How far are Portuguese residential buildings from NZEB?

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Abstract
Aiming to achieve carbon neutrality in 2050 and in line with the goals of the European Union, Portugal has established a set of goals and objectives. To achieve the climate and energy goals, it is important that Portugal promotes a deep renovation of the existing building stock, to gradually complete the decarbonisation of buildings by 2050.

With these objectives in mind, with this work we will present the energy needs for heating and cooling of Portuguese residential buildings for different construction seasons and climatic zones. The construction periods chosen are related to historical milestones in Portugal. The first period matches with the first regulation on energy efficiency in Portuguese buildings (thermal performance of buildings in the 1990's); and the second period, with the implementation of the Buildings Energy Certification System (SCE) in 2013, according to the EPBD recast (2010).

In the first task of this work the Portuguese building stock was characterized and the reference buildings (defined under EPBD 2010/31/EU and Delegated Regulation (EU) 244/2012) were identified. Then, virtual models of the reference buildings were created and occupancy and use profiles more suitable to the national reality were selected, which allowed obtaining the energy needs for heating and cooling under thermal comfort conditions, on an hourly basis, in a dynamic simulation environment (Energy Plus).

The results obtained for the simulated cases in 7 Portuguese cities (including the islands) with different climates and for different constructive seasons reveal that we are in the right way but we need to do more in order to achieve the nearest 2030 goals. At the same time some conclusions are drawn in order to help Portuguese decision makers to implement some policies that can improve faster the way to NZEB buildings.

Introduction
In Portugal, in 2011, the Statistics Portugal (the National Statistical Institute, IP – NSI) conducted the XV general population census and the V general housing census (2011 Census). The publication of the final results of these population and housing censuses provided several relevant information for the characterization of the Portuguese housing stock. According to these data, there were in Portugal 3,544,389 buildings classified according to the time of construction as shown in Figure 1.

At the time of the 2011 Census, in Portugal, 25 % of the existing buildings had been built before 1960, 45 % had been built between 1961 and 1990, and 30 % had been built after 1991. Furthermore, it was found that more than 50 % of the buildings built before 1960 were in need of repair (small, medium and large) or were very degraded; of the buildings built between 1961 and 1990 it was found that almost 30 % were in need of repair.

The building sector is responsible for about 30 % of energy consumption in Portugal (General Directorate of Energy and Geology 2021). In 2019, about 5,968,354 existing housing units contributed to energy consumption and to the greenhouse gas (GHG) emissions (INE 2020).

In Portugal, the Regulation of Thermal Behaviour Characteristics of Buildings (RCCTE), approved by Decree-Law No.

40/90 (Portuguese Government 1990) was an important milestone in the improvement of construction. It was the first regulation to impose minimum requirements to the design of new buildings and major renovations.

The Energy Performance of Buildings Directive 2010/31/EU (EPBD) (European Commission 2010) replaced Directive 2002/91/EC setting a more ambitious framework to improve the energy efficiency of European Union (EU) buildings. The EPBD is the main legislative instrument at EU level to achieve energy performance in buildings. The Directive requires Member States (MS) to establish minimum requirements for the energy performance of newly constructed buildings and existing buildings undergoing major renovations; applies energy performance certificates (EPCs) to buildings; sets the requirement for all new buildings, by the end of the decade, to have nearly zero or very low energy needs and qualify them as nearly zero-energy buildings (NZEB). In 2018 Directive 2010/31/EU was amended by Directive (EU) 2018/844 (European Commission 2018) of the European Parliament and of the Council.

According to Article 2 of the EPBD (European Commission 2010) a NZEB '… means 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 energy from renewable sources produced on-site or nearby.'

The Portuguese Decree-Law No. 118/2013 (Portuguese Government 2013), ensured the transposition of Directive 2010/31/EU, approved the Energy Certification System of Buildings (SCE), the Regulation of Energy Performance of Residential Buildings (REH) and the Regulation of Energy Performance of Buildings for Commerce and Services (RECS) and aims to ensure and promote the improvement of the energy performance of buildings.

The Energy Certificate (EC) is a document that evaluates the energy efficiency of a building on a scale from F (very inefficient) to A+ (very efficient), issued by qualified experts within the SCE. The energy certification of buildings is mandatory in all new buildings and in the case of major interventions and whenever a property is sold or rented. According to the Decree Law 118/2013 (Portuguese Government 2013) new buildings must comply to a minimum energy class of B- while buildings that are subject to a major renovation must comply to a minimum energy class of C.

The Energy Certification System in Portugal does not have defined reference values for each energy class. The Energy Class of a building is determined by the location and orientation of the building, whether it is an apartment or a dwelling, as well as the composition of its shell (walls, roofs, floors and glazing). The equipment associated with air conditioning (ventilation, heating and cooling) and the production of domestic hot water also have an influence. The indicative primary energy values are calculated per m^2 of living area and per year, allowing different housing units to be compared to each other.

Since the implementation of the SCE, until the first quarter of 2021 (ADENE 2021), 1,402,631 ECs have been issued, of which 1,236,975 ECs are for residential buildings. In Figure 2 is represented the distribution of the residential buildings ECs issued by energy class. Of these, 30.8 % correspond to buildings classified as at least efficient (classes B- to A+), while the remaining 69.2 % correspond to buildings classified as not very efficient (classes C to F).

The NZEB concept, applicable under national law, has different rules for residential or commercial buildings. According to Ordinance No. 98/2019 (Portuguese Government 2019a), to be a NZEB, a residential building must meet the following requirements:

- The value of the nominal annual needs of useful energy for heating (N_{ic}) for NZEBs shall be less than or equal to 75 % of its maximum value (N_i);
- The nominal value of the primary energy needs (N_{tc}), for NZEBs shall be less than or equal to 50 % of the maximum reference value (N_t), ensuring an energy class A;
- Renewable energy sources shall ensure at least 50 % of the annual primary energy needs.

Within the scope of the Directive (EU) 2018/844 of the European Parliament and of the Council (European Commission 2018), Article 2.º-A imposes that MS shall draw up a Long-Term Strategy for the Renovation of Buildings (LTSR) in order to promote the renovation of the housing stock. Approved by the Resolution of the Council of Ministers No. 8-A/2021 (Portuguese Government 2021a), the Portuguese Long-Term Strategy for the Renovation of Buildings (ELPRE) establishes the indicative objectives for the horizons of the decades 2030, 2040 and 2050, compared to the 2018 registers, by reference to the entire national stock of existing buildings:

- Renovated building area, in the proportion of 363 680 501 m^2 for 2030, 635 637 685 m^2 for 2040 and 747 953 071 m^2 for 2050;
- Primary energy savings of 11 % for 2030, 27 % for 2040, and 34 % for 2050;
- Reduction of hours of discomfort in housing, by 26 % for 2030, 34 % for 2040, and 56 % for 2050.

ELPRE classifies thermal comfort as an energy renovation criterion for residential buildings. In this sense, to ensure acceptable comfort conditions, existing buildings have to reach category III according to the European Comfort Standard EN 15251:2007 (EN 15251 2007).

The Renovation Wave Strategy (European Commission 2020) to improve the energy performance of buildings, aims to at least double renovation rates in the next ten years and make sure renovations lead to higher energy and resource efficiency. But only 1 % of buildings undergo energy efficient renovation every year, so effective action is crucial to making Europe climate-neutral by 2050. According to the Buildings Performance Institute Europe (BPIE): '… to be aligned with the 2030 Climate Target, the European Commission should correct the Renovation Wave headline ambition in terms of targeted annual renovation rates, aiming at reaching an annual deep renovation rate of 3 % by 2030' (Buildings Performance Institute Europe 2021).

The data published in the SCE portal [ADENE 2021] allow for the quantification of the ECs issued by energy class. In Portugal there are about 157,049 NZEBs (12.7 % of the 1.2 M ECs assigned to residential buildings), corresponding to about 2.63 % of the housing stock. The amount of NZEBs

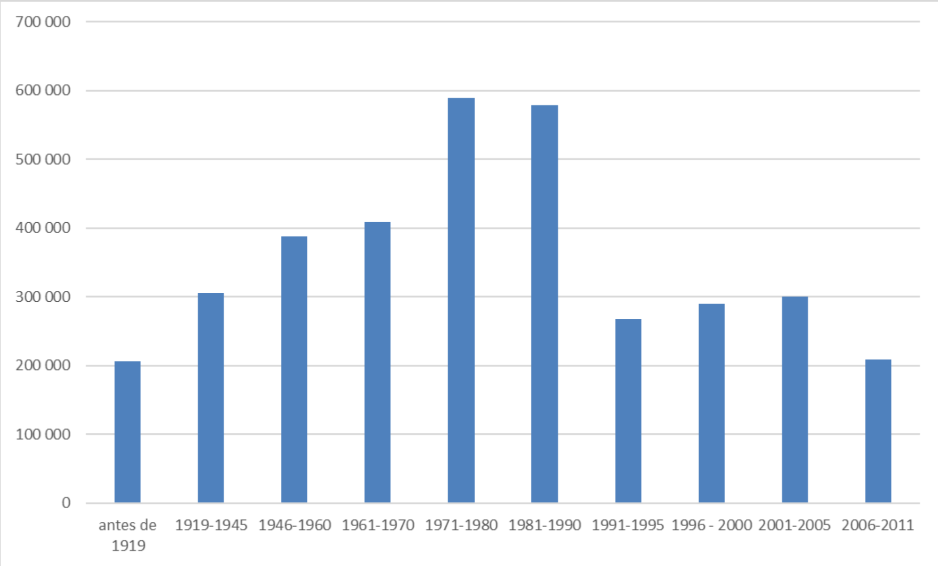

Figure 1. Buildings according to the time of construction [INE 2012].

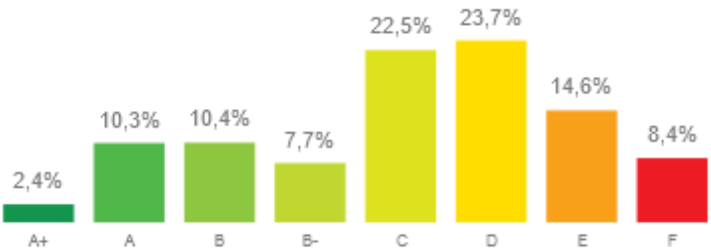

Figure 2. Energy Certificates issued by class [ADENE 2021].

was achieved with the contribution of new buildings, major refurbishments and some existing buildings. Based on data from the SCE portal (referring to the 1.2 M ECs assigned to residential buildings), there was an increase in new buildings accounting for about, 21.62 % in 2018, 26.75 % in 2019 and 30.86 % in 2020. As for major refurbishments, there was also an upward trend, accounting for about 5.11 % in 2018, 6.02 % in 2019 and 6.58 % in 2020. For existing buildings, the scenario is completely different, about 97.3 % of certified buildings are not NZEB.

With the goal of achieving carbon neutrality by 2050 and in line with the European Union's targets, Portugal has established a set of goals and objectives for the 2030 horizon. The National Energy and Climate Plan (PNEC 2030) published through the Council of Ministers Resolution no. 53/2020 (Portuguese Government 2020), articulated with the Roadmap for Carbon Neutrality 2050 (RNC 2050), published through the Council of Ministers Resolution no. 107/2019 (Portuguese Government 2019b), aims to achieve the energy and climate goals and targets set for Portugal in 2030.

There are several financing instruments available to citizens and companies that aim to promote an economic, social, and territorial development policy in order to contribute to the achievement of national energy and climate targets and objectives. With national/European financing we have the following financing mechanisms:

- Efficient House 2020 (Efficient House 2020): Aimed at providing soft loans for operations that promote the improvement of the environmental performance of private housing buildings, with a special focus on energy and water efficiency, as well as urban waste management. The promoter of this program is the government and has an allocation of M€ 200 for the period 2018 to 2021.
- Program in Support of More Sustainable Buildings (PAE+S) (Environmental Fund 2020): a set of incentives for the promotion of energy efficiency in buildings and their decarbonization. Aimed at individuals who own residential units or buildings built up to the end of 2006, this program will allocate €4.5 million in 2020 and 2021 (€1.75 million in 2020 and €2.75 million in 2021).
- Plan to Promote Efficiency in the Consumption of Energy (PPEC) (ERSE 2017, 2021): To promote measures aimed at improving efficiency in electricity consumption, through actions undertaken by the various agents in the sector (from suppliers to consumers).
- Sustainability and Resource Efficiency Operational Program (PO SEUR): Contribute to the priority of sustainable growth, responding to the challenges of transition to a low carbon economy, based on a more efficient use of resources and promoting greater resilience to climate risks and disasters.

Methodology

The methodology used in this work comprises the following steps: identification of the reference buildings and their main characteristics; selection of the profiles best suited to the national reality (occupancy, lighting and domestic hot water heating); creation of the virtual building models based on the data collected and perform dynamic thermal simulation using Energy Plus software to obtain the energy needs for heating and cooling of the archetypes in 7 regions of Portugal. After that we will try to "measure" how far we are from NZEB buildings in Portugal and identify some ways/policies to overcome this problem.

The identification and characterisation of the reference buildings was made according to statistical data of buildings in Portugal, and according to the methodology defined by the EPBD 2010/31/EU and Delegated Regulation (EU) 244/2012. Then, only buildings built between 1961–1991 and buildings built after 2013 were selected, in order to estimate the energy needs of buildings built before the thermal legislation in Portugal (about 45 % of the building stock in 2011) and buildings built according to the current thermal legislation (with minimum thermal requirements). The virtual models of the reference buildings were created on EnergyPlus and occupancy and use profiles more suitable to the national reality were selected, which allowed obtaining the energy needs for heating and cooling under thermal comfort conditions, on an hourly basis.

The task of profiles selection takes some time and careful reflection, knowing the important impact that these have on the final energy needs of the building. The occupancy profile establishes the occupation regime of the dwelling, the number of occupants present in the dwelling throughout the day and allows accounting for the internal gains derived from their metabolic activity. The profile referring to the use of lighting characterizes the use of lighting systems throughout the day, this profile was obtained from the data of (Remodece 2008). These profiles allow the proper assessment of the internal gains from the dwelling occupancy. The Domestic Hot Water (DHW) profile was obtained from (Portuguese Government 2013) based on a reference of 40l/person per day.

After creating the virtual models of the selected buildings, the next step is to perform dynamic simulations for the different climate zones chosen. The results obtained determine the estimated energy needs for heating, cooling and DHW for each case study. The results obtained allowed us to draw conclusions about the impact of energy performance regulation in buildings, identify how far we are from NZEB and try to understand the best way to get there.

Energy consumption of residential buildings in Portugal

The Directive 2010/31/EU (EPBD) proposed the development of a comparative methodology framework to calculate the cost-optimal levels of minimum energy performance requirements for buildings and their components (European Commission 2010). The Delegated Regulation (EU) No. 244/2012 complemented the EPBD and specified rules for comparing the cost-effectiveness of energy efficiency measures and the use of renewable energy sources in new and existing buildings (European Commission 2012a). According to the guidelines accompanying Commission Delegated Regulation (EU) No. 244/2012, a reference building is mainly intended to represent the typical and average existing building stock, as it is impossible to calculate the cost-optimal situation for each and every building. This document also contains recommendations for the selection of the reference buildings (European Commission 2012b).

Portugal has defined the reference buildings for single-family and multi-family buildings (or apartment blocks) for each of the following building epochs:

- Buildings constructed before 1960;
- Buildings constructed between 1961 and 1990;
- Buildings constructed between 1991 and 2012;
- Buildings constructed after 2013.

The definition of the reference buildings by construction period for Portugal involved the characterization of the buildings by dimensional parameters and by thermal parameters of the construction elements. The dimensional characterization of the reference buildings for both single-family and multifamily buildings is shown in Table 1, for two distinct construction periods. The full characteristics of the reference buildings are available at (Pinto & Fragoso 2018).

The thermal transmittance coefficient U is used to characterize the building elements of both categories of reference buildings (Table 2). For the buildings built between 1961 and 1990, a single set of representative parameters is used to characterize the different building elements for all climatic regions of the country. These parameters are representative of the constructive solutions used at the time, such as: simple wall of 22 cm holed brick masonry, plastered on both sides, with a total thickness of 26 cm; sloping roof covered with ceramic tile, light ceramic block slab 15 cm thick and 2 cm stucco ceiling coating, strongly ventilated attic; and single-glazed sliding metal win-

Table 1. Dimensions of the reference building.

Reference Buildings	Single-family		Multi-family	
	1961–1990	After 2013	1961–1990	After 2013
Typology	three bedroom	three bedroom	two bedroom	three bedroom
Living space floor area (m^2)	100	165	70	105
Building envelope area (m^2)	308	361	134	183
Roof area (m^2)	100	82,4	70	105
Window area (m^2)	15	33	10.24	16.74

Table 2. Thermal characteristics of the reference buildings.

Reference Buildings		Between 1961 and 1990	After 2013 (reviewed 2016)					
			Mainland			Islands		
Parameter	Unit		I1	I2	I3	I1	I2	I3
U_{wall}	W/(m².ºC)	1.76	0.4	0.35	0.3	0.8	0.6	0.45
U_{roof}	W/(m².ºC)	2.8	0.35	0.3	0.25	0.45	0.4	0.35
U_{floor}	W/(m².ºC)	2.1	0.35	0.3	0.25	0.45	0.4	0.35
U_{window}	W/(m².ºC)	4.1	2.8	2.4	2.2	2.8	2.4	2.2
$g_{glazing}$	–	0.85	0.75	0.75	0.75	0.75	0.75	0.75
g	–	0.3	0.04	0.04	0.04	0.04	0.04	0.04
Rph	(h^{-1})	0.4/0.6	0.4/0.6	0.4/0.6	0.4/0.6	0.4/0.6	0.4/0.6	0.4/0.6

Table 3. Climatic data of each Portugal region in study.

Regions of Portugal	Climate Zones		Heating Degree Days (T_{base} 18 ºC) (ºC day)	Average Outside Temperature (ºC)	
	Winter	Summer		Winter	Summer
Bragança	I3	V2	2,015	5.5	21.5
Porto	I1	V2	1,250	9.9	20.9
Coimbra	I2	V2	1,304	9.7	20.9
Lisboa	I1	V2	1,071	10.8	21.7
Faro	I1	V3	987	11.3	23.1
Ponta Delgada	I1	V2	604	14.4	21.3
Funchal	I1	V2	818	14.8	20.2

dows without thermal break, global solar factor with mobile and fixed protection activated of 0.30 and shading by opaque light-coloured interior shutters.

For more recent buildings, built after 2013, it is necessary to have different sets of parameters according to the location of the buildings, whether they are located on the mainland or on the islands and according to the severity of the climate in that region. These parameters are in accordance with the minimum requirements for the thermal transmittance U, defined on the REH for the different climatic regions. The constructive solutions used in this type of buildings are: double wall of brick masonry (with insulation in the air gap) or simple (with insulation on the outside) and inclined roof with concrete structure with insulation above the slab, the insulation must have the necessary thickness to comply with the thermal transmission coefficient defined in the REH; and double-glazed windows (thermal cut aluminium or PVC), global solar factor with mobile and fixed protection activated of 0.04 and shading by exterior plastic shutters.

The climatic conditions of each region influence the thermal behaviour of the building and the performance of the systems. To represent the different climatic conditions existing in Portugal, 7 different locations were considered (Table 3). Data regarding climate zone (winter and summer), heating degree days and average outside temperature (winter and summer) were collected from 5 cities in continental Portugal and from each most populated city of each national autonomous region.

The classification into winter and summer climate zones is defined by heating degree days ($HDD_{Tbase18}$) and average outside temperature during summer ($T_{ext, Summer}$). Thus, classification as winter climate zone I1 is obtained when $HDD_{Tbase18} \leq 1{,}300$, as zone I2 if $1{,}300 < HDD_{Tbase18} \leq 1800$ and as zone I3 when $HDD_{Tbase18} > 1800$. Whereas classification as summer climate zone V1 is obtained when $T_{ext, Summer} \leq 20$ °C, as zone V2 if 20 °C $< T_{ext, Summer} \leq 22$ °C and as zone V3 when $T_{ext, Summer} > 22$ °C (Aguiar 2013).

Based on all the parameters described above, the virtual modeling of the buildings has been done using the Energy Plus software, in order to perform dynamic thermal simulation case by case. In Table 4, there is a summary of the estimated energy needs for each case, under thermal comfort conditions, for the regions that have been investigated in the study.

For the representative constructive solutions of each construction period, the minimum requirements imposed by regulations are preponderant factors in the thermal performance of buildings. In addition, the climatic conditions of the various regions of Portugal have a great influence on the thermal behavior of buildings, as proven by the results obtained in the various simulations performed (Table 4).

Table 4. Synthesis of the results (energy needs in kWh/m²/year) obtained, for the reference buildings, in the 7 climate zones.

Climate Zones	Single-family						Multi-family					
	Between 1961 and 1990			After 2013			Between 1961 and 1990			After 2013		
NUTS III	Heating	Cooling	D.H.W.	Heating	Cooling	D.H.W.	Heating	Cooling	D.H.W.	Heating	Cooling	D.H.W.
Bragança	140.5	4.9	23.8	54.3	8.7	14.4	102.3	26.0	25.5	44.2	1.2	22.6
Porto	67.7	2.4	23.8	26.2	4.2	14.4	52.4	24.6	25.5	19.0	2.1	22.6
Coimbra	67.7	2.4	23.8	26.2	4.2	14.4	52.5	26.0	25.5	18.8	2.6	22.6
Lisboa	49.8	1.7	23.8	19.2	3.1	14.4	38.8	29.7	25.5	12.1	4.0	22.6
Portimão	40.2	1.4	23.8	15.6	2.5	14.4	31.9	40.3	25.5	8.8	6.5	22.6
Ponta Delgada	25.1	0.9	23.8	9.7	1.6	14.4	17.7	19.3	25.5	4.4	4.9	22.6
Funchal	20.6	0.7	23.8	8.0	1.3	14.4	16.4	8.7	25.5	4.0	2.5	22.6

The key factor in reducing energy needs is, without any doubt, the improvement of the passive building envelope conditions. The introduction of thermal insulation in the walls, roof and floor, together with the adoption of more efficient windows, with double glazing and thermal break frames, complying with the minimum requirements imposed by the regulation, greatly contributes to improve the energy performance of the buildings.

Existing Policies

Over the years, several programs and plans have been implemented in order to improve energy efficiency and to contribute to pursuit some energy and environmental policy goals in Portugal. The following is a brief review of two programs with measures targeting the residential sector; the PPEC, released in 2006 and already with several editions, and the PAE+S, a support program that had its first edition in 2020.

The PPEC aims to promote measures to improve efficiency in electricity consumption in industry and agriculture, commerce and services, and residential. In the 2017–2018 PPEC edition, only around 3 million Euros (of the total available budget of €23 million) was allocated to the residential segment. According to the evaluation criteria of the measures of this PPEC edition (ERSE 2017), the residential segment presented higher values for the cost-benefit ratio (CBR) in all aspects of evaluation, from the point of view of the plan (PPEC CBR), consumer (participating CBR) and social (social CBR). Revealing that the energy efficiency measures implemented in the residential sector are extremely beneficial to the electricity sector, to the consumer, and to the environment.

It is important to mention that from all the selected measures, only one is aimed at improving the building envelope and this was the last measure selected (for the residencia sector) and was co-financed by only 53 %. Analyzing the measures selected in previous editions of PPEC, it was clear that there were no measures to improve the building envelope, revealing that in recent years there were no incentives directed to measures aimed at reducing the energy needs of buildings. Measures targeting active systems usually present higher scores and thus are designed, proposed and selected for the PPEC plan.

The PAE+S aims to finance measures that promote rehabilitation, decarbonization, energy efficiency, water efficiency and circular economy in buildings, contributing to the improvement of the energy and environmental performance of buildings. This program is aimed at existing and occupied residential single-family buildings, autonomous fractions in multi-family buildings, or multi-family buildings, built prior to 2006. In its first edition, PAE+S was allocated €4,500,000 (€1,750,000 in 2020 and €2,750,000 in 2021), with a co-funding rate of 70 % but with a maximum limit per measure on which the co-funding will be made (Environmental Fund 2020).

This plan is directed only to residential buildings, allowing to support measures that aim for improving the opaque envelope (application of thermal insulation in the roof or floors and exterior or interior walls), in the glazed envelope (purchase of efficient windows, class A+ or higher), in active systems (heating and/or cooling and DHW), renewable energy production (photovoltaic systems), water efficiency and interventions that promote the incorporation of biomaterials.

In these programs and plans aiming at improving for energy efficiency, the budget is usually small, although the selected measures have higher CBR's associated to a very low cost of saved energy values. On the other hand, it is worth highlighting support packages exclusive to a certain sector, such as the PAE+S, directed to the residential building sector, in particular, to those built before 2006. It is important to create specific programs aimed at reducing the energy needs of buildings through measures targeting the building envelope, as demonstrated in the previous chapter. The results obtained from the dynamic simulations carried out allow to conclude that it is possible to reduce the energy needs even further, so adjustments to the existing regulations can be made. The simulation results show the differences between the energy needs of an existing building (built between 1960 and 1991) compared to a new building (built according to the REH); the difference in performance represents the potential for implementing energy efficiency measures in the existing building. With a very high number of buildings with poor energy performance (according to the SCE available data), for the intended building stock renovation, specific measures and more funding are crucial.

The regulation for PPEC 2021 have already been approved (ERSE 2021), this new PPEC edition support and encourage the implementation of measures to improve efficiency in electricity and gas consumption. The plan maintains its competitive nature, providing for the selection of measures based on their merit according to the level of savings to be achieved and should be launched later this year.

The Recovery and Resilience Plan (RRP) is a national application under the Portugal 2030 Strategy and is based on three structuring dimensions: resilience, climate transition and digital transition (Portuguese Government 2021b). With a budget of about €14,000 M in subsidies, with an implementation period until 2026, the RRP is an ambitious plan and with strategic relevance, allowing the resume of sustained economic growth, thus strengthening the goal of convergence with Europe over the next decade.

Based on the climate transition theme, €620 M of investments are planned to promote energy efficiency in buildings. Under the responsibility of the Environmental Fund (Environmental Fund 2021), these investments will be divided into: €300 M in energy efficiency in residential buildings; €250 M in energy efficiency in central public administration buildings and €70 M in energy efficiency in service buildings.

The implementation of ELPRE will be leveraged by the RRP, within the scope of the Next Generation EU, which provides for an investment of €620 M between 2021 and 2026. ELPRE has set very ambitious short-term (2030) targets for the renovation of the residential sector. For the next decade this strategy foresees the renovation of 70 % of the existing buildings, which corresponds to a renovated building area of 299,524,729 m^2, a primary energy saving of 15 % and a reduction of discomfort hours of 26 % (Portuguese Government 2021a). Based on data from the SCE portal (referring to the 1.2M ECs assigned to residential buildings), for existing buildings, about 97.3 % of certified buildings are not NZEBs, from those 88.6 % correspond to buildings classified as not very efficient (classes C to F). In recent years, there has been an increasing trend in the number of major renovations until the year 2020, as shown (in blue) in Figure 3. The decrease in the number of building renovations in the year 2020 can be explained by the impact of the COVID-19 pandemic. For 2021, also due to the coronavirus pandemic, is expected a final number of renovations lower than the trend registered previously.

Using excel's FORECAST function, which allows to predict a future value based on existing (historical) values, a forecast of the number of building renovations up to 2050 was obtained. The forecast of major renovations until 2050, represented (in orange) in Figure 3, shows an increase in the number of major renovations in the coming years based on the data registered until 2020. Although the forecast is positive, analyzing the forecast data on a cumulative basis, it shows only a total of 0.29 M major renovations. This is extremely low compared to the targets proposed in ELPRE.

Conclusions

According to the 2011 census and also taken into account the yearly estimates on completed constructions the Portuguese housing stock is too old and was mostly built prior to the emergence of legislation on thermal requirements the potential for improvement is huge and strong and effective measures targeting both new and existing buildings are needed.

Encouraging, in a large scale, the energy certification of the buildings in Portugal, would allow both a deep knowledge of

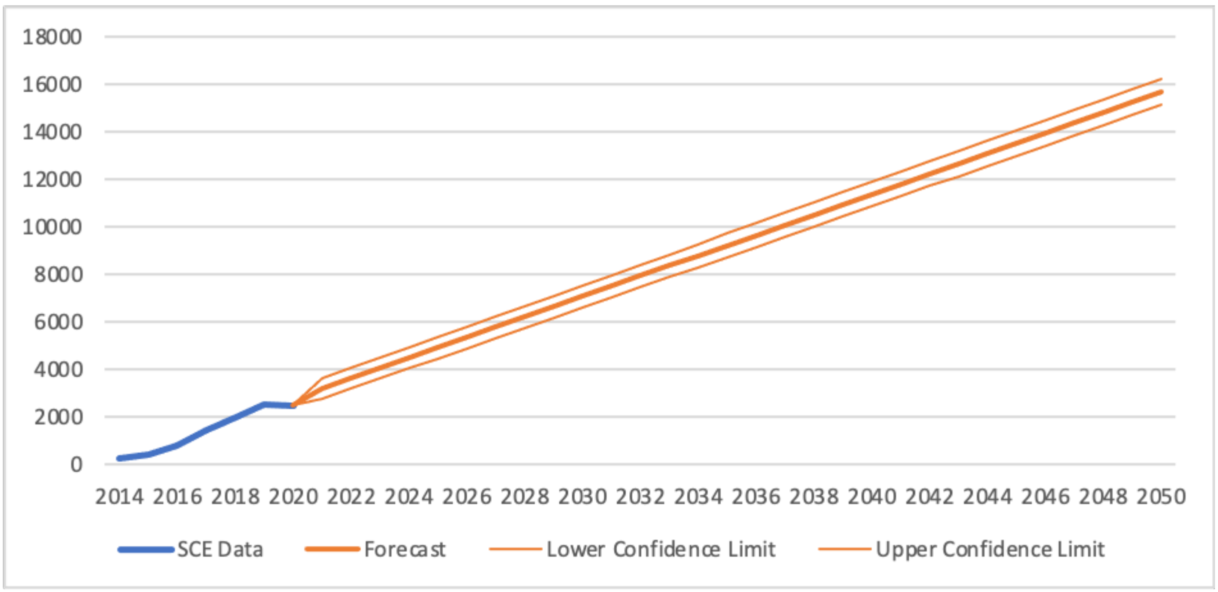

Figure 3. Forecast of the number of building renovations up to 2050 based on the SCE portal data.

the real situation of the building sector and the design of specific incentive programs and measures. This would contribute to an adequate formulation of energy policies to support the deep renovation of the existing building stock; however, a second crucial issue is the funding.

After scrutinizing the energy efficiency support programs in Portugal, it is obvious that, in the recent years, energy policies neglected energy efficiency measures that act directly on the passive behavior of buildings. It is necessary to change the way energy efficiency candidature measures are assessed or create specific funding programs that target the building's envelope.

The simulation results make evident the potential energy savings that can be obtained through the implementation of measures at the building envelope level, comparing a building constructed in an era before the existence of legislation with a building constructed today (meeting the minimum requirements imposed by legislation).

The data published by the Portuguese Energy Agency (ADENE) in the SCE portal allow for the quantification of the ECs issued by energy class in Portugal. Based on this data, there are in Portugal about 157,049 NZEB's, corresponding to 12.7 % (A+ and A class) of the EC's assigned to residential buildings. With the entry into force of the EPBD (EPBD 2018) it became mandatory that all new buildings constructed from January 1, 2021, are NZEB's. With this imposition it is expected that the number of NZEB's in Portugal will increase at a good pace in the coming years, however, there is much to do in relation to existing buildings.

We are in the right way to achieve NZEB in residential buildings in Portugal, but at a somewhat slow pace. Buildings with energy certificate A or A+ are to be considered NZEB. As we show the majority (87.3 % of the 1.2 M certified buildings in Portugal) are not in these classes. So, the energy needs in residential buildings for heating, cooling and DHW have to continue to decline. This can only be obtained with more and substantial incentives/policies and also more focused ones. New policies and incentives in Portugal are welcome! The strategy must be the same (equal) that the one followed by the introduction of renewables in Portugal ("strong and aggressive").

In addition to incentives/policies, it is also important to facilitate access to tax benefits for owners who invest in energy renovation of buildings. Given the changes that are coming in the next few years with the energy transition in buildings, it will be important to disseminate best practices and promote training actions, for the population in general and also for the agents directly involved in these processes.

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