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Implementation and Challenges of the Passive House Concept in Portugal: Lessons Learnt from Successful Experience

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Abstract: The European Green Deal defined by the European Commission on December 2019 presents an ambitious set of measures for the European Union and its citizens to accomplish the challenge of climate change, making Europe until 2050 the first neutral continent, where there are no net emissions of greenhouse gases. The Passive House (PH) concept has the same ambitious goal, targeting the reduction of the carbon footprint while promoting a construction design that gives primacy to the optimum energy balance, assuring comfort and quality with a minimum impact on the final building cost and operation. However, the PH concept is still not an easy process to implement in the traditional construction sector, especially in South European territory, as is the case of Portugal. Contextually, the present study through the discussion of a case study research method applied to European PH successful experience, has defined guidelines for the implementation of this concept within sustainable development principles. The methodology strategy starts with the information collection from Hanover, Brussels, and Tyrol case studies. Then, a statement regarding the current situation of Portugal in respect of the PH numbers and policies was performed. Moreover, the information gathered, as well as the experience of learnt lessons, were compared to the Portuguese reality. As a final procedure, barriers and obstacles for the Portuguese case have been identified through the analysis and understanding of the country's social dynamics, and also with the crossing of sustainable development principles. Thus, the present research enables us to propose guidelines to increase the PH implementation in Portugal.

Keywords: public policies; social dynamics; territorial governance and management; urban planning; energy efficiency; Passive House

1. Introduction

Several authors have stated Passive House (PH) as the reference standard for energy efficiency in buildings, reducing its ecological footprint [1–3]. The standard is not limited to a specific type of architecture, building typology, or use. The concept has been applied to real executed residential and office buildings, schools, day-care centres, supermarkets, churches, etc. It comprises an innovative design, apart from the conventional methodologies and technologies in architectural design, implying deep changes. Thus, an evolution in the construction sector is mandatory towards innovative buildings, achievable with the application of key enabling technologies with new and improved resources, designed on the basis of people's quality of life, and aligned with the EU strategic energy and sustainable development goals.

According to the Portuguese Directorate General for Energy and Geology (DGEG) [4], the building sector is responsible for consuming 40% of the final energy in Europe, and about 30% of the final energy in Portugal. Thus, more than 40% of this consumption of final energy can be reduced through the application of energy efficiency procedures, representing an estimated annual reduction of 400 million tons of CO_2 emissions, targeting almost the total commitment of the EU (European Union) in the scope of the Kyoto Protocol. Moreover, according to the Intergovernmental Panel on Climate Change (IPCC) [5], the building sector represents the largest unexplored source of cost-effective energy saving and greenhouse gases (GHG) reduction potential in Europe. For all these reasons, the need for the development of construction techniques and an evolution towards the implementation of strategies that result in sustainable buildings as well as energy efficiency with high thermal comfort and indoor air quality (IAQ), while reducing GHG emissions is perfectly clear. In this context, the PH standard stands out as the design tool with the most potential towards energy efficiency in the building sector, with stricter requirements regarding the thermal comfort, energy efficiency, and IAQ.

2. State-Of-The-Art

2.1. Territorial Governance and Public Policies: A Brief Overview

2.1.1. Portugal—Country Overview

Portugal has a resident population of 10.031 million people [6]. Geographically, Portugal has an approximate area of 92,226 km^2 and is situated on the west coast of continental Europe [6–8]. The climate is classified by warm temperatures and hot summers (Csb) in the central and north regions of the country, and warm summers in the south (Csa), according to Köppen classification. November and December are the wettest months, and the driest periods occur between April and September [9].

In 1955, Portugal became a member of the United Nations and since 1986 a member of the EU, also being one of the founding members of NATO, eurozone, and the Organisation for Economic Co-operation and Development (OECD). Portugal is ranked 26th of 167 in the global Prosperity Index (PI) ranking [10]. The PI could be defined as a practical tool developed to help identify what specific actions need to be taken to contribute to strengthening the pathways from poverty to prosperity.

Regarding the government, Portugal is a parliamentary republic, based on the constitution established in 1976 and amended in 2005. Sovereignty is exercised by the President of the Republic, the Assembly of the Republic, the government and the courts. The democratic organisational structure of the state includes the existence of local authorities: Parishes, municipalities, and administrative regions responsibly by the obligation to comply with the standards regarding the private and public urban building sector [11]. Regarding the town and country planning instruments, the state is charged with programming and implementing a housing policy supported by urbanisation plans. At the national level, the supervision of the Energy Certification System (in Portuguese, the abbreviation is SCE) is assumed by the DGEG, and its management is assured by the Energy Agency (ADENE). The core competencies of ADENE also include policy implementation, and programs and strategic measures for energy efficiency and dissemination [12].

2.1.2. Construction Sector

Nowadays, the past 2010 economic crisis is still affecting the Portuguese construction sector. The number of companies working in the building construction sector in 2016 dropped to 147,149, representing 18.9% below the 2010 level, despite a slight increase (+0.6%) that occurred over 2014–2015. It is also known that the production in the construction of buildings dropped 45.0%, and in civil engineering by 50%, over 2010–2016. In general, a total turnover in 2016 amounted to EUR 32.1 billion, 37.9% lower than 2010, signalling a severe profitability loss. However, this value represents 1.9% of the increase when compared to 2015 values, highlighting a reversal of the downward trend [13].

In 2016, a total of 11,344 new buildings were built, which represents a good indicator of the economy recovering in the sector, although still considerably below the 2001 peak, showing that the residential sector has suffered considerably from the crisis. Housing availability and accessibility became an important issue, in which 58% of the young people aged between 18–34 are still living in their parent's houses, and only 2% of the housing stock are being rented through social/supported leases [13].

Portugal is in line with the European goals, in the field of sustainable construction and energy efficiency. Such initiatives include the Energy Efficiency Fund, which co-finances the energy efficient renovation of buildings, as well as energy efficiency measures in transport infrastructure. The upcoming EUR 100 million scheme Efficient House (in Portuguese, *Casa Efíciente*) will also grant loans to finance energy efficiency interventions on at least 100,000 buildings [13].

2.1.3. Public Policies on Portuguese Thermal Regulation

Despite the economic situation and regarding the energy efficiency European goals, Portugal is aligned with the EU goals. An energy policy with a strong emphasis on energy efficiency and in promoting renewable energies, ensuring the continued transposition of the European Directives' goals into national legislation (Figure 1) has been implemented.

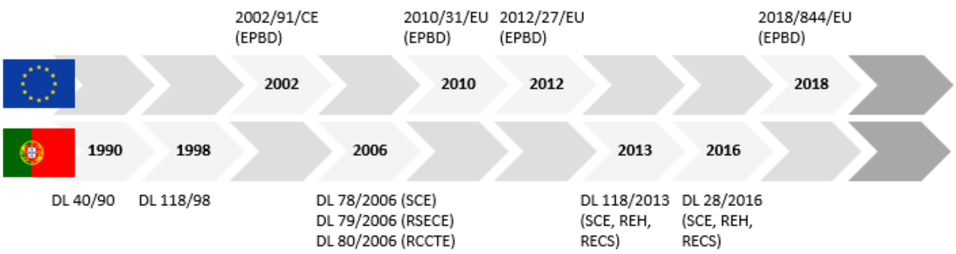

Figure 1. Timeline of the evolution of the European Directives and Portuguese thermal regulation.

Directive 2018/844/EU (recast), from 9 July 2018, amends the existing Directive 2010/31/EU and Directive 2012/27/EU and represents the first of the eight legislative actions to be adopted in the Clean Energy for All Europeans package. It introduces targeted amendments to Directive 2010/31/EU, aimed a faster renovation of existing buildings, with the goal of a decarbonised building stock by 2050 and the mobilisation of investments. Thus, Member States have until 10 March 2020 to transpose its provisions into national law [14].

Portugal is far from their savings requirement [15], with the energy savings achieved between 2014–2016 of only 38% against the expected savings.

2.1.4. Energy Context

The Portugal energy transition from fossil to organic fuels has been one of the last when compared with other EU countries. In recent decades, Portugal's energy dependence has ranged from 80% to 90% of the total energy consumed. However, the current focus on endogenous renewable energy to reduce the hydrocarbon imports as well as to reduce the dependence on imported fossil fuels has led to declining carbon dioxide emissions in the electricity sector (Figure 2). Additionally, the trend in residential building for heating zones has been reduced by 35% since 2000. These reductions in heating demand were mostly due to better insulation of buildings, refurbishment of old buildings, and improvements in the efficiency of the equipment for heating and cooling [16]. In the global context, the energy demand for buildings—and particularly electricity consumption for heating and cooling, as well as other appliances in buildings—is now growing faster than decarbonised power, leading to a resurgence in buildings-related emissions.

Regarding building sector technologies, only lighting is on track to meet the Sustainable Development Goals (SDG), while building envelopes and equipment for heating are well off track; cooling and appliances are both showing improvement, but significant policy effort will be needed to place these technologies on the track of the SDG [17].

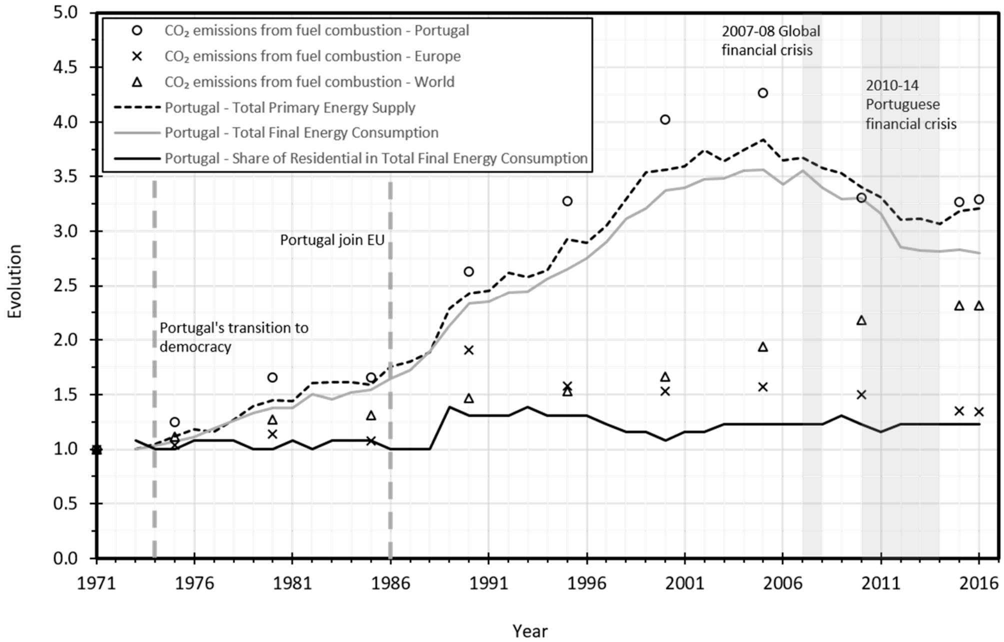

Figure 2. Energy evolution from 1971 to 2016 (based on [18,19]).

2.2. *The Social Dynamics in Portugal*

Society has been defined by its own cultural traditions, social identity, and collective memory. These are the social links of a common past that brings balance for societies. On the other hand, it is changing over the time, evolving the relationships between internal and external factors conducting to a social progress. Demography, economy, policies, and urban planning play a significant role in territory and landscape transformations, as well as on environment and ecology changes. The relationship between natural and urban systems are, according to Castanho et al. [20], part of the same space whose integrated management is a requirement and a sustainability condition of the territories and cities.

Architecture and building techniques are defined by the social identity and cultural tradition, as well as the social progress and sustainability concerns. In this perspective, focusing on Portugal's mainland, Portuguese traditional construction techniques have evolved accordingly with the social transformations in the former decades, slowly adapting the thermal comfort and IAQ requirements for buildings [21].

Despite the Portuguese regulation related to the energy performance of buildings since 1990 with the Portuguese Decree Law 40/90, integrating the European Community and the transposition of the European Directives regarding energy efficiency and sustainability concerns to the national legislation were the first step towards the social and cultural transformation of Portuguese traditional construction techniques.

Economic and social conditions are the main factors in social dynamics, and consequently they have a significant importance on construction sector and its developments. The Portuguese economy and demography have experienced several setbacks over the past decades, particularly from 2007 to 2012/2014, with direct implications on the resident population: The unemployment index; the gross of domestic product; and especially in the real estate market prices. During the last economic crisis, from 2007 to 2012/2014, the prices evolution has a significant increase. Figure 3 depicts the evolution curves of the demographic and economic evolution in Portugal's mainland according to the Portuguese National Institute of Statistics [6].

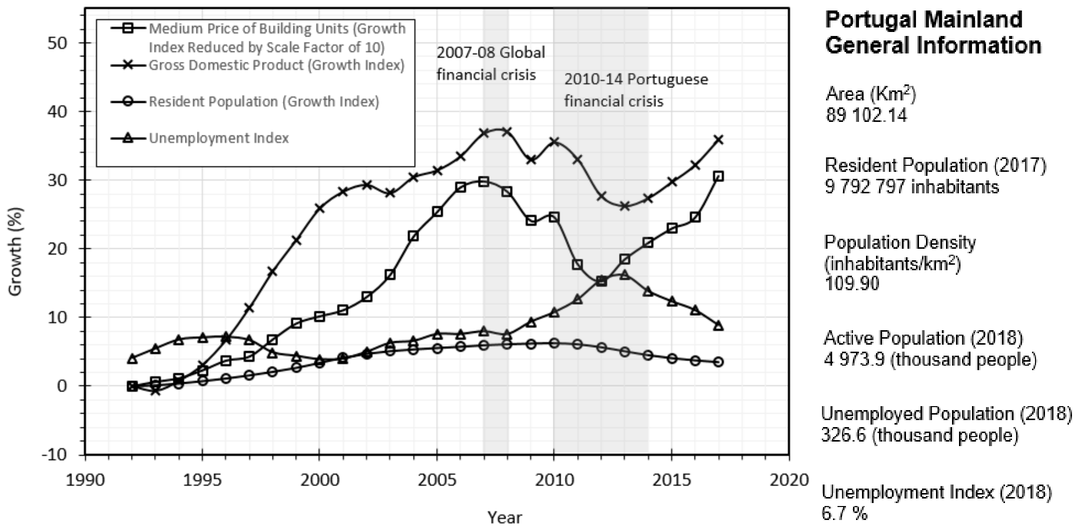

Figure 3. Portuguese indicators evolution of demographic and economic growth (1992–2017). Source: Portuguese National Institute of Statistics [6].

Active measures focusing the implementation of energy efficient strategies are being developed by the EU, in order to support and promote the urban rehabilitation, support the revitalization of the cities, and encourage the energy efficiency in buildings among its State Members. One of this measures takes place through financial programs such as the IFRRU 2020 [22] for Portugal, which consists of a financial instrument comprising different funding from Portugal 2020 and other European entities, intending to improve investment for energy retrofit from the building to urban level.

Establishing specific goals for energy efficiency is another strategy developed by the EU. This measure is the origin of the Portuguese National Action Plan for Energy Efficiency (PNAEE) [23] and intends to reduce the primary energy consumption, to reduce the GHG emissions, and to increase the use of renewable energy sources as well as the promotion of the energy efficiency. The main objective of the PNAEE is to make energy efficiency the priority for energy policies through the regulation and policy making for systems, products, and buildings efficiency and its certification, and with financial instruments and funding programs that specifically focus the investment on energy efficiency solutions. The Energy Efficiency Fund (FEE) [24], the Portuguese Carbon Fund, and other financial programs within Portugal 2020 are examples of these funding programs.

According to Ian Williams [25], sustainable urban development starts by promoting the citizens' wellbeing. A truly sustainable city would involve an integrated and green environment with attractive housing, working, and living conditions for all sectors of the society. Proper housing conditions are essential for attractive and liveable cities, and therefore achieving and maintaining the social cohesion. Thus, it is vital to build a modern resource-efficient infrastructure based on renewable energy sources as well as increasing the circular economy of materials. A proactive leadership is paramount to anticipate shocks and understand the long-standing vulnerabilities experienced due to urban stresses. Thus, political leadership might be resistant to new measures and institutional arrangements, since long experienced stresses could not be perceived as "urgent matters" to take into consideration for investing public resources. Nevertheless, to expand the understanding of risks is of great importance in order to achieve a better preparation, as well as to continue raising awareness about resilience, facilitating populations, governments, and businesses in making the right decisions in light of all pertinent information. Finally, sharing research results is crucial to help governments, decision-makers, and civil society to craft the appropriate solutions towards a more sustainable and resilient cities with innovative buildings of optimal thermal comfort and IAQ, while a significant carbon footprint is reduced.

3. The Passive House Concept

The PH concept has a goal to reduce the carbon footprint while promoting a construction design that gives primacy to the optimum energy balance, assuring comfort and quality with a minimum impact to the final building price. The high energy performance of buildings achieved by complying with the requirements of the PH concept is subjacent in the EPBD recast 2018 in its ambitious goal of all new buildings to have nominal energy demands near to zero. High performance of the building's thermal envelope and the use of efficient appliances are the major strategies pointed out to reduce the energy consumption and GHG emissions in the building sector, therefore comprising the basis of the PH concept. The high energy efficiency based on passive solutions contribute to the sustainability of urban centres on different levels: Environmental, economic, and social [26,27].

This concept was developed in Germany by the Passive House Institute, and it is currently considered one of the most demanding standards of a building's energy efficiency [28]. Passive Houses are buildings with comfortable indoor conditions (indoor temperature range between 20 °C to 25 °C) during all seasons with the energy demand for heating and cooling limited to a maximum of 15 kWh/(m^{2}a). The concept is based on 5 principles that must be complied with (detailed in [28]). In order to achieve these requirements, it is necessary to combine a high performance thermal envelope with a mechanical ventilation with a high efficient heat recovery system to ensure high indoor air quality as well as controlled air changes between indoor and outdoor environment [27,29,30].

Even though the PH concept has been initially developed for Central European cold climates, where cooling is neglected, for South European warmer climates, cooling energy is of paramount importance to avoid overheating during the summer season. Several research studies were performed over the PH concept implementation in different climatic regions. Schnieders et al. [29] studied the applicability of Passive Houses for the world's relevant climate zones, namely Yekaterinburg, Tokyo, Shanghai, Las Vegas, Abu Dhabi, and Singapore, concluding that Passive Houses can be applied nearly anywhere in the world. Focusing on the Southern European and Mediterranean climates, the Passive-On project identified that the main issue of household energy use is not only to provide warm houses in winter, but is also to provide cool houses in summer, limiting the overheating rate [31]. Schnieders et al. [29] also performed an important research work, consisting of a parametric study of the Hanover (row building) for Passive Houses in South West Europe, including Lisbon and Oporto, located in Portugal mainland. Schnieders concludes that the annual heating and cooling demand requirements are reached for most of the locations in South West Europe [29]. Regarding Portugal mainland, the efforts of the research academy in the PH implementation for the Portuguese climate has been widely investigated, with a total of 10 scientific articles (found in Scopus) and more than 20 publications in conferences. Selecting the most representative journal articles of the Portuguese insights and challenges towards the PH concept implementation, Figueiredo et al. [26,31] studied the PH applicability in different climatic regions in Portugal mainland. The study developed by Figueiredo et al. was performed using dynamic simulation models, calibrated and based on a real PH building, concluding that the implementation of the PH concept has been attained for all Portuguese regions successfully, and also that the PH concept should be highly incentivised in Southern European countries [26,31,32]. From this study, the authors concluded that an adaptation of the technical solutions according the climate region is mandatory for the PH application to be well succeeded [26].

Another study explores the optimization procedures applied for the selection of constructive solutions, including the adaptability of the PH standard for several climate regions of Portugal mainland [33]. The authors defined several models as well as constructive solutions complying with the PH requirements, allowing stakeholders and designers to select the best solution that suits economic feasibility and high thermal comfort [33]. Additionally, the authors concluded that, despite the low thermal inertia characteristic of lightweight construction, and consequential high risk of overheating, the PH concept is feasible for Portugal's mainland, nevertheless, some adaptations of the constructive solutions are needed.

Regarding a refurbishment case study in Portugal's mainland, Rodrigues et al. [27] applied an EnerPhit concept for a XIX century heritage building located in Oporto. Despite the architectural constraints to install a continuous thermal insulation by the inner side of the thermal envelope, and consequently the reduction of the thermal inertia, the EnerPhit requirements have been achieved. A parametric study was performed for different climate regions, achieving different solutions to improve the XIX century building compliant with the EnerPhit requirements [27].

4. Methodology

The methodology was divided into four main phases (Figure 4). A literature review was performed, enabling us to cover and cross the social dynamics in Portugal issue, as well as the overall PH concept application around the world and the detailed application in Portugal. Moreover, the data for the study was collected through the previous analysis of the selected sites, by analysing the process of planning and design of each case study. Finally, the directions to overcome the social and political obstacles for the implementation of PH concept in Portugal were identified.

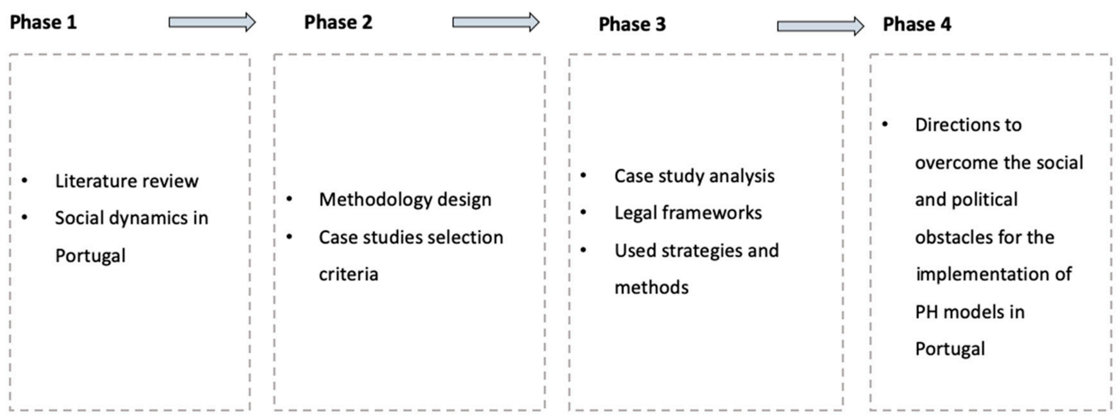

Figure 4. Methodological scheme.

5. Case Studies Assessment

5.1. Case Studies Selection

Since the development of the PH concept in the early 90s, several research studies were performed to evaluate its applicability and implementation in different climate zones. Due to the similar cold climate conditions which the PH concept has been developed for, it first spread into German-speaking countries of Central Europe, and soon after to Scandinavian countries in Northern Europe [34,35]. Regarding the Southern European countries, the PH concept started to be implemented relatively late when compared to Central Europe, with the first passive house built in Italy dating from 2003, followed by France with its first passive house built in 2007, and spreading through the Southern European countries such as Spain, Greece, and Portugal (with its first certified passive house built in 2012), according to the Passive House online database [36].

Despite the existence of several PH exemplary constructions, nowadays built in various Southern European countries, with climate conditions similar to the Portuguese scenario, such as Spain (192 PH buildings), Italy (94), France (353), Greece (22), Cyprus (1), Turkey (2), Croatia (2), and Slovenia (2) according to the latest numbers from the Passive House online database [36], none of the abovementioned countries comprehended an integrated and successful approach towards the implementation of the PH concept as the national or regional standard for achieving high energy efficiency in the buildings sector, nor to perform towards the EU strategic goals for energy performance and reduction of GHG emissions. In this sense, the regions selected in the present study to be analysed as successful examples, namely Hanover, Brussels, and Tyrol, are not similar to the Portuguese weather profile, but the overall integrated approach for PH standard implementation is noteworthy and of significant relevance in terms of guidelines to be learned and followed.

The commitment in reducing energy consumption and promoting the use of high energy efficient technologies have been supported by the EU through the successful Passive House Regions with Renewable Energies (PassREg) project [37,38] (with a 3-years duration, dating from May 2012 to April 2015) and coordinated by the Passive House Institute. In March 2014, the PH Institute published a position document recognizing the important role of municipalities on climate protection and consequently on the energy efficiency in buildings [39]. The PH Institute intended with this document to assist municipalities with a ten-point programme containing specific recommendations and detailing how cities and communities can take their commitment forward with an effective approach.

The PassREg project [37,38] was supported by the Intelligent Energy Europe Programme of the EU with the goal to trigger the implementation of the Nearly Zero Energy Buildings (NZEB) throughout the EU using the PH standard criteria for new constructions as well as refurbishments, thus counting with 14 partners in 11 countries. The project methodology was based on European regions and municipalities that either were already front runners (such as Hanover, Brussels, or Tyrol) with a significant number of certified Passive House buildings, or were striving to become such regions. Through the PassREg project, the front runners that had already implemented successful cost-effective measures, were optimized, and made visible. The experience obtained and the lessons learnt by this successful example supporting the implementation of the PassREg concepts provided the basis to be adapted and implemented in the aspiring regions. Thus, the concept of PassREg used the so-called Front Runner Regions (FRR) that were remarkably successful in implementing the PH standard with additional supply from renewable sources in their municipalities and regions, as models for the Aspiring Regions (AR). According to the PassREg Final Report [38] all the knowledge learned with the FRRs should be transferred and applied for the ARs development. Figure 5 summarizes the regions/cities participants in PassREg.

The regions of Hanover, Frankfurt, Heidelberg, Brussels, and Tyrol represent the pioneers and the best experience of successful implementation of the PH concept strategies into the regions' municipal sustainability commitment. Thus, the case study selection focused on the FRRs, and a statement of the Portuguese reality has been performed, using Aveiro region as a detailed demonstrator (Figure 6), since it is the Portuguese region where the first PH buildings were built, and comprising the highest number of certified PH constructions. Along with Hanover and Brussels, the Tyrol region has been selected as one of the reference FR regions, due to the similarities with the Portuguese region of Aveiro, in terms of the importance of the local University scientific research contribution towards raising awareness of both decision-makers, stakeholders, and the local community for the advantages of the PH implementation in terms of energy efficiency, suitability, and cost-effectiveness, as well as the important role played by the two local PH associations, as further explained.

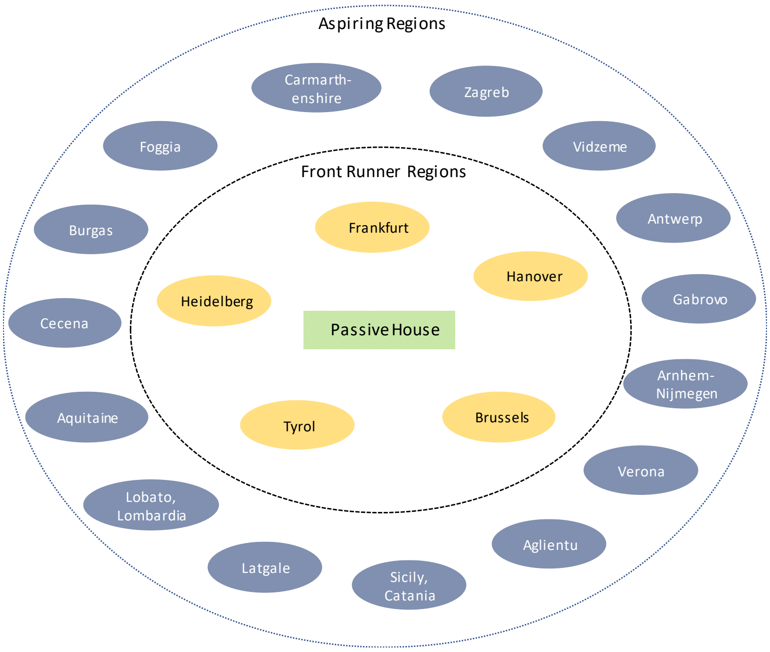

Figure 5. Front runner regions (FRR) and aspiring regions (AR) according to PassREg project.

Figure 6. Selected case studies' locations and demonstrators: (A) Hanover; (B) Brussels; (C) Tyrol; (D) demonstrator—Aveiro region.

5.2. Front Runners and Aveiro as an Aspiring Region

5.2.1. Hanover (Germany)

The German city of Hanover has been one of the pioneers in implementing PH concept strategies into its sustainable development, climate protection, and energy efficiency policies. Since the mid-80s until today, Hanover Municipality has experienced a longstanding political consensus in terms of perceiving sustainable development as a major priority, defining the strategic goals regarding energy use and conservation, as well as renewable energy sources. For achieving the defined goals, Hanover City Council has implemented specific standards covering new constructions built on municipal property based on the PH concept. Long-term policy instruments and a regulatory framework already implemented, dating as far back as 1994, are responsible for the policies regarding the defined energy goals to be successful.

The PH application in the region of Hanover is not mandatory, however, the municipality encourages entrepreneurs to apply the concept in new and refurbished buildings. The application of the PH standard is supported financially by proKlima fund. The Hanover municipality started an incentive programme (*ImpulsProgramme Passive House*) in 2003 in order to promote entrepreneurship as well as to support the development of new and existing companies, in the areas of energy efficiency and construction, based on the PH concept approach [40]. To overcome the additional capital investment in building according to the PH standard, which discourages some investors, the Hanover municipality has applied combined schemes for financial support, namely the proklima fund; the KfW (*Kreditanstalt fur Wiederaufbau*); and BAFA (*Bundesamt für Wirtschaft und Ausfuhrkontrolle*). Regarding families with small children (below 16 years), a specific financial support has been developed, reducing the price if the purchase is made on municipal land, ranging from a 10% to 40% reduction. The need to apply combined schemes for financial support revealed that financial incentives are still necessary to encourage investment in energy efficient standards, with particular expression when it comes to social housing sector [40].

Another strategy has been the awareness regarding the paramount importance of the stakeholders to acquire adequate expertise and skills in terms of renewable energy sources and low-energy buildings, during their elementary vocational training. Professional consultations as well as topical information have also been provided to all stakeholders. Efforts were made for developing an extensive network (national and international) for knowledge and technology transfer of energy efficiency and environmentally-sound strategies [40]. Moreover, in order to raise public awareness and to promote long standing commitment to climate protection, the local authorities have taken different approaches: From changing children's behaviour patterns in day-care centres and schools, to providing "door to door" advice. For achieving the strategic goals incorporating environmental and climate protection topics in schools' curricula has proven to be an important contribution.

Several demonstration projects of residential and public buildings have gradually been constructed according to the PH concept, as well as to the low-energy standards. The starting point was 32 terraced houses built in Kronsberg complying with the PH requirements, followed by 330 new residential buildings in "E-park in der Rehre", according to the PH concept requirements as well. A day-care centre and a primary school were also pilot constructions complying with the PH standard. After the success and effectiveness of these pilot projects, the Hanover municipality has decided to massively apply the low-energy standards in every new building.

The success factors for Hanover's development policy for climate, energy efficiency, and renewable energy sources have been the result of decades of democratic traditions in the city's government, with a strong political consensus achieved towards considering shifting sustainable development to a priority of the local governmental plan. Thus, the citizens' requirements were the focus of political attention, and it has introduced an integrated planning process applying a "bottom-up" approach in decision-making as well as in the implementation of the approved decisions. Finally, the local government considered the options made, related to the municipal land, as of long-term public interest [40].

In terms of energy policy, Hanover's decisive factors for the fast implementation of low-energy standards have been a determined political support for pilot constructions, particularly those fulfilling the PH requirements; strong incentives from German and EU financing institutions; promoting the use of energy efficient technologies; the construction of a solid system of Public-Private-Partnerships (PPP); and a strong commitment, as well as a direct and close involvement of the major energy supplier for the Hanover region, namely the Stadtwerke Hannover AG [40].

5.2.2. Brussels (Belgium)

The remarkable progress of Brussels to step up and become one of the FR regions in terms of energy policy definition and energy efficient buildings is noteworthy. The low energy building standard of Brussels starts with the Directive 2002/91/EC of the European Parliament, related to the building's energy performance. Brussels authorities, transposing the EU Directive into local law, passed the standard OPEB, with the following general principles: Promoting the improvement of the building's energy performance, considering environmental aspects, as well as indoor environment requirements and cost-effectiveness; to minimize primary energy demand; to reduce CO_2 emissions; and to develop a certification procedure regarding buildings energy efficiency [41]. Taking into account that by 2007, there were no buildings compliant with the PH requirements and low energy buildings were considered as luxury items, construction companies, architects, industries, and end consumers were deeply sceptical about the needed investments [41]. In this sense, in order to become a FR, Brussels regional government has acted as a catalyst behind the quick progress in formulating low-energy policies. A solid political commitment of the local authorities and a successful exchange of knowledge about the best practices with other EU regions, by being an active member of Energy Cities, a best practice exchange forum with other European regions concerned with energy efficiency, were the two key factors for Brussels' progress regarding low-energy laws.

The major climate disasters of 2006–2007 sparked public awareness for the climate changes issue and the success of the Exemplary Buildings program revealed PH standards to be affordable and with no need of raising costs of renovation and construction to unacceptable levels. Thus, the Brussels-Capital region government has decided to further increment the development of the local market towards the implementation of the PH concept, targeting young construction professionals. In 2007, the PH concept begins to gain expression in Brussels, and by July 2009, Brussel's government imposes the PH standard on all regional new public buildings by 2010. On May 2011, it adopted new energy target regulations to be complied with for all new construction (private and public) by 2015, making the PH standard the first step for achieving zero energy buildings [41].

The law changes towards the NZEB, and the adoption of the PH standard towards achieving these energy efficiency goals, were accompanied by several support programmes to investors. Another key factor for the success of Brussels in implementing such measures has been the "leading by example" approach, meaning that the local government firstly adopt suitable energy efficiency measures and practices. The Local Action Plans for Energy Management (P.L.A.G.E.) targeted to public and private buildings offering regional government funds for buildings renovation with high energy consumption that will not be renovated soon. The P.L.A.G.E. program has the goal to implement energy reduction measures and training administrators according to the PH concept. Brussels Regional Development Agency (SDRB), Brussels Regional Housing Authority (SLRB), and the initiative named "Sustainable Neighbourhood Contracts" has played a significant role in improving Brussel's living environment by promoting eco-friendly and energy efficiency measures in construction, providing continuous and specialized support, and as major financing institutions of the Exemplary Buildings programme, mentioned earlier.

Brussel's regional legislative actions were supported by several funding incentives and energy subsidies to improve the energy efficiency in the construction sector. A fourfold increase in regional budgets and a tenfold increase of financial aid for energy efficiency have been observed in the 2004–2007 period. The Exemplary Buildings programme (BatEx) is the main financial incentive instrument of the Brussels regional authorities for encouraging demand for high energy efficiency construction. The long-term objective of the Exemplary Buildings programme is to promote energy efficiency in buildings [41]. Additional objectives regarding lessons learnt within experiences obtained are fundamental to implement and replicate the strategy for future applications. Thus, three key factors are of paramount importance for the Brussels authorities: Funding new and existent building projects, complying with the PH requirements; support for organisations from certified passive house consultants; increase the PH owners and designers' visibility to promote the concept.

Additionally, another instrument of the Brussels government has been the subsidised energy system, in place since 2002 and comprising more than 20 types of subsidies by 2007, covering a partial value of the initial investment towards the PH concept building implementation. Despite 80% of the beneficiaries being individuals, these funds are also eligible for corporations willing to reduce energy demand in buildings. These subsidies were adjusted according to household income, thus ensuring equity among candidates, especially on low-income families [41].

Focusing these low-income families, whose burden of renovation costs is the heaviest, and therefore house renovations towards improving energy efficiency are not an attractive investment, since the initial costs are high and the financial benefits are slow to be noticed, Brussels' policy framework package included a zero-interest loan, called Green Social Loan, which can be provided to individuals who wish to improve the insulation of their home's thermal envelope, thus reducing energy consumption in order to comply with the PH standard criteria [41].

The major stakeholders involved were the Sustainable Building Facilitator Network, which is composed of an expert group in the energy strategies towards efficiency, offering consulting services regarding detailed projects focusing on energy consumption reduction as well as use optimisation. The Employment-Environment Alliance is comprised by professional and other organizations as well as unions, focusing on environmental defence, and embodies the decision of the Brussels regional government to stimulate the bottom-up solutions for energy efficiency. The Brussels Enterprise Agency (BEA), is a public organization offering substantial project support in the subjects of "green buildings" and technology. In 2006, the Ecobuild Cluster was born, focusing on low energy constructions and promoting a network between several stakeholders based locally [41]. The non-profit organizations *Plateform Maison Passive* (PMP) and the *Passiefhuis Platform* (PHP), are leading the promotion of construction according to the PH concept, providing for the francophone and the Flemish communities of Brussels, respectively.

As a consequence of the PH concept becoming a necessary standard in the region, providing adequate training for the professionals during the scholar education as well as professional qualification became necessary. In that sense, training initiatives specifically focused on the PH concept and NZEB have been organized by Brussels Environment, by *Plateform Maison Passive*, and by *Passiefhuis Platform* at different training centres and educational facilities in the Brussels region. Since 2009, Brussels Environment maintains a professional development program for engineers, architects and contracting authorities, which is extended to the entire sector. A total of 18,000 training hours each year are spent on topics of energy, materials, water management, biodiversity, land use and comfort, by Brussels Environment [41].

Regarding visibility and the public support, one of the most important non-profit awareness-raising initiatives is, since 2009, the issuing of the quarterly magazine "Be Passive", entirely dedicated to low-energy buildings and the PH concept. The initiative of the PMP and PHP have an audience target composed by all professionals involved in construction sector [41]. Additionally, PMP and PHP in joint collaboration also organise annual events such as the "Ice Challenge" event, the annual PH fair, and the PH Symposium, in order to increase visibility on PH concept advantages, building technologies, and the latest developments in energy-efficient construction, as well as in passive buildings. The Brussels-Capital region also participates in international projects such as the Intelligent Energy-Europe programme (IEE) and the Seventh Framework Programme for Research and Technological Development. All these active and sustained awareness-raising activities by public and private institutions have been crucial for the Brussels success model.

5.2.3. Tyrol (Austria)

With a longstanding tradition and expertise in low energy and passive building construction, Austria is the country with the highest density of passive buildings in the world [42]. Nevertheless, the Tyrol province stayed back from this process of low energy building construction, with only 2% of all newly constructed buildings in the region complying with the PH criteria by 2002. Since then, this percentage experienced a rapid growth due to the development and implementation of policy instruments and regulations at national and regional levels. According the EU Directive 2006/32/EC, the adopted energy strategy of Austria, presented in the national action plans for energy efficiency, set the goal of achieving by 2016 energy savings of 9% of its average consumption regarding the 2001–2005 period. The actions taken to achieve the energy savings goals were aimed primarily at building environmentally, thus increasing the share of new PH constructions; energy and thermal retrofit of all post-war buildings until 2020; promoting renewable energies; and the increase of energy savings in buildings based on specific financial incentives.

"Energy Strategy 2020" has been the most relevant policy instrument at the regional level for the province of Tyrol, with the goal of reducing the dependence on imported energy sources through increasing building's energy efficiency and changing the user's behaviour. The construction of new buildings, as well as refurbishment complying with the PH concept, aiming the reduction on energy consumption in space heating and air conditioning without compromising the occupants comfort is one of the most important strategies of this policy instrument [42].

In Austria, similarly to the Brussels example, the public sector plays an important role by "leading by example", through major renovations of public buildings; development of innovative laws based on energy efficiency, defined by the central federal procurement agency; inclusion of sustainable detailed criteria in the public procurement due to the national plan; and promoting widespread information campaigns by several federal initiatives, particularly the *"klima: aktiv"* national programme [42].

The national policy on reducing GHG emissions and producing electricity from renewable sources are on the basis of the creation of the energy strategy of Austria, through the development of the National Energy Efficiency Action Plans, the Austrian Programme on Technologies for Sustainable Development, and the creation of the Smart Energy Demo—Fit for SET. Regarding the regional policy instruments, the Energy Strategy Tyrol 2020 comprises a package of measures towards improving energy efficiency, promotes the use of renewable energy sources for energy production, and guarantees the energy supply for purposes of implementing the requirements of the EU Directive concerning energy efficiency improvement. The measures are also aimed at increasing by more than 50% the share of energy from renewable energy sources [42]. In what concerns the building sector, the Energy Strategy Tyrol 2020 focuses on space heating and air-conditioning of residential and services buildings and intends the reduction of the electricity consumption; the promotion of the share of energy from renewable energy sources; and training for designers and workers in the construction sector towards ensuring high-quality in design and workmanship. Moreover, training has been provided to municipalities and municipal staff in what relates to energy certificates. The last regional policy instrument is a ten-point action programme of the province, named Energy Autonomous Tyrol Project, aiming to cover future Tyrol's energy needs with locally produced energy in order to become energy independent through the locally production of energy from renewable sources, such as the sun, wood, and water, within one generation.

In 2008, most Austrian provinces joined efforts in terms of policymaking in order to harmonize the regional technical construction standards. Regarding low-energy and passive buildings, the Austrian Institute for Construction Engineering sets the requirements for building's heating demand, and by the *klima:aktiv haus* standard, supporting the sustainable development and the reduction of total energy demand as well as CO_2 emissions, thus including criteria for energy efficiency, ecology, quality of planning, materials and construction systems, as well as comfort and quality of ventilation, being very similar to the PH standard [42].

In the scope of financing measures in the construction sector, for new low-energy and passive buildings as well as thermal renovation of existing ones, subsidies of national and regional level were developed. Two national programmes were defined: *klima:aktiv*—Austrian Climate Protection Programme, that is a climate protection programme playing an important role in the Austrian federal climate strategy, and consisting in several measures of regulation, taxes, and subsidies, focused on introducing and promoting environmentally sound technologies and services; and the Austrian Programme on Technologies for Sustainable Development, which corresponds to a research and technological programme aimed at effectively stimulating the restructuring of the economy towards sustainability [42]. Regarding regional programmes, the Tyrol's province programme for operational energy consulting has been primarily conducted by the Chamber of Commerce cooperating with the *Energie Tirol* and *klima:aktiv*, mainly focused on the optimization of energy use by means of new technologies. The programme has been named Action Programme "Tyrol Economy": Energy Consulting.

Lately, in October 2013, housing subsidies in Tyrol came into force with attractive subsidies aimed at the renovation of residential buildings. Compliance with the defined requirements for space heating is a precondition to be eligible towards receiving the subsidies and it has been taken into account that for covering increased criteria for building's energy efficiency, a second level of grant subsidy can be obtained.

5.2.4. Aveiro (Portugal)

The city of Aveiro is located on the coastline of the central Portugal mainland and has been a privileged location concerning the implementation of the PH standard in Portugal. From a total of 11 buildings constructed following the PH requirements in Portugal mainland, eight are located in the Aveiro region. In 2012, the first two Portuguese PH buildings, two semi-detached private houses, have received the PH certification from the PH Institute. Despite all the PH buildings being private, architectural constraints are not a significant issue, since different techniques and constructive systems have been applied, ranging from the traditional masonry construction to the actual trend of lightweight steel frame construction systems. Regarding refurbished buildings, two EnerPHit buildings are also located in Aveiro, the first one being an office within a multi-office building, and the second one a private single-family house located on the coastline.

The implementation of the PH concept in Portugal mainland is recent, however, most of the effort is being made by the academic community in terms of scientific research, through performing investigation studies towards the PH implementation for Southern European climate conditions. Regarding the PH implementation for the Portuguese mainland different climate regions, a total of 10 scientific articles and more than 20 publications in conferences were identified through literature review.

Aveiro represents the Portuguese region with the highest number of PH, most probably as a consequence of the presence of two PH Associations located in the city, as well as the efforts of the academic research community of the Aveiro University, as mentioned, that has been contributing to inform the local community, raising awareness of the advantages that the PH concept represents in terms of energy efficiency, thermal comfort, and IAQ in the building sector, through communication actions, workshops, training sessions, and direct contact with architects and designers of the Aveiro region.

No local policies are foreseen in order promote highly efficient energy buildings in the region, in terms of municipal incentives or tax reduction, despite the already mentioned national legislation. In this sense, a long way to go is still necessary, to widely promote the PH concept implementation in Portugal.

5.3. Learnt Lessons

Regarding the three most successful cases of front runner regions that acted as example on the PassREg project, namely Hanover (Germany), Brussels (Belgium), and Tyrol (Austria), some common denominators between these regions in order to set the example in the implementation of successful, cost-effective strategies towards achieving high standards of energy efficiency buildings with PH concept are identified.

The initial conditions and the approaches taken for each region were different, according to the PassREg success guide [43] as well as the project information [38,44]: For Hanover, the success attained was based on longstanding political consensus on the strategic goals for the region; for Brussels, ambitious legislation combined with a successful incentive scheme lead to a rapid increase of PH construction; and Tyrol stands as the good example of regional and local initiatives and the pioneering role of limited profit housing associations [44].

The most important learnt lesson is that a stable and coherent legal framework is of paramount importance. However, it only works with success when combined with a suitable incentive system, achievable and accessible to all. Another factor of success, characteristic of all three regions, has been the close interaction between the different levels of governance, as well as a sustainable networking activities among stakeholders, public awareness campaigns, and local leadership [44].

For Hanover, the importance of the pioneer and demonstration projects must be highlighted. Hanover's approach revealed how important beacons are in order to convince stakeholders, potential investors, and private owners, while the PH construction at *zero:e-park* started hesitantly and has been mainly realized by "ecologically motivated owners", potential investors of the following group were particularly convinced by neighbours [38].

The characteristics described for the three FRR successful cases, were part of a system that made the implementation of the PH standard in these regions a success. This system comprises all the participants with all its expertise, abilities, interests, and networking. Moreover, for Hanover, the *proKlima* fund was paramount for raising awareness. In Brussels, the fast growth of energy efficient buildings has been a result of the combined efforts from the governmental departments, funding programmes, and the PH associations. For Tyrol, the research work performed by Innsbruck University and the efforts of *Energie Tirol* and *IG Passivhaus Tirol* have been paramount towards the success of the implementation approach, thus being noteworthy that national institutions and arrangements might not have been able to reach the regional targets alone [44].

To the successful implementation of the PH concept and renewable energy sources into the buildings sector, it has been learned with the PassREg project that a political consensus is of paramount importance, capacities must be built, effective and coherent policymaking as well as new legislation must be drawn, and stakeholder acceptance needs to be attained. All these processes are time consuming, requiring effort, commitment, continuity, and knowledge. In general, specialized information about the inexpensive and easily applicable PH concept with renewable energy sources, towards attaining zero energy buildings, in order to achieve the EU energy goals is unknown to the political decision-makers. In this sense, local authorities play a particularly important role in driving the change due to the power of decision towards local framework policies, instead of changing national regulations. For that, the role played by the academic community and the PH Associations, to disseminate adequate knowledge to local authorities about the PH concept, is of paramount importance. Moreover, the PassREg project made clear the importance of the pilot projects, the beacon PH buildings constructed as examples in the various FR and AR regions, "with convincing architecture, building quality, affordability and user-friendliness" [38]. Associated with these exemplary constructions, awareness-raising actions, information and targeted training for the technicians, craftsmen, architects, designers, tradespeople, contractors, investors, and all of those involved in the construction process, relating to PH and renewable energy sources has to be made available locally. The third most important lesson learnt is the need of a solid financial incentive structure in order to help encourage decisions for more pioneer PH projects to be built.

5.4. Barriers and Obstacles in Portugal

Based on the learnt lessons along with the crossing analysis of the Portuguese national framework described in Section 2, it was possible to identify various barriers and obstacles for the implementation of the PH concept in Portugal's mainland. Therefore, as similar to what occurs in several other countries, in Portugal the most relevant obstacles for the implementation of the PH concept are related to the lack of knowledge of the building industry's technicians and main actors, including governmental decision makers, both locally and nationally. For instance, there are the limiting technical capacities not only to implement the PH concept, but also for the acceptance of the concept itself in the Portuguese market [45].

Besides, the concept of Sustainable Construction could also be seen as a barrier for the PH concept implementation in Portugal—once the sustainable concept is assessed by many parameters, factors, and indicators designed in a manner to provide an answer to all the spheres of the Sustainable Development. Thus, it becomes evident the difficulty to achieve this typology of construction within Portuguese territory.

Based on the exposed, it is not possible to present an indicator or a parameter that could assess sustainability as an absolute term. In fact, there are many specifics that could be seen as an obstacle for the classification of the sustainability of a building, i.e., it could present a good environmental performance, however, it does not fill the minimum requested demands in other themes. Therefore, it cannot be considered as a sustainable construction [46].

Moreover, in the Portuguese reality, another obstacle is strictly connected with the reduction of energy consumptions. Those pre-established reductions should be achieved through solutions that were already implemented in the Portuguese territory, based on a large experience of their usage. Therefore, it is a huge obstacle for the PH concept implementation. In this regard, the PH concept is seen only as experimental, and therefore excluded from the possible solutions.

Furthermore, considering the energy in the building sector in Portugal, most of the studies and official reports affirm that the energy consumption associated with this sector is too high. Thus, the main goal is to update the building sector for a more efficient one. In fact, from 2018, it has started to be applied to the public buildings as per the European Directives. Moreover, from 2020, the Portuguese Government will aim to apply the EU directive to all new buildings—to foster the NZEBs. However, to achieve this goal (the NZEBs), it is pivotal to understand that the buildings sector covers a large range of fields, and should not only be considered the constructive factors, but also all the logistics related to building construction. Thus, the sustainability concept and sustainable development principles are critical to pursue this NZEB´s objective. In fact, only well-conducted cooperation and crossing of many thematic and technical fields during the most relevant phases of the building construction process (project, construction, and exploitation of the building) will allow new solutions for the performance, comfort, and energy efficiency of the building. Therefore, the promotion of multidisciplinary teams is pivotal.

Contextually, one of the major obstacles associated with NZEBs in Portugal is related to the opportunity to outbreak into the market. Thus, it is necessary that the satisfaction levels by the final users will be high. Other studies conducted in Central Europe (Germany and Austria) show that the energy efficiency of a house is an important factor, but not critical for the user in the decisive moment of choosing a new house. It shows that many other variables as price, geographic location, size, and neighbouring, among many others, are pivotal for such a decision. Therefore, the Portuguese social dynamics and the associated evolution play a key role in the future of the implementation of the PH concept [47].

With the economic issues related to the low energy consumption buildings and considering the Portuguese economic reality, this construction typology is still seen as utopian. This barrier probably represents the most difficult to overcome in the Portuguese scenario, by its complexity. Thus, the political and financial-economic spheres play a key role in Portugal. In fact, they are the catalyst for the overcoming of this obstacle, if public policies and incentives for the construction of buildings based on the PH concept through the promotion of incentives that enables an easy of financing to PH construction projects. On this subject, there is the example of the Project Passive-On [48] ongoing in Germany, where the government created conditions that foster this typology of constructions. In the Project Passive-On, incentives were created that allow for the building of the first PH partially or totally funded by public funds. The implementation of the German or a similar normative in South European territories is seen as a major benefit to overcome the economic barrier in Portugal. Nevertheless, even with the public funding support, it was needed approximately 15 years for the construction rhythm to achieve the hundreds of PH in one year in German [48].

Contextually, it should be understood that these kinds of projects and initiatives, as with the Passive-On project, could help in the process of PH implementation, however, they will not achieve the expected results if there is not a combination of several strategies, methods, and solutions that can face these obstacles from different angles, fields, and perspectives. Therefore, considering the complexity of the issue as well as the Portuguese Social dynamics, there is no clear answer or solution for this problem. The authors believe that only a transversal and a multidisciplinary solution could create the fertile conditions to foster the PH concept in Portugal. Moreover, to overcome such barriers and obstacles, the learnt lessons extracted from the case studies analysis in the present study along with the EU guidelines and technical reports should be taken into consideration by the technicians, main-actors, and decision-makers to provide the above-mentioned multidisciplinary and consequently wide scope answers for the PH concept implementation.

From the case studies of successful experience in EU territory, it has been possible to define major guidelines, which are possible to extract and apply in the future sustainable development strategies and plans to be designed and implemented in Portugal, according the following topics:

- political actors must know that PH combined with renewable energy sources can be used to fulfil the European Buildings Directive;
- architects and tradespeople require specific expertise to implement PH and renewable energy sources;
- investors need the right financial incentives so that a decision towards PH along with renewable energy sources is facilitated.

6. Final Conclusions

The present research provides a meaningful contribution for the implementation and interest of the Passive House concept in the Portuguese building scenario, through the definition of lessons learnt from the front-runners identified and selected, where the concept is already well established and with many built projects. Moreover, there still exist barriers and obstacles to its acceptance, as presented and discussed.

The Passive House concept application as an effective measure aligned within the European building energy goals areas has proved to be the path to low-energy building design and the basis for the NZEB concept. Moreover, the PH implementation in the front-runner regions were successfully implemented with effective results regarding the buildings energy efficiency.

Summarizing the list of lessons learnt it is important to highlight:

- a legal framework combined with an active system based on incentive policies that are achievable and accessible to all is of paramount importance;
- new legislation has to be drawn, and different stakeholder´s acceptance is needed to be attained for a successful implementation;
- the academic community and the PH associations must team-up to play an important and effective role in the dissemination, as well as in the adequate knowledge transfer to local authorities and designers, contractors, and other players in the construction sector.

Moving up to the barriers and obstacles identified, a list of three highlights is presented:

- The lack of knowledge within the building industry, from the design stage (designers, technicians', investors/promotors) to the execution stage (contractors, installers);
- the construction techniques in Portugal are mainly based on a large experience of their use. Therefore, the PH concept implementation has a huge obstacle at the level of changing workmanship construction techniques, as well as the incorporation of building systems/equipment, such as MVHR (mechanical ventilation units with heat recovery);
- the public policies and incentives for the construction of buildings based on the PH concept are totally inexistent.

The authors highlight that an additional investment by the application of new policies is extremely needed for the future success of the implementation of Passive House concept in Portugal, as well as in other southern European countries with similar climate conditions.

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