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Article

The Social, Educational, and Market Scenario for nZEB in Europe

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Abstract: Nearly Zero Energy Buildings (nZEB) are a significant part of the energy efficiency strategy of the European Union. As buildings represent approximately 40% of the final energy use in Europe, the reduction of their energy demand is key for a sustainable future. This paper takes a qualitative approach and presents data about professional and market barriers, as well as the educational market in relation to the implementation of nZEB policies for new and retrofit buildings in 11 European countries. Different levels of policy enactments and market penetration are reported and are generally found to be more advanced in western and central European countries. Furthermore, gender equality is examined in the building sector in relation to nZEB and presents significant gaps, with a more balanced situation reported in southern Europe. The accreditation and targeted education of nZEB experts is still almost non-existent in the examined countries, and the need for training of building professionals is highlighted as a critical missing component of current policy. This research aims to be the first step towards the creation of educational material and programmes as a mean to accelerate the transition to nZEB.

Keywords: nZEB; building professionals skills; EPBD; education

1. Introduction

The Energy Performance of Buildings Directive (EPBD), recast in 2010, requires that from 31 December 2018 all the new buildings occupied and owned by public authorities are Nearly Zero Energy Buildings (nZEB), and from the end of 2020 all new buildings are nZEB [1]. An nZEB is a building that has a very high energy performance, determined in accordance with Annex 1 of the EPBD [1]. The remaining nearly zero or very low energy demand should be covered to a very significant extent by energy from renewable sources, produced on site or near-by. Examples and models for nZEB already exist throughout the European Union countries, even though the national nZEB definitions and the techniques required to achieve nZEB differ [2,3]. The definition of nZEB and its transposition into national legislation highlight the importance of the energy performance of the built environment as part of the sustainability strategy of the EU. Because 40% of the energy consumption and 36% of the CO_2 emissions in the EU are related to the built environment, there has been an increased focus on improving the energy efficiency of buildings [4]. From the 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive, the measures and regulations associated with improving the overall energy performance of buildings, using both passive and active strategies, have been re-evaluated and have evolved even further [1,5]. The recent "Clean Energy for All Europeans" package of measures promotes new legislative proposals for the strengthening of renewable energy use and overall energy efficiency in the built environment [6]. This is further enhanced by the European Commission's political agreement, dated 19 December 2017, to update the Energy Performance of Buildings Directive and to further promote the nZEB targets applicable within the EU market.

The education and accreditation of building professionals in renewable energy systems integration and in the sustainable construction techniques required to deliver the nZEB targets, is a critical factor in the successful implementation of the policy. Previous research on the implementation of building energy efficiency policies dealt mainly with the evaluation of accreditation schemes in various European countries. Perez-Lombard et al. evaluated the framework of building energy certification, with a view to providing guidelines for building professionals in order to assist with appropriate decision making [7]. Andarolo et al. presented a comparative analysis of the energy performance certificatification (EPC) implementation in the 27 EU Member States [8]. Further analysis of the level of implementation of the EPBD, including both the challenges and specificities of transposition into national legislation and the design of national methodologies for the building energy performance certification, has been undertaken. Casals presented the challenges of this process at the European Union level and gives a detailed analysis of the Spanish case [9] and Dascalaki et al. discussed the case of Greece [10]. More recently, numerical evaluation of the nZEB strategies employed and the optimization of energy use achieved have been the focus of researchers. Kampelis et al. [11] analyzed the gap between actual building energy use and predictive numerical modelling by simulating various building services systems and envelope components. Ferrari and Beccali [12] evaluated alternative retrofit options required to turn an existing office building into an nZEB office building, in terms of their relative technical and economic performances. Harkous et al. further evaluated the optimal combination of passive and active strategies and systems that contribute to the zero energy use in nZEBs [13]. Analyzing the impact of design and energy system strategies on nZEB is critical to the improvement of specifications. Beyond that, researchers are analyzing life cycle costs, embodied carbon, and embodied energy as factors that should be accounted for when designing a new-build nZEB or when refurbishing an existing building to the nZEB standard. Sesana and Salvalai, give an overview of life cycle analysis methodologies and evaluate their applicability to the nZEB design process, whereas Giordano et al. emphasize the importance of considering embodied energy on the life-time energy demand of nZEB [14,15].

Research into the enhancement of the design strategies needed to deliver improved nZEB implementation is critical. However, the actual effect and market penetration of such research largely depend on the level of its application through the practice and expertise of the relevant building

professionals. European Union-funded platforms such as BuildUp [16] and projects such as the Meeting of Energy Professional Skills [17], PROF TRAC- Open Training and Qualification Platform on nZEB construction and renovation [18], and Zebra 2020 [19] all aim to provide for improved implementation through the establishment of continuing professional development options for existing building professionals in the EU member states. Thus, the relation between nZEB policies, on the one hand, and the educational opportunities and professional skills available in Europe, on the other, becomes a decisive factor in the implementation of the nZEB target within the European Union.

This paper aims to analyze the current situation of nZEB implementation in Europe through the prism of policy maturity, the broader economic climate, and the current state of the market. Data were collected about the nZEB educational market and the needs of building professionals with a specific focus on the housing sector. The discussion presents the relation between the above factors and the level of nZEB penetration for 11 European countries with an aim to suggest solutions and enhancement strategies.

2. Methodology and Data Collection

A qualitative approach was followed and, through data mining and surveys, data that showcased the social and legislative background and the market and employment issues associated with nZEB were collected. The data collection focused on European Union level and local national sources such as public authorities, energy ministries, technical chambers, professional bodies, universities, laboratories, relevant companies, and organisations. Current policies, promotion instruments, legislative requirements, training market products, market and professional barriers, the role of female building professionals, and the broader engagement of human resources are analyzed for the 11 European countries, shown in Table 1.

Table 1. Research countries.

Countries
Italy
Greece
Cyprus
Spain
Denmark
Germany
Belgium
United Kingdom
Ireland
Romania
Macedonia

For each country, the collected information analyzed the following:

- Market survey data on current activities and policies focused on implementing nZEB in the housing sector, combined with an analysis of national and European data about available technologies, training products, and the level of workforce engagement
- Market survey data on professional and social barriers that have to be overcome in order to achieve nZEB design, construction, and, in particular, housing refurbishment.
- Data and analysis on the role of female building professionals with a view to increase female engineers', architects', and building managers' employability

2.1. Geographical Scenario

The examined countries were clustered for the analysis according to their geographical location in four geographical scenarios:

- Eastern European countries: Romania, Macedonia
- Western European countries: Ireland, United Kingdom
- Central European countries: Germany, Belgium, Denmark
- Southern European countries: Greece, Spain, Italy, Cyprus

This was done in order to capture the emerging situation in some countries relative to the more mature examples evident in others. Furthermore, the climatic zones of the geographical areas are quite distinct, leading to distinct technological approaches to fulfilling the nZEB targets. This is a parameter that affects the building energy efficiency and has been addressed similarly in relevant research [20,21]. The clusters also largely reflect the EU Commission's (EU 2016/1318) four recommended climate zones of Mediterranean (Southern), Nordic (Central), Continental (Eastern), and Oceanic (Western), even though these recommended climate zones emerged subsequent to the clustering process.

2.2. Social Scenario

The first step was the evaluation of the social scenario in order to assess the context of nZEB implementation, status, initiatives, and projects in the examined countries. The requirements for the 10 EU member countries state that from 1 January 2019 all new public buildings will have to be nZEB (European Union, 2010). All other new buildings will have to be nZEB from 1 January 2021 (The European Parliament, 2010). An analysis of the policy implementation in the 11 countries was conducted, and the main results indicate that in all countries apart from Macedonia, the nZEB requirements, as defined by the EPBD recast, have been largely transposed into national legislation.

To date, there has been flexibility regarding regulatory enforcement and target setting in all the EU countries, as the different climatic, social, and economic conditions in the member states allow for different solutions. However, the member states must ensure that the requirements of Article 9(1) of the EPBD are met by 31 December 2020 for all new buildings, and two years earlier for all new buildings owned and occupied by public authorities [1].

The different definitions of the nZEB target defined across the 11 member states are shown in Table 2.

Table 2. National Definition and Targets for nZEB in the countries, source: [2].

Countries	National nZEB Target (kWh/m^2/Year)
Greece	Under development
Italy	Under publication
Spain	Under development
Cyprus	100 kWh/m^2/year for residential—125 kWh/m^2/year for non-residential
UK	39 kWh/ m^2/year for apartments and mid-terraced houses—46 kWh/m^2/year for end-terraced, semi-detached, and detached houses
Ireland	For a typical new dwelling this will equate to 45 kWh/ m^2/year and for existing between 125–150 kWh/m^2/year
Germany	The KfW Efficiency House 55 should have a maximum primary energy demand of 55% and a maximum transmission heat loss of 70% relating to the reference building
Denmark	20 kWh/m^2/year for residential and 25 kWh/m^2/year for non-residential (Energy Frame 2020) and 30 and 41 kWh/m^2/year for Energy Frame 2015
Belgium	Lower than 70 kWh/m^2/year and a production of at least 10 kWh/m^2/year of renewable energy
Romania	For residential individual is set to be 115 kWh/m^2/year for 2019 and 98 kWh/m^2/year for 2020—for residential collective is set to be 100 kWh/m^2/year for 2019 and 93 kWh/m^2/year for 2020
Macedonia	-

Nevertheless, with the Commission Recommendation 2016/1318 of 2016 [22], numeric benchmarks for nZEB, based on primary energy use, have been specified for each of four designated climatic zones, as shown in Table 3.

Table 3. Numeric benchmarks for nZEB primary energy use indicators at EU level source: [22].

Climate	Building Category	Net Primary Energy (kWh/m^2/Year)	Primary Energy Use Covered by On-Site Renewables (kWh/m^2/Year)
Mediterranean	Offices	20–30	80–90 covered by 60 onsite renewables
	New single family house	0–15	50–65 covered by 50 onsite renewables
Oceanic	Offices	40–55	85–100 covered by 45 onsite renewables
	New single family house	15–30	50–65 covered by 35 onsite renewables
Continental	Offices	40–55	85–100 covered by 45 onsite renewables
	New single family house	20–40	50–70 covered by 30 onsite renewables
Nordic	Offices	55–70	85–100 covered by 30 onsite renewables
	New single family house	40–65	65–90 covered by 25 onsite renewables

Member States are advised by the Commission to assess existing construction practices as soon as possible to make sure that the nZEB targets are achieved. Policies, promotion, and monitoring schemes for nZEB within each of the member states should, according to the Commission, become more specific and more directly aligned to the nZEB targets.

3. Data Analysis and Discussion

3.1. The Relation between Policy Implementation and nZEB Training Market Products

The analysis of the policies related to nZEB has revealed that countries of the north-west geographical region present the greatest level of implementation of national legislation for the promotion of nZEB. In particular, Germany, Denmark, Ireland, the United Kingdom, and Belgium are the countries whose national legislation had already established standards that were among the highest of the examined countries [23–26].

The accreditation and targeted education of nZEB experts is still virtually non-existent in the examined countries, despite the legislative alignment with EPBD requirements. Thus, the need for training and education of the building professionals is critical to the success of the policy. For each of the 11 examined countries, the varying level of nZEB applicability to the building stock is a crucial factor for the creation, implementation, and success of the training programs required.

Furthermore, the training market products that are related to nZEB and the energy efficiency in the built environment were identified, with a focus on existing nZEB or similar University courses, modules, and programs that are both substantial in training provision (minimum of 10 European Credit Transfer and Accumulation System credits—ECTS) and accredited by national technical chambers and/or accrediting institutes. The countries with the most accredited relative courses were Denmark and the United Kingdom, as highlighted in Table 4. It is thus observed that in countries with higher implementation of nZEB policies towards nZEB, there are more accredited programs.

The market penetration for technologies and products used in nZEB for each country is relevant to the numbers of qualified nZEB professionals and accreditation schemes in place. Table 5 provides information regarding the national nZEB-related qualification and accreditation schemes, along with the identified gaps between current nZEB-related educational programs and market requirements.

Table 4. Existing Accredited Courses and Programmes related to nZEB, source: [17,27] **.

Countries	University Courses / Programmes of Minimum 10 ECTS	Accredited Programs (CPD) from National Technical Chambers
Greece	9	2
Italy	12	5
Spain	10	8
Cyprus	14	Trainings frequently organised by the chamber of professional engineers *
UK	20	7
Ireland	6	Environmental Accreditation Programme: set of 5 modules by RIAI and 1 CPD course by Engineers Ireland *, 1 by Passive House Academy
Germany	5	2—Energy Efficiency Experts List and Energy Consultant for Architectural Monuments
Denmark	29	Trainings organised by Green Building Council Denmark, Passive House in Denmark, and Cradle to Cradle Denmark
Belgium	9	7
Romania	17	8 and recent train to nZEB courses by TUCN and INCERC
Macedonia	4	2

* These are courses of less than 10 ECTS. ** This review, which was conducted in Q2, 2015, is not exhaustive and may miss out on emerging courses or courses that have been modified to include either retrofit or nZEB. The review concentrated on schools and institutes delivering courses in engineering, architecture, building surveying, and construction management, as these are likely to be the institutions with the facilities and staff most likely to deliver such courses. The review is mainly focused on postgraduate and CPD upskilling of building professionals.

Table 5. Identified gaps between current educational nZEB related programs, qualifications, and training and market requirements.

Country	Qualification Related to nZEB	Accreditation Route	Identified Gaps between Current Educational nZEB Related Programs and Market Requirements
Greece	Certified energy auditors by the Ministry of Environment, Energy, and Climate Change	For permanent accreditation, candidate auditors should undergo a training course and must be successfully examined	The general training courses for energy auditors are not sufficient to meet the needs for skilled engineers in the nZEB sector, so it is expected that new training courses, focused on nZEB design and retrofit, will be offered by academic institutions or Vocational Training Centers. -Companies of the construction industry have been severely affected by the ongoing economic crisis
Italy	Experts in Energy Management (EGE), energy managers, energy certifiers, CasaClima energy consultants, Protocol ITACA expert	EGE are regulated by the specific legislation ITACA Protocol, however, are recognized by the National Technical Chambers and controlled by the Institute for Innovation and transparency in government procurement and environmental compatibility	It is expected that many of the training programs will have to be updated, in particular regarding technical rules on the calculation for building energy performance. It must be stressed that only some of the many courses on the building energy are focused on nZEB design and retrofit
Spain	Certified registered assessors	All the current accreditation courses include an examination assessment upon completion of training. The successful examination is a satisfying parameter for a professional who wants to become a domestic or non-domestic energy assessor, or displays energy certificate assessor	The main issue with the existing training products is that they do not focus on the nZEB design, construction issues, and standards. Therefore, the building professionals do not receive education regarding the targets that should be achieved in new or refurbished buildings to achieve nearly zero energy standard
Cyprus	Certified energy auditors	Training seminars are organized by the Cyprus Energy Service, and auditors must be approved in the corresponding exams to be allowed to register with the Scientific and Technical Chamber of Cyprus	-Lack of regulation in technical professions and financing -Companies of the construction industry have been severely affected by the ongoing economic crisis

Table 5. *Cont.*

Country	Qualification Related to nZEB	Accreditation Route	Identified Gaps between Current Educational nZEB Related Programs and Market Requirements
UK	Competent person scheme, approved assessors. Various accreditation courses/schemes exist in the United Kingdom regarding the Energy Assessor scheme. BRE, CIBSE, Elmhurst Energy, National Energy Services, Stroma, ECMK, Quidos, and Sterling Accreditation are the market dominant accreditation schemes	The current accreditation courses include an examination assessment upon completion of training. The successful examination is a satisfying parameter for a professional who wants to become a domestic or non-domestic energy assessor, green deal adviser, or display energy certificate assessor	The current accreditation courses do not focus on the nZEB design, construction issues, and standards. In the UK, there is much debate about the future of EBPD in the light of Brexit, but at present all legislation based on the EPBD transposition is in place. New changes to Part L Building Regulations are due soon
Ireland	Building certifiers, thermal modelers, energy efficiency designers	A definition of the competencies required of the energy efficiency designer is required in order to establish courses to allow specialists to emerge to offer services to the market. This role is confused with that of the rating of buildings ("BER/EPC assessors") or the management of energy use within buildings ("Energy Managers") rather than the design of buildings to meet a defined energy efficiency performance	The regulatory environment has suffered greatly from the economic collapse of 2008, with few new houses being built even now to the 2011 energy efficiency standard. This has resulted in a consequential delay in introducing even more stringent efficiency standards for new buildings as the current standards for new housing have yet to bed-down with the industry
Germany	Energy efficiency expert and energy consultant for architectural monuments	For all recognized training, a test is required. The training offers that are available on the market meet the requirements for training to access the energy efficiency experts list's two optional routes: Module "Consulting" and Module "Planning and Implementation"	The current existing courses in total cover fundamental contents in the topic area nZEB in retrofit of residential buildings, but the single modules refer to specific fields of activity and do not focus on the nZEB standard
Denmark	Energy consultants	To achieve an accreditation, the professionals have to participate in the necessary courses required by The Danish Energy Agency according to the specific role as consultant at the market (Energy Consultant)	A change of content or new knowledge is related to needs described by the stakeholders, and may result in change of the Danish energy strategy
Belgium	Energy efficiency experts (PEB experts)	PEB (Performance Energétique des Bâtiments) accreditation is, more than ever, important for professionals of the construction sector in Belgium. From January 2017, professionals without the agreement PEB 2015 may not take any more charges related to urbanism and construction of new buildings or retrofit of buildings	Energy Efficiency Experts (PEB experts) are well educated in Belgium, but a clear gap exists at the level of SER (Systems of Renewable Energy). Not enough installation specialists exist
Romania	Professional energy efficiency assessor	Compliance with the energy efficiency requirements in refurbishment projects is certified by Ministry of Education and Ministry of Regional Development	Only the Energy Audit and LEED or BREEAM programmes get close to nZEB content, as they include EU and national legislation regarding energy efficiency requirements according to the building regulations. The main issue with the existing training products, be it university courses, organisational CPD courses, or accreditation courses, is that they have a very low focus on the nZEB design, construction issues, and standards
Macedonia	Authorised energy auditors	The existing courses include an examination assessment upon completion of training. The successful examination is a satisfying parameter for a professional who wants to become a national energy assessor or display energy certificate assessor	The current programmes that are close to nZEB content are only the courses that include energy efficiency requirements according to the building regulations

3.2. *Identification of Market Barriers*

Further to the analysis of the educational programs, the market, and the industry needs for nZEB solutions are analyzed. More specifically, the factors that are related to this are costs, qualified

building professionals, and interest of the public. It is a fact that in the examined countries, the cost of retrofitting existing buildings is still considered to be prohibitively high. Similarly, when designing a new building to deliver nearly zero energy, the active renewable energy systems, such as solar panels, add extra costs to a conventional design in addition to those of improving building fabric to reduce energy losses. The impact of adding such technologies to the complex process of procuring a building is only beginning to be investigated in the literature with mixed results [28–30]. Often, the assumed contribution of these technologies is optimistic in reality for a variety of complex reasons, which are often related to conflict with established building or procurement practices and conflicts with other policy instruments, notably decarbonization of the grid. In the absence of lifecycle cost analysis, based on a clear long-term view of carbon taxes, primary energy factors, feed-in tariffs, and other emerging regulatory impacts, their contribution to cost-optimized energy efficiency is unpredictable. Such unpredictability undermines the decision making process related to nZEB investments.

3.2.1. Southern European Countries

The analysis revealed that south European countries that have been undergoing an economic crisis (Greece, Spain, Italy, and Cyprus) have experienced a reduction in the number of sustainable building projects, as the associated costs are now perceived as higher [27].

In Greece, Santamouris et al. found out that the reduction of family income has led households to consume 15% less energy during the winter of 2011 compared to 2010, even as 2011 was colder [31]. In follow-up research involving the monitoring of 43 low- and very low income houses during the winter of 2012–2013 in Athens, it was found that indoor temperatures were set to much lower values than the minimum threshold required for comfort and health [32]. This trend has an effect on residential energy consumption levels, not as a result of energy saving campaigns but due to the impact of increasing energy poverty levels.

Furthermore, extra barriers emerged when previously attractive feed-in-tariffs for PV's on buildings were severely reduced, even instances where existing contracts were reduced unilaterally by the state actions [33]. This resulted in a full standstill in new PV installations, a situation that was not changed even by the new PV net-metering scheme adopted in May 2015. To make matters worse, the advent of the banking capital controls of July 2015 essentially stopped any new investment in residential RES installations. Furthermore, many schemes that were providing financial support for the retrofit of buildings such as the 'Saving at home' program have stopped [34]. It has recently been announced that this successful incentives program recommenced.

In Italy, currently there is a growth in maintenance and refurbishment, from €106.5 billion in 2006 to €115.1 billion in 2013. The renewable energy sources sector in 2013, despite strong shrinkage in the photovoltaic sector in 2012 and 2013, amounted to a value of investments of €7.5 billion, against €660 million in 2006. It should be noted that this growth has been strongly supported by incentives that facilitate these activities. The main obstacle to integrating renewables in small domestic buildings is the legislative one. Often, building code or urban rules for the protection of architectural and historical value do not allow the systems to be installed. Another barrier is the cost of the intervention and the difficulty of accessing public funds, tax breaks, or incentives [35].

In Spain, the economic slowdown has also had a significant effect since 2008. One of the main sectors affected is the construction and building industry, which has slowed down significantly. Building refurbishment, which gives the opportunity to renovate the building stock based on an nZEB philosophy, is also decreasing. However, it still represents 47.5% of total construction projects [36]. From 2005 to 2011, Spain intensively promoted several national policies in order to enhance renewable energies and energy efficiency projects, which allowed greater penetration of renewable energies to meet domestic demand. Since 2011, national policies changed dramatically, limiting the opportunities for on-site power generation in buildings. Then, in 2013, the Spanish Government approved a package of measures intended to encourage energy-efficiency in buildings, which to some extent supports the installation of thermal renewables in the residential sector [37]. Law 8/2013; Royal Decrees 233/2013,

235/2013, and 238/2013; and Order FOM/1635/2013 are regulations related to the residential sector and the rehabilitation, efficiency, and construction of buildings, which impact on the stimulus of the renewable thermal energy sector, mainly in the areas of solar, biomass, and geothermal. In addition to changes in the legal framework, the high cost of small scale renewables installations in buildings, together with the lack of trained professionals and the low level of new construction at planning stage, further limits the potential development of renewable energy in this segment. The lack of customer knowledge and reliable advice also makes the implementation of nZEB measures difficult, since there is little information available to building administrators or residents regarding energy management and energy usage in buildings. Overall, it is the financial barrier that is the most important due to the high initial investment, the difficulty of accessing initial capital, and the calculation of investment returns [38,39].

In Cyprus, a boom in the construction sector took place from 2000 onwards, and a third of the entire building stock was built during this period. However, the economic recession since 2010–2011 has affected significantly the construction and building industry. In 2013, building permits issued by the regulatory authorities dropped by more than 70% from the record high of more than 350,000 permits issued in 2007 and 2008. The situation has been stagnant in the last few years, with limited signs of improvement. As a result of the economic crisis, training of professionals in the building sector has been greatly affected, with consequential retardation of the progress of nZEB implementation in practice [40].

3.2.2. West Europe Countries

In the UK, the economic recession of 2008 has significantly impacted the construction and building industry. In 2007, the construction industry accounted for almost 9% of the United Kingdom's GVA (Gross Value Added), whereas in 2011 this percentage has been reduced to 6.7%. The greatest decline has been recorded in the housing sector, with a reduction of 40% [41]. Consequently, this crisis, in combination with the policies withdrawal, has affected the construction or refurbishment according to the zero carbon standards. Since 2014, the construction and building industry has entered a growth phase, with a rise of 2% in 2014 and 4% predicted for 2015. This increase will affect mainly new buildings and may also impact, to a certain extent, refurbishment due to the increased use of energy efficiency measures and products that can lead to cost reduction.

In Ireland, the construction output, from a high of €38 billion in 2007, declined to just €9 billion in 2012 and staged a modest recovery to €11 billion in 2014. Over the same period, the market for architectural services has declined from €408 million to €91 million, with consequential decline in the income of architects and the profitability of architectural practices [42]. It is questionable if the market for residential retrofit, outside of the public sector, would exist at all without the incentive of the current generous, albeit poorly targeted, grant system. Moreover, the absence of a feed-in tariff or a renewable heat incentive scheme has retarded the development of the market for renewable energy systems in the residential sector, beyond compliance with the minimum threshold of 10 kWh/m^2 for new dwellings.

3.2.3. East Europe Countries

In Romania, the period after the economic recession of 2008 has affected significantly the construction and building industry. Romania recorded the highest volume of construction in 2008, with an increase of over 26% over 2007 levels, according to the National Institute of Statistics [43]. In 2009, this percentage was reduced to 15%. The greatest decline was recorded in the residential sector, with a reduction of 20% [43]. Consequently, this crisis has also affected new construction. On the other hand, an increased focus emerged on energy efficiency in the period 2008–2013, especially in the commercial building sector: hotels, building offices, and shopping malls. Since 2013, the residential sector has entered a growth phase, averaging 2.6% annually. This growth rate was repeated in 2014, based on a 32.6% share of residential buildings and 16.6% for the non-residential [43]. More significant

growth has been registered in 2015, with a rise of 13.4% in the first quarter (compared with the same period in 2014), and the same upward trend is predicted for the whole year. This increase is reflected in the residential (16.9%) and non-residential (8.2%) sectors [43].

In Macedonia, the period after the economic recession in 2008 significantly affected the construction and building industry. In 2008, total construction work was reduced by 4%, with the greatest reduction recorded in the residential buildings: −28.6% compared to 2006. Consequently, this crisis has affected the new constructions. Starting in 2012, the construction sector has entered a growth phase, with an increase of 31.7% relative to 2006. The percentage increase for the residential buildings was only 3.3%—much less than the 29.5% achieved for non-residential buildings [44].

3.2.4. Central Europe Countries

In Germany, a 10-year long building sector recession ended in 2005, with investment in real terms 5% less than the peak building investment recorded in the mid-1990s. In 2013, the construction investment price was at 1991 levels, but this was still 17% below the price recorded in 1994. In contrast, the gross domestic product recorded in 2013 exceeded the 1991 value by one third in real terms [45].

In Belgium, the economic recession of 2008–2009 has affected significantly the construction and building industry combined owing to the decisions of some regional governments to reduce the incentives for renewables. Since 2014, the construction and building industry in Belgium has again entered a growth phase, with a rise of a few % per year (2–3% in 2014 and 5–6% predicted for 2015) [46,47].

In Demark, the successive Governments have initiated a huge number of investments in the building and energy sectors, and there are currently no significant economic barriers in the country in relation to nZEB.

3.3. Identification of Professional Barriers Including Gender of Professionals

Since the 2007 financial crisis, the property development and construction sectors have experienced a sluggish recovery, notably in Southern Europe where real estate investment continues to lag behind other European regions.

While this slow recovery has had a great effect on the economy and on building professionals, as well as nZEB developments, it has also had a significant influence on employment rates. The overall increase in unemployment—which reached record highs—has affected the availability of building professionals. Women's participation in building and nZEB related professions has also been severely affected, all the more so given the low base to begin with. Overall, within this financial environment, the availability of professionals involved in the nZEB sector has been reduced, and the overall lack of investment in the real estate and construction sectors has slowed down the emergence of nZEBs.

3.3.1. South Europe Countries

In Greece, a report appeared in the journal of the Technical Chamber of Greece (TEE) in 2000, in which women engineers were reported to reach almost 27% [48]. A later study conducted by TEE showed that the participation of women in the engineering profession was increasing steadily, reaching 28.2% in 2007. Indicative is also the differentiation between older professional engineers, registered in TEE during 1971–1975, in which women represented only 14%, and younger engineers (2001–2006), in which women engineers reached 37%. Apart from young engineers, significantly higher than the average representation of women in Architecture (46.6%), Chemical Engineering (36.6%), and Civil Engineering (33.5%) was found [49]. The same study was repeated in 2009, and showed that among young engineers, the participation rate for women had reached 38%.

Specifically in relation to energy auditors, although there are no official statistics published, a search of the official site of building energy auditors showed that for the Thessaloniki municipality, 18 female engineers were registered out of a total of 77 (23.4%) [50]. Similar numbers were found for

the central Athens area, with 29 female energy auditors out of 115 (25%). It may be assumed that similar statistics apply for the whole country.

The last known and credible data concerning unemployed engineers in Greece are from 2009, and are, therefore, considerably out of date, especially considering the enormous increase in unemployment since then and the extreme decrease in construction activity. Results from a study of TEE show that non-employed engineers reached 13%, the highest number recorded since 1997 [51,52]. It must be noted, however, that engineering unemployment statistics may be misleading. This is because engineers in Greece have to pay their own social insurance costs if they are self-employed (i.e., freelance engineers). This is also related to their registration as professional engineers for tax purposes. This leads to a common situation for young engineers, in which they are officially considered self-employed, but, in fact, have either an extremely low income or even no income at all. Quite indicative was a public announcement made in October 2014 by the Thessaly branch of TEE, in which it was estimated that engineering unemployment had reached almost 80% [53].

In Italy, according to 2013 data, women as a proportion of engineers, architects, and similar professions stand at 16.8%, with a 66.3% disparities rate. The proportion of women engineers employed has fallen below 65% (among men is 73%), whereas in 2012 it stood at 72%. In Italy, women get better school results than boys in all subjects—including math—but make up only 23% of those that are enrolled in degree programs in engineering and 38% on courses related to science [54]. In Italy, gender differences across fields of study are often smaller than those observed in other OECD countries. For example, 40% of all new engineering graduates in Italy are women. As for the architectural profession, there are 152 thousand Italian architects. Around 41% (about 62 thousand) are women, 10% more than in 1998. Over the past six years, the average net monthly earnings of master degree graduates in architecture five years after graduation was approximately 20% higher for males. In general, the difference is 37.5%, measured in terms of average annual income in 2013. Although in recent years this difference has diminished, it remains very high when compared with the European average of 29% [55–57].

In Spain, from a historical perspective from the 1960's to the 1990's, female presence in Architecture and Engineering studies has rapidly evolved in the Spanish Universities and the marketplace. Women's presence has increased from 2.43% in 1969 to 29.20% in 2013. In spite of the fact that the majority of university alumni today are women, and that they finish their studies with better average grades than their male counterparts, there are certain disciplines that are still resistant to female participation. Such is the case of engineering and sciences in which less than 30% are women. Female presence in Engineering in Spain is still one of the lowest feminine representations in Spanish Higher Education. At the University level, the trend is clear, with only the 28.1% of the students in the Spanish technical curricula being women in the 2003/4 academic year. However, the rate of retention before graduation is higher among women than men, with almost 33% of graduates being women.

Distribution of women among different technical fields is also evident. Agronomic engineering is close to parity, forestry is slightly over 31%, while architecture and building engineering is rapidly increasing with 60% and 37%, respectively, which denotes the interest of women in the building sector. In the majority of the remaining technical schools, the percentage of women among new students lies somewhere between 23 and 30%, except for computer sciences, which has an extremely low participation of women (11.57%) [58].

In the labor market, there is a rate of unemployment of approximately 7% in the case of male engineers and 29% in the case of female engineers [59,60]. Among the employed, the presence of men is significantly higher in Universities, and especially in companies. Oddly, there are more women than men dedicated to research activities in non-profit private institutions.

The unemployment rate among industrial engineers is 8.1% but rises to 38.1% for those under 30 years; it stands at 5.6% for those between 30 and 50 and is reduced to 2.6% for industrial engineers over 50 years [61]. In terms of gender, unemployment affects more women (21.4%) than men (14.4%) [62].

In Cyprus, in 2012 [63,64], the employment rate of women in the Cypriot labor market equals 59.4% and thus was slightly above the EU average (58.6%). However, unemployment for women in Cyprus was at 11.2%, which was higher than the EU average in 2012 (10.6%). Secondary education in 2012 was more common for Cypriot women (73.6%) than the EU average (70.9%). College/University attainment of Cypriot women was equal to 37.5%, clearly above the EU average (25.8%), but the challenge remained to motivate high school students to enter gender atypical fields of study (including engineering). In general, the share of women studying in the fields of Engineering/Manufacturing/Construction (25.9%) exceeded the EU average by 0.2% and the share for Science/Maths/Computing (38.1%) by 0.7%. It is reported that the share of employed engineering workers among all employees in 2007 was 1.74% [65]. The same report shows that the female employed engineering workers in Cyprus as a share of the total in 2007 reached 26.1% (average share in Europe was 16.6%). According to the Statistical Service in Cyprus, in 2014 the average number of employed professionals in the construction sector was 25,170, of which 2246 were women (8.9%), and the average number of unemployed professionals in the construction sector was 10,795, of which the 965 were women (8.9%). This data, however, does not refer to all female and male engineers and building professionals in Cyprus, it only refers to the construction sector.

3.3.2. West Europe Countries

The United Kingdom has the lowest rate of female engineers in the EU, with only 9% of the engineering workforce being female [66]. Only 3.4% of engineering and manufacturing apprentices and only 5.5% of the engineering professionals and 4.45% of engineering technicians are female [66,67]. Furthermore, UK schools do not promote the participation of female students in technical subjects such as physics and mathematics. In 2012, physics was the most popular subject amongst male students, but it ranked 17th in preference amongst the female students, with only 21% of physics A level entries being female in 2013. Stereotypical behaviours are frequently observed in UK schools, with girls being encouraged to take up textiles, biology, food technology, and, in general, subjects that are not related to engineering studies. Nevertheless, of all the students that take A levels, girls outperform boys and perform better in mathematics and physics [68]. As far as higher education is concerned, only 21% of the students in engineering, manufacturing, and technology are female [66]. This percentage reduces even further in the market, with only 3.4% of engineering and manufacturing apprentices and 1.9% of construction apprentices being female. Indicatively, in 2012 only 400 women started an engineering apprenticeship in comparison to 12,880 men. In 2011, women represented only 1% of the total apprenticeships in construction, planning, and the built environment.

By 2020, the United Kingdom will require 830,000 professional scientists and engineers, which means that it will need to double the number of recruits into engineering to meet the demand. Currently, only 39% of the female engineering graduates enter roles in engineering and technology, and less than 13% of the science, technical, and engineering (STEM) workforce is female. The most gender-segregated industry is construction, with only 11% female [69].

The unemployment rates in the engineering industry of the United Kingdom have been reduced in the recent years (8.4% for architecture and building in comparison to 9.5% in 2011, 9.5% civil engineering in comparison to 11.4% in 2011 [66,70]).

In Ireland, in the three registered building professions, men outnumber women by almost five to one. 13% of Engineers are female, 29% of Architects are female, whilst just 5% of Building Surveyors are female [42,71]. In the case of Architecture, very high levels of post-qualification attrition are recorded, wherein close to 50% of graduate architects are female, but significant numbers fail to remain in the profession for their entire careers. A survey commissioned by the Royal Institute of the Architects of Ireland reported that 41% of all registered architects had lost their jobs between January 2008 and March 2009 [42,72]. Of the registered professions, there were 160 architects listed as unemployed in Ireland in 2014 out of a total of 2600, a percentage of 6.2%. Unemployment in engineering is considerably less with widespread shortages of engineering graduates in many sectors. However, within the civil

engineering sub-discipline, which is most involved in the delivery of building-related engineering projects, there were 200 engineers recorded as unemployed in 2014 out of a total of 6900, a percentage of 2.9%. There are approximately 230 registered building surveyors, and the National Skills Bulletin indicates a skills shortage in the profession. Overall, there is a combined pool of a little under 11,000 people eligible under Irish law to certify compliance with building regulations and an average unemployment rate of 3.2% within that sector. Such a low level is normally considered close to full employment [73]. With next to full employment and an increasing shortage of sufficiently upskilled professionals and additional demand for nZEB skills through extension of nZEB-related building regulations to non-residential buildings, professionals are unable to take time off to upskill. The legacy of the crash also means that professional practices are underinvesting in upskilling of their staff.

3.3.3. East Europe Countries

In Romania, poor statistical data exists regarding women's participation in engineering, but according to most of the technical universities, more than 40% of civil engineering and architecture undergraduates and post graduates are women.

Regarding the discipline of architecture, at least 40% female participation in building design is found in individual or associated architecture offices. Engineering employment rates in Romania have shown an increase in recent years, especially due to the fact that important multinational companies have established new businesses here, mainly in university cities. According to data from the Technical University of Cluj Napoca [74], the employment rates for architecture are 72%, for civil engineering 36%, for electrical and electronic engineering 46%, and for mechanical engineering 50%.

In Macedonia, the most gender-segregated industry is construction, with only 6.3% of participants being women [75]. The employment rate for women in 2014 was 32.4%, which is significantly lower than the employment rate of 50.1% for men. But, in the construction sector, women represented only 6.3% of total employees in 2014. The unemployment rate for 2015 was 25.1% for women and 26.7% for men, and they were mainly concentrated in the 15 to 24 years age group.

3.3.4. Central Europe Countries

In Germany, the proportion of women currently enrolled in engineering disciplines at universities is significantly lower than that of men. Only in the study of architecture are there about equal numbers of men and women. However, the proportion of women in recent years has been increasing. In the professions, the difference is even greater. Thus, with the architectural profession, for example, the proportion of women is only 31% [76]. An evaluation by the Federal Chamber of Engineers in 2011 reported a female proportion of 15% for civil engineers and of 34% for architects and planners [77]. The job market for architects and civil engineers is closely linked to the development of the construction industry. Given still low interest rates and a continued high level of investment activity, the situation in the construction sector is quite good. Unemployment among civil engineers in 2010 amounted 2%. Thus, it has decreased continuously since 2007 from 3.3%. Among architects, the rate of unemployment in 2010 was 2.9%. Again, compared to 2007 when the rate was 3.5%, there has been a slight decrease [78].

In 2011, the number of unemployed engineers further decreased from 3158 to 2376. In the same year, the number of unemployed architects decreased from 3559 to 2724 [79].

In Denmark, of all qualified engineers, those involved in the building industry amount to about 14.1% civil engineers and 5.3% mechanical services engineers. There is a construction market predominance of men among civil engineers: 84% are men and 16% are women. As of 1 January 2017, the unemployment rate is generally low at 2% overall, 2.6% for female engineers, and 1.8% for male engineers [80]. For architects, the unemployment under the age of 30 years is 17.7% [80].

In Belgium, the rate of female engineers is one of the lowest in Europe at only 9.5% [81,82]. In the architectural and civil engineering sector, it reaches less than 6% [83]. The most gender-segregated industry in Belgium is construction, with only 7–8% female participation [84]. The unemployment rates in the engineering industry in Belgium have been quite low in recent years: less than 5% for

architecture and building in 2014 and 9% for civil engineering and electro-mechanical engineering. These unemployment rates are lower than the 2012 values of 7% and 10%, respectively [85].

4. Conclusions

From the data analysis and discussion in Section 3, it can be concluded that the countries of the central-west geographical region have achieved the greatest implementation of national legislation for the promotion of nZEB. In many of the countries studied, the transposition of EPBD had been strongly supported by regulations that came into force for its alignment (Italy) and new proposals for nZEB implementation (Germany) including national definitions (Ireland, Germany, Denmark, Romania). New instruments and incentives for the improvement of energy efficiency in existing buildings have started in some countries (Greece, Cyprus, Denmark, and Romania) but have stopped in others (United Kingdom). New projects focused on nZEB and positive energy buildings have been initiated in most countries [86,87]. The level of nZEB implementation in residential buildings is increasing (e.g., Denmark, Germany, Belgium, and Cyprus). Whilst overall, nZEB targets have been set by the European Commission for all member states for implementation by the 2018 deadline set out in the EPBD; these remain to be incorporated into local regulation by any Member State.

Promotion instruments and existing educational courses related to nZEB further indicate the strength of the market and the potential for the delivery of nZEB in practice. These are also more prominent in west and central Europe. Furthermore, the global economic crisis that has significantly affected the building sector has more severely impacted some of the countries of the south and east than those of the central Europe, with unemployment rates as high as 80% for the south and as low as 2% in central Europe, as presented in Section 3.3. However, it is interesting to note that the participation of women in the building professions and, consequently, in the nZEB industry is overall more significant in the countries of the south-east regions. Overall, a balanced participation of women in the nZEB industry can have a stimulating effect in boosting the industry as the availability of skilled professional increases.

Suggested Strategy for the Enhancement of nZEB Market

The results of this research can be used as a potential route towards the improvement of nZEB market uptake along with future implementation of the national and local regulations regarding the nZEB. This work highlights that the issues of low nZEB market penetration are not due to a lack of policy on a European level; rather, that they are due to the lack of financial incentives and the shortage of skilled professionals. Market penetration can be enhanced by upgratting the skills of the relevant building professionals and increasing their employability.

This research gives input and direction to training courses developed primarily in the form of three major reports, which are publicly available:

- National Integrating Report: provides information on the most important contents and national and European best practice examples.
- Training Information Report: identifies the training needs of the target professions. The collected data present the various current educational programmes in the examined countries.
- Market Barriers Report: identifies the most important market barriers in each country with an identification of the societal and professional requirements involved. The role of the female building professionals in each country is presented with a focus on nZEB, as well as their unemployment rates.

The information of these reports has further fed directly into the design of training courses, learning objectives, and developed materials as a mean to enhance the nZEB skills of building professionals in the countries presented in the analysis. The courses have a multidisciplinary approach and include engineering topics such as building modelling, systems, renewable energy sources, architectural and design aspects, and economic and management issues. More specifically, the training

courses are delivered by the MEnS EU project and have three distinct forms: lectures, webinars, and hands-on exercises [17]:

- Short international accredited educational and training programs, with an integrated approach that allows the participants to learn through real time lectures. The participants can be local or international for each course.
- The MEnS E-Learning platform, in which participants can access the lectures as online webinars and documented educational material. This enables interaction between professionals in Europe and is a tool that builds on top of the BUILD-UP portal [88].
- Hands-on accredited exercises "*Front Meeting of Skills*" on real case studies of buildings, organized in four countries; Denmark, Cyprus, United Kingdom, and Belgium.

Based on this common Continuous Professional Development (CPD) methodology, the training programs were delivered three times in each examined country, with priority given to women and unemployed so they can participate in necessary upskilling to re-enter the labor market. Each of the training programs corresponds to 10ECTS credits and 60 approximate delivery hours, and they are created based on the learning outcomes at Level 7 (post-graduate education) of the European Qualifications Framework [89]. This enables cross-country co-operation and utilization of the credits throughout the European countries.

In total, following completion of the course delivery and counting the participation in the various lectures, online trainings events, and case studies, more than 1800 building professionals have significantly increased their knowledge and skills in nZEB delivery. It ought to be noted that the overview given in this paper is open to further improvement, according to the continuous evolution of the NZEB topic.

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