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Towards Nearly Zero-Energy Buildings in Mediterranean Countries: Challenges for Real Estate Professionals from the Latest European Regulations

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Abstract

The Energy Performance of Buildings Directive 2010/31/EU demands that all new buildings are nearly zero-energy (NZEBs) by the end of 2020, thus requiring from European countries to draw up national plans and develop their first NZEBs.

According to the EU Directive, after December 31st, 2020, building projects that do not meet the requirement of "nearly zero (fossil) energy" consumption, will not be granted a construction permit. However, only a limited number of zero-energy consumption buildings do exist nowadays, while their design, construction and operation constitute a great challenge for a variety of reasons.

The purpose of this study is to examine the Cyprus case study. More specifically to identify the most critical sustainability design and construction parameters for NZEBs, through a thorough analysis of the European Directives, National legislation and international scientific resources, to highlight the main differences between conventional and NZEB developments in Mediterranean countries such as Cyprus and evaluate the principles and techniques for a more sustainable construction industry in Cyprus. The main focus is to investigate and highlight the barriers faced by various construction industry practitioners and professionals, in the application of the underlying legal and technical framework for NZEBs.

Through this process, several conclusions were drawn, which were also affirmed by the findings of the empirical quantitative research conducted via an online questionnaire addressed to construction and real estate professionals across Cyprus. First, the necessity of applying the principles of sustainability and NZEBs to maximize energy efficiency is undeniable and unanimously recognized by industry professionals. In terms of compliance to the European Directives on Energy Efficiency, the current policy framework in Cyprus and other countries has made relatively little progress towards providing effective and efficient solutions to existing barriers because little focus has been drawn on solving them.

The government does not offer sufficient incentives to citizens for home upgrades although refurbishing costs are significant. The state has also failed to meet its own targets on bringing government buildings up to speed with the EU directive.

There are also challenges in the research and development of NZEBs, as well as technical, financial, social, environmental/health-related and organizational/legal barriers to the implementation of new NZEB developments and NZEBs retrofit. From the limited range of technical solutions that can be used because of existing building structure and technical systems, the excessive investment costs, the lack of knowledge and interest for energy efficiency among residents and building owners to the sensitive balance between comfort and efficiency as criteria for selection of materials and waste management and the necessity of communication and consensus in NZEB refurbishments involving multiple homeowners, these challenges must be addressed for sustainable NZEB developments to be the new norm. To this end, industry professionals can and should play a key role in raising awareness and promoting the principles of sustainability and NZEBs, although this entails their own adequate training to remain up to date with the latest technical and regulatory requirements.

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Chapter 1: Introduction

1.1. Research Problem

The Energy Performance of Buildings Directive 2010/31/EU demands that all new buildings are nearly zero-energy (NZEBs) by the end of 2020, thus requiring from European countries to draw up national plans and develop their first NZEBs.

According to the EU Directive, after December 31st, 2020, building projects that do not meet the requirement of “nearly zero (fossil) energy” consumption, will not be granted a construction permit. However, only a limited number of zero-energy consumption buildings do exist nowadays, while their design, construction and operation constitute a great challenge for a variety of reasons.

The first reason is that existing buildings require a vast amount of energy to function, and most of this energy is wasted because of their inappropriate architectural design. This means that architects have to adapt and change their design approach by finding new ways of obtaining the similar or even better functions with reduced energy requirements.

In addition, mechanical engineers must dramatically change their approach, forgetting forever the practice of oversized plants and systems, resulting to redundant increase in costs and energy consumption. For a NZEB to be designed, a new professional must be added to the design team, the so-called “energy and comfort expert”. This professional must be integrated right from the earliest phases of the design process. The professional team must work together in an interactive and iterative manner, making the definition of the concept design the most important phase of the entire design process. This challenge is not limited to the design phase, but also extends to the operation: even the best-designed building may waste energy if it does not operate appropriately and if its occupants are not energy-conscious.

By taking into consideration the wider perspective, apart from the European countries which will need to comply with the abovementioned Directive, many other countries will also adopt the policy of NZEBs, resulting to a significant rise in the amount of such buildings, with a consequent impact on the electric system.

The present study intends to provide a framework for a transition towards NZEBs in Cyprus, as well as to identify the barriers towards NZEB implementation in Cyprus.

The current policy framework has made relatively little progress towards providing effective and efficient solutions to existing barriers because little focus has been drawn on solving them. Following a situation analysis, possible recommendations, policies, and measures for overcoming these barriers are suggested. In order to highlight good case studies that could be applicable to the Cypriot context, best practices in other EU Member States and worldwide are studied extensively.

1.2. Research Aim & Objectives

The primary goal of this study is to identify and list all the challenges, problems and difficulties that real estate professionals, such as architects, civil engineers and contractors, may encounter due to the implementation of the new EU directive, including increased initial costs, lack of substantial information and knowledge regarding sustainable design, misunderstanding of long-term economic and environmental benefits of sustainable development, lack of national plans and legislation and more.

The objectives of this study are:

1. To identify the most critical sustainability design and construction parameters for NZEBs through an extensive review of international scientific resources.
2. To analyze the requirements of the latest European Directives and National legislation.
3. To identify the main differences between conventional and NZEB developments in Mediterranean countries such as Cyprus.
4. To evaluate the principles and techniques for a more sustainable construction industry in Cyprus.

5. To list the views of various construction and real estate industry practitioners and professionals, as well as the barriers they face in the application of the underlying legal and technical framework for NZEBs.

1.3. Research Methodology

The empirical part of this research is based on quantitative methods, with the preparation of an appropriate questionnaire provided to 26 real estate professionals such as civil engineers, architects, consultants, contractors or real estate agents, with the purpose of obtaining a more comprehensive perception of the industry's current status on NZEBs, thus allowing to identify the problems regarding the implementation of the latest EU directives in Cyprus and to provide suggestions for the integration of sustainable design in the real estate sector, as well as to clearly understand the drawbacks of the implementation of the European and National legislation for buildings with nearly zero energy consumption in Cyprus.

1.4. Dissertation Structure

The chapters following the introduction are presented in this section.

Chapter 2 (Literature Review) includes the definition of NZEBs and a detailed presentation of the latest related European regulations and national legislation. Furthermore, a thorough comparative analysis is performed on the characteristics and requirements of conventional buildings against NZEB developments, based on international and national studies.

Then, Chapter 3 (NZEBs – The Case of Cyprus) focuses on the legal and regulatory framework, along with the sustainability principles and techniques that are currently into effect in the construction industry of Cyprus, while also documenting the barriers faced by sector professionals in the application of those principles and techniques.

Chapter 4 (Methodology) describes the methodology applied to conduct the research and offers information about the empirical research sample and data gathered and analyzed.

Chapter 5 (Statistical Analysis & Discussion) presents the results of the statistical analysis carried out using the questionnaire data and discusses the findings, comparing them to previous research.

Finally, Chapter 6 summarizes the conclusions of this study, explains the limitations of the study and provides recommendations for future research.

Chapter 2: Literature Review

2.1. Key Concepts & Definitions

Buildings are responsible for 40% of the primary energy use and 24% of the green-house gas emissions worldwide. Furthermore, space heating and cooling are the primary energy usages in the European Union (EU), reaching 50% (546 Mtoe) of final energy consumption in 2012 (Ascione, et al., 2017; UNEP, 2009; Carpino, et al., 2017; Huang, et al., 2018).

Nearly zero energy buildings (NZEBs) are considered as a promising solution to mitigate the energy and environmental problem. There are various definitions of NZEBs. The definition provided within the EU Directive 2010/31/EU (see Section 2.3.2) mentions that an NZEB is "a building that has a very high energy performance, for which the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renew-able sources, including energy from renewable sources produced on-site or nearby". Essentially, the overall primary energy consumption of an NZEB should be equal to or less than the energy production from renewable energy sources on-site during a specified period (usually one year) (Ascione, et al., 2017; Tzortzaki, 2017; Kwiatkowski, et al., 2017).

Although the more flexible term "nearly zero energy building" was ultimately used in the recast of the European Directive, the initial term referred to "Net Zero Energy (NZE) building", which combines energy efficiency and renewable energy utilization to reach a balanced energy budget over a yearly cycle (Shubin, et al., 2019; ECEEE, 2011). Alternatively, according to the European Council for an Energy Efficient Economy, ECEEE (2011), a Net Zero Energy building is "where, as a result of the very high level of energy efficiency of the building, the overall annual primary energy consumption is equal to or less than the energy production from renewable energy sources on site". Along with this definition, there are also several related "Net Zero" terms, which are described below (ECEEE, 2011):

- Net Zero Site Energy: a site ZEB generates at least as much energy as it consumes annually, when accounted for at the site.

- Net Zero Source Energy: a source ZEB generates at least as much energy as it consumes annually, when accounted for at the source. Source energy is the primary energy required to produce and supply energy to the site.
- Net Zero Energy Costs: in a cost ZEB, the amount of money paid to the building owner by the utility for the energy exported to the grid is at least equal to the annual amount paid by the owner to the utility for energy consumption and services.
- Net Zero Energy Emissions: A net-zero emissions building (or Zero Carbon Building) generates at least as much emissions-free renewable energy as it consumes from emissions-producing energy sources.

2.2. Key Features & Characteristics of NZEBs

NZEB systems consist of energy usage systems (e.g. air-conditioning systems), renewable energy systems (e.g. photovoltaic systems and wind turbines), electrical energy storage (ES) systems and thermal energy storage (TES) systems. The renewable energy technologies that are widely adopted in NZEBs include photovoltaic systems (PV), wind turbine (WT), diesel generators (only when using biodiesel), etc. A proper sizing of these systems is critical for the NZEB to perform as desired in aspects of thermal comfort, energy balance, and grid dependence (Huang, et al., 2018).

Therefore, the technologies typically implemented in NZE buildings include (Shubin, et al., 2019; Karlessi, et al., 2017):

- High-efficiency building envelope components
- Heating, Ventilation, and Air Conditioning (HVAC) systems, which minimize consumption
- Renewable Energy Systems, which are incorporated at a building and/or community level and generate the remaining required energy from renewable sources.
- Energy management systems at building and community levels, which optimize the energy consumption and distribution.

The expansion of the NZE concept to a community scale entails several potential technological benefits (Shubin, et al., 2019):

- When demand for particular technologies or components is aggregated, thus reaching higher levels, it enables the utilization of economies of scale.
- Achieving NZE balance at a community (instead of building) level could promote the development of a wider variety of building forms, styles and building integrated technologies.
- Energy resources can be managed at a community level and allocated among buildings.
- Establishing technologies at a community level favors the implementation of multi-building systems, like commercial Photo-Voltaic (PV) installations or bio-fueled district heating centers, which can be installed on large structures, like parking facilities and commercial buildings, or in other available community locations.

Consequently, expanding the concept of nearly zero or net zero energy to a community of multiple NZEBs could further promote design flexibility, cost reduction, energy and resource management. Nevertheless, the proper scale or size of such communities should be estimated to make the best use of their advantages and minimize energy related costs (Shubin, et al., 2019).

Technological solutions in buildings play a major role in achieving net zero energy goal. The value targeted by each country may be vary among climate zones, design and architectural preferences, building types, but the concept of measures remains the same as is the most important factor for the implementation of the NZEB approach. So the points that should be considered for the improvement of the energy efficiency level of a building and the decrease of the energy consumed are the following (Tzortzaki, 2017; Ashmawy & Azmy, 2018):

- Orientation and shape, maximizing heat gains from the sun, avoiding overheating in summer and reducing heating needs in winter. In fact, building orientation and openings may have a key role in maximizing thermal comfort and minimizing energy consumption in cooling, heating, lighting etc. The building longitudinal direction axis along the East-West direction is often preferred, ensuring that the southern facade absorbs the maximum amount of the heat in the cold period and the north facade receives less amount in the hot period, according to the azimuth and elevation angles of the sun in winter and summer.

- Advanced insulation, minimizing heat losses through exterior elements (e.g. walls, windows, roof), which may account for 50% of total heat losses in a building.
- Reduced thermal bridges, i.e. localized areas of the building envelope where the heat flow is different (usually increased) in comparison with other areas nearby when there is a difference in temperature between the interior and exterior part of a building, causing significant heat losses. Reduction of thermal bridges can be achieved through the installation of expanded polystyrene or mineral wool, the installation of protection layer, autoclaved cellular concrete or reinforce concrete, etc.
- Airtightness, which is the resistance of the building envelope to inward or outward air leakage and is very important for an energy efficient building, especially at connections between different elements such as doors and windows. It can be ensured by applying various methods of insulation and air leakage prevention.
- Advanced energy efficient windows, which perform better in terms of day lighting with the combination of the position and the shape of the building, solar heat gaining, as it allows sun heat to enter the building directly and heat losses reduction, as it prevents the captured solar heat from leaving the building. In order to perform these functions successfully, windows should meet several requirements in relation to their location in the building, design and materials used, window to wall ratio and glass thickness. Different types of advanced windows are used in different climates.
- Use of thermal mass, which is the ability of building materials to store heat (thermal storage capacity). The main importance of materials with thermal mass for an energy efficient building is their ability to absorb heat, store it, and release it later. Examples of thermal mass may be: parts of the building

structure (walls, floors, ceilings, and stairs), furniture, finishing materials and passive solar heat storage containers. Utilization of thermal mass reduces heating and cooling loads, temperature swings and improves thermal comfort in the building. The utilization of heavyweight construction materials with high thermal mass can significantly reduce total energy consumption in buildings. However, the amount of thermal mass should be optimized, taking into account the amount of glazing and the climate conditions.

- Ventilation strategies, including natural and forced ventilation. Ventilation in energy efficient buildings is very important for providing fresh air and reducing cooling loads. Natural ventilation is possible due to pressure difference at the inlets and outlets of a building envelope and the difference between indoor and outdoor temperatures, as a result of wind velocity usually takes place through opening windows and, therefore, causes heat losses; moreover, it does not always provide a sufficient amount of fresh air. As an energy efficiency building is airtight and aims at minimizing energy losses, this method of ventilation is usually not optimal. Forced ventilation is achieved by mechanical means, using fans to reach and control the appropriate air speed. The main feature of such a ventilation strategy is heat exchanger. Warm exhaust air flows from the room to the heat exchanger and delivers the heat to its plates. At the same time colder fresh air enters the heat exchanger from outside the building. The heat captured on the plates is used to warm up fresh air and supply it to the room. The main advantage of the heat recovery is that exhaust and fresh air are not mixed. This principle allows for almost 100% recovery of the temperature difference, if the exchanger is long enough. Usually the percentages presented for being achieved are between 75% and 85%. Energy efficiency heat recovery ventilation consumes a low amount of energy (2-7 kWh/m2 year) and reduces heat losses (which could take place in case of opening windows so in the case of natural ventilation) considerably.
- Energy efficient lighting. There are several types of lighting available on the market, which perform at different efficiency levels: incandescent, discharge and light emitting diodes. Incandescent bulbs are the standard light bulbs and halogen lamps with the shortest lifetime and very low efficiency. They have

the lowest investment and highest operation costs. Discharge lamps have higher efficiency and lifetime than incandescent ones and include fluorescent tubes, compact fluorescent lamps (CFLs) and metal halide lamps. They are widely spread on the market and available at competitive prices. The most recent lighting technology is light emitting diodes (LEDs). They have a very long lifetime and high efficiency.

- Automation System. Building automation is the connector of all the single requirements for NZEB, such as a well-insulated and airtight building shell, efficient HVAC system and a high share of renewable energy. Main functions of building automation system are to control all energy related components, to monitor the energy use and the storage management and ensure the thermal comfort.
- Heat Pumps, i.e. a thermodynamic system capable of transferring heat from a body at a lower temperature – “source” – to a body at a higher temperature – “hot well” – thereby supplying more energy than non-renewable systems. Heat pumps are responsible for the heating provision and for the Domestic Hot Water in Building. The types of heat pumps that are mainly used are ground source heat pumps and air-to-water heat pumps. This technological solution is a well-proven measure to approach NZEB requirements. Also, installation of exhaust air heat pumps can help meet NZEB requirements.

2.3. European Regulation & National Legislation on NZEBs

2.3.1. Climate Energy Package & EU Directive 2012/27/EU

During the past decades, the concept of Energy Efficiency has become a major factor in the fight against climate change and the reduction of energy cost for citizens and cities across all member countries of the European Union. One of the most significant European Energy policies was the Climate Energy Package, which was agreed in 2008 as a milestone towards a “Low Carbon Economy in 2050", in order to resolve the energy trilemma through (Tzortzaki, 2017):

- the enhancement of energy supply security, since Europe imports more than 50% of the energy resources it consumes,
- the reinforcement of competitiveness of European Economies by ensuring affordable energy prices,
- the promotion of Environmental Sustainability.

The Climate Energy Package, which was succeeded by the Paris Climate Agreement in 2016, involved the so-called 20/20/20 targets, requiring the decrease of greenhouse gas emissions by 20% by 2020, as compared to 1990 levels, the usage of renewable sources reaching 20% of the total energy consumed by 2020 and the enhancement in energy efficiency by 20% compared to the projections for 2020. The concept of Energy Efficiency refers to specific targets for energy saving in four main categories: residential, services, transport and industrial, as presented in the table below which shows potential energy savings, so that EU members are able to achieve the target of 20% by 2020 (Tzortzaki, 2017).

Table 1: Potential Energy Savings to Achieve -20% by 2020 (energy measured in Megatons of Oil Equivalent) (Tzortzaki, 2017)

Sector	2005 Energy Consumption (Mtep)	2002 Energy Consumption Unchanged Scenario (Mtep)	2020 Potential Savings (Mtep)	2020 Global Potential Saving
Residential	280	338	91	27%
Services	157	211	63	30%
Transport	332	405	105	26%
Industrial	297	328	95	25%

Remarkable progress has been made by the European Union over the past decade. In 2014, its primary energy consumption was only 1.6% above the 2020 target, while total energy consumption was 2.2% below the 2020 target. In fact, projections of the

European Commission in early 2011 indicated that approximately half of the 20% target would be reached, which led to the release of a new Directive on Energy Efficiency in November 2012. The 2012 Energy Efficiency Directive initiated a series of measures to help the EU achieve its 20% energy efficiency goal by 2020. Under the Directive, all EU countries are mandated to utilize energy more efficiently at all stages of the energy supply chain, from generation to final consumption. The Commission suggested an update to the Energy Efficiency Directive, involving a new 30% energy efficiency target for 2030, along with measures ensuring that the new target is met. New policies and measures were enforced at a national level, so as to guarantee significant energy savings for both industrial use and consumers (Tzortzaki, 2017; Pirpitsi, 2017; Giama, et al., 2020):

- Energy distributors or retail energy sales companies must take proper actions to ensure that annual energy savings reach 1.5%.
- A variety of methods are available to EU countries in order to attain the same level of energy savings, such as the enhancement of heating systems performance, the installation of double-glazed windows or roof insulation.
- EU countries must provide their public sector with energy efficient buildings, products and services.
- EU members must ensure that energy efficient renovations are carried out annually on at least 3% of government buildings (measured by floor area).
- Energy consumers should be enabled to manage energy consumption more efficiently, through the provision of individual metering for free and easy access to data on consumption.
- SMEs and large firms must be offered incentives to undertake energy audits and identify methods to decrease energy consumption.
- New energy generation facilities must monitor their efficiency levels.

Apart from the aforementioned general targets set by the European Commission, each EU member was mandated to set their own indicative national energy efficiency targets, based on primary or final energy consumption, primary or final energy savings, or energy intensity (Tzortzaki, 2017).

2.3.2. Energy Performance of Buildings Directive (EPBD) Recast 2010/31/EU

In the context of diminishing energy dependence and abating the consequences of the greenhouse effect, the European Union introduced the "Energy Performance of Buildings Directive" (EPBD) as a means to reduce the energy consumption of buildings. Directive 31/2010/EU entails the introduction of nearly zero-energy buildings yet without specifying a set of standards or offering a comprehensive guidance framework procedure to estimate building energy efficiency. Therefore, EU countries are expected to provide those specifications. Of course, considering local conditions in each member's definition does not prevent the adoption of a uniform methodology in all EU countries (Tzortzaki, 2017; ECEEE, 2011; Kwiatkowski, et al., 2017).

The 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive are EU's core legislation on limiting energy consumption of buildings, although on November 30 2016, the Commission recommended an update of EPBD to promote the use of smart technology in buildings and modernize existing rules. The Commission also established the EU Building Stock Observatory, a new buildings database tracking the energy performance of buildings across Europe (Tzortzaki, 2017).

Under the existing Energy Performance of Buildings Directive (Tzortzaki, 2017; Ascione, et al., 2017; Carpino, et al., 2017; Kwiatkowski, et al., 2017):

- Energy performance certificates must be comprised in all advertisements of building sale or rental.
- EU countries must provide inspection templates for heating and air conditioning systems or put in effect measures with comparable results.
- All new public buildings must be NZE by 31 December 2018 and all new non-public buildings must be NZE by 31 December 2020.
- EU member states must define minimum energy performance requirements for the construction or major renovation of buildings and for the replacement or retrofit of building elements (heating and cooling systems, roofs, walls etc.).
- EU countries must assemble lists of national financial measures to enhance the energy efficiency of buildings.

Taking into account the variations in climate conditions and building culture across Europe, the Energy Performance of Buildings Directive mandates EU countries to provide national definitions and design a national roadmap toward nearly Zero-Energy Buildings that would adequately consider specific national and regional conditions. More than 25% of the 2050 building stock is still to be built, so the effective implementation of low energy buildings across Europe must be actively supported through the provision of guidance, common principles and audits. It is crucial to create a set of sustainable, robust and feasible country definitions and EU standards to promote the successful implementation of the Directive, in order to achieve the forecast savings potential and maximize the socioeconomic benefits. Each step towards very low-energy buildings is expected to generate a deep transformation of the construction sector and significant growth in the market of very efficient technologies. On the other hand, the renovation of the existing building stock and the improvement of its energy performance will also contribute significantly in the improvement of European energy efficiency, since the average annual rate for the construction of new residential buildings in the EU is about 1%, while the replace rate is at 0.07% of the existing stock (Tzortzaki, 2017; Ascione, et al., 2017; D'Agostino, et al., 2017).

Although the EPBD does not propose a uniform approach for the development of nearly Zero-Energy Buildings or a methodology for the calculation of energy efficiency, it does offer a set of guidelines as reference for EU member states to design their own national plans and regulations, taking into account their particular location, climate and economic conditions. Consequently, each country has to provide a specific definition for Nearly Zero Energy (NZE) buildings, along with the measures that should be undertaken based on the following stipulations (Tzortzaki, 2017; Kampelis, et al., 2017):

- A detailed definition of the NZEB building needs to be more specific than just the repetition of the general NZEB definition from EPBD into a national legal document. The definition should be fixed in a legal document, or at least clearly referred as the national application of the NZEB definition in the national plan.

- A very high energy performance of the building; the express of the level of the performance should not be a defined value but can be expressed for example by a certain high class in the Energy Performance Certificate (EPC), a building level such as "passive house" or expressed by a percentage that gives how much improved is the performance than the national minimum energy performance requirements that already exist.
- A very low amount of required energy by the building; this energy can be defined either as energy need, either as final energy, either as primary energy expressed as a numerical indicator kWh/m^2.
- A very significant contribution of renewable energy to cover the remaining energy use; this point can be defined either as a percentage of renewable energy contribution, or as a minimum amount of renewable energy expressed in kWh/m^2 per year.

2.3.3. National Legislation in Cyprus

In Cyprus, the initial European Energy Performance of Buildings Directive (EPBD), which preceded the latest recast discussed in the previous section, has been partially implemented since December 2007, when mandatory thermal insulation of building shells was introduced for the first time, even in the absence of an average thermal permeability coefficient (U-value). In the case of residential buildings, the Directive has been fully implemented since January 1st, 2010, including the establishment of building energy certificates, while full implementation for other building types began in September 2010. An important step to full compliance with the Directive was achieved through linking its implementation on newly built buildings and those undergoing radical renovation with the existing framework and mechanism for licensing and development control, as provided within the Road and Building Regulation (Exergia, 2012; Energy Department, 2017).

Cyprus adopted Directive 2010/31/EU into their national legislation in December 2012. Based on this new legal framework, technical requirements for NZEB were defined, detailed requirements for technical building systems were issued and minimum energy performance requirements have since been twice revised, based on the calculation of cost-optimal levels. The new minimum energy performance requirements were implemented on 1 January 2017 and are considered to be the final step for leading Cyprus into a smooth transition towards NZEB. The overall responsibility of the implementation of the EPBD in Cyprus lies with the Ministry of Energy, Commerce, Industry and Tourism (Giama, et al., 2020).

The current legal and regulatory framework on NZEBs in Cyprus is thoroughly analyzed in Section 3.1 of the next Chapter, along with a critical overview of the progress in its implementation.

2.4. International Experience on NZEB Developments

During the past years, extensive research has been carried out regarding Net or Nearly Zero Energy Buildings, providing generic information and/or particular evidence about the international experience on NZEB developments. This section summarizes the findings of a series of research papers and scientific or industry-related documents, most of which have been published within the last four years, so as to depict the current status quo in the field of sustainable developments.

Giama et al. (2020) perform a comparative analysis of the applied energy policies and regulatory tools for sustainable buildings between Greece and Cyprus. After discussing the EU roadmap for energy and carbon emissions until 2050 and the underlying legislation framework for the energy and environment at the building sector, the authors present the national legislation framework and NZEB regulations that are currently in effect in the two countries. According to the study, Cyprus adopted Directive 2010/31/EU into their national legislation in December 2012, defining technical requirements for NZEB, issuing thorough guidelines for technical building systems and reviewing minimum energy performance requirements, in accordance with cost-optimal levels. These requirements were put in effect on 1 January 2017 finalizing Cyprus' shift towards NZEBs. On the other hand, in Greece, the Ministry of

Environment and Energy (YPEN) is responsible for the implementation of the EPBD. The Directive 2010/31/EU was adopted in 2013 as authorized by the Greek Parliament under Law 4122/2013. Ever since, new buildings must comply with minimum energy performance requirements defined in the "Regulation on the Energy Performance of Buildings" (KENAK), under Law 4122/2013 and revised Law 4342/2015, which ensure that every new building of the public sector from 1 January 2019 and every new private building constructed after 1 January 2021 should be NZEB. However, despite the rapid development of the legislative framework and regulations on low carbon, energy efficient buildings, there are many incomplete steps towards compliance with requirements and targets for renewable energy sources and greenhouse gas emissions (Giama, et al., 2020).

Morck et al. (2019) and Wittchen et al. (2019) perform a life-cycle cost (LCC) and life-cycle environmental assessment (LCA) of NZEBs under a common project called CoNZEBs, which aims to explore whether LCC and LCA analyses carried out in Germany, Denmark, Italy and Slovenia, within a period equal to or greater than 30 years, would reveal the optimum energy levels in terms of cost-effectiveness and environmental impact. These analyses were implemented for well-defined reference/typical multi-family buildings for three specific energy use levels (minimum EP, NZEB and beyond NZEB). In their paper, the authors present the results of completed analyses in Denmark, according to which typical NZEBs are less cost-effective than minimum EP, although beyond NZEB can be more cost-effective. Both NZEB and beyond NZEB can be more environmentally friendly than minimum EP. All three alternative NZEBs decrease the CO_2-equivalent emissions by 31-43 kg/m² over a 30-year period. Furthermore, they reveal that insulation thickness can be diminished through the use of an extra solar heating or PV system, or energy efficient water taps, without having any significant negative impact on indoor thermal comfort or on resilience and passive habitability (Morck, et al., 2019; Wittchen, et al., 2019).

Asdrupali et al. carry out a research to explore the viability of green roofs as a passive system allowing energy savings and limiting the phenomenon of urban heat island. To this end, they analyzed the data from several measurement instruments installed on an innovative roof-lawn system, including heat-flow meters, surface and air temperature probes, which provide information on thermal heat exchanges. They used a nearby conventional roof for benchmarking. The results of this study show that roof-lawn systems may prove beneficial, demonstrating higher thermal inertia, no overheating and less thermal diffusion, and better indoor condition for building occupants. Finally, the author suggest that future research takes into account the structural part of the roof (Asdrubali, et al., 2019).

Ballarini et al. discuss the transformation of a non-residential, office building into a NZEB, involving a combination of envelope and technical building systems refurbishment measures (such as HVAC and lighting) and assess the effects of this refurbishment on energy performance and visual and thermal comfort. Results show that energy retrofit actions on the building envelope may significantly improve thermal performance, in terms of both energy savings and thermal comfort. Nevertheless, a decrease in daylighting would incur higher electricity demand for lighting (Ballarini, et al., 2019).

Venus et al. al. (2019) and Weiss et al. (2019) present their research on parametric multi-objective energy and cost analysis in the life cycle of NZEBs, which was performed using an exhaustive approach to better understand the effects that technical variables have on energy, environmental and economic performance over the whole life cycle of several multi-family, school and office buildings in Sweden. Their intent was to identify the most significant technical NZEB design variable sets and organize them into a reliable framework. More than 216,000 variants were explored via this approach, using on one hand a variety of technologies, like insulation of the building envelope, ventilation or electricity and heat supply, and on the other hand various sets of boundary conditions, like observation period, user behavior, energy price increases or CO_2 costs. The analysis of results in terms of energy and economy (individually and combined) allowed the identification of consistencies, trends and optimizations over the life cycle (Venus, et al., 2019; Weiss, et al., 2019).

Abdullah & Alibaba (2018) explore the possibility of installing photovoltaic-integrated shading devices (PVISD) to meet the targets of nearly autonomous solar electricity and acceptable thermal comfort in a window-based naturally-ventilated office space. Utilizing specific parametric building thermal simulation and analysis tools, as well as microclimate metrics and analysis to depict a spatial map of the traces of passive strategies, their work demonstrated that these passive design instruments can accomplish an adaptive comfort acceptability limit of 80% based on the ASHRAE 55 standard, while the PV system generated 70% of the total electricity demand (Abdullah & Alibaba, 2018).

Santos-Herrero et al. (2018) suggest a new multidisciplinary methodology to study new strategies to attain NZEBs and conclude that the Model Predictive Control (MPC) may be a valuable tool for energy consumption optimization, particularly in public buildings, through the use of Renewable Energy Sources (RES) (Santos-Herrero, et al., 2018).

In their study, Gonzalez-Malencha et al. (2018) evaluate on-site renewable energy technologies with storage in buildings and assess optimal configurations for zero or ZBEs or NZBEs, through the development, testing and application of a single-objective hourly-basis mixed integer linear programing optimization model developed in GAMS and solved by CPLEX. It takes into account the rooftop availability for the installation of solar PV and mini wind turbines, as well as the available volume constraint for installing battery. At first, the model was tested for various possible electricity prices in a virtual case. Then, a case study for a real building in Portugal was performed, according to scenarios based on actual grid-electricity tariffs. Feed-in tariffs in different schemes were also examined, as well as the cost evolution of technologies and the implementation of a bi-hourly tariff. Results demonstrate that the proposed model is appropriate to assess options to develop ZBEs or NZEBs, based on renewable technologies. However, to achieve competitive NZEBs, certain requirements should be satisfied, particularly regarding price variances between purchasing and selling electricity tariffs (Gonzalez-Malencha, et al., 2018).

Wells et al. (2018) investigate existing NZEB models, evaluate extant NZEB literature, identify policies promoting NZEB development and recommend NZEB fields for further research. They also focus on the progress of NZEBs in Australia, where there is little support for NZEBs, especially in mainstream community, and a lack of specific policies. Therefore, the authors suggest that distinct policies should be introduced for residential and non-residential buildings, while a more robust building code is also necessary to guarantee increased compliance. They conclude that since Australia has the benefit of already enjoying a high diffusion of renewables, a stronger building code would help achieve the desired output in residential NZEBs (Wells, et al., 2018).

Al-Saeed & Ahmed (2018) evaluate design strategies for NZEBs in Middle East and North Africa (MENA) region. Their research studies existing NZEB standards and definitions for European countries with a hot and warm climate, assesses primary energy consumption for existing buildings in the MENA region and proposes a standard for NZEB and positive energy buildings measured in kWh/m2/year for the MENA region. They implemented a building simulation which shows that high energy consumption in existing buildings in the MENA region can be reduced significantly by enhancing building fabric and utilizing solar photovoltaics (PV), while additional design improvements, such as increasing airtightness and using high-efficiency solar PV, favored the development of positive energy buildings which generate more energy than they use (Al-Saeed & Ahmed, 2018).

In their article titled "Data on cost-optimal Nearly Zero Energy Buildings (NZEBs) across Europe", D'Agostino & Parker (2018) report data regarding the design optimization of a residential building model situated in typical European locations, with the intent of identifying cost-optimal options and efficiency measures in new buildings based on climate conditions. The presented data involve energy consumption, renewable energy production and potential energy savings and costs of the building prototype, visualizing energy consumption before and after the optimization, as well as particular efficiency measures, costs and renewable production. The decrease in electricity and natural gas consumption towards the NZEB target can be illustrated along with incremental and cumulative costs per location. Additional data refer to building geometry, costs, CO2 emissions, envelope, materials, lighting, appliances and systems (D'Agostino & Parker, 2018).

Garcia & Kranzl (2018) also perform a cross-country comparative analysis on how the ambition levels of NZEB definitions and the integration of the Directive 2010/31/EU into national law vary in four EU Countries: Germany, Spain, Austria and England (as part of UK), through the assessment of energy performance of certain typical buildings. Results indicate a significant diversity in building code scopes and national

NZEB definitions, with only 25% of the studied residential buildings consistently complying with the NZEB definition in all four selected countries. A series of factors including climate conditions, primary energy factors, energy requirements, ambition levels and calculation methodologies, instigate an uneven cross-country comparison. On the other hand, although primary energy consumption measured in kWh/m2a is the principal quantitative energy indicator according to the directive 2010/31/EU, it may not be the most appropriate criterion for an EU level comparison (Garcia & Kranzl, 2018).

Ferrara et al. (2018) carry out a critical review on the methods used for energy performance assessment, global cost calculation and selection of energy efficiency measures appropriate for design optimization. They also discuss the conventions made in cost-optimal methodology applications, as well as the gaps between the cost-optimal performance and zero-energy target and proposed cost-optimal set of technologies to be utilized for cost-optimal NZEB design in various contexts. The authors conclude that the cost-optimal approach is an efficient method for outlining the future of NZEB design across Europe (Ferrara, et al., 2018).

Ray-Hernandez et al. (2018) perform an analysis on energy performance, CO_2 emissions and operating costs of the renewable energy technologies employed within an existing multipurpose NZEB called LUCIA and located in Valladolid, Spain. Their work shows that data monitoring can supply the necessary information on actual requirements for electricity, heating and cooling. The studied building is equipped with solar energy photovoltaic systems, a biomass boiler and a geothermal Earth to Air Heat Exchanger (EAHX) for ventilation thermal loads. Energy performance efficiency vastly depends on the building's specific features, the control algorithm and the location's climate. Therefore, these factors should be considered in establishing design strategies for new NZEBs. The combined use of Photovoltaic PV System, biomass and EAHX leads to an annual decrease of CO_2 emissions by up to 123-170 tons, corresponding to annual economic savings of up to 43,000–50,000 €/year (Rey-Hernandez, et al., 2018).

Corrado et al. (2017) introduce a methodology of energy audit and cost analysis for the refurbishment of public buildings toward the NZEB target. For the purposes of the research, a school in Torino was studied. The process involved the establishment of a numerical model of the building, adjusted according to real data on operation, climate and energy consumption, the application of cost-optimization for the identification of energy efficiency measures defining the minimum global cost in 30 years lifetime, as well as the enhancement of measures to ensure both compliance with NZEB requirements and cost-effectiveness (Corrado, et al., 2017).

Paoletti et al. (2017) carry out a detailed analysis of the construction features of a sample of NZEBs from 17 European countries, in the context of the EU IEE ZEBRA2020 project, paying special attention on the effect of boundary conditions on the adopted technologies. Their study shows a general high insulation level of the envelope and recurrent specific technologies in the Heating Ventilation Air Conditioning (HVAC) system (i.e, heat pumps and mechanical ventilation), while climatic conditions do not have a significant impact on the design approach and NZEB characteristics (Paoletti, et al., 2017).

In their paper titled "Towards Nearly Zero Energy Buildings in Europe: A Focus on Retrofit in Non-Residential Buildings", D'Agostino et al. (2017) focus on retrofit and enumerate the differences between deep, major and NZEB renovation and also present best practice policies and measures to target retrofit and investment related to non-residential buildings. Moreover, they provide a comparison of for NZEB energy level requirements as defined by EU countries for both new and existing residential and non-residential buildings. The authors show that despite the increased attention paid to the refurbishment of NZEBs over the last decade, the accomplishment of a complete implementation of retrofit is still one of the greatest challenges for the EU (D'Agostino, et al., 2017).

Zuhaib et al. (2017) also focus on NZEBs in the retrofit industry but from a different viewpoint, as they study the attitudes and approaches of Irish professionals. Their research shows that there is much uncertainty and hesitancy among professionals in achieving the Irish NZEB targets. The growing retrofit industry is characterized by low-quality auditing and pre/post-retrofit analysis. Project budgets and marginal profits compromise basic services and depth of retrofits. Unaligned value supply chain, poor collaboration among NZEB professionals and disjointed services hinder industry standardization (Zuhaib, et al., 2017).

Kwiatkowski et al. (2017) also deal with retrofitting, focusing on existing public buildings in Poland, for which there is no particular definition of NZEB. In detail, they present an integrated energy design (IDE) process to achieve NZEB standard in public buildings through retrofitting, using an educational building as an example case. Their intent is to discuss barriers occurring in such projects and propose solutions that would help attain the defined targets, not only to decrease energy consumption or increase energy generation from RES, but also to enhance the visual and social traits of the studied building (Kwiatkowski, et al., 2017).

Kampelis et al. (2017) evaluate the performance gap in industrial, residential and tertiary sector NZEBs, in terms of energy efficiency, advanced controls and renewable energy systems. The authors compare energy dynamic and quasi-dynamic models using data originating from smart monitoring systems, indoor and outdoor environment measurements and power usage and generation measurements. The results of this comparison are then used to address the performance gap between energy efficiency prediction in the design phase and measurements' evaluation in operational phase (Kampelis, et al., 2017).

Touloupaki and Theodosiou (2017) propose a new NZEB design workflow methodology, integrating evolutionary algorithms and energy simulation, and investigate its capabilities and current limitations. Taking advantage of powerful collaborations between existing software tools, the proposed methodology appears promising for the enhancement of the architectural synthesis process. The success of generative design implies that this technique can transform the way architects design, as long as the procedures and software are more user-friendly. Furthermore, the need to address multiple, contradicting objectives at the same time, during all stages of the design process, is getting more and more imperative, making the establishment of a holistic approach for sustainable building design an urgent request. New software tools have been developed, promoting automation and interoperability, in order to simplify tasks, reduce modelling time and aim interdisciplinary collaboration. These tools now enable architects to broadly explore the vast solution space in an efficient manner, driving the design towards optimized alternatives in the early design stages. Digital design and optimization should not be treated as a threat for conventional architecture since they are merely tools under the architect's control, assisting him to identify the better performing solutions over a problem, and cannot embed qualitative criteria such as aesthetics. However, more work is required to fully exploit technological advances and overcome year-long problems of building design. Inefficiency in the collaboration between architects, engineers and contractors must be tackled by emphasizing in the development of advanced and user friendly, integrated data systems. Interoperability between existing software is a key factor that will allow the seamless execution of complex workflows. New possibilities are now open for exploration: collaborative, cloud-based technology will transform business models in the construction industry, by allowing us to design better buildings in less time through data management and integration. Cloud systems now offer a combination of massive computational resources and connectivity in an unprecedented scale across a wide range of activities. They provide reliable and scalable computational power to many enterprises without the associated costs and internal IT teams. BIM is the evolution of old CAD, but its use in the early stages of the design procedure seems rather problematic, due to its detailed nature (Touloupaki & Theodosiou, 2017).

Tournaki et al. concentrate on the development of NZEBs for accommodation in the tourism industry, under the NEZEH, "Nearly Zero Energy Hotels", initiative. Their study involves 16 pilot hotel projects in 7 European countries, aiming to transform into NZEB through a process of four steps: energy audit for the evaluation of current energy status and recommendations on proper actions; feasibility study and rollout plan; tendering, contracting and financing of the refurbishment project; training of management and staff. In the context of this research, a ranking tool has been developed to prioritize measures for hotels, based on country, region and hotel type. Results show that the positive impact of hotel retrofitting towards NZEB is considerable and involves significant energy and cost savings (Tournaki, et al., 2016).

Finally, Goggins et al. (2016) and Moran et al. (2017) discuss the results of several case studies on Irish buildings, which concentrate on the life-cycle cost and environmental analysis of NZEBs, based on energy and global warming potential (GWP) as indicators and using numerous heat sources, like gas boilers, biomass boilers, domestic gas-fired combined heat and power units, heat pumps and renewable technologies. With the de-carbonization and improved efficiency of the electricity grid, the low GWP emissions of biomass fuels and the reduction of fossil fuels, the authors suggest that future buildings are by design super-insulated with high air-tightness performance and minimum heating requirements and operate using heating systems, like biomass boilers and heat pumps, that have limited impact on the natural environment (Moran, et al., 2017; Goggins, et al., 2016).

2.5. Challenges & Barriers in the Application of Sustainability Principles & Techniques in the International Construction Industry

Wells et al. (2018) have successfully summarized most of the common challenges in the research and development of NZEBs, which they also characterize as "drivers for future growth". Those challenges include (Wells, et al., 2018):

- Lack of a unanimous, all-encompassing definition of a NZEB, which hinders comparability among NZEB developments and identification of best practices.
- Lack of consistency in government policies worldwide promoting public awareness about the application of energy efficiency standards.
- Lack of adequately detailed literature on the role of government promotion and public acceptance of NZEBs.
- Lack of research on accounting for embodied energy, especially accounting for energy consumption in manufacturing of building materials and of renewable energy devices, like solar PVs.
- Lack of exhaustive discussion regarding the financial viability of NZEB developments.

In their report titled "Transition towards NZEBs in Cyprus", D'Agostino et al. (2017) summarize the main common barriers and challenges related to the decision-making process towards NZEBs at EU level (D'agostino, et al., 2017):

- Technical: Limited range of technical solutions that can be used because of existing building structure and technical systems, while technically feasible solutions are often costly and not financially viable.
- Financial: Excessive investment cost.
- Social: Lack of knowledge and/or interest for energy efficiency among residents and building owners, often due to lack of awareness combined with challenges with architectural and cultural values.
- Environmental/health: Criteria for selection of materials and waste management balance between comfort and efficiency.
- Organizational/legal: Ownership structure and need for consensus among several homeowners can hinder NZEB refurbishments.

Furthermore, the authors list the challenges towards NZEBs retrofit at EU level (D'agostino, et al., 2017):

- Technical: Limited range of technical solutions considered viable for NZEB renovations based on existing building structure and technical systems.
- Financial: Building owners are unlikely to make a return on investment.
- Social: Communication and information is necessary early in the renovation process to increase acceptance among residents.
- Environmental/health: Risk of moisture must be taken into consideration when ensuring building airtightness.
- Organizational/legal: Extensive communication between involved organizations and actors is required early in the process.

On the other hand, Attia et al. (2017) provide an overview and document the future challenges of NZEB design in Southern Europe. Their work summarizes the results of a cross-comparative study of the societal and technical barriers of NZEB implementation in 7 Southern European countries and provides recommendations based on available empirical evidence to further lower those barriers in the European construction sector. The study reveals that most Southern European countries are not adequately prepared for NZEB implementation and especially for the challenge/opportunity of retrofitting existing buildings. Creating a common methodology to further pursue NZEB targets, concepts and definitions in combination with the climatic, societal and technical state of progress in Southern Europe is vital. The authors suggest specific actions to turn the identified gaps into opportunities for future development of climate-adaptive high-performance buildings in terms of technical development, organization-infrastructure, legislation and enforcement and education-awareness. They also explain that there is need for sufficient financing of human capital including (Attia, et al., 2017):

- procurement officials and technical staff in local authorities,
- building professionals/researchers,
- research and technical staff in industrial stakeholders in most Southern European countries.

A discontinuation can be identified between developing innovative technologies from the building industry and the lack of engagement due to financial constraints. There is also a significant lack of awareness of how energy is consumed by inhabitants of residential buildings. On the other hand, it is commonly acknowledged that energy targets for cultural and historic buildings pose an even greater challenge (D'agostino, et al., 2017).

In the case of NZEBs refurbishment, the existing building structure limits the range of viable existing technical solutions. This constraint is more obvious in buildings where the architectural value needs to be preserved, increasing the difficulty of retrofit processes. Additionally, existing technical NZEB solutions are considered expensive, adding to the main financial challenge of increased investment requirements in NZEB retrofitting projects. A return on investment seems intangible while also considering savings throughout the life-cycle of the building and initial investment costs are lower than those of the overall operational costs. Payback period for NZEB renovation may take between 15-30 year, thus residents may not benefit from this payback period. Besides, a landlord cannot, or might not want to, raise rents and become uncompetitive in the market as the difference between non-NZEB and NZEB is not considered by the tenants (D'agostino, et al., 2017).

Another barrier is the lack of knowledge among professionals and residents in the field of NZEB renovation. Communication of best practices in NZEBs renovation is crucial to increase awareness of professionals and general public about energy efficient renovation and technical solutions. A follow-up is also vital to ensure that residents properly use buildings. Communicating with residents and end-users is necessary, since proper end-user behavior after a completed refurbishment is also a challenge in the retrofitting process. Similarly, communication and information between involved actors and organizations of the renovation project, as well as with the residents, are among the factors that can provide a successful NZEB renovation (D'agostino, et al., 2017).

Finally, in relation to financial barriers, public authorities are primarily responsible for establishing financing structures for national or local contexts. Offering motives through financing can further promote private investment for NZEB renovation, as legislation and financial incentives have a strong influence in developing NZEBs projects (D'agostino, et al., 2017).

Chapter 3: NZEBs – The Case of Cyprus

3.1. Legal and Regulatory Framework in Cyprus

This section documents the legislation, regulations and technical instructions on the harmonization of Cypriot legislation with EPBD. The relevant legislation consists of the Laws on Energy Efficiency of Buildings Regulation 142(I)/2006 and 30(I)/2009, as well as the Roads and Construction (Energy Efficiency of Buildings) Regulations of 2006 (429/2009.) These laws provide that all buildings being constructed or radically renovated must comply with the minimum energy performance requirements set out in the relevant Ministerial Decrees (446/2009). They also set out the regulations for issuing energy performance certificates for buildings and apartments, as well as for boiler, heating and air conditioning inspection. Finally, the Ministerial Decree on the Regulation of the Energy Efficiency of Buildings, Law "Methodology for Calculating the Energy Efficiency of Buildings" (414/2009) defines the methodology used for calculating the energy efficiency of buildings for Cyprus, so as to comply with Article 3 of the Energy Efficiency of Buildings Directive (2002/91/EC). It describes the original prEN and CEN templates used to develop a computation process and how a specific application (iSBEMCY) is designed to meet these requirements (Exergia, 2012; Energy Department, 2015; Giama, et al., 2020).

In addition, the Energy Department of the Ministry of Commerce, Industry and Tourism has issued the following Technical Guides (Exergia, 2012):

- "Certification Guide on Energy Performance of Existing Residential Buildings ": The purpose of the Guide is to set out the procedures for certifying the energy performance of existing residential buildings, in order to generate uniform and comparable results.
- "Building Insulation Guide", 2nd edition: This guide outlines and explains the general principles of building shell insulation and provides both the coefficients of maximum permitted thermal permeability for various building shell components and the methodology for calculating them, as well as the document template for the presentation of such calculations.

- "Solar Systems Technical Guide": This guide sets out the minimum specifications that solar systems must meet, as well as other issues related to their rational use.

The national action plan for increasing the number of NZEBs, issued in 2012 and revised in 2016, included the course of actions to be fulfilled until 2020. The requirements for NZEBs involve lower U-values, maximum heating demand for residential buildings, maximum lighting power installation for office buildings, maximum primary energy consumption and a minimum contribution of RES. The requirements vary only between residential and non-residential buildings, while the same requirements apply for new and existing buildings (Giama, et al., 2020).

In order to offer a specific definition of the NZEB in Cyprus, the national plan had planned an in-depth study of the potential energy saving among the three categories of most common residential buildings (detached two-story houses, terraced houses and apartments on building blocks) in the 4 climatic zones of the country, as described in the national methodology for the energy performance of buildings. The parameters identified to characterize a building as NZEB were (Tzortzaki, 2017):

- Architectural Design: orientation, compactness and summer comfort control
- Insulation of opaque surfaces: walls, roof, floor (in contact with the ground, the air and closed environment)
- Shading strategies and applications (fins, overhangs, shutters, etc.)
- Windows and other transparent surfaces: Thermal characteristics, U-value, shading,
- Air permeability of the building for detached buildings and apartment buildings (high and low rising)
- Ventilation, natural and mechanical, in order to achieve good air quality to control air humidity and to ensure the durability of the building while reducing the energy consumptions of the heating, cooling and the use of ventilators.
- Heat recovery systems when applicable
- Heating systems, use of conventional hybrid or only renewable heating systems (the heating system should be analyzed according to the following

parameters adaptation to the building characteristics (including its use), their energy efficiency, their environmental impact (especially of the carbon footprint) and the long term availability of the resource.

- Optimization of the solar hot water production
- Investigation of the gains from programming that would manage the absence of the occupants
- Natural cooling methods
- Cooling systems, use of conventional, or hybrid and renewable systems should be analyzed according to the following parameters: adaptation to the building characteristics (including its use), their energy efficiency, their environmental impact (especially of the carbon footprint) and the long-term availability of the resource.

In detail, the targets set for the NZEB definition, regarding maximum primary energy, U values, power of lighting and percentage of RES that should cover the primary energy, are depicted in the following table (Tzortzaki, 2017):

Table 2: NZEB Targets in Cyprus (Tzortzaki, 2017)

	Residential		**Non-Residential**	
	New	**Existing**	**New**	**Existing**
Energy	**(kWh/m² per year)**			
Primary Energy	100	100	125	125
U values	**(W/m² -K)**			
External Walls	0.4	0.4	0.4	0.4
External Roofs and Floors	0.4	0.4	0.4	0.4
Windows and Doors	2.25	2.25	2.25	2.25
	(W/m²)			
Average Power Lighting			10	10
	(%)			
RES	25	25	25	25

In the past years, there have been certain initiatives to improve the provided knowledge and skills regarding NZEB in Cyprus. For instance, in late 2015, the University of Cyprus initiated a series of free postgraduate level training courses on NZEBs, aiming to endow building professionals through the development of skills in energy efficiency and integration of renewables in the retrofit of existing housing stock and to familiarize building professionals with NZEB strategies and technologies so as to accelerate the implementation of the recast EU Energy Performance in Buildings Directive (EPBD) (Tzortzaki, 2017).

Nowadays, buildings in Cyprus are responsible for 30% of energy consumption versus 40% in the European Union and energy needs are expected to increase with the sector’s growing trends. Therefore, reducing energy consumption and the use of renewable energy sources in the building sector are important measures needed to reduce greenhouse gas emissions. Following the incorporation of the EU Directive (2010/31/EU) into the national law, the series of laws that were imposed on the construction of new buildings together with the installation of photovoltaic systems in homes, business and government buildings have brought Cyprus closer to attain its targets regarding energy consumption in buildings, which has been estimated to have dropped by 20% (Financial Mirror, 2019).

After a series of laws and amendments introduced by parliament, new buildings built after 31 December 2018 had to be issued an Energy Performance Certificate classifying them as Energy efficiency class B, requiring the use of materials insulating the interior while being obliged to generate part of their energy needs from renewable energy sources. Housing units built after the end of 2018 should be generating up to 25%, blocks of flats 3% and other building types 7%. From the beginning of 2020, however, criteria for constructors to obtain a building license are even tougher, as all buildings have to be classified as class A, demanding high-performance thermal insulation (walls, ceilings, windows, exposed floors) and very low heating requirements, while also maintaining a primary energy consumption of under 100kWh per m^2 on an annual basis, ensuring minimal shading on the building windows and generating at least 25% of their primary energy consumption with the use of renewable energy sources (RES) (Financial Mirror, 2019).

Experts believe that Cyprus has made substantial progress in limiting energy consumption, as a newly-built house today consumes nearly half the energy a similar house built in the 1990s does. Nevertheless, there are many steps ahead in order to meet the ultimate goal of rendering every building in the country a NZEB. The government should offer more incentives to people for home upgrades since costs are unaffordable for an average household. In fact, to insulate a house with work needed on walls, windows and roof, and probably install a photovoltaic system, the cost for such a project could reach 30,000€, while approximately 300,000 households are estimated to necessitate such an upgrade. Experts suggest that the government seeks further financing from the EU, as during the period 2017-2019, Cyprus received approximately 73 million euros for such schemes (Financial Mirror, 2019).

Of course, there are multiple techniques to render a building NZE, as mentioned in previous chapters, including appropriate building orientation and wall-to-window ratio, cooling systems exploiting underground water deposits, insulation and planting on roofs. That way, efficient insulation could reduce home electricity costs by 70% (Financial Mirror, 2019).

On the other hand, experts argue that the government has a long way to go to bring government buildings up to speed with the EU directive. Whereas the state is regulating new buildings with legislation and energy performance certificates, it appears to have fallen behind on its own obligations towards the EU and targets set for 2020. In fact, even though the government had an obligation to refurbish 3% of state buildings annually since 2014, little work has been done in that direction, with only a couple of buildings having been slightly renovated a few years back, all the while schools are suffering from the lack of air conditioning, when the government could have upgraded schools with insulation works and other innovative measures without needing to install any other air-cooling systems. In the same context, municipalities do not have a solid strategy regarding the construction of towers, especially in coastal areas. However, the Ministry supports that it is currently assessing how much energy goes into state-owned buildings and are drawing up plans to bring needs down to near zero, while also running public works for the complete renovation of state buildings and installation of photovoltaic systems, as well as funding programs for citizens who wish to upgrade their homes (Financial Mirror, 2019).

3.2. NZEB Developments in Cyprus

Following the thorough study of extant literature regarding the international experience on NZEB developments, this section focuses on the latest advances in the field of NZEB in Cyprus.

Sivitanidou & Nikolopoulou (2019) examine the bioclimatic design, sustainability and environmental behavior of Cypriot vernacular farmhouses, which are operating in village outskirts as part of small-scale family-owned farmstead, contributing significantly to the primary sector of Cyprus' economy. Current uses of these farmhouses have caused random alterations in their morphology, layout, construction and usage, which beforehand ensured thermal comfort and household autonomy. These alterations rendered farmhouses climatically inefficient and non-compliant with Bioclimatism and Sustainability principles. The authors worked with multiple case studies applying a fully-integrated mixed methods design and triangulation of qualitative and quantitative data from ethnographic participant observation, post-occupancy evaluation survey, interviews, in-situ documentation and environmental monitoring. Preliminary results reveal both a concrete and immaterial relationship between the house, its residents and the environment, reinforced in time because of tradition, accrued knowledge and experience, as well as need, shortage and practicality. The intricate combination of socio-cultural, economic, technological, aesthetic and environmental factors brings about this inter-reliant, dynamic and adaptive interchange, ultimately leading to the intuitive application of a bioclimatic design and the incorporation of sustainability in the form, configuration, construction and operational modes of farmhouses. As Cyprus makes efforts to comply with EU requirements on sustainable development of rural environments and adopt NZEB practices, the Cypriot vernacular farmhouse can provide useful lessons in building design and performance and a guide for its strategic retrofitting (Sivitanidou & Nikolopoulou, 2019).

Another research on low-energy design strategies for retrofitting residential buildings in Cyprus was carried out by Ozarisoy and Altan (2019). The authors recognize that some of the common problems on mass housing estates, such as modernist urban detached or semi-detached and suburban row houses, in Cyprus are linked with the lack of green areas and the neglect of climatic features of the building site, resulting in neighborhoods designs that are not compliant with urban planning regulations and legislation. 30% of the existing building stock comprises of these purpose-built residential building stock models. This study examines the possibility of specific design interventions in detached two-storey houses in a Mediterranean climate with the intent of limiting the use of fossil fuel for heating and cooling, in order to develop and test viable retrofit strategies for energy performance optimization in existing residential buildings. To this end, the authors monitored the energy performance of a building before and after the retrofitting phases as base case scenario models and simulated the adapted energy-efficient retrofit measures using a suitable energy performance analysis software. Results indicate the difference between a retrofitted building and the existing state of a building in their respective energy use effects (Ozarisoy & Altan, 2019).

Economidou et al. (2018) focus on the impact of various policy scenarios on future energy requirements of the Cypriot building sector, in terms of both the existing framework and new proposed policies. In this context, the authors use the Invert/EE-Lab model to evaluate three policy scenarios regarding the Cypriot building sector's energy efficiency potential up to 2050 and to suggest policy solutions to attain that potential. The energy consumed for heating, cooling, hot water, and lighting in the entire Cypriot building stock is expected to drop by up to 16% in 2050 compared to the baseline scenario. Under the optimistic scenario, nearly 60% of the building stock in 2050 will be energy efficient, consuming less than 50% of the energy used by the average building stock in 2012. Finally, the authors provide suggestions on the improvement of the financial landscape in buildings until 2050, based on the model's outcomes (Economidou, et al., 2018).

In their research, Kyprianou Dracou et al. (2017) model and simulate advanced technologies for conserving and generating energy, in two sample buildings located in the area of Peyia, Cyprus. Simulations were carried out through free-running and thermostatically-controlled conditions using Design Builder software, so as to attain the NZE target involving a reduction of the net regulated energy to an average of 0-20 kWh/m2 per year and a generation of at least 50 kWh/m2 per year in each building. Results showed that the NZEB target can be achieved as long as most of the energy used in the buildings is generated from renewable energy sources and the regulated building loads are reduced via energy conservation technologies (Kyprianou Dracou, et al., 2017).

In their papers titled "Energy Refurbishment Towards Nearly Zero Energy Multi-Family Houses, for Cyprus" and "Achieving Nearly Zero Energy Multi-family Houses in Cyprus through Energy Refurbishments", Serghides et al. (2017) explore the measures and practices necessary to accomplish NZE houses in Cyprus, as well as the methodology of cost optimization. The study focuses on Multi-Family houses. The model building was designed using the official governmental software iSBEM_cy tool, according to the European Directives 2002/91/EC and 2010/31/EC, with the purpose of upgrading it into a NZEB, through the evaluation of energy refurbishment effectiveness based on energy savings and payback period. Two scenarios were developed and assessed in terms of energy efficiency and cost effectiveness of the conservation measures. The efficiency of each strategy and technique employed towards the minimization of energy consumption and greenhouse gas emissions was evaluated, based on the findings and on cost effectiveness. Research outcomes were explored to assess whether the NZEB requirements, as developed by the MECIT, are appropriate for the existing Multi-Family houses in Cyprus and whether substitute strategies should be applied in order to reach the target of NZEB and effectively decrease energy consumption and CO_2 emissions (Serghides, et al., 2017; Serghides, et al., 2017).

3.3. Challenges & Barriers in the Application of Sustainability Principles & Techniques in the Construction Industry in Cyprus

In addition to the general challenges and barriers that international experience has revealed, in Cyprus, in particular, the legislative and regulation framework on NZEBs is fairly robust and on the right track. It mostly concerns new buildings, since retrofitting towards NZEB has high initial investment costs compared to the building's lifespan, making it an unattractive solution (Giama, et al., 2020).

The construction sector, contributing to around 8% of national GDP and 12% of total employment, is a vital part of Cyprus economy, in line with the situation in the majority of EU countries. The increased focus on building energy efficiency can vastly affect future advances of the construction sector and, thereby, its contribution to the national economy, both in terms of value added and employment (D'agostino, et al., 2017).

Consequently, it is necessary to concentrate on the qualitative characteristics of the construction sector's human capital, so as to guarantee that professionals in the building sector have the required knowledge and skills to successfully contribute to the accomplishment of national targets for 2020 and 2030. In general, investment in the training of experts, with a specific focus on energy efficiency, is vital both for the acquisition of new knowledge and skills and for ensuring that this knowledge is put to practice in numerous issues related to the Energy Performance of Buildings Directive (EPBD) and Energy Efficiency Directive (EED) (D'agostino, et al., 2017).

There are only certain specific requirements for training and qualifications in the main EU energy efficiency legislations. Combining the requirements of EPBD Article 175 and EED Article 16, as well as those of EPBD Article 20 and EED Articles 8, 16 and 17, EU countries are mandated to guarantee that certification and/or accreditation systems for the qualification and training of experts are accessible to energy services providers, energy audits, energy managers and installers of energy-related building elements. Furthermore, the Renewable Energy Directive (RED) establishes an overall policy for the production and promotion of energy from renewable sources in the EU, including schemes for accreditation of training and certification of installers of small-scale RES systems in buildings such as: biomass boilers and stoves installers, solar photovoltaic installers, solar thermal systems installers and geothermal systems installers. Beside this specific requirements, training of professionals is recognized as an essential part of any national plan to reach energy efficiency targets, which are not limited to the EPC inspectors and auditors but involves all the workers in the construction process and business (D'agostino, et al., 2017).

The discussion on the implementation of professional trainings in energy efficiency in building starts by considering the overall national context. Indeed, despite recent years' improvements, overall professional training is not widespread and Cyprus has one of the lowest participation rates in upper secondary vocational education and training (VET) in the EU. Eurostat data7 show that it came to 13.6 % in 2013, compared to the EU average of 48.9 %, with general education clearly predominating as a result (D'agostino, et al., 2017).

The situation of Cyprus was the subject of an extensive in-depth study under the EU BUILD UP Skills, an initiative implemented under the framework of the Intelligent Energy Europe program (IEE Calls for proposals 2011, 2012 and 2013) to increase the number of qualified workers in the building workforce in Europe. The project focuses on the continuing education and training of craftsmen and other on-site workers in the field of energy efficiency and renewable energy in buildings. Research related to Cyprus under Pillar I10 was published in the BUILD UP Skills Cyprus report. The report identified in 2012 a lack of a sufficient number of skilled workforce for the implementation of measures relating to the construction of energy efficient buildings. At the same time, insufficient appropriate training programs for the training of the workforce were highlighted. The Build-up skills-Cyprus Report examined and estimated the employment needs for selected technical occupations in the field of energy efficiency in buildings in Cyprus. The qualitative characteristics of the labor force was also considered and analyzed. Concerning the skills relating to key technologies for the achievement of the energy efficiency targets for 2020, the analysis identified the following ones (D'agostino, et al., 2017):

- Installation and maintenance of biomass systems
- Installation and maintenance of heat pumps and shallow geothermal systems

- Installation and maintenance of photovoltaic systems
- Installation and maintenance of solar systems for domestic hot water
- Installation and maintenance of solar systems for heating and air-conditioning
- Installation of conventional thermal insulation / thermo-insulation plaster
- Installation of external thermal insulation
- Installation of doors and windows
- Installation of solar protection systems
- Installation and maintenance of central heating or other types of heating
- Installation and maintenance of cooling and air-conditioning appliances
- Installation and maintenance of mechanical ventilation systems
- Installation and maintenance of automation systems and electronic monitoring and control systems for central heating and cooling and air-conditioning appliances, including BMS33.

In addition to the challenges already introduced, other issues emerged from the review of the current situation in Cyprus (D'agostino, et al., 2017):

- Retraining for authorized experts

The need of specific retraining for the experts already authorized to issue Energy Performance Certificates (EPC), to tackle the new challenges that will come with the introduction of NZEB. This is a specific issue within a more general challenge, discussed earlier, on developing and offering training modules and programs specifically focused on NZEBs.

- Retraining for qualified experts

The need to retrain qualified experts, recognized on the basis of Directive 2002/91/EC, in order to make them sufficiently trained to interact with owners, to deal with real energy consumption and to make reliable recommendations for energy efficiency investments. This is an important aspect to consider since it is part, together with information and dissemination activities, of a broader and more ambitious goal of knowledge and capacity building, which aims at linking the training of experts with the general public (e.g. building owners), public authorities and other relevant stakeholders not directly involved in the construction process.

- Employers' engagement

A lack of employers' engagement in the education of students (for vocational education and training - VET) and professional training course (on the job training) has been identified as a point of weakness. The economic crisis and the slowdown in the construction sector negatively contributed to this aspect, however, also structural barriers exist: one of them is that the Cyprus economy, and the building sector in particular, consists predominantly of small and medium-sized and micro-enterprises, for which providing work-based learning and apprenticeships to students of VET programs is a challenge. The same applies to a large number of self-employed in the construction sector, which have very limited, if none, subsidies for the cost of their training and specialization. In a time when also public finances are constrained, the most important training programs developed and implemented are those financed through European funds.

Chapter 4: Methodology

4.1. Theoretical Context

Research is the process of data collection, analysis, and interpretation facilitating the understanding of a specific phenomenon, through the logical and systematic search for new and valuable information. It is distinguished into basic research, i.e. study aiming to increase scientific knowledge, and applied research, which uses basic research to resolve problems or develop new processes, products or techniques. Therefore, the principal objectives of research include (Bhawna & Gobind, 2015):

- The discovery of new facts or the verification and testing of known facts
- The analysis of a phenomenon, process or event with the purpose of identifying a causal relationship
- The development of new scientific theories, concepts and tools contributing to the understanding and/or resolution of scientific and nonscientific problems.
- The resolution of scientific, nonscientific and social problems.
- The resolution of problems in everyday life.
- The resolution of new or existing unsolved and challenging problems.
- The discovery of new things.

The process of research involves the following steps (Bhawna & Gobind, 2015):

- Selection of a research topic
- Definition of the research problem
- Collection of literature references
- Evaluation of the current status of the research topic
- Formulation of hypotheses
- Research design
- Investigation
- Analysis of gathered data
- Interpretation of results
- Preparation of report

There are three main research approaches with further distinctions (Bhawna & Gobind, 2015):

- Quantitative Research involves the systematic empirical investigation of observable phenomena via statistical, mathematical or computational techniques, aiming to develop and employ mathematical models, theories and/or hypotheses pertaining to phenomena. It is distinguished into Descriptive Research, which examines the current state of a situation, through the observational identification of attributes of a studied phenomenon or the exploration of possible correlation between at least two phenomena, Experimental Research, that is the study of an intervention treatment into a study group and quantification of its results and Causal Comparative Research, involving the investigation of potential cause-and-effect relationships between independent and dependent variables.
- Qualitative Research is a holistic approach of discovery through a situated activity that locates the observer in the world and consisting of a set of interpretive, material practices that make the world visible. It aims to provide a deeper understanding of a specific organization or event, rather than a superficial description of a large sample of a population, as well as an explicit rendering of the structure, order and broad patterns found among a group of participants. It is further divided into Case Study, Ethnography Study, Phenomenological Study, Grounded Theory Study and Content Analysis.
- Mixed Methods Research, which is the of collection, analysis and “mixing” of both quantitative and qualitative research and methods in a single study to understand a research problem.

4.2. Research Methodology

The empirical part of the present study applies a descriptive quantitative approach, employing a properly constructed questionnaire, described in the following section.

In detail, the author used the knowledge acquired from reviewing extant literature and studying the case of Cyprus, in order to design a questionnaire, which would help obtain a more comprehensive perception of the Cypriot industry's current status on NZEBs and identify the problems professionals may face regarding the implementation of the latest EU directives in Cyprus.

Upon constructing the questionnaire, the next step was to distribute it to the target research sample, collect the responses, apply statistical methods of data processing and analysis and present the results in the form of charts and tables.

4.3. The Questionnaire

4.3.1. The Questionnaire

An appropriate questionnaire was designed for the purposes of the present study, consisting of three parts.

The first part contains 5 demographic questions concerning the respondents' gender, age, professional experience, profession / area of expertise and location of work.

The second part includes 17 close-ended or open-ended, short-text questions. In detail, the first question inquires the participants whether they are familiar with the term "Sustainability" and if yes, to what extent they apply its principles in their work.

The second question asks the respondents whether they have employed any sustainable materials in any of their projects, and if not why.

The third question asks the participants whether they are familiar with the term "(Nearly) Zero Energy Buildings - (N)ZEBs" and if yes, to what extent they apply its principles in their work.

The fourth question refers to possible ways and means of achieving NZEBs, offering the possibility of multiple answers.

The next question focuses on the participants' knowledge of the current and imminent EU Directives on Energy Performance of Buildings.

The sixth question asks them whether they are ready to hire sustainability professionals to pursue more sustainable development and NZBEs projects.

The seventh question refers to the current experience of the Cypriot construction industry on sustainable development and NZBEs and whether it can ensure the smooth communication and collaboration between all stakeholders and at all project stages.

The eighth question requires the respondents view on the price levels of projects for sustainable and NZE buildings.

The ninth question inquires them whether contractors – developers – construction companies have the required know-how and expertise to undertake sustainable and NZEB projects for both new and existing buildings.

The following question asks for an estimated range of cost difference between conventional and NZE buildings.

Next, participants are asked whether there are enough economic and financial incentives (sponsorships, tax deduction etc.) granted to potential buyers from the Cypriot state for the promotion of sustainable and NZE buildings.

The twelfth question is about the adequacy of required assessment tools for successful comparison between sustainable and NZE buildings in Cyprus.

The thirteenth question asked whether the volume and quality of available information, building codes and material/system prototypes in Cyprus is sufficient for the successful development of a sustainable NZE building and if, for instance, there are enough resources to facilitate LEED certification.

The next question asks whether the participants would employ certified materials and systems in their projects in order to achieve better energy efficiency performance.

Similarly, the fifteenth question asks whether the participants would employ renewable energy systems in their projects in order to achieve better energy efficiency performance and if yes, the kind they would use.

The sixteenth question is about the investors' willingness to invest in energy conservation systems for buildings destined for sale or renting.

Finally, the last question of Part B asks participants whether they believe that potential building owners in Cyprus would accept higher initial costs for the establishment of new sustainable, energy efficient systems under the assumption that those would lessen the buildings' environmental impact in the long-run.

The third part of the questionnaire, the respondents have to evaluate the levels of their clients' willingness to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient and energy friendly, the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years and the degree of their interest in receiving additional training in areas related to the design, development etc. of sustainable, energy efficient buildings. The alternative answers are on a 5-point Likert scale where 1 equals "none" and 5 equals "very high".

The entire questionnaire is presented in Appendix A.

4.3.2. Research Sample

Due to the limitations imposed by the covid19 pandemic, the questionnaire survey was performed online during a two-week period in May, employing Google Forms, which offers a free platform for creating questionnaires and other form types. Once the questionnaire was prepared in its online form, it was distributed via email and social media. The use of Google Forms has several benefits, among which the automatic validation of answers, ensuring that all mandatory questions are answered, as well as the automatic generation of charts. In total, 26 valid questionnaires were gathered.

Out of the 26 respondents, 92.3% were male and 7.7% female (Figure 1).

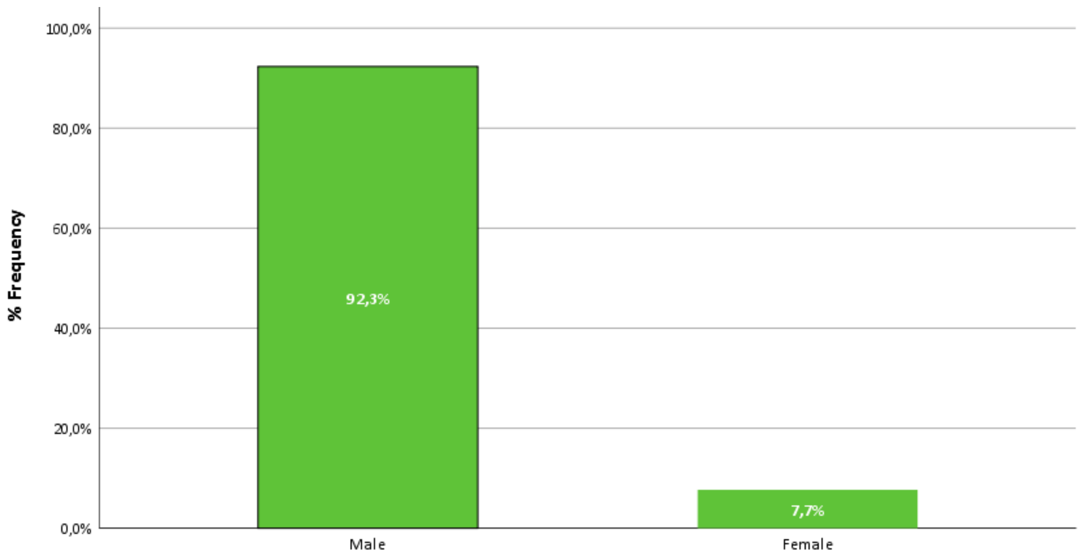

Figure 1: Gender of Respondents

With respect to the age of participants, 15.4% were 25-34 years old, 57.7% belonged to the age group 35-44, 11.5% were 45-54 years old and 15.4% were older than 55 years old.

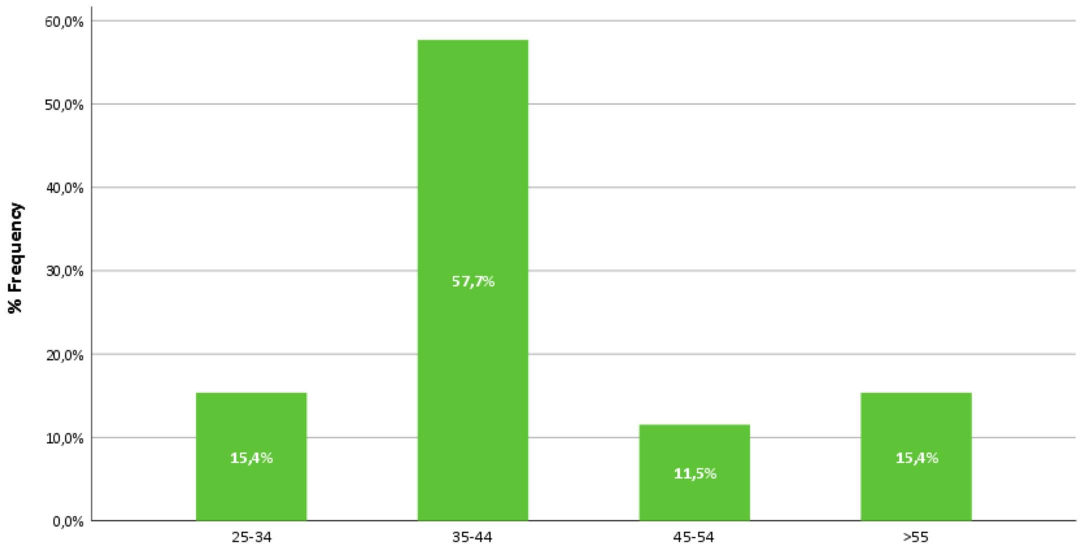

Figure 2: Age of Respondents

Regarding their professional experience, 42.3% has been working for less than 10 years, 38.5% for 10-19 years, 7.7% for 20-29 and 11.5% for 30-39 years, while no participants had a professional experience of 40 years or more.

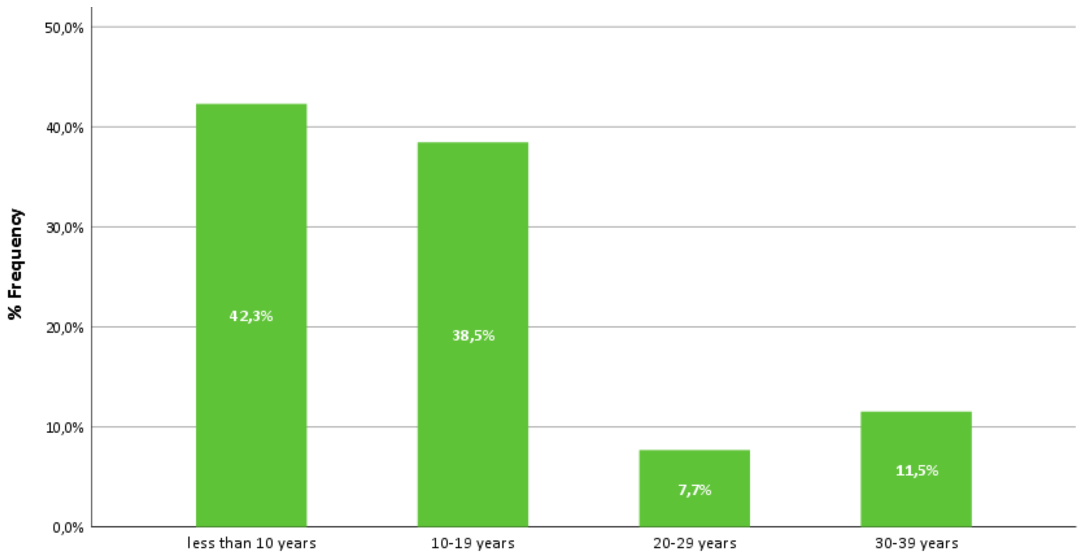

Figure 3: Professional Experience of Respondents

Despite the relatively small size of the sample, there were participants of various professions / areas of expertise. The majority of respondents were either Developers (38.5%) or Real Estate Agents (38.5%), but there were also three Consultants (11.5%), one Contractor (3.8%), one Valuer (3.8%) and one Urban Planner (3.8%).

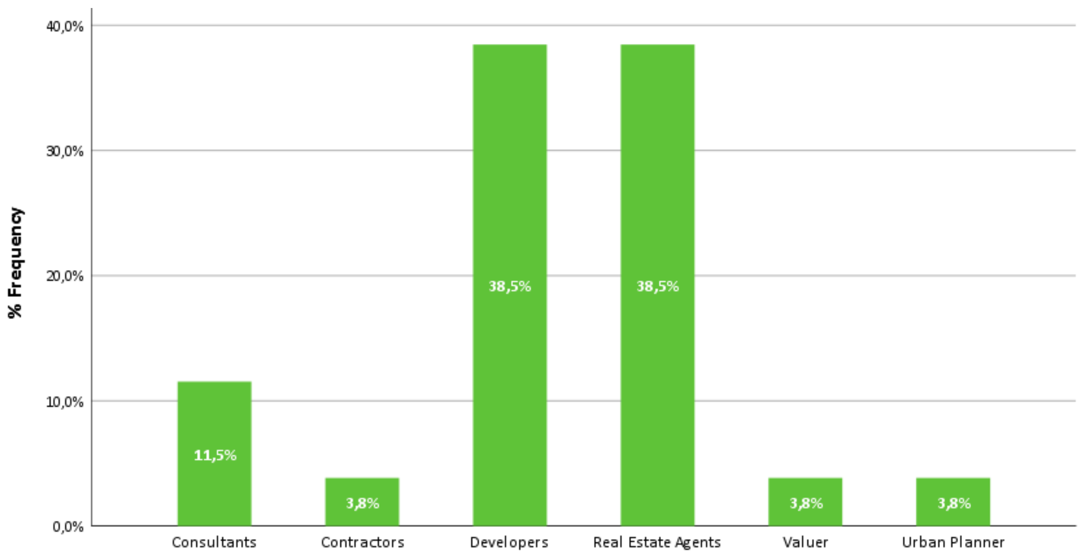

Figure 4: Profession – Area of Expertise of Respondents

Finally, most of the participants (69.2%) work in Limassol, while 11.5% work in Famagusta, 7.7% in Nicosia, 7.7% in Paphos and 3.8% in Larnaca.

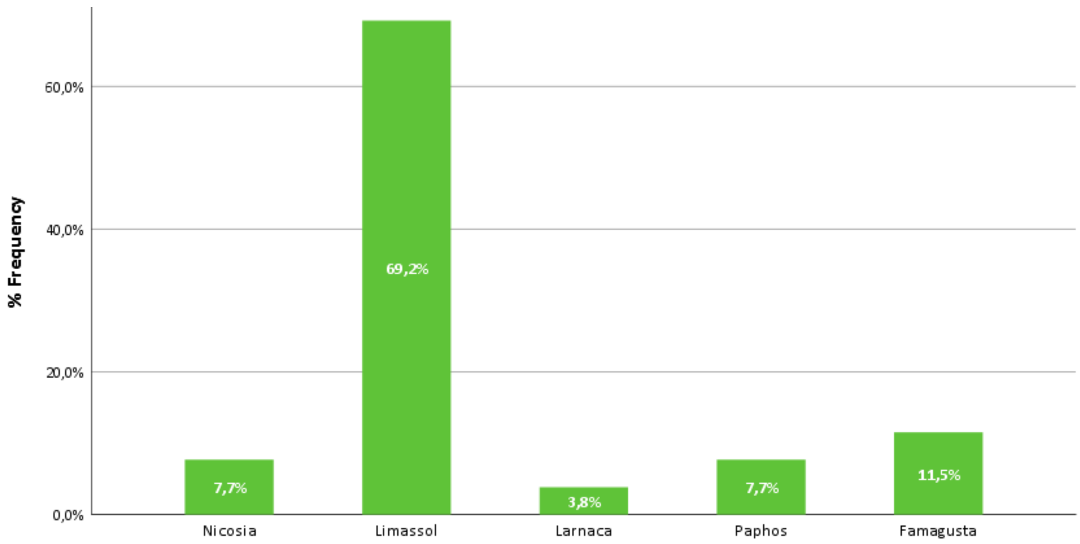

Figure 5: Location of Work of Respondents

4.3.3. Data Processing & Analysis

The responses were exported from Google Forms and imported into Excel for processing and variable coding. Then, the processed data was inserted into the statistical package SPSS to calculate basic descriptive statistics, generate frequency charts and investigate potential relationships among variables.

Chapter 5: Statistical Analysis & Discussion

5.1. Results of Statistical Analysis

5.1.1. Distribution of Responses

Responding to the first question, all participants were familiar to the term "Sustainability".

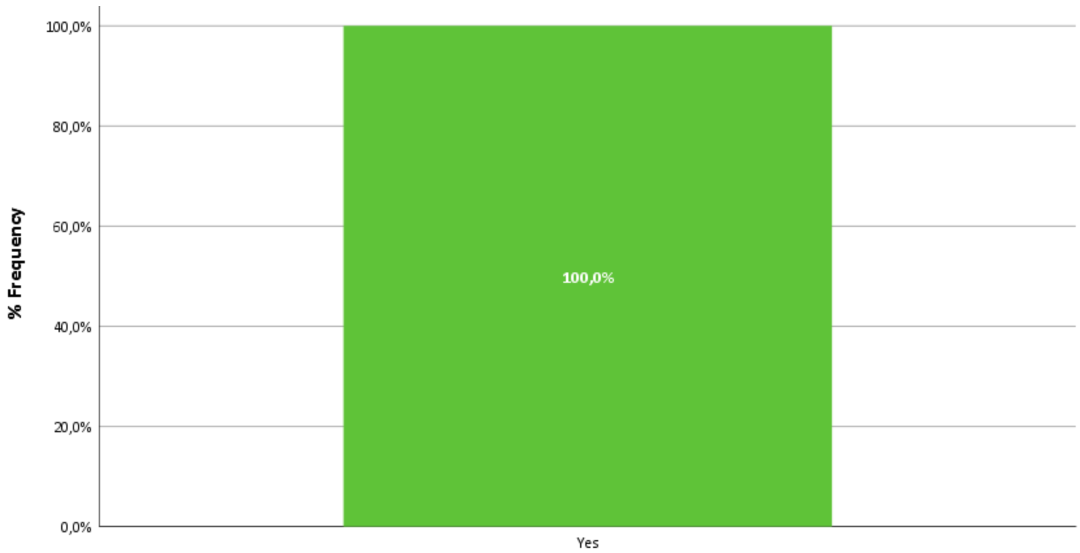

Figure 6: Responses to Question B1a: Are you familiar with the term "Sustainability"?

When asked to what extent they apply the principles of Sustainability in their work, 76.9% responded "somewhat", 15.4% "mostly" and 7.7% "not at all".

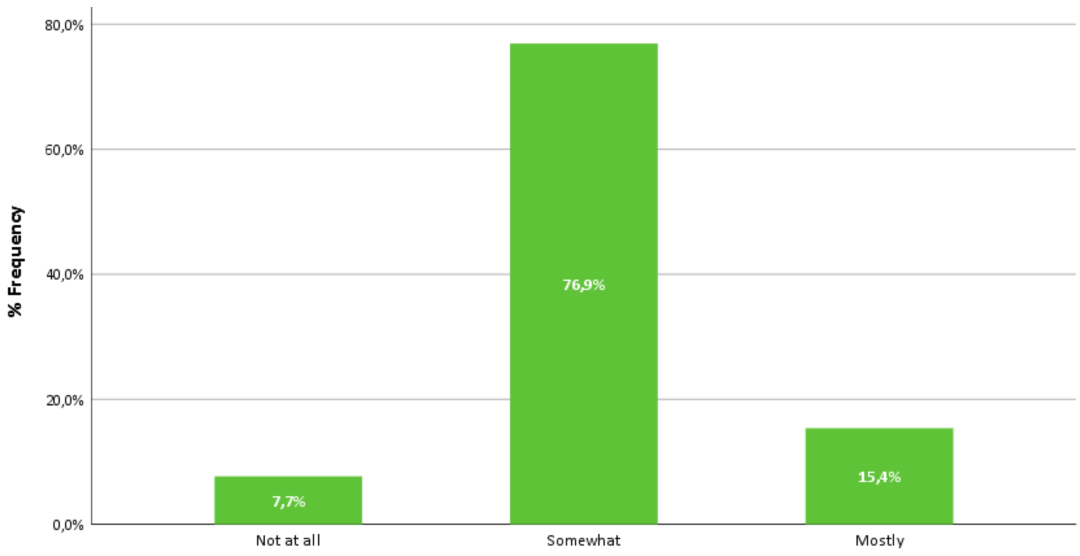

Figure 7: Responses to Question B1b: To what extent do you apply the principles of Sustainability in your work?

In response to the second question about the use of sustainable materials in their projects, 57.7% of the participants responded positively and 11.5% negatively, while 15.4% were uncertain and for 15.4% this question was unrelated to their work.

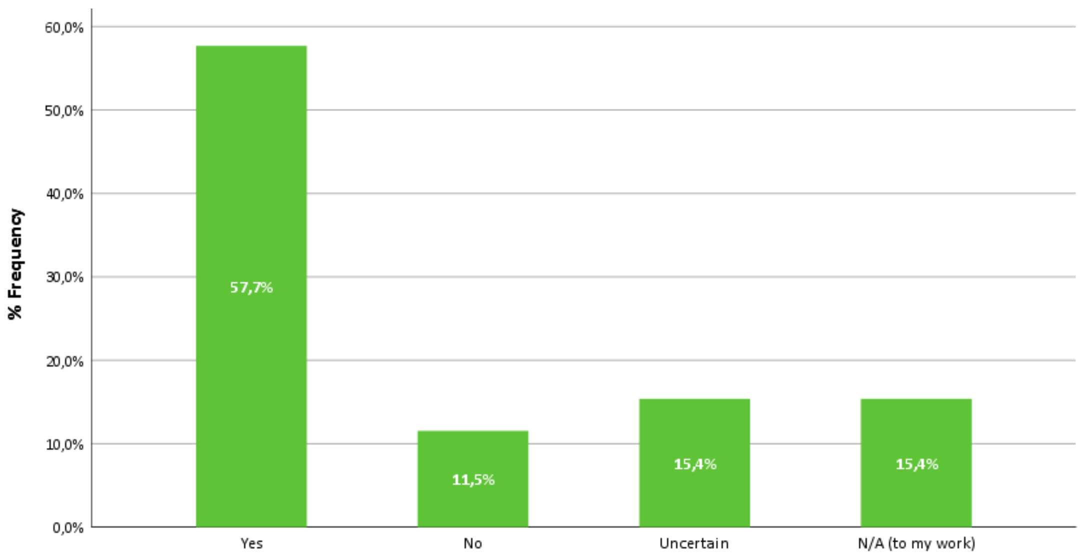

Figure 8: Responses to Question B2a: Have you employed any sustainable materials in any of your projects?

In the complementary question about the reasons that the respondents have not employed sustainable materials in their projects, 3 mentioned Unavailability, 3 High Prices and 2 Customer Preferences.

Similarly to the first question, in response to the third question, all participants were familiar to the term "(Nearly) Zero Energy Buildings - (N)ZEBs”.

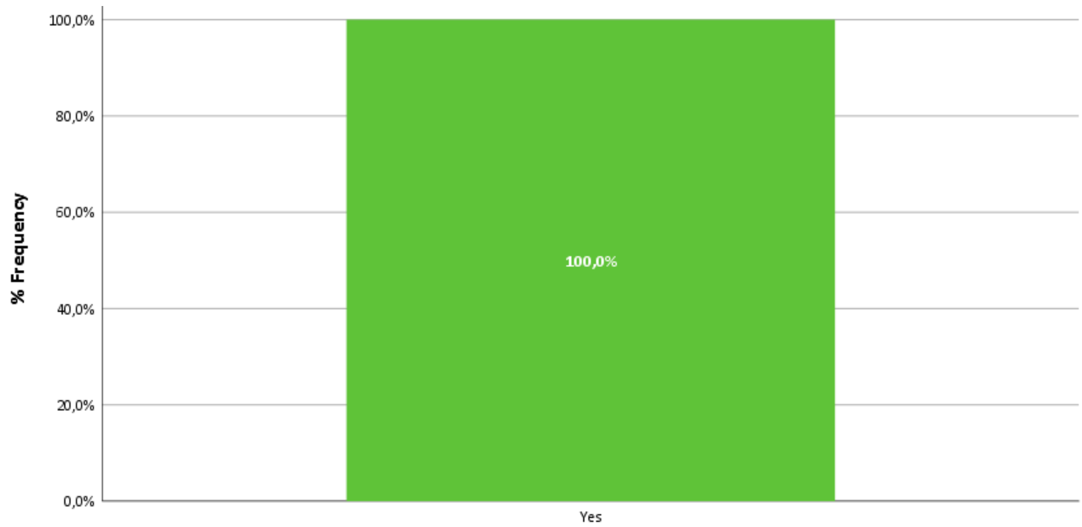

Figure 9: Responses to Question B3a: Are you familiar with the term "(Nearly) Zero Energy Buildings - (N)ZEBs"?

Regarding the extent to which they apply the principles of NZEBs in their projects, 61.5% answered “somewhat”, 15.4% “mostly”, 3.8% “not at all”, while for the remaining 19.2% this question was not applicable to their work.

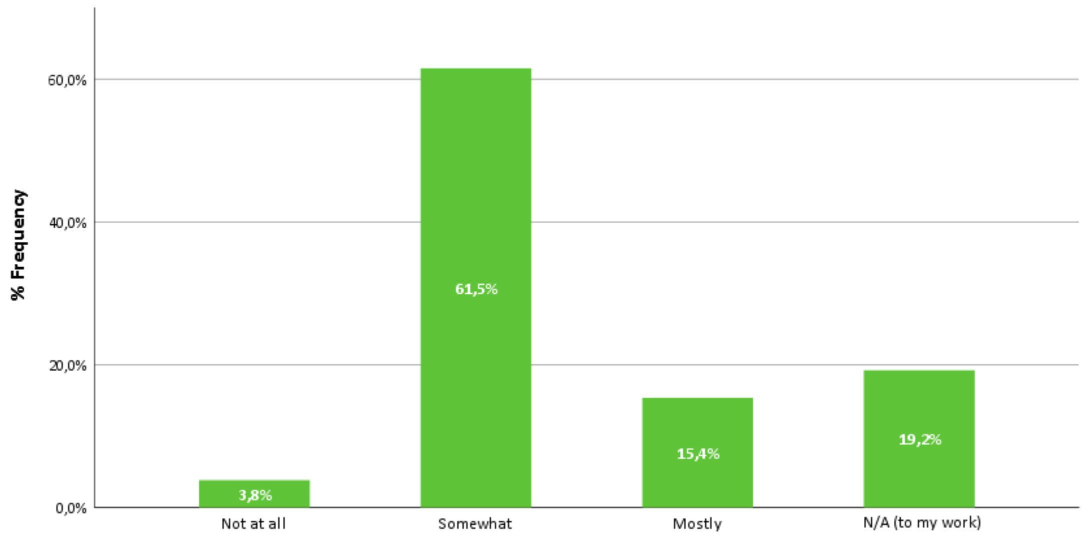

Figure 10: Responses to Question B3b: To what extent do you apply the principles of (N)ZEBs in your work?

When asked about the means of achieving NZEBs in their projects, participants were given the possibility to select one or more of certain recommended answers, as well as to provide their own:

- High-efficiency building envelope components were selected by 21 out of 26 participants (80.8%).
- HVAC systems were selected by 17 participants (65.4%).
- Renewable energy systems were chosen by 20 respondents (76.9%).
- Energy management systems were chosen by 15 participants (57.7%).
- 1 participant (3.8%) offered an additional answer ("recycling of office paperwork/equipment") which clearly shows that they do not have a solid understanding of NZEBs.
- 1 participant (3.8%) answered that this question is not applicable to their work.

Interestingly, in the following question about the participants' familiarity of the current and imminent EU Directives on Energy Performance of Buildings, 65.4% answered positively and 23.1% negatively, while 11.5% were uncertain.

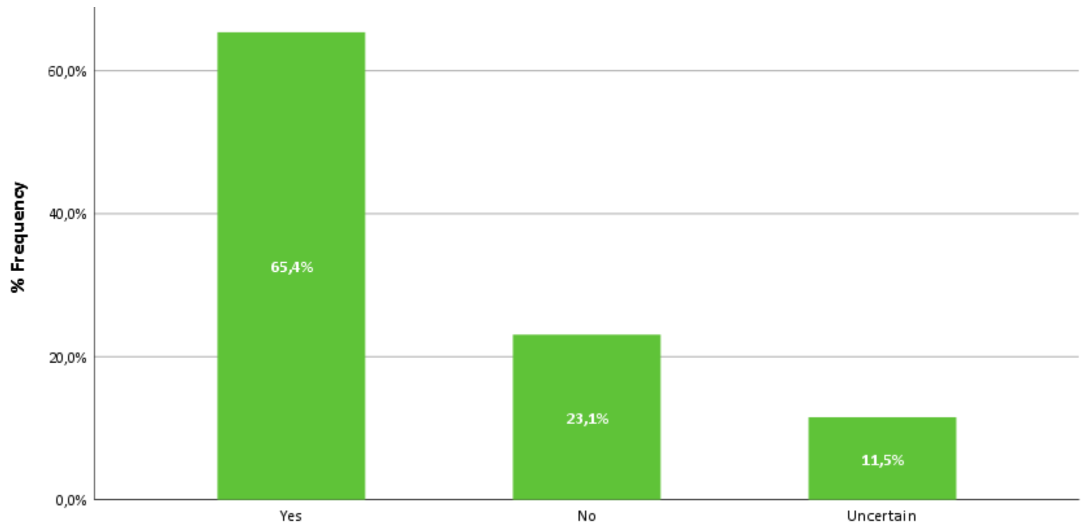

Figure 11: Responses to Question B5: Are you familiar with the current and imminent EU Directives on Energy Performance of Buildings?

When asked if they are ready to hire sustainability professionals to pursue more sustainable development and NZBEs projects, 46.2% responded positively, 23.1% negatively and 11.5% were uncertain, whereas for 19.2% this question was not applicable to their work.

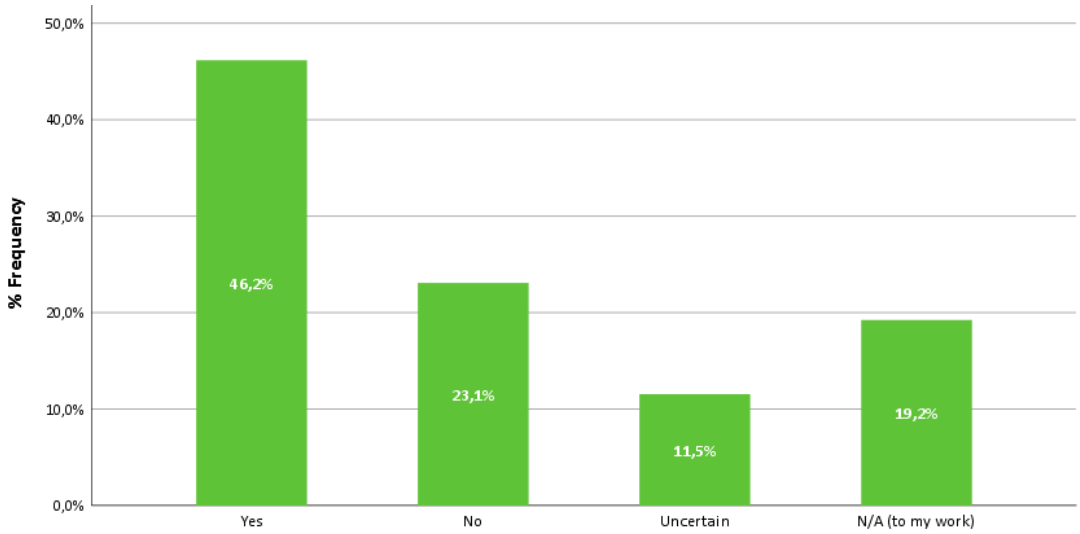

Figure 12: Responses to Question B6: Are you ready to hire sustainability professionals to pursue more sustainable development and NZBEs projects?

The next question inquired participants on their view about the current experience of the construction industry on sustainable development and NZBEs in Cyprus and whether it can ensure the smooth communication and collaboration between all stakeholders and at all project stages. Apparently, most respondents were negative (38.5%) or uncertain (34.6%) and only 26.9% were positive.

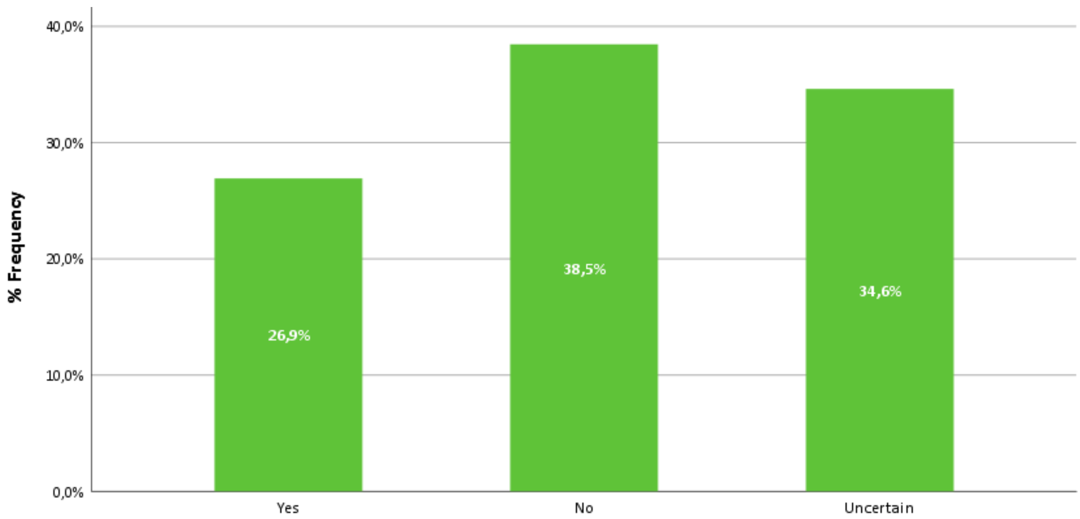

Figure 13: Responses to Question B7: Do you believe that in Cyprus the current experience of the construction industry on sustainable development and NZBEs can ensure the smooth communication and collaboration between all stakeholders and at all project stages?

In response to whether professionals that take on projects for sustainable and NZE buildings should charge higher prices, 53.8% of the participants were positive, 26.9% negative and 19.2% uncertain.

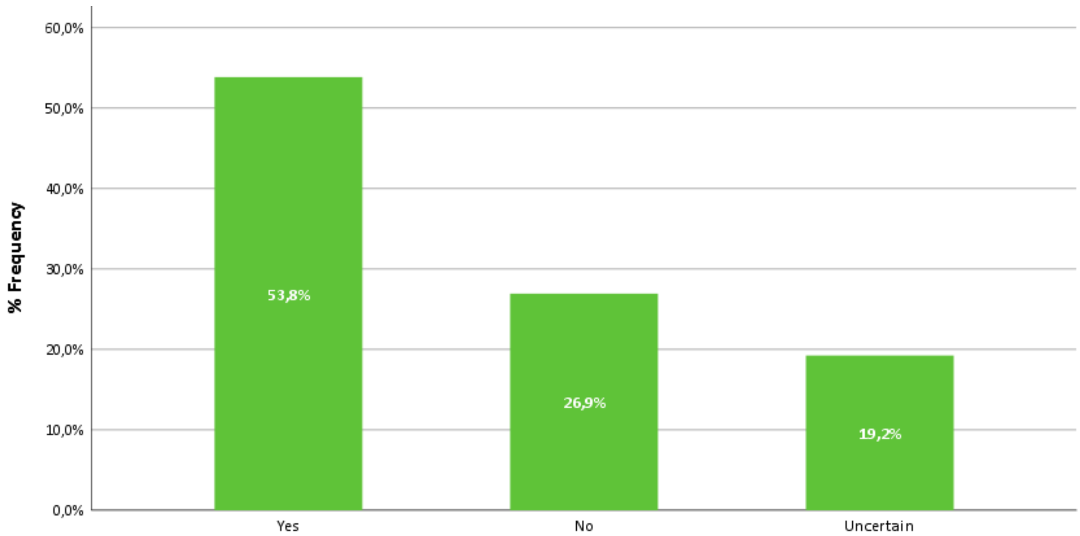

Figure 14: Responses to Question B8: Do you believe that professionals that take on projects for sustainable and NZE buildings should charge higher prices?

When asked if they believe that contractors, developers, construction companies have the required know-how and expertise to undertake sustainable and NZEB projects (for both new and existing buildings), 38.5% answered positively and 34.6% negatively, with the remaining 26.9% being uncertain.

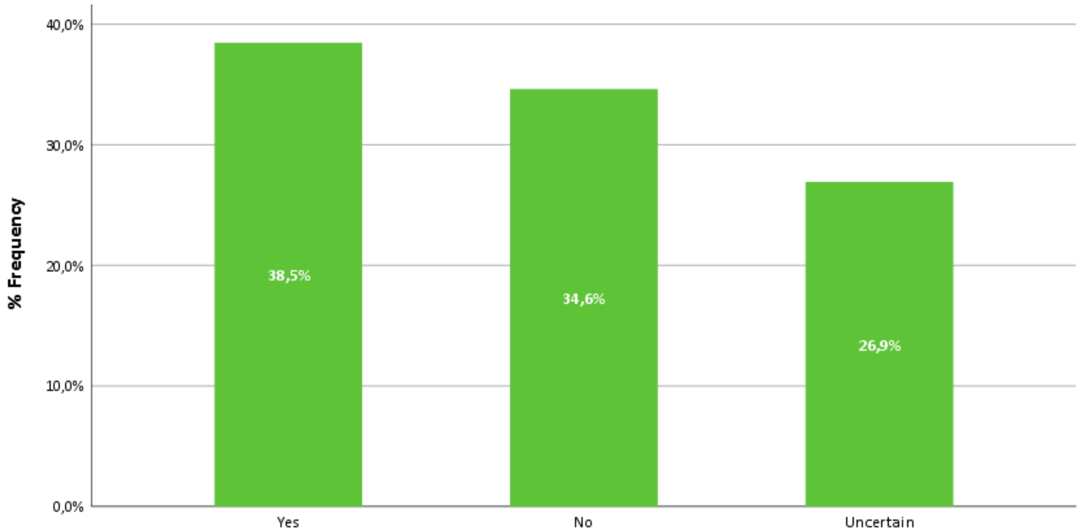

Figure 15: Responses to Question B9: Do you believe that contractors, developers, construction companies have the required know-how and expertise to undertake sustainable and NZEB projects? (for both new and existing buildings)

For the next open-ended question, participants were required to provide an estimated cost difference between a conventional building and an NZEB is? Please provide a range for both new and existing buildings. A variety of estimation were offered by the respondents. Those who answered in terms of monetary cost mentioned the following estimations:

- 10,000€ - 20,000€
- 1,300€ for contemporary, 1,600€ for NZEBs
- 20,000€ - 30,000€
- 20,000€
- 30,000€ (x3)
- 400€ - 600€ per sqm
- Around 150€ per sqm
- Conventional buildings €900 - €1200, NZEB €1200 - €1500 per sqm (x2)

On the other hand, those who answered with percentage rates mentioned:

- 10% - 20% (x2)
- 10% – 15% for new, 5% - 10% for existing
- 10% (x2)
- 10% for new buildings
- 15% - 20%
- 20% for new, 30% for existing
- 30%
- 5% - 10% (x3)
- 15% – 20% for new, 25% - 30% for existing

There was also one participant who responded that there is "no big difference" and another who explained that they "would not know the cost difference but there is definitely savings in the running of business in the long run".

Next, when asked about the adequacy of economic and financial incentives (sponsorships, tax deduction etc.) granted to potential buyers from the Cypriot state for the promotion of sustainable and NZE buildings, most participants (65.4%) responded that there are not enough incentives and 23.1% were uncertain, whereas only 11.5% replied positively.

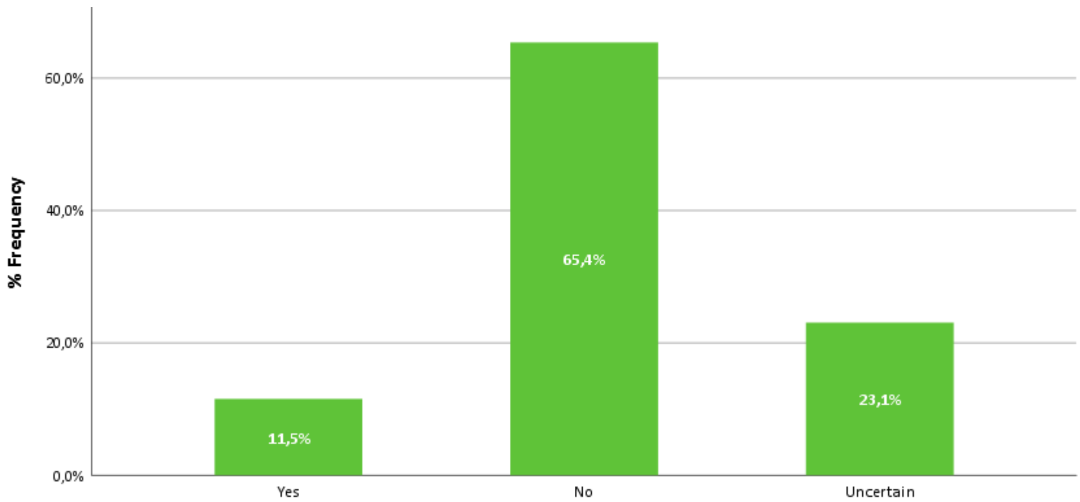

Figure 16: Responses to Question B11: Do you believe that there are enough economic and financial incentives (sponsorships, tax deduction etc.) granted to potential buyers from the Cypriot state for the promotion of sustainable and NZE buildings?

In the following question about the existence of required assessment tools for successful comparison between sustainable and NZE buildings in Cyprus, 46.2% of the participants responded negatively, 30.8% were uncertain and only 23.1% were positive.

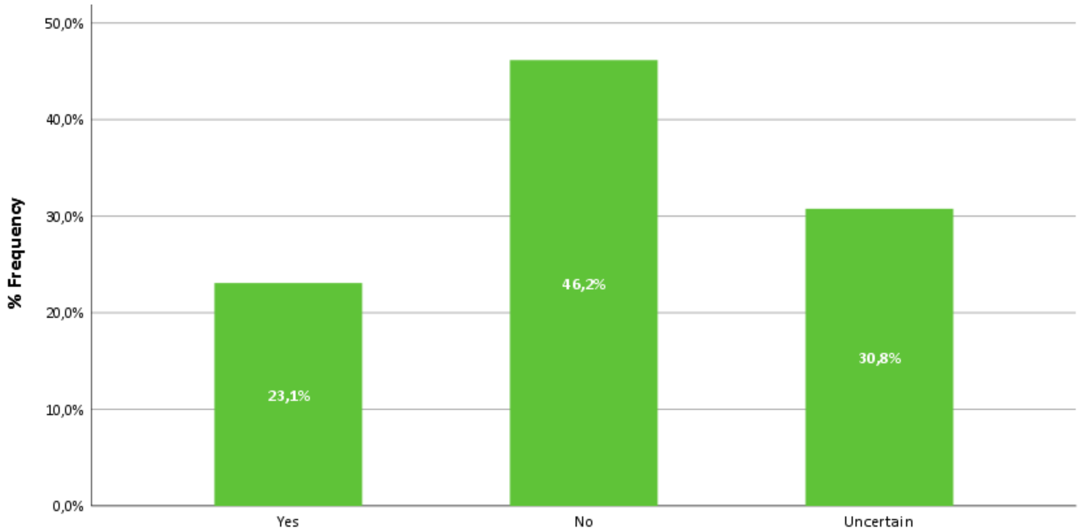

Figure 17: Responses to Question B12: Do you believe that in Cyprus the required assessment tools for successful comparison between sustainable and NZE buildings do exist?

The thirteenth question of Part B revealed a potential lack of information, in terms of volume and quality, regarding building codes and material/system prototypes for the successful development of a sustainable NZE building (such as resources for LEED certification), as 38.5% of the respondents were uncertain and 34.6% negative, while 26.9% believed that there is sufficient and high-quality information.

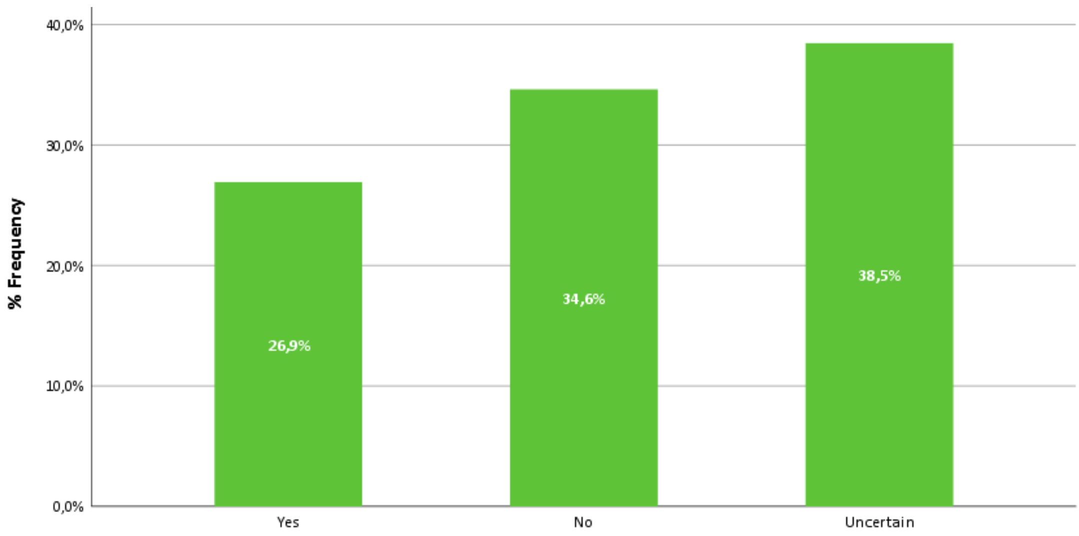

Figure 18: Responses to Question B13: Do you believe that in Cyprus the volume and quality of available information, building codes and material/system prototypes is sufficient for the successful development of a sustainable NZE building? For instance, are there enough resources to facilitate LEED certification?

In the following question, 61.5% of the respondents said that they would employ certified materials and systems in their projects in order to achieve better energy efficiency performance, whereas 15.4% were not sure and 23.1% answered that this question did apply to their work.

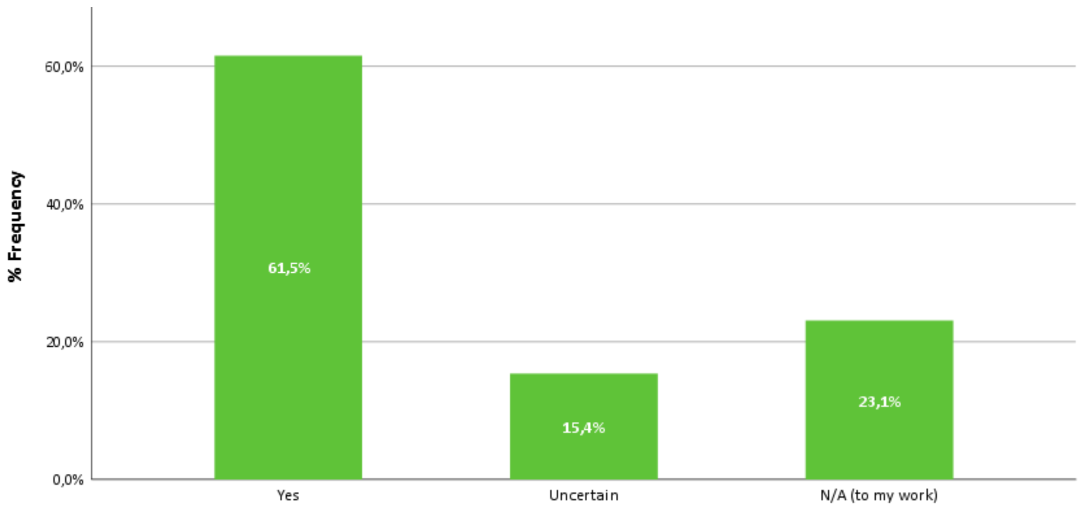

Figure 19: Responses to Question B14: Would you employ certified materials and systems in your projects in order to achieve better energy efficiency performance?

Similarly, when asked if they would employ renewable energy systems to achieve better energy efficiency performance, 69.2% answered positively, 7.7% were uncertain and, again, 23.1% could not relate to the question.

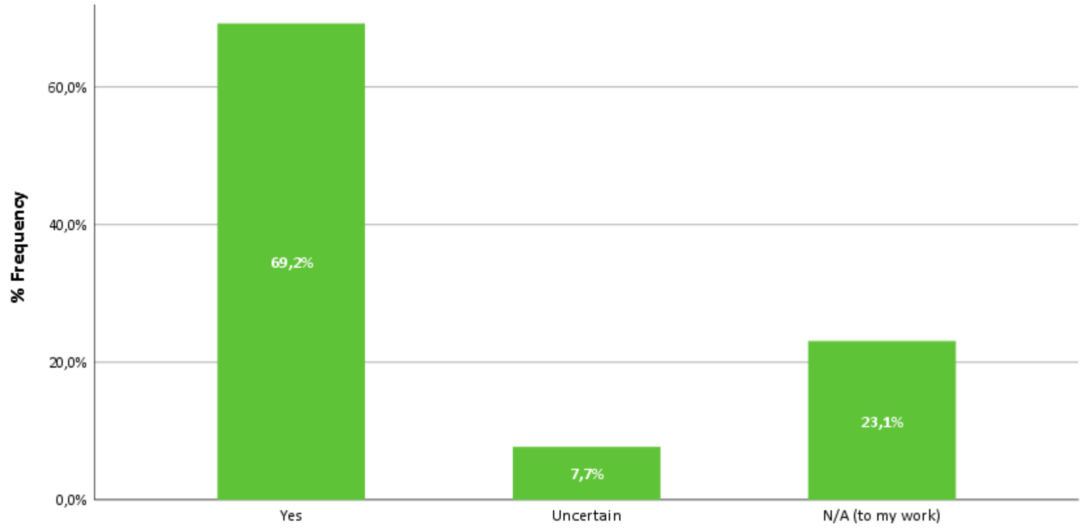

Figure 20: Responses to Question B15a: Would you employ renewable energy systems in your projects in order to achieve better energy efficiency performance?

In the complementary question about the kind of RES they would employ, 15 participants (57.7%) mentioned solar energy and photovoltaic systems, 2 participants (7.7%) added other energy sources as well (wind, hydro and biomass) and 1 participant (3.8%) mentioned passive systems in general. There were also 2 participants (7.7%) who mentioned energy efficient fire places and 1 participant (3.8%) who referred to thermal insulation, although this does not related directly to RES.

When inquired if they believe that investors would invest in energy conservation systems even for buildings destined for sale or renting, the majority of participants (73.1%) answered positively, 15.4% were uncertain and only 11.5% were negative.

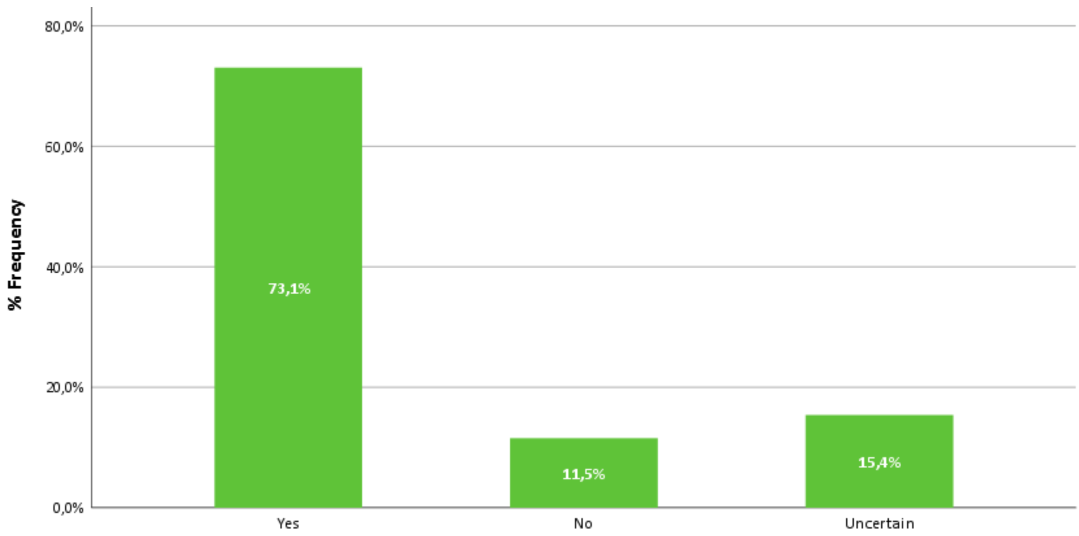

Figure 21: Responses to Question B16: Do you believe that investors would invest in energy conservation systems for buildings destined for sale or renting?

In the last question of Part B, asking whether potential building owners in Cyprus would accept higher initial costs for the establishment of new sustainable, energy efficient systems under the assumption that those would lessen the buildings' environmental impact in the long-run, more than half of the respondents (53.8%) were positive, 23.1% were negative and another 23.1% uncertain.

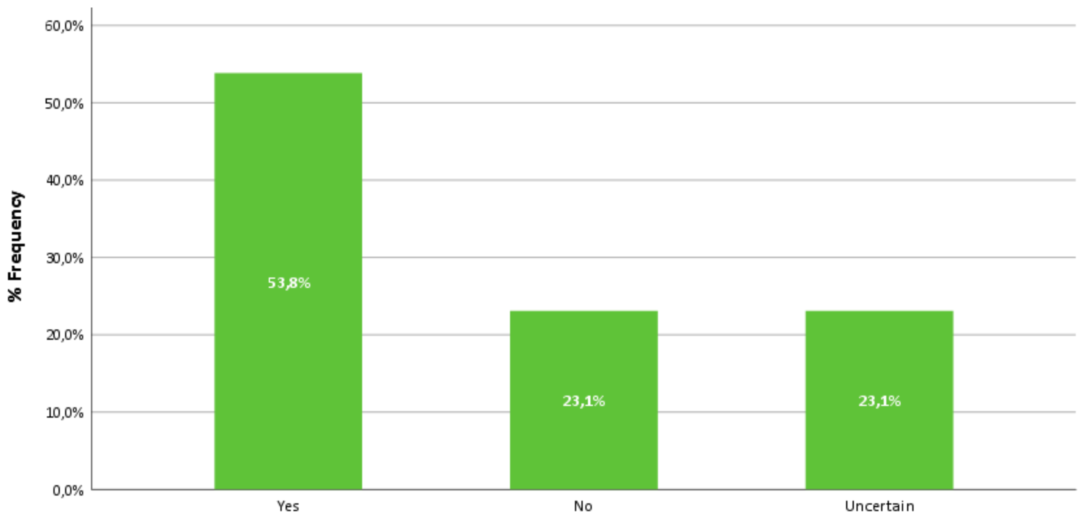

Figure 22: Responses to Question B17: Do you believe that potential building owners in Cyprus would accept higher initial costs for the establishment of new sustainable, energy efficient systems under the assumption that those would lessen the buildings' environmental impact in the long-run?

In the third part of the questionnaire, the first question required the evaluation of the participants' clients' willingness to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient. It appears that the majority of responses were concentrated in the middle, with 38.5% mentioning moderate levels, 23.1% low levels and 23.1% high levels of willingness, while 7.7% of the respondents believe that their clients would not be eager to pay more for insufficiently tested materials and systems and another 7.7% that their clients would be very willing to take on the potential risk so as to achieve better energy efficiency.

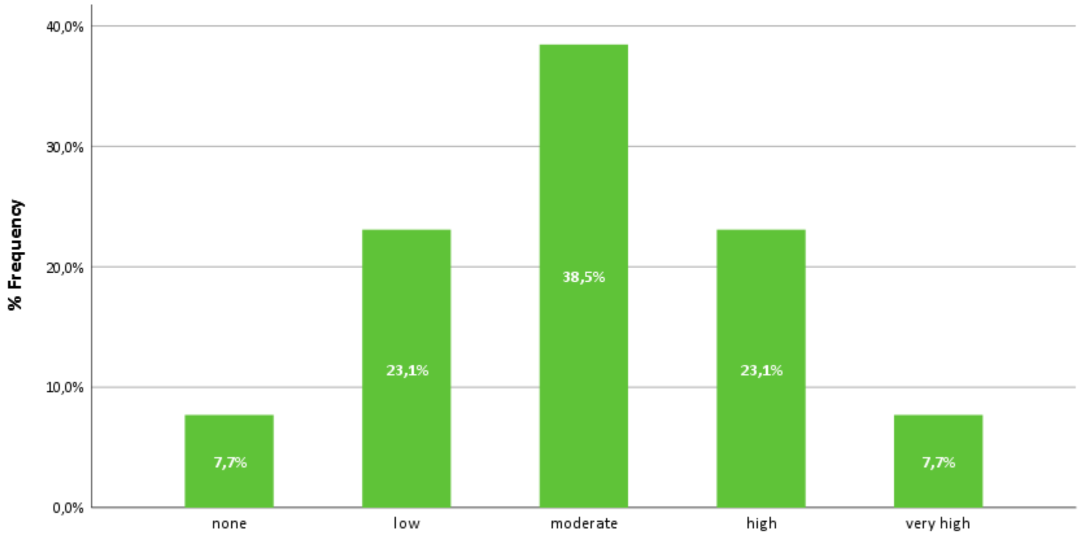

Figure 23: Responses to Question C1: Evaluate the levels of your clients' willingness to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient

In a similar question about how willing the participants' clients would be to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is environment friendly, it seems that the respondents believe that their clients would be less eager to cover the additional costs. In detail, 26.9% mention high levels of willingness, another 26.9% mention moderate levels, while 46.1% in total believe that their clients would be little to not at all eager to pay for insufficiently tested materials and systems for more environment friendly buildings.

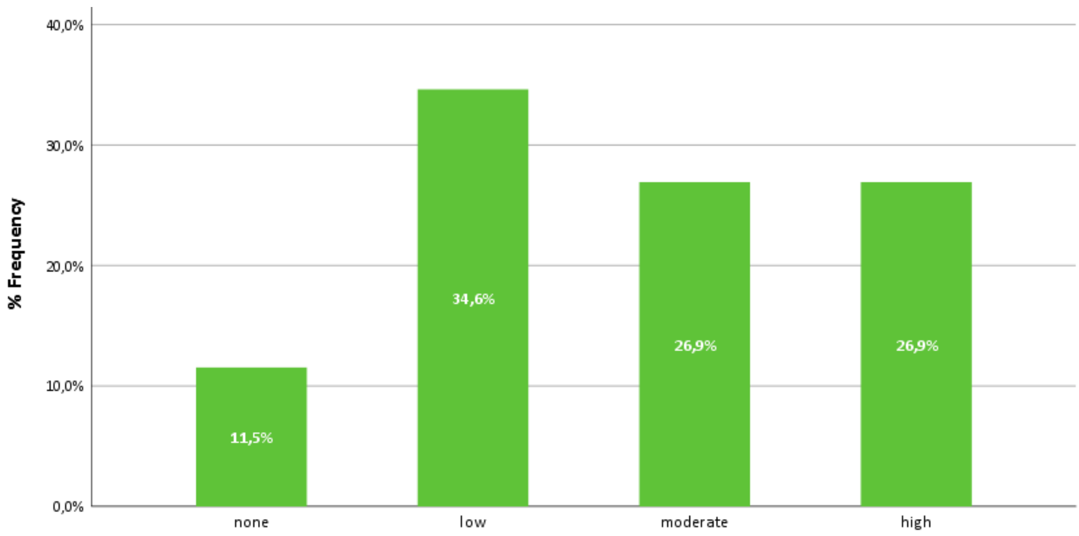

Figure 24: Responses to Question C2: Evaluate the levels of your clients' willingness to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is environment friendly

When asked about the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years, in total 38.4% of the participants mention a high or very high possibility, 26.9% consider the possibility moderate, whereas 34.6% find it low or zero.

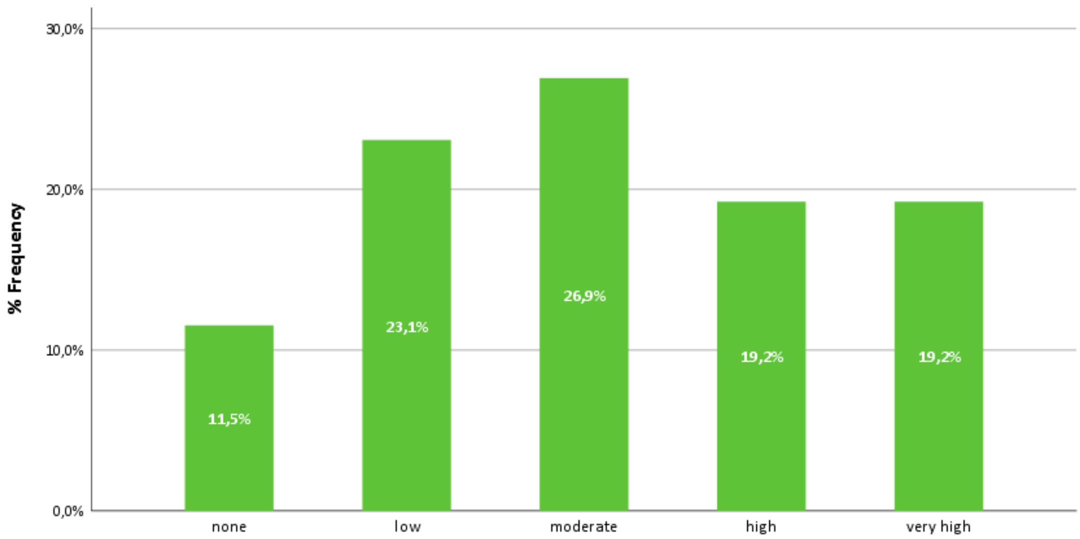

Figure 25: Responses to Question C3: Evaluate the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years

Finally, when asked about how interested they are in receiving additional training in areas related to the design, development etc. of sustainable, energy efficient buildings, 42.3% of the respondents were moderately interested, 42.3% showed high or very high interest and 25.3% displayed low or no interest at all.

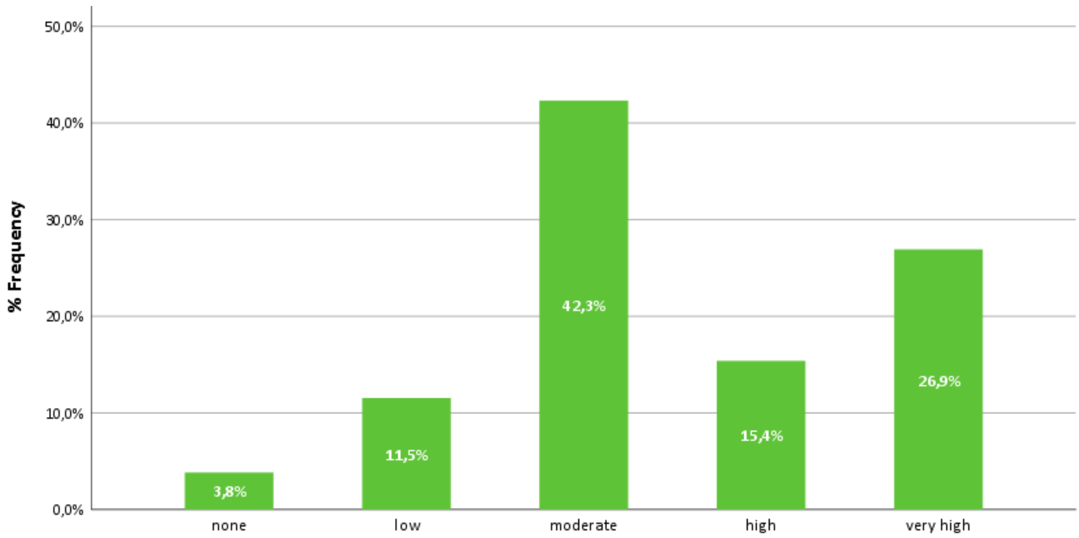

Figure 26: Responses to Question C4: Evaluate the degree of your interest in receiving additional training in areas related to the design, development etc. of sustainable, energy efficient buildings

5.1.2. Investigation of Statistically Significant Relationships

Despite the small sample size, an attempt was made to identify any statistically significant relationships between the variable. Given the type of variables, i.e. categorical (either nominal or ordinal), the examination of possible correlations was based on Spearman's rho coefficient, for which the p-value should be less than the level of significance (α = 5%), to denote a statistically significant association between the studied variables.

First, the investigation focused on the potential association between demographic variables and the questions of the other two parts of the questionnaire. Apparently, only two statistically significant associations were identified, as shown in the table below. The first implies that there could be a difference between the views of the two genders about the current experience of the construction industry on sustainable development and NZBEs and whether it can ensure the smooth communication and collaboration between all stakeholders and at all project stages. However, since there were only 2 female participants, this observation is not conclusive. On the other hand, the second statistically significant association was found between the location of work and the participants' opinion on whether professionals undertaking projects for sustainable and NZE building should charge higher prices.

Table 3: Statistically significant associations between demographic variables and other questions

Demographic Variable	Question	Spearman's rho	p-value
Gender	Do you believe that in Cyprus the current experience of the construction industry on sustainable development and NZBEs can ensure the smooth communication and collaboration between all stakeholders and at all project stages?	-0.389	0.049 < α = 5%
Location of Work	Do you believe that professionals that take on projects for sustainable and NZE buildings should charge higher prices?	-0,539	0,005 < α = 5%

Then, the statistical analysis concentrated on testing for potential associations between the different pairs of questions of the other two parts of the questionnaire. Spearman's rho coefficient was used as a criterion to identify statistically significant correlations between the variable pairs. In detail, the Spearman correlation coefficient (Spearman's rho, for short) is a nonparametric measure of the strength and direction of association between two variables representing paired observations and displaying a monotonic relationship, i.e. either increasing/decreasing together or as one increases the other decreases. Spearman's rho determines the degree to which a relationship is monotonic, or in other words, it identifies whether there is a monotonic component of association between the two variables. The value of Spearman's rho coefficient ranges between 0 and 1 and denotes the strength of the association. Values closer to 0 imply a weak association, while values closer to 1 indicate a stronger association. The sign (+/-) of the coefficient indicates the direction of the association. A positive sign means that the variables increase or decrease together, whereas a negative sign implies that as one variable increases the other one decreases. Finally, to ensure a statistically significant relationship, the p-value, which is returned by SPSS along with the Spearman's rho value, is compared against the predefined significance level α (usually α=5%). When the p-value is lower than or equal to the significance level, then the association between the variables is statistically significant.

All statistically significant associations are summarized in Table 2, according to which:

- The extent to which participants apply the principles of Sustainability in their work is significantly associated with their view on whether professionals undertaking projects for sustainable and NZE buildings should charge higher prices.
- There is a significant association between the participants' experience of employing sustainable materials in their projects and their readiness to hire sustainability professionals to pursue more sustainable development and NZEB projects in the future.
- The extent to which participants apply the principles of NZEBs in their work is significantly associated with how willing their clients would be to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient.
- The participants' familiarity with the current and imminent EU Directives on Energy Performance of Buildings is significantly associated with the degree of their interest in receiving additional training in areas related to the design, development etc. of sustainable, energy efficient buildings
- Apart from the participants' experience of employing sustainable materials in their projects, their readiness to hire sustainability professionals to pursue more sustainable development and NZEB projects in the future is also significantly associated with:
    - their view on whether the current experience of the construction industry on sustainable development and NZBEs in Cyprus can ensure the smooth communication and collaboration between all stakeholders and at all project stages
    - the potential use of certified materials and systems in their projects in order to achieve better energy efficiency performance

    - the potential use of renewable energy systems in their projects in order to achieve better energy efficiency performance
    - the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years
- The participants' view on whether the current experience of the construction industry on sustainable development and NZBEs in Cyprus can ensure the smooth communication and collaboration between all stakeholders and at all project stages is also significantly associated with their view on the existence of required assessment tools for successful comparison between sustainable and NZE buildings in Cyprus.
- The participants' opinion on whether the volume and quality of available information, building codes and material/system prototypes in Cyprus is sufficient for the successful development of a sustainable NZE building is significantly associated with their view on the existence of required assessment tools for successful comparison between sustainable and NZE buildings in Cyprus.
- The potential use of certified materials and systems in the participants' projects in order to achieve better energy efficiency performance is also associated with:
    - the potential use of renewable energy systems for the same reasons
    - the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years
- The potential use of renewable energy systems in the participants' projects in order to achieve better energy efficiency performance is also associated with the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years.
- The participants' opinion on whether investors would invest in energy conservation systems for buildings destined for sale or renting is significantly associated with:

    - their view on whether potential building owners in Cyprus would accept higher initial costs for the establishment of new sustainable, energy efficient systems under the assumption that those would lessen the buildings' environmental impact in the long run
    - how willing their clients would be to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient
    - how willing their clients would be to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is environment friendly
    - the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years
- The participants' view on whether potential building owners in Cyprus would accept higher initial costs for the establishment of new sustainable, energy efficient systems under the assumption that those would lessen the buildings' environmental impact in the long run is also significantly related with:
    - how willing their clients would be to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient
    - how willing their clients would be to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is environment friendly
- The participants' estimation on how willing their clients would be to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient is also significantly associated with:
    - how willing their clients would be to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is environment friendly

  - the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years
  - the degree of their interest in receiving additional training in areas related to the design, development etc. of sustainable, energy efficient buildings
- The possibility of the participants being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years is also significantly associated with the degree of their interest in receiving additional training in areas related to the design, development etc. of sustainable, energy efficient buildings.

Table 4: Statistically significant associations between pairs of question variables

Variable1	Variable 2	Spearman's rho	p-value
To what extent do you apply the principles of Sustainability in your work?	Do you believe that professionals that take on projects for sustainable and NZE buildings should charge higher prices?	0.505	0.008 < α = 5%
Have you employed any sustainable materials in any of your projects?	Are you ready to hire sustainability professionals to pursue more sustainable development and NZBEs projects?	0,393	0,047 < α = 5%
To what extent do you apply the principles of (N)ZEBs in your work?	Evaluate the levels of your clients' willingness to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient	0.497	0.010 < α = 5%
Are you familiar with the current and imminent EU Directives on Energy Performance of Buildings?	Evaluate the degree of your interest in receiving additional training in areas related to the design, development etc. of sustainable, energy efficient buildings	-0.501	0.009 < α = 5%
Are you ready to hire sustainability professionals to pursue more sustainable development and NZBEs projects?	Do you believe that in Cyprus the current experience of the construction industry on sustainable development and NZBEs can ensure the smooth communication and collaboration between all stakeholders and at all project stages?	0.461	0.018 < α = 5%
	Would you employ certified materials and systems in your projects in order to achieve better energy efficiency performance?	0.684	0.000 < α = 5%
	Would you employ renewable energy systems in your projects in order to achieve better energy efficiency performance?	0.647	0.000 < α = 5%
	Evaluate the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years	-0.511	0.008 < α = 5%

Do you believe that in Cyprus the current experience of the construction industry on sustainable development and NZBEs can ensure the smooth communication and collaboration between all stakeholders and at all project stages?	Evaluate the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years	-0.603	0.001 < α = 5%
Do you believe that contractors, developers, construction companies have the required know-how and expertise to undertake sustainable and NZEB projects? (for both new and existing buildings)	Do you believe that in Cyprus the required assessment tools for successful comparison between sustainable and NZE buildings do exist?	0.474	0.014 < α = 5%
Do you believe that in Cyprus the volume and quality of available information, building codes and material/system prototypes is sufficient for the successful development of a sustainable NZE building?	Do you believe that in Cyprus the required assessment tools for successful comparison between sustainable and NZE buildings do exist?	0.508	0.008 < α = 5%
Would you employ certified materials and systems in your projects in order to achieve better energy efficiency performance?	Would you employ renewable energy systems in your projects in order to achieve better energy efficiency performance?	0.915	0.000 < α = 5%
	Evaluate the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years	-0.460	0.018 < α = 5%
Would you employ renewable energy systems in your projects in order to achieve better energy efficiency performance?	Evaluate the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years	-0.400	0.043 < α = 5%
Do you believe that investors would invest in energy conservation systems for buildings destined for sale or renting?	Do you believe that potential building owners in Cyprus would accept higher initial costs for the establishment of new sustainable, energy efficient systems under the assumption that those would lessen the buildings' environmental impact in the long-run?	0.445	0.023 < α = 5%
	Evaluate the levels of your clients' willingness to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient	-0.574	0.002 < α = 5%
	Evaluate the levels of your clients' willingness to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is environment friendly	-0.599	0.002 < α = 5%
	Evaluate the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years	-0.404	0.041 < α = 5%
Do you believe that potential building owners in Cyprus would accept higher initial costs for the establishment of new sustainable, energy efficient systems under the assumption that those would lessen the buildings' environmental impact in the long-run?	Evaluate the levels of your clients' willingness to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient	-0.535	0.005 < α = 5%
	Evaluate the levels of your clients' willingness to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is environment friendly	-0.411	0.037 < α = 5%

Evaluate the levels of your clients' willingness to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient	Evaluate the levels of your clients' willingness to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is environment friendly	0.771	0.000 < α = 5%
	Evaluate the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years	0,482	0.013 < α = 5%
	Evaluate the degree of your interest in receiving additional training in areas related to the design, development etc. of sustainable, energy efficient buildings	0,523	0.006 < α = 5%
Evaluate the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years	Evaluate the degree of your interest in receiving additional training in areas related to the design, development etc. of sustainable, energy efficient buildings	0.512	0.007 < α = 5%

5.2. Discussion of Findings

The empirical research has led to a few interesting findings. First, all construction and real estate professionals who participated in the survey were familiar with the terms of “Sustainability” and “NZEBs” and most of them apply the principles of both terms, at least to some extent. At this point, it should be noted that in the limited sample, the percentage of professionals that were not directly related to the construction sector was rather increased, which may contribute in understanding how the real estate market perceives these terms and the underlying legal framework, but at the same time does not allow safe conclusions regarding the perceptions of professionals in construction.

Regardless of the limitations, survey results showed that more than half of all the professionals have employed sustainable materials in their projects.

Additionally, the most well-known methods of achieving NZEBs were high-efficiency building envelope components and renewable energy systems, followed by HVAC systems and energy management systems.

About 65% of the professionals in construction and real estate sectors were familiar with the current and imminent EU Directives on Energy Performance of Buildings.

Given the fact that these directives are in effect for more a decade and that in the past few years, there have been specific targets to be met regarding NZEBs, this percentage cannot be considered particularly high, regardless of whether the professionals participating in the survey are mostly in the construction or real estate sector, thus mostly representing the supply or demand in the market.

Despite their familiarity with sustainability, NZEBs and the underlying legislation, more than one third of the professionals are still negative or hesitant in hiring sustainability professionals to pursue more sustainable development and NZBEs projects. This attitude could be partly explained by the fact that more than 70% of all professionals were negative or uncertain about the current experience of the construction industry on sustainable development and NZBEs in Cyprus and whether it can ensure the smooth communication and collaboration between all stakeholders and at all project stages. Similarly, approximately 60% of all professionals were also negative or uncertain when asked if they believe that contractors, developers, construction companies have the required know-how and expertise to undertake sustainable and NZEB projects (for both new and existing buildings).

On the other hand, more than half of the participants in the survey do believe that professionals that take on projects for sustainable and NZE buildings should charge higher prices. Nevertheless, results showed that most participants do not have a clear idea of the cost difference between a conventional building and an NZEB, thus making various estimations, in the form of either monetary amounts or percentages. The most frequent answers involved a percent range of 5-20% and, in monetary terms, 30,000€ or 300€ per sqm. There were also mixed estimations about whether the cost of NZEBs is higher and whether the cost difference is higher for construction of new buildings or for refurbishing of existing buildings.

Another important finding was related to professionals' view on the adequacy of economic and financial incentives (sponsorships, tax deduction etc.) granted to potential buyers from the Cypriot state for the promotion of sustainable and NZE buildings. Only 11.5% believe that the government offers sufficient incentives, whereas the vast majority is negative or uncertain.

In the same context, most professionals also question the adequacy of existing assessment tools for successful comparison between sustainable and NZE buildings in Cyprus. This negative stance could be explained by a possible lack of information, in terms of volume and quality, regarding building codes and material/system prototypes for the successful development of a sustainable NZE building (such as resources for LEED certification).

On a positive note, more than 60% of the professionals who responded to the survey would employ both certified materials and systems and renewable energy systems in their projects to achieve better energy efficiency performance. Most of those who would use RES in their projects referred to solar energy and photovoltaic systems and few mentioned other passive systems in general and other renewable energy sources, such as wind, hydro and biomass.

Also, more than 70% of the professionals believe that investors would invest in energy conservation systems even for buildings destined for sale or renting, while more than 50% think that building owners in Cyprus would accept higher initial costs for the establishment of new sustainable, energy efficient systems under the assumption that those would lessen the buildings' environmental impact in the long-run.

Construction and real estate professionals were fairly split among the different degrees of their clients' potential willingness to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient or environment friendly, with most of them estimating that the clients would not be very eager to take on such risk.

Approximately, 3 out of 4 professionals consider the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years as moderate, high or very high, against 1 out of 4 who believes that this possibility is low or even zero.

Finally, a significant 3 out of 4 professionals expressed moderate, high or very high interest in receiving additional training in areas related to the design, development etc. of sustainable, energy efficient buildings, whereas 1 out of 4 showed low or no interest at all.

The abovementioned findings are summarized in the following Figure.

Figure 27: Summary of Empirical Survey Findings

Consequently, the responses provided by construction and real estate professionals denote that the main barriers faced by various industry practitioners in the application of the underlying legal and technical framework for NZEBs in Cyprus are:

1. The inadequate number of professionals with the required know-how and expertise to see through the implementation of sustainable NZEB projects on a broader scale.
2. The lack of information, regarding building codes and material/system prototypes for the successful development of a sustainable NZE building (such as resources for LEED certification).
3. The lack of information, in terms of volume and quality, addressed to potential buyers, so that they opt for sustainable NZEB projects instead of conventional buildings.
4. The inadequacy of economic and financial incentives (sponsorships, tax deduction etc.) provided from the Cypriot state to potential buyers, so as to promote the construction or refurbishment of sustainable and NZE buildings.
5. The high underlying costs of implementing sustainable NZEB projects.

The challenges and barriers documented through the process of the empirical research are aligned with the findings of other studies in extant literature.

On the other hand, the attempt to investigate potential statistically significant relationship between the various variables of the survey proved fruitful, thus leading to several interesting findings. Starting from the role of demographics, there could be a difference between the views of the two genders on the current experience of the construction industry on sustainable development and NZBEs and whether it can ensure the smooth communication and collaboration between all stakeholders and at all project stages. However, since there were only 2 female participants, this observation is not conclusive. Moreover, a significant association was found between the location of work and the participants' opinion on whether professionals undertaking projects for sustainable and NZE building should charge higher prices, which could be attributed to the current performance of the construction and real estate sectors, the underlying material and immaterial costs and the availability of skilled professionals in each region.

The extent to which participants apply the principles of Sustainability in their work seems to be linked with their opinion on whether professionals undertaking projects for sustainable and NZE buildings should charge higher prices, perhaps because those who possess the know-how and so apply the principles of Sustainability have a more clear view on the related costs.

Professionals' experience in the utilization of sustainable materials was found to be associated with their readiness to hire sustainability professionals to pursue more sustainable development and NZEB projects in the future, possibly because those who do employ such materials recognize the need for appropriately skilled professionals.

The extent to which professionals apply the principles of NZEBs in their work is associated with how willing they think their clients would be to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient. In this case, it could be deduced that the lack of experience in NZEB projects may hinder professionals from persuading their clients to take on that risk and, in turn, experienced professionals could provide more robust arguments in favor of such an investment.

Professionals' familiarity with the current and imminent EU Directives on Energy Performance of Buildings is linked with the degree of their interest in receiving additional training in areas related to the design, development etc. of sustainable, energy efficient buildings. It is expected that professionals who recognize their lack of knowledge would be more interested in pursuing additional training.

Professionals' eagerness to hire sustainability professionals to pursue more sustainable development and NZEB projects in the future is also significantly associated with their view on whether the current experience of the construction industry on sustainable development and NZBEs in Cyprus can ensure the smooth communication and collaboration between all stakeholders and at all project stages, the potential use of certified materials and systems in their projects in order to achieve better energy efficiency performance, the potential use of renewable energy systems in their projects in order to achieve better energy efficiency performance and the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years. These associations are rather straightforward, since professionals would be willing to hire skilled staff if they expect an increase in sustainable and NZEB projects, acknowledge the imminent need for such personnel and have a clear image of the existence (or the lack thereof) experienced workforce in the country.

The ability of the current experience of the construction industry on sustainable development and NZBEs in Cyprus can ensure the smooth communication and collaboration between all stakeholders and at all project stages is also linked with the existence of required assessment tools for successful comparison between sustainable and NZE buildings in Cyprus. Again, this association is clear, as the industry's experience depends on the available tools and at the same time, comparison among different projects of the same kind can help acquire more experience.

As expected, the existence of required assessment tools for successful comparison between sustainable and NZE buildings in Cyprus is, in turn, also associated with the adequacy of available information, building codes and material/system prototypes in Cyprus for the successful development of a sustainable NZE building. All these parameters have a common origin, which is the technical, regulatory and legal framework that supervises and supports the implementations of sustainable NZEBs.

The potential use of both certified materials and systems and RES for improved energy efficiency performance (which are interrelated) is also associated with the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years. These associations are again straightforward, since sustainable NZEBs require certified materials and systems and RES, so a professional who expects to undertake such a project will also expect to employ those materials and systems.

Professionals' view on whether investors would invest in energy conservation systems for buildings destined for sale or renting is significantly associated with their view on whether potential building owners in Cyprus would accept higher initial costs for the establishment of new sustainable, energy efficient systems under the assumption that those would lessen the buildings' environmental impact in the long run, how willing their clients would be to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient and environment friendly and the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years. The aforementioned variables were found associated with each other in pairs.

Finally, the degree of professionals’ interest in receiving additional training in areas related to the design, development etc. of sustainable, energy efficient buildings was also associated with the possibility to undertake a similar project within the next 5 years and with their clients’ eagerness to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient. Basically, these relations imply that when the demand for sustainable NZEBs increases, professionals are more eager to receive additional training to acquire the necessary skills and be able to take up more projects.

Chapter 6: Conclusions, Limitations & Recommendations

6.1. Conclusions

This study has met its objectives of identifying the most critical sustainability design and construction parameters for NZEBs (see Table 5), through a thorough analysis of the European Directives, National legislation and international scientific resources, highlighting the main differences between conventional and NZEB developments in Mediterranean countries such as Cyprus (see Table6) and evaluating the principles and techniques for a more sustainable construction industry in Cyprus, as well as listing the barriers faced by various construction industry practitioners and professionals in the application of the underlying legal and technical framework for NZEBs (see Table 7).

Table 5: Most Critical Sustainability Design and Construction Parameters for NZEBs

Technologies	High-efficiency building envelope components HVAC systems Renewable energy systems Energy management systems
Architecture / Design	Building orientation – shape – window-to-wall ratio Ventilation strategies Energy efficient lighting Thermal storage capacity Advanced airtightness and insulation
Legal / Regulatory Framework	European (Climate Energy Package, Directive 2012/27/EU, EPBD Recast 2010/31/EU) National Legislation (in Cyprus since 2012) National Technical Guides (Certification Guide on Energy Performance of Existing Residential Buildings, Building Insulation Guide 2nd ed., Solar Systems Technical Guide)
Economic - Financial Parameters	Funding programs and other incentives (sponsorships, tax deduction etc.)
Education – Training	Postgraduate training courses Qualifications / certifications of professionals

Table 6: Main Benefits of NZEB Against Conventional Developments

More energy efficient and environment friendly (Lower CO_2-equivalent emissions, decreased thermal diffusion, increased energy savings and thermal comfort)
Introduction of new, innovative technologies
Design flexibility, cost reduction, energy and resource management (can be further promoted via expansion of NZEB concept to community level)
Growing retrofit industry

Table 7: Primary Barriers & Challenges Faced by Construction Industry Professionals in the Implementation of NZEB Projects

Inadequate number of professionals with the required know-how and expertise to see through the implementation of sustainable NZEB projects on a broader scale
Lack of information, regarding building codes and material/system prototypes for the successful development of a sustainable NZE building (such as resources for LEED certification)
Lack of information, in terms of volume and quality, addressed to potential buyers, so that they opt for sustainable NZEB projects instead of conventional buildings
Inadequate economic and financial incentives (sponsorships, tax deduction etc.) granted from the Cypriot state to potential buyers, so as to promote the construction or refurbishment of sustainable and NZE buildings
High underlying costs of implementing sustainable NZEB projects

Through this process, several conclusions were drawn, which were also affirmed by the findings of the empirical quantitative research conducted via an online questionnaire addressed to construction and real estate professionals across Cyprus. First, the necessity of applying the principles of sustainability and NZEBs to maximize energy efficiency is undeniable and unanimously recognized by industry professionals. In terms of compliance to the European Directives on Energy Efficiency, the current policy framework in Cyprus and other countries has made relatively little progress towards providing effective and efficient solutions to existing barriers because little focus has been drawn on solving them.

Even though Cyprus has made substantial progress in limiting energy consumption, there are many steps ahead in order to meet the ultimate goal of rendering every building in the country a NZEB. The government does not offer sufficient incentives to citizens for home upgrades although refurbishing costs are significant. The state has also failed to meet its own targets on bringing government buildings up to speed with the EU directive. Whereas the state is regulating new buildings with legislation and energy performance certificates, it appears to have fallen behind on its own obligations towards the EU and targets set for 2020. Nevertheless, government officials claim that it is currently assessing how much energy goes into state-owned buildings and are drawing up plans to bring needs down to near zero, while also running public works for the complete renovation of state buildings and installation of photovoltaic systems, as well as funding programs for citizens who wish to upgrade their homes.

On the other hand, there are also challenges in the research and development of NZEBs, involving the lack of a universal definition of NZEBs, consistency in government policies worldwide promoting public awareness about the application of energy efficiency standards, adequately detailed literature on the role of government promotion and public acceptance of NZEBs, research on accounting for embodied energy, especially accounting for energy consumption in manufacturing of building materials and of renewable energy devices, like solar PVs, as well as lack of exhaustive discussion regarding the financial viability of NZEB developments.

To conclude, there are several barriers related to the implementation of new NZEB developments and NZEBs retrofit: technical, financial, social, environmental/health-related and organizational/legal. From the limited range of technical solutions that can be used because of existing building structure and technical systems, the excessive investment costs, the lack of knowledge and interest for energy efficiency among residents and building owners to the sensitive balance between comfort and efficiency as criteria for selection of materials and waste management and the necessity of communication and consensus in NZEB refurbishments involving multiple homeowners, these challenges must be addressed for sustainable NZEB developments to be the new norm. To this end, industry professionals can and should play a key role in raising awareness and promoting the principles of sustainability and NZEBs, although this entails their own adequate training to remain up to date with the latest technical and regulatory requirements.

6.2. Limitations of Present Study

This study was conducted during the outbreak of covid-19 pandemic, thus constraining the author’s ability to reach a larger number of construction professionals. Since the research sample was limited to 26 professionals, it may not be safe to assume that certain findings can be generalized.

6.3. Recommendations for Future Research

Future studies could focus on increasing the research sample to include as many professionals as possible from all areas of expertise and across all Cypriot regions, in order to draw more specific conclusions on the role of demographics in professionals’ perceptions, on whether the current challenges and barriers have been addressed and on how future challenges would affect professionals’ attitude towards sustainable NZEB projects.

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Appendix A: The Questionnaire

This questionnaire is part of a study on the barriers and challenges real estate professionals in Mediterranean countries face as a result of the latest European regulations on nearly zero-energy buildings.

Anonymity of respondents is guaranteed. Participation to the survey is voluntary and participants can quit at any time without any implications. The data collected will be used only in the context of and for the purposes of this survey.

Thank you in advance for taking the time to fill in the questionnaire.

Part A

1. Gender

   ☐ Male ☐ Female

2. Age

   ☐25 – 34 ☐35 – 44 ☐45 – 54 ☐>55

3. Professional Experience (in years)

   ☐ less than 10 ☐ 10 – 19 ☐ 20 – 29 ☐ 30 – 39 ☐ 40 or more

4. Profession – Area of Expertise

   ☐ Consultants ☐ Contractors

   ☐ Developers ☐ Real Estate Agents

   ☐ Other ______________

5. Location of work

☐ Nicosia ☐ Paphos

☐ Limassol ☐ Famagusta

☐ Larnaka ☐ Other ______________

Part B

1. Are you familiar with the term “Sustainability”?

☐ Yes ☐ No ☐ Uncertain

If yes, to what extent do you apply the principles of Sustainability in your work?

☐ Not at All ☐ Somewhat ☐ Mostly

2. Have you employed any sustainable materials in any of your projects?

☐ Yes ☐ No ☐ Uncertain ☐ N/A (for my work)

If no, why? (multiple options possible)

☐ Unavailability ☐ High Prices ☐ Customer Preferences ☐ Other ________

3. Are you familiar with the term “(Nearly) Zero Energy Buildings - (N)ZEBs”?

☐ Yes ☐ No ☐ Uncertain ☐ N/A (for my work)

If yes, to what extent do you apply the principles of (N)ZEBs in your work?

☐ Not at All ☐ Somewhat ☐ Mostly ☐ N/A (for my work)

4. How do you think you can achieve NZEBs in your projects? (multiple answers possible)

☐ High-efficiency building envelope components

☐ Heating, Ventilation, and Air Conditioning (HVAC) systems

☐ Renewable energy systems

☐ Energy management systems

☐ Other____________________

☐ N/A (for my work)

5. Are you familiar with the current and imminent EU Directives on Energy Performance of Buildings?

☐ Yes ☐ No ☐ Uncertain

6. Are you ready to hire sustainability professionals to pursue more sustainable development and NZBEs projects?

☐ Yes ☐ No ☐ Uncertain ☐ N/A (for my work)

7. Do you believe that in Cyprus the current experience of the construction industry on sustainable development and NZBEs can ensure the smooth communication and collaboration between all stakeholders and at all project stages?

☐ Yes ☐ No ☐ Uncertain

8. Do you believe that professionals that take on projects for sustainable and NZE buildings should charge higher prices?

☐ Yes ☐ No ☐ Uncertain

9. Do you believe that contractors – developers – construction companies have the required know-how and expertise to undertake sustainable and NZEB projects? (for both new and existing buildings)

☐ Yes ☐ No ☐ Uncertain

10. How much do you believe the cost difference between a conventional building and an NZEB is? Please provide a range for both new and existing buildings.

____

11. Do you believe that there are enough economic and financial incentives (sponsorships, tax deduction etc.) granted to potential buyers from the Cypriot state for the promotion of sustainable and NZE buildings?

☐ Yes ☐ No ☐ Uncertain

12. Do you believe that in Cyprus the required assessment tools for successful comparison between sustainable and NZE buildings do exist?

☐ Yes ☐ No ☐ Uncertain

13. Do you believe that in Cyprus the volume and quality of available information, building codes and material/system prototypes is sufficient for the successful development of a sustainable NZE building? For instance, are there enough resources to facilitate LEED certification?

☐ Yes ☐ No ☐ Uncertain

14. Would you employ certified materials and systems in your projects in order to achieve better energy efficiency performance?

☐ Yes ☐ No ☐ Uncertain ☐ N/A (for my work)

15. Would you employ renewable energy systems in your projects in order to achieve better energy efficiency performance?

☐ Yes ☐ No ☐ Uncertain ☐ N/A (for my work)

If yes, what kind of renewable energy systems would you employ?

____

16. Do you believe that investors would invest in energy conservation systems for buildings destined for sale or renting?

☐ Yes ☐ No ☐ Uncertain

17. Do you believe that potential building owners in Cyprus would accept higher initial costs for the establishment of new sustainable, energy efficient systems under the assumption that those would lessen the buildings' environmental impact in the long-run?

☐ Yes ☐ No ☐ Uncertain

Part C

(1= none, 2 = low, 3 = moderate, 4 = high, 5 = very high)

Please evaluate …		1	2	3	4	5
… the levels of your clients' willingness to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is energy efficient		☐	☐	☐	☐	☐
… the levels of your clients' willingness to pay for innovative materials and systems that have not been sufficiently tested in Cyprus, so that their building is environment friendly		☐	☐	☐	☐	☐

… the possibility of being asked to undertake the design and development of an energy efficient, environment friendly, sustainable building within the next 5 years		☐	☐	☐	☐	☐
… the degree of your interest in receiving additional training in areas related to the design, development etc. of sustainable, energy efficient buildings		☐	☐	☐	☐	☐