlight, and linked to a higher degree with the duration of the sunlight rather than its intensity.

Brussels capital region

In Brussels, each dwelling must have at least one window providing a view to the outside without obstacles closer than 3 metres. Additionally, habitable spaces, with the exception of the kitchen, must have access to daylight. The net glazing surface area in the habitable space must be minimum 1/5 of the floor surface area unless the glazing surface is located on the roof, in which case the minimum ratio is 1/12.
Apart from the above-mentioned requirements, there are no standards on lighting in residential buildings at the moment. Nevertheless, the Technical-Scientific Centre of Construction (Centre Scientifique et Technique de la Construction) suggested adapting Belgium's standard NBN 12464-1, about lighting in working places, to the needs of residential buildings and providing a reference technical document198.

Moreover, Bruxelles Environnement recommends:

At least 50% (100% in the case of optimal comfort) of "traffic" areas ("zones de circulation") should be partially provided with natural lighting.

At least 20% of glazing surface should be provided for all day and night areas.

An optimum level of comfort should also include a visual perspective (taking into account as a minimum a view angle of at least 90°) of no less than 20m into the courtyard199.

5. State-of-the-Art of nZEB regulation

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
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 (pending final approval). 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, as a result the code includes mandatory renewable energy requirements (for individual house): 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

Country		Description	In favor of BIPV ?
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
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	Yes

	Country	Description	In favor of BIPV ?
		energy.	
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 5.1 Renewable energy requirements in EU countries that can encourage BIPV implementation [12]

This table and the background can be found more in detail in deliverable D2.4.

6. Conclusions

From this study, "European climate zones and bio-climatic design requirements", we can outline several interesting conclusions that will have an impact on the design of nZEB buildings.

1. There are different systems for European climate classification and climate design zones; a uniform system for Europe will be very useful;
2. The EHI and ECI [1,2] fit good with the Köppen-Geiger classification
3. Based on this we proposed an updated the nZEB zoning map [3] and make a new zoning map for nZEB zones;
4. Based on the available information of four main European climate zones we made an overview of nZEB design typologies (see also D2.3);
5. Combined with the regulation in different European countries, we can identify the possibilities and potential for BIPV systems (see also D2.3).

To reach the result mentioned in 3, we combined the Köppen-Geiger classification with the European Heat Index, the European Cooling Index and the nZEB zoning. This actually gives a new nZEB zoning map. Climate borders are different from political borders. So in several countries, there will be different climate zones for nZEB and this could lead to an update of the local rules.

Thermal Comfort Regulation will impact the design of nZEB. It will especially influence the building envelope (thermal skin and quality of windows) and the installations (ventilation). There is no direct relation between these regulations and the application of BIPV. As can be seen in table 4 has the application of BIPV a relation with the nZEB regulation. This relation can be direct (a certain percentage of RES) is given) or can be indirect (a very low indicator that can only be reached by the application of RES). As the nZEB directive is not explicitly in favor of any specific technology, RES can include different systems. The fact is that from a research on nZEB projects, it can be stated that PV systems are used in 70% of the cases. [15]

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[i] The energy-plus building is a passive building (BEPAS) that exceeds its energy needs through renewable energy production like PV systems