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Adoption of Energy Design Strategies for Retrofitting Mass Housing Estates in Northern Cyprus

Bertug Ozarisoy [1,*] and Hasim Altan [2]

1 School of Architecture, Computing & Engineering, University of East London, London E16 2RD, UK
2 Department of Architectural Engineering, University of Sharjah, Sharjah 27272, UAE; hasimaltan@gmail.com
* Correspondence: ozarisoyb@gmail.com; Tel.: +44-7-961-974-826

Received: 28 June 2017; Accepted: 13 August 2017; Published: 21 August 2017

Abstract: This research project is undertaken in the Turkish Republic of Northern Cyprus (T.R.N.C.). The objective of the research is to investigate the occupants' behaviour and role in the refurbishment activity by exploring how and why occupants decide to change building systems and how to understand why and how occupants consider using energy-efficient measurements. The housing estates are chosen from 16 different projects in four different regions of the T.R.N.C. that include urban and suburban areas. The study is conducted through semi-structured interviews to identify occupants' behaviour as it is associated with refurbishment activity. This paper presents the results of semi-structured interviews with 70 homeowners in a selected group of 16 housing estates in four different parts of the T.R.N.C. Alongside the construction process and its impact on the environment, the results point out the need for control mechanisms in the housing sector to promote and support the adoption of retrofit strategies and to minimise non-controlled refurbishment activities. The results demonstrate that European Union Energy Efficiency directives need not only inform households about technological improvements that can be installed in their residential properties, but should also strongly encourage and incentivise them to use them efficiently. Furthermore, the occupants' energy consumption behaviour and the applicable policy interventions will make the difference between implementing policy which in fact delivers on its aims for energy efficiency and sustainability.

Keywords: construction process; energy efficiency; refurbishment activity; retrofitting; Cyprus

1. Introduction

This research project is undertaken in the Turkish Republic of Northern Cyprus (T.R.N.C.). This research investigates the socio-political developments that have had an impact on the architecture and the urban planning process in this particular region. The study focuses on identifying refurbishment activities capable of diagnosing and detecting the underlying problems alongside the challenges offered by the mass housing estates design and planning in addition to identifying the cultural influences in the refurbishment process, which allow for the maximisation of expected energy savings. The rapid construction activities are responsible for the consumption of approximately two-thirds of global energy demand in urban and suburban areas, and are therefore responsible for major changes in the built environment [1]. The Intergovernmental Panel on Climate Change report in 2007 indicates that urbanisation has led to an increase in temperatures of 0.006 °C per decade since 1900 on the global land record and 0.002 °C on the global and ocean record [2]. In the T.R.N.C. the increasing number of construction activities has had an impact on the environment, which is included in future assessments of problems for the mass housing sector. At the same time, as a result of an increase in summer temperatures and a decrease in temperatures during winter months have brought changes in urban energy use. The Ministry of Environment and Natural Resources Department of Meteorology—T.R.N.C. (Cevre ve Dogal Kaynaklar Bakanligi Meteoroloji Dairesi Mudurlugu in Turkish) statistics in 2015 shows that the average annual temperature was 17.2 °C between 1960 and 1991 and this increased to 17.7 °C between 1991 and 2007 [3]. These results show that the island is threatened by the climate change impact now affecting the whole planet but within the T.R.N.C.

The rapid construction during the "property boom" years led to a revived interest in the property market. The expectations of the Annan Plan and changing market conditions throughout the world is prominent evidence that people from countries such as Russia, Turkey, Greece, the United Kingdom, and Germany began to show significant interest in buying their "second homes" in the T.R.N.C. [4]. The increasing energy demand by the residential sector was felt mainly through rapid construction activities and a renewed concentration on economic improvement. In the T.R.N.C., the rapid and varied construction activity throughout the building sector resulted in economic growth. The State Planning Organisation—T.R.N.C. (Devlet Planlama Orgutu—K.K.T.C. in Turkish) in 2008 statistics show that, in the pre-construction period between 1997 and 2001, the GNP rate had an average of 1.8% [5]. However, during the accelerated construction activity period between 2002 and 2006, this rate had jumped to 11% per annum. It should also be noted that during this same time the construction industry accounted for 8.1% of GNP in the T.R.N.C. [5]. The results show how construction activity activated interest in construction projects. However, the situation led to unsustainable environmental problems, ecological constraints and energy issues.

The solutions of retrofit strategies should be effective, environmentally acceptable and feasible given the type of mass housing projects under review, with due regard for their location, the climatic conditions, within which they are undertaken, the socio economic standing of the house owners and their cultural assessments, local resources and legislative constraints. Furthermore, the study goes on to insist on the practical and long-term economic benefits of implementation of retrofit strategies under the selected research methodology (ethnographic study) and why this should be fully understood by the construction companies and householders.

The literature review has been obtained by a combination of descriptive and explanatory research methods to inform the research background and elaborate the justification of the research context on the researcher's knowledge and experiences. For this purpose, the research carries out a literature review on these key-drivers to support the theoretical framework and give information on the construction industry and its process in the T.R.N.C. It details the energy consumption of the residential buildings under review, as well as the energy efficiency and retrofit strategies in order to understand how the European Union (EU) objectives are regulating the housing sector as a way to improve conditions both in policies and practices in the residential sector. In these theoretical foundation methods, the literature survey has been carried out through a collection of periodicals (i.e., reports, journals, articles, books) on the European Union energy efficiency standards, implementations, policy documents and the related sources on the retrofit practice by other EU member states have been studied to understand the role of EU objectives, allowing for a better understanding for the identification of the research problems. The subsequent sections in this paper are structured as follows; the paper will first discuss the background and justification of research, followed by the hypothesised relationships with regard to the relevant literature. This is then continued with explanations on the methodology employed. Preliminary findings and discussions are given prior to the conclusion. Limitations and future research directions will also be discussed.

2. Location and Climate

Cyprus, located in the eastern Mediterranean, is the third largest island after Sicily and Sardinia. It is located in the Eastern Mediterranean part. Its closest neighbours are Turkey to the north and Lebanon, Syria, Israel, Egypt and Greece to the south and southwest. It sits on latitude 35° N and longitude 33° E (Table 1). It is the most eastern member of the European Union after being admitted as an EU member on 1 May 2004. According to the Cyprus Meteorological Service data, in 2013, the main geomorphological characteristics of the island are as follows: coastal climatic zone, inland climatic zone, semi-mountainous climatic zone and mountainous climatic zone (Figure 1) [6].

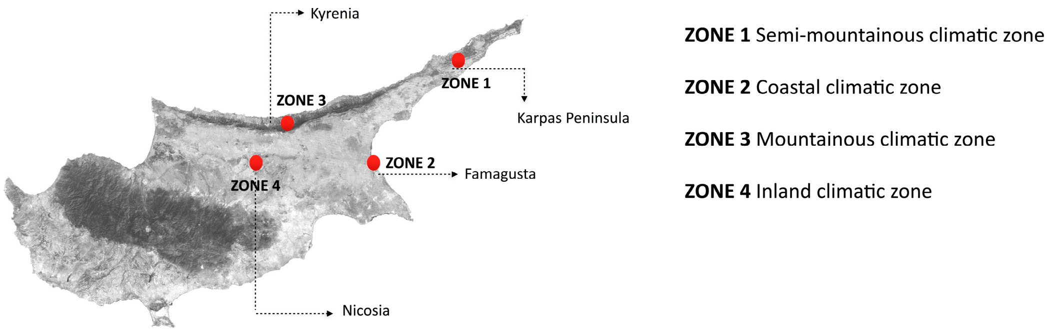

Figure 1. The geographical map of Cyprus.

The Cyprus Meteorological Service data in 2013 indicates that, generally, in July and August the mean daily temperature rises by approximately 30 °C on the central plain [6]. According to the same report, the mean daily temperature is recorded at 23 °C on the Troodos mountains. It is also noted that the average maximum temperatures are 37 °C and 28 °C, respectively. It is important to say that these temperature rates are not so bad for summertime. However, in July and August, there are a few days where temperatures can reach up to 45 °C inland and 40 °C on the coast [6]. Temperatures in the mountainous regions are much cooler than other regions during summertime (Table 1).

Temperatures in winter in Cyprus are 3–10 °C on the central plain and 0–5 °C on the higher parts of the Troodos Mountains. Naturally, temperatures on lower ground and the coastline are significantly lower, ranging between 8 °C and 12.5 °C [6]. In general, and using the available data, Cyprus has relatively mild winter conditions. However, there are occasions during the winter period when temperatures may drop below 0 °C, especially at higher altitudes in the Troodos mountains and sometimes inland. Very low temperatures are unusual near the coast where they tend to be further down the temperature scale, even 2–3 °C on the coldest of winter nights.

Table 1. Geographical data and boundary conditions assumed.

Geographical Data			
Place Cyprus	Altitude 11952 m	Latitude 35° N	Longitude 33° E
Thermal Data			
Degree day: 2259 Average heating period temperature: 7.3 °C		Climatic Area: Average solar radiation on a horizontal plane during the heating period: 7.92 MJ/m^2	
Summer Condition Data			
Month of max solar radiation: July Summer max temperature: 45 °C		Average monthly summer max temperature: Difference in temperature during the hottest day: 12 °C	

3. Construction Industry and its Impacts on Energy Use

In developing countries where urban growth and rapid urbanisation are occurring, uncontrolled urban sprawl, poor land use planning and poorly built housing estates has led to an impact on the current state of urbanisation and growth [7]. Hence, regarding the T.R.N.C. case, changing the physical layout of the land together with un-planned land use are two major factors, which have resulted in architectural, urban and environmental devastation (Figure 2). For instance, construction companies started their invasive developments in many cases without any official permission in the virgin shorelines, mountain regions and riverbeds and also before laying down any ground infrastructures such as roads, water, and electricity. This situation has prevented efficient services being made available to the project sites for their completion; therefore, it has resulted in the abandonment of the mass housing estates by the construction companies.

(**a**) (**b**)

Figure 2. Invasive (**a**); and destructive (**b**) mass housing development of the untouched natural habitat.

In the T.R.N.C., urbanisation started in the 1980s because of the development in the economy, which prompted a simultaneous demand in the mass housing sector. This led to rapid construction of the apartment blocks, detached, semi-detached and terraced houses being built randomly across the country in both urban and suburban areas. As a result of this exponential growth in the property market, there is no political agenda for controlling urban planning, infrastructure and the physical quality of the building and its adaptability to the local environmental climate. This led to poorly built houses without any initiative in the reduction of energy consumption from the buildings.

One of the main principal problems in evaluating the energy performance of the recently built housing stock is represented by the lack of current building regulations in the Town Planning Law 55/89 (Sehir Planlama Yasasi in Turkish). The current policies are adopted from similar regulations left over from the British administration [8]. The Town Planning Law no longer reflects the need and priorities of today's development of urban and suburban areas. Because of the structure of the Town Planning Law 55/89, the problems of its existing poor urbanism approach in planning concerns are now an on-going hindrance to the introduction and enforcement of proper architectural design tools and control mechanisms in the construction of buildings [9].

The following research, which has been published previously, indicates that there is a lack of awareness in understanding the importance of energy use. One strategy for reducing this deficiency in understanding is to explain the variance in energy performance in terms of the gap between design and construction process (Figure 3) [10]. Furthermore, the identification of the building diagnosis varies according to the age, size, type, etc. of building [11].

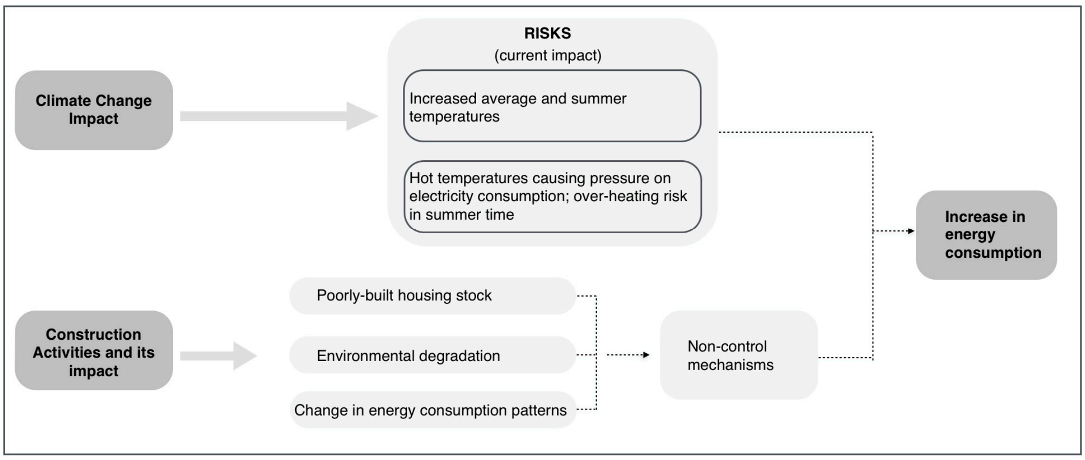

Figure 3. Model definition for justification of the research gap.

Recent studies indicate that the evolution of mass housing estates after the property boom in the T.R.N.C. brought massive changes in construction strategy, which now responds less favourably to occupants' requirements and also their current social and economic aspects [12–15]. To reverse the above man-made problems, an improvement in the physical quality of building stock is directly related to demands such as a reduction in energy consumption and thus reduction in carbon dioxide emissions [16]. In this study, the one main point is for the construction companies to assess and adopt the necessary principles of retrofit strategies to the present mass housing stock to bring into effect the above stated matters.

The approach here is to look at buildings that have been built by privately owned construction companies and have already been retrofitted by occupants to make the building more energy efficient and adaptable to the local environment. This research is prompted by a recognition that the current planning policies have not been effective in taking into account the energy consumption of the recently built mass housing estates by the construction companies in the T.R.N.C. between 2003 and 2015 (the property boom occurred during this particular period because of the political changes in Cyprus). This research reveals that there is an urgent need for the governmental bodies to bring out new and effective polices for the mass housing sector to force the construction industry to apply the necessary retrofit strategies on a rapid and large-scale basis to reduce energy consumption.

4. Current Energy Efficiency Awareness

To put the question of energy efficiency in buildings in the T.R.N.C. into context, former and current energy policies, as well as the current energy consumption situation is presented in Figure 4 (Phase I & II).

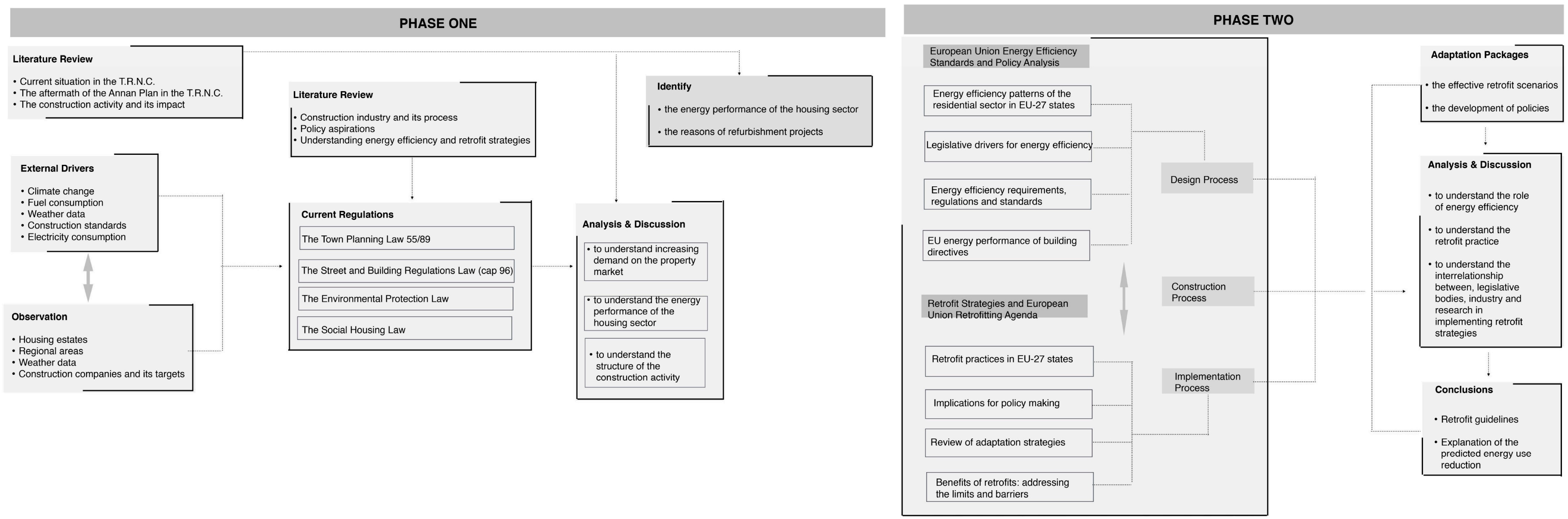

Figure 4. The collected and reviewed data on current regulations in the T.R.N.C.

4.1. Energy Consumption and Policies

The research concept sits within the context of concerns both over climate change owing to anthropogenic emissions of carbon dioxide and associated greenhouse gases and over future energy security owing to depletion of fossil fuel reserves. In accordance to the statement, high energy consumption creates serious problems in the European Union member states. Buildings are responsible for 40% of world energy consumption [17]. The Electricity Authority of the T.R.N.C. (KIB-TEK—Kibris Turk Elektrik Kurumu in Turkish) in 2017 indicates that residential sector consumption consumed 230.367 MkWh (Million kilowatt-hours) in 2003 and this figure rose to 377.971 MkWh in 2015 (Figure 5) [18].

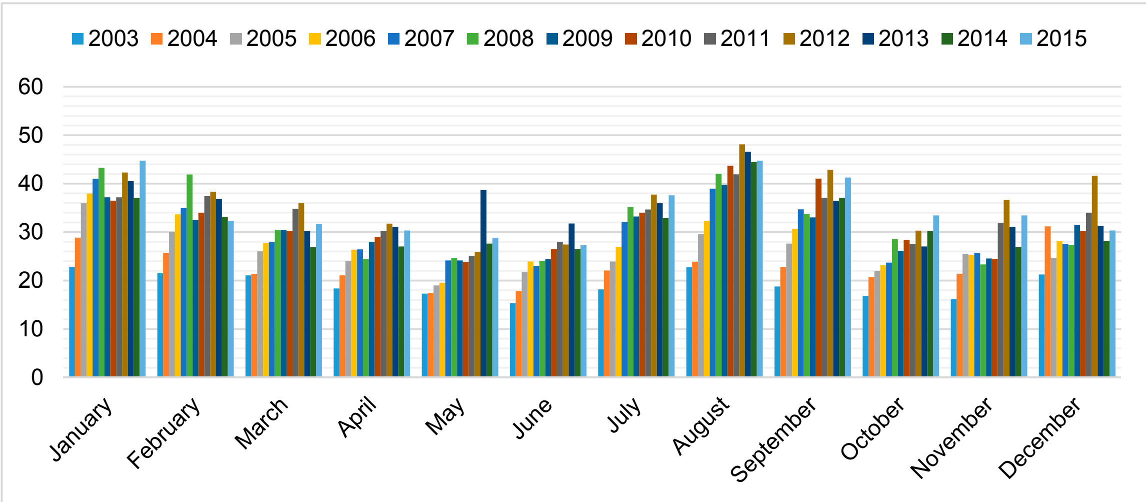

Figure 5. The energy consumption of residential buildings between 2003 and 2015.

The need for convergence between the predicted and the actual energy consumption, in a high energy performance building, is an essential factor in the design and construction process. For this reason, the recast of the direction on the energy performance of buildings 2010/31 requires the adoption of an action plan for the significant decrease of the energy consumption of buildings by 2020 [19]. However, the T.R.N.C is an isolated country internationally, for political and historical reasons, and its exclusion from European directives has meant that the action plan has not been implemented by governmental bodies.

In a similar way, the Republic of Cyprus has already implemented energy efficiency requirements and issued energy certificates for their own construction industry under the European Union objectives. It has also started paying more attention to the monitoring of the housing stock and promoting energy saving strategies to the occupants. This process is intended to match the standards demanded by other European states and is, at the same time, a recognition of the absolute need to improve their housing conditions. Apart from the issues concerning the energy use of buildings within the implementation bodies, are the European Union objectives being introduced to highlight the significance of control mechanisms in the area of the housing sector and the importance of prioritising areas on the outskirts of urban areas and suburban areas in transition and areas of environmental importance.

Some current and previous research has been conducted on energy efficiency and other forms of energy saving in housing. A considerable amount of literature has been published on energy-saving measures and strategies and their adaptability to individual dwellings (e.g., solar panels, types of insulation, and high-efficiency boilers), apartment blocks (e.g., heating and cooling demand) or neighbourhoods (e.g., district heating). What we know about energy consumption reduction is largely based upon empirical studies that investigate how government or institutions pay attention to implementing energy-efficiency regulations, including taxes and subsidies. Additionally, several studies have documented that there is a lack of control mechanisms between energy regulations and implementation process [20–26]. Recently, researchers have shown an increased interest in assessing tools for sustainability or, conversely, the environmental impact of buildings such as employing "life cycle assessment" principles [27–29]. However, the issue of embedding of energy efficiency has received considerable critical attention in the management of private institutions, organisations or privately owned construction companies.

The improvement of quality of the building components of the existing housing stock has been a matter of concern in housing energy management and improving energy efficiency in the T.R.N.C. Although the energy performance of existing building stock has not been recognised as a research subject in this context, the importance of implementing energy efficiency regulations and installation of energy-efficient technologies has considerably increased in the last decade in EU member states. It is also worth mentioning that energy efficiency in the built environment is now a frequently debated subject, particularly in Europe and in the UK, explored in many scholarly and professional publications. However, a lack of research has been conducted in terms of understanding energy performance of existing buildings and thermal comfort level conditions of occupants' in the residential buildings in the T.R.N.C.

4.2. Policy Initiatives for Reducing Energy Use in the Residential Sector

For EU and its member states, energy has become a significant issue. It has assumed a priority status in terms of its urgency as a problem and the action plans reflect and highlight its importance. The emergency plans now in place are directed to entire communities and reveal the importance of energy conservation. In responding to this challenge for energy conservation, one feature of the various schemes is an examination of on-going consumer trends and their effects on climate change. The problem with energy is that there is a progressive and inexorable rise in the cost of energy and an increasing demand on fossil fuel use. These two key indicators have led to a turning point for the importance of energy reduction, as well as the current legislative constrains on energy efficiency has been presented in Figure 4 (Phase I & II).

Couched within this emerging energy debate in the EU and its member states, the EU Framework Programme for Research and Innovation 2014–2020 includes in its action plan the need to legislate the policy priorities of the Europe 2020 strategy. This plan incorporates long-term aims for addressing the major concerns of energy demand shared by citizens in Europe and elsewhere. This strategy plan consists of different research areas related to the energy issue in the built environment. It is essential to determine that the objectives focus on social challenges such as: secure, clean and efficient energy; climate action, environment, resource efficiency, raw materials-secure, clean and efficient energy; and fighting and adapting to climate change [30].

The Directive 2012/27/EU indicates that the increasing level of dependence on energy imports and scarce energy resources brought into the EU and its member states sets unprecedented challenges for considering energy reduction. The climate change impact is also altered too. It has to be said that implementation of energy efficient technologies is an effective solution for addressing these challenges. Inevitably, the target plans assume to improve the EU's energy security in terms of reducing primary energy consumption and decreasing energy imports. Incidentally, implementation of energy-efficient technologies helps to reduce carbon dioxide emissions in a cost effective way. At the same time, these innovative technologies aim to mitigate climate change impact [30].

The current policy on energy-efficiency in Europe was adopted by the European Commission in March 2011. The Energy Efficiency Plan 2011 claims that the EU and its member states are responsible for operating a roadmap that will lead to an effective low carbon economy by 2050 [31]. For as this assessment indicates, the majority of action plans are undertaken for implementing energy-efficiency programmes across wide sectors of the economy but with particular emphasis on the residential sector. By considering carbon dioxide emissions, it is also noticeable that the Energy Efficiency Plan 2011 reports that the housing sector is estimated to be responsible for 41% of the total energy consumption in the EU [31]. It is also well understood that it is one of the most complex and articulated sectors to bring control mechanisms for implementing the energy-efficient technologies.

In particular, the T.R.N.C., because it is a small and isolated system as an island, depends primarily on imports to address its energy demands. The Republic of Cyprus energy system is isolated, resulting in significant barriers for the upgrade of the system and this creates high energy costs [32]. Furthermore, the Republic of Cyprus does not have any legislation and regulations concerning the energy performance of buildings; the energy saving potential was considerably high until becoming an EU member.

In this context, the research explores why the European Union Energy Performance Directive has assumed great importance and has become a very influential objective in our concern for the conservation of energy use in buildings since 2002. It is the first document to set the agenda for improving housing stock within the EU states and its purpose is to identify control mechanisms for the housing industry. To be able to set the agenda, there is a great deal of interest in retrofitting projects. It can be seen that it starts in the design-thinking process, through the construction phases, the redevelopment of buildings or regeneration of existing mass housing estate development regions within the association of concerning occupant's thermal comfort, to reduce energy consumption of buildings. Despite years of spuriously undertaken scientific research about conserving energy and the implementation of energy saving methods in the housing sector, the retrofit strategies have been on the board for at least a decade.

4.3. Energy Efficiency Programmes

Governing principles and implementation procedures that are useful in this context have arisen (Figure 6). Indeed, to achieve a reduction in energy consumption and an implementation of energy efficient technologies, on-going research in the field is needed [33]. According to above stated matters, this study uses the reveal of the energy demand in existing legislation from ELIH-Med (Energy Efficiency of Low Income Housing in the Mediterranean) and Era-co-build (European co-operative organisation) survey data, conducted in 2012 by the EU, which is the most recent data set available at the time of undertaking the research for this study. The definition of low zero carbon of several type of dwellings in Cyprus has been constituted by data collected from two on-going projects, "The Financing Mechanisms on Energy Efficiency of Low-Income Housing in Mediterranean Areas" (ELIH-Med) and "Countdown to Low Carbon Homes, ERACOBUILD" [34]. These projects are the first to be undertaken in Cyprus. The analysis has revealed some remarkable data concerning the low carbon emissions of selected pilot residential buildings in Cyprus. The ELIH-Med project aims to identify and implement innovative technical solutions to improve energy efficiency in low income housing in Cyprus. At the same time, the Era-co-build is aimed to create a larger market for systematic retrofitting schemes of residential buildings and investigated ways to motivate house owners, contractors and stakeholders to do an integral holistic retrofit. In general, the motivation and reasons for retrofitting of the existing housing stock are related to comfort improvement, quality of living and the necessity of optimising indoor thermal comfort conditions and improvements, and is also about energy saving targets. The results of ELIH-Med and Era-co-build data have been used to understand the changes in energy performance within the sector over the past decade [34]. Therefore, using the low-income housing retrofits to investigate the aims of this research was the most reasonable option at the starting point of this work.

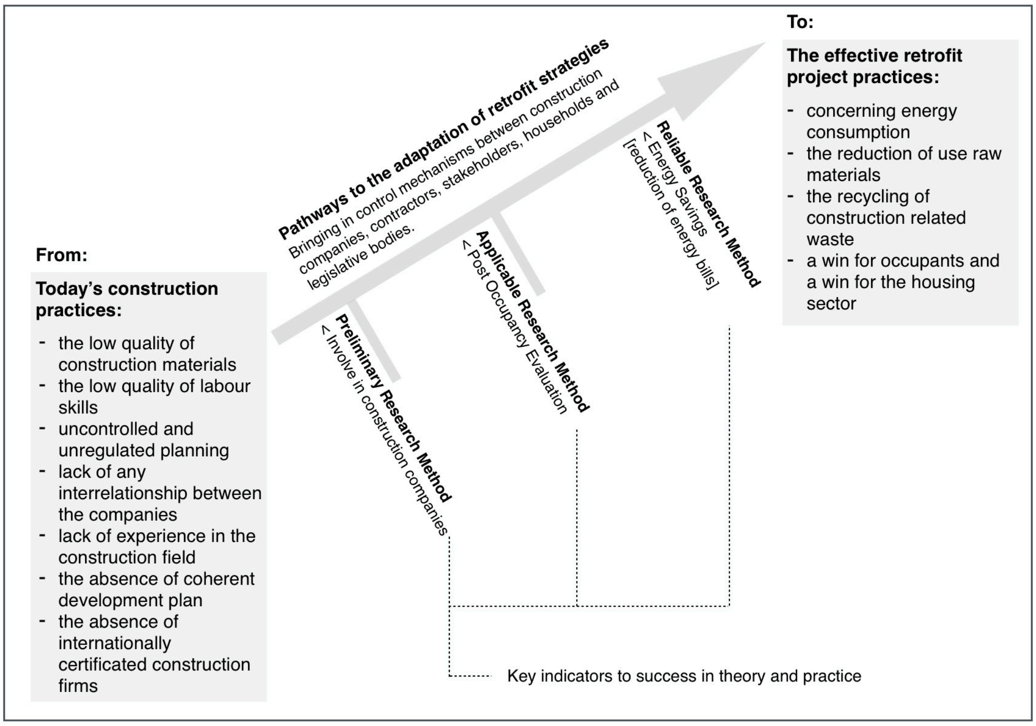

Figure 6. Model approach to the retrofit strategies.

Previous survey data for energy use patterns in the residential sector were focused primarily on individual technologies and did not consider occupant's thermal comfort and effective energy savings. However, this study exploits existing housing stock data for the T.R.N.C. to gain an insight into the key parameters related to energy use for applying energy efficient technologies. Traditionally, in the disciplines of architecture and building engineering, energy demand is addressed through individual building modelling based on the physical parameters of building form, fabric and systems. Simplistic and generalised assumptions are made about occupant's thermal comfort in terms of understanding occupant's energy use patterns and internal gains [35]. On the other hand, it is clear that counting carbon dioxide emissions of low-income housing through a conducted survey of ELIH-Med and Era-co-build addresses to what extent building energy performance, often assumed to relate primarily to physical building characteristics, is determined by interactions between occupant's thermal comfort and energy efficiency systems, as well as building and climate characteristics.

5. Method and Data

5.1. A Case Study Model: Northern Cyprus

The territory is characterised by a fragmented endlessly repetitive stream of self-built residential areas and privately-owned construction company built mass housing estates with no recognisable distinctions between city centres. Compared with other densely built Mediterranean cities, Northern Cyprus is dominated by large scale residential developments, not only in the coastal regions but also its mountainous regions, including urban agglomerations. At the same time, almost half (45%) of the owner-occupied building stock comprises self-built houses, often detached. The rest are low-rise flats (13%) or high-rise flats (44%) [35]. It is also noted that most urban agglomerations consist of a mix of housing types such as single and multi-family mix, single or multi-family and apartment block mix or apartment block and high-rise mix. Large scale residential tower blocks and mass housing estate developments, developed and regulated by privately owned construction companies. Such projects are often the size of whole city districts but are rarely geared towards the concept of a socially and functionally diverse and structurally open city.

Current problems are aggravated when considering the implementation of energy-efficient technologies that better suit occupant's thermal comfort needs are required, that is, mass housing estate developments. It is obviously seen that the supplied building stock could not match the energy efficiency implications and current tools to bring a linkage between existing construction practice and the power of adoption of energy design strategies for retrofitting existing mass housing estates in Northern Cyprus.

5.2. Rationale for Selecting Case Study Mass Housing Estate Developments

In response to research objective, and the need for a comprehensive, up-to-date analysis of case study buildings energy use, a "top-down" existing building stock analysis was applied. At the same time, a primary database was developed of annual energy use and associated building parameters for identification of energy use in three different construction eras in the 1970s, 1990s and 2010s in the residential sector. The research database was based on data collected under the Display Energy Certificate (DEC) scheme. A secondary research database was formed as a sub-set of revealing the monitoring results of 16 pilot-study buildings from the ELIH-Med (retrofitting of existing low-income buildings) research project in Cyprus. Statistical analysis was carried out to assess the impact of specific building parameters as energy determinants for both databases. To generalise findings and creating a representative sampling for the context, in accordance with research aim and objectives, an "archetype-based" method was taken. Archetype of three distinct construction periods (1970s, 1990s and 2010s) and quality of existing building stock were defined using data in the primary and secondary databases. Archetypes were based on three principal activity groups (demographic structure of households, building geometry and orientation) and two other forms of primary environmental strategy (heating and cooling demand) giving in three different retrofitting scenarios in total. These three concepts consider the housing stock in terms of characteristics, quality and developments. Distributions of results were obtained for each retrofitting options by analysing occupant's awareness in energy use and two principal forms relating to buildings' geographical location and climatic condition of the study area.

5.3. Research Design Model

This research consists of interdisciplinary collaboration in the area where single disciplinary studies often takes place. In that sense, there is communication and collaboration between research, design, and the implementation of policies and objectives for the construction industry. This research utilises a combination of qualitative research methods (ethnographic case study): on-site observations, semi-structured interviews and focus group discussions are all contained within this underlying approach.

Before undertaking these ethnographic studies, observations were carried out to include photographic documentation of housing estates, drawings, and maps of cities and housing estates. These observations are based on the collection of data relating to the selected case study mass housing developments in the field. After the collection of the necessary data through on-site observations, the study focuses on a case study approach to carry out analysis on the most problematic buildings in four different climatic regions of the research context. The researcher applied ethnographic studies as follows:

(1) Semi-structured interviews with construction company owners to understand the current condition of the construction industry and to understand the nature and benefits of implementing energy efficient technologies.
(2) Semi-structured interviews with house owners to understand their willingness to participate in implementing retrofit strategies in their homes.

(3) Focus group discussions with house owners to investigate why house owners intend to be involved in the refurbishment activity of the recently built mass housing estates.

These methodologies were set out to address the issues of the housing sector. Although these research methods were tested in the T.R.N.C., it was designed to be applicable in the Republic of Cyprus with similar energy saving targets. In addition, the research hypothesis is that energy saving actions such as adoption of retrofit strategies could contribute to the reduction of the negative environmental impacts of the uncontrolled construction and refurbishment activities. This was mostly tested on mass housing estates, which were recently built, mainly by private construction companies.

This research includes some case studies, which consider different aspects of the housing estates such as location, characteristics, demographic structure of households and also information on the construction companies. The housing estates were chosen from 16 different projects in four different regions (coastal, inland, semi-mountainous and mountainous climatic zones) including urban and sub-urban areas, thus have a good representation of the common drivers in the property market with different levels of required refurbishment activity and different samplings from different climatic regions. It is further emphasised that the documentation of the field data has come from the identification of construction companies' projects, their policies, their targets and the problems they encountered in both the design and building process. This goes some way in providing information on the current condition of the industry in a particular centre or region.

During the research process, the researcher contacted 15 construction companies (Table 2). The research aim and targets were presented to get permission from these companies to examine their housing estate projects. For this purpose, 15 small and medium size architectural companies were identified in terms of their willingness to participate in the research process. These companies were key players, which have responded to the growing demand in the property market. Their structures and target groups showed variations within the location of the construction company and its projects. Before starting to conduct semi-structured interviews with households, a questionnaire-based survey on "Refurbishment Activity and Energy Consumption Patterns" was prepared.

This was partly to hear their views on how the retrofit strategies impacted on their own cultural assessment, but also to collect concrete examples of retrofitting experiences, which could be (anonymously) related to policy actors (institutions) to hear their responses. These data collection methods were to look at selected housing estate projects in terms of understanding typical energy consumption values and the effect of refurbishment activities. This method was also utilised in examining how occupants can play a key role during the implementation of the retrofit strategies. These interviews were intended to utilize information for each occupant's demographic structure needs and intentions in its involvement of any aspect of the refurbishment process.

Table 2. List of the interviewed construction companies.

No.	Company Name	Active Year	Location of Its Projects	Scale	Profile of the Company	Implementing of the Energy-Efficient Technologies	Target Group
1	Company A	1973	Famagusta-Iskele	Medium	Architecture firm in house expertise—holiday lets and commercial units	Low	Upper-middle income/middle income
2	Company B	1996	Famagusta	Medium	Architecture firm in house expertise	Non-used	High income/upper middle income
3	Company C	1989	Famagusta-Iskele	Medium	Architecture firm in house expertise—holiday lets and commercial units	Non-used	High income/upper middle income/middle income
4	Company D	1988	Famagusta-Iskele-Nicosia-Kyrenia	Medium	Architecture firm in house expertise	Non-used	High income/upper middle income
5	Company E	1984	Famagusta-Nicosia-Kyrenia	Medium	Architecture firm in house expertise and city planning	Strong	High income
6	Company F	1997	Famagusta-Iskele	Small	Architecture firm in house expertise and holiday lets	Non-used	Upper-middle income/middle income
7	Company G	1988	Kyrenia	Small	Architecture firm in house expertise	Non-used	Upper-middle income/middle income
8	Company H	1995	Famagusta-Kyrenia	Small	Architecture firm in house expertise	Non-used	High income/upper middle income
9	Company J	1991	Kyrenia	Medium	Architecture firm in house expertise	Non-used	High income/upper middle income
10	Company K [funded by Turkey]	1984	Famagusta-Nicosia-Kyrenia	Medium	Architecture firm in house expertise—commercial units—urban planning	Non-used	Middle income/low income
11	Company L	1980	Famagusta	Small	Architecture firm in house expertise and commercial units	Non-used	Middle income
12	Company M	2003	Famagusta-Nicosia-Kyrenia	Small	Architecture firm in house expertise-commercial units and infrastructure	Non-used	Upper-middle income/middle income
13	Company N	2003	Famagusta-Iskele	Small	Architecture firm in house expertise—holiday lets and commercial units	Non-used	High income/upper middle income/middle income
14	Company P	1995	Kyrenia	Medium	Architecture firm in house expertise and tourism developments	Non-used	High income
15	Company R	2003	Nicosia	Small	Architecture firm in house expertise	Non-used	High income/upper middle income

The people who were interviewed in order to participate in this study are all residents of single- or multi-family owner occupied housing units. The participants were people who do not identify themselves as vulnerable. Each was given a questionnaire to complete and was also interviewed by the researcher. Furthermore, the economic, physical, social and cultural environment in which the study was guided was observed. This approach combines regular site visits to the same households for two seasons (summer and winter) for a report on the environmental impact of the built environment over a period of one year in different climatic locations. The researcher contacted households in different project sites to get permission to re-undertake the questionnaire survey in the following research period. The interview guide was therefore pilot-tested. The objective of this methodology is to calibrate the policies of implementing the adaptation of retrofit strategies to illustrate a trend of refurbishment activity in the recently built mass housing estates. This method was used as background information for this study to fill a research gap and contribute to knowledge on implementing an adaptation of retrofit strategies.

The qualitative analysis software of NVivo (QSR International: Melbourne, Australia) was used to analyse the fieldwork data. The analysis was guided by a preliminary thematic analysis of the key concepts prompted on the interviews. The first three concepts consider the housing stock in terms of characteristics, quality and developments. The other three concepts deal with current polices and action plans to introduce control mechanisms for retrofitting projects. It should also be noted that the semi-structured interviews and focus group discussions were conducted with households only on certain selected buildings and so the findings of the study apply to the narrow field under investigation and was not broadened to include some form of generalised opinion.

Another contribution to the field is the general evaluation carried out on understanding energy consumption of recently built housing estates in the T.R.N.C. As this study shows, there is very little research available or undertaken in the academic world that targets "retrofit strategies". This research concept finally led to assessing and generating new pathways of research and innovative design tools in the management of the mass housing renewal and urban development but at the same time involving the notion of a socio-cultural paradox. The aspect of this research is to understand how it is best possible to integrate the application of energy efficiency technologies to the adaptability of the prototype retrofit scenario. It included cross-cultural studies as a research concept to investigate the pattern interpretation of energy consumption use and retrofitting.

5.4. Undertaken Approach for Conducting on Questionnaire Survey

To ensure systematic analysis of the key aim and objectives of the research, the methodology adopted particularly for the mass housing estate developments is hereby explained. The design chosen for this research is a "Before-and-after design", which, as the name implies, is a set of semi-structured interviews with house owners and privately-owned construction companies taken from a group of respondents, who are then subjected to an experimental variable before being undertaken again. In this case, a two-phased questionnaire survey is conducted (phase A and phase B) where phase A is used as a control group. The experimental variable is the articulated refurbishment work done by respondents. The sample of respondents are not the same; however, they are matched samples in that they both are within four climatic regions in the T.R.N.C., are mass housing estate development projects, have been regulated privately owned construction companies, comprise similar sized, solid walled system without any insulation material implementation and energy-inefficient houses, and all are common representative residential building typology for the undertaken research context. The socio-demographic analysis undertaken later in the survey analysis ensures significantly comparable samples of respondents in both phases.

An analytical survey was administrated to identify how households of selected mass housing estate buildings identified to be energy-inefficient react to and perceive the challenges of implementation of energy efficiency building systems. The survey was also conducted to develop an understanding of house-owners' behaviour during the un-regulated refurbishment process.

The questionnaire-based survey therefore investigates occupants' and privately-owned construction companies' experience during the energy upgrade works are done by means of a two-phased survey questionnaire (A and B).

According to the State Planning Organisation, Economic and Social Indicators statistics (2015), The Follow up and Coordination Department in the T.R.N.C. comprises 3246 households, of which 1200 private and social houses were eligible for the sampling criteria [36]. The sample fraction initially aimed for was 10% of the total selected households; however, 70 households were successfully recruited for the study, constituting 4% of the total, which is still relatively reasonable fraction. The researcher decided to use a stratified sampling approach to select households from the State Planning Organisation statistical index of representative mass housing estate development projects eligible for the study. The questionnaire includes ethnographic background information about the respondents and the household, a set of questions about environmental attitudes and values, and questions about behaviour related to the building. More specifically, some questions are based upon the amount of energy advice and information provided to households for understanding energy conservation measures. A few questions were prepared, including:

- Have you made any changes since your house/apartment you bought it? If "Yes", what sort of changes did you make?
- At this stage would you consider ways of reducing energy consumption?
- Do you know anything about energy saving methods?
- What do you think would be the benefits of using energy-efficient technologies?
- Do you know anything about the energy efficiency objectives of the European Union?
- Do you know how implementing effective retrofit strategies can reduce annual energy bills?

6. Analysis and Results

The study found that refurbishment activities are identified according to the degree to which the building systems used by occupants with reference to three main indicators are interrelated: the age of the building, the construction material and its energy demand. Through these variations, it is possible to define a decay representing all major classes of buildings in the residential sector and to utilise obsolescence as an indicator in an analysis of the buildings [36]. This is one of the main reasons why different building typologies are widely investigated and considered strategic in the selected mass housing estates. For these reasons, an expected analysis is co-related to both these parameters concerning the construction material and its system, the obsolescent part of the building systems, the energy efficient requirements and the interventions that come into play over time.

In Figure 7, it can be seen that more than half the sample has already replaced their building systems, while 42% install energy efficient lightings. This may be due to the high numbers of electricity suppliers that provide energy efficient light bulbs and economically inactive respondents who might spend most of their time at home, thus consuming more energy than households with employed members.

Another important fact is the role of the house owners' requirements in the design process and how these may impact the construction process. Therefore, the great challenge is to create collaborative mechanisms whereby both the construction companies and the house owners may contribute and coordinate efforts in solving the energy problem. To reach this goal, the demographic structure of occupants and their behaviour is required. Each single household has to be convinced and assured of the reasonableness and the economic advantages that will accrue from investing in the improvement of building systems concerning energy efficiency in and on their property. Thus, to obtain reliable and effective results in terms of energy efficient improvements, it is important that the interventions are articulated by occupants in the housing sector, as they represent now the common problems of the new-built housing stock. In this research context, the selected mass housing estate development projects are composed of heterogeneous buildings with different typologies and dimensions, and consequently with different built purposes applied.

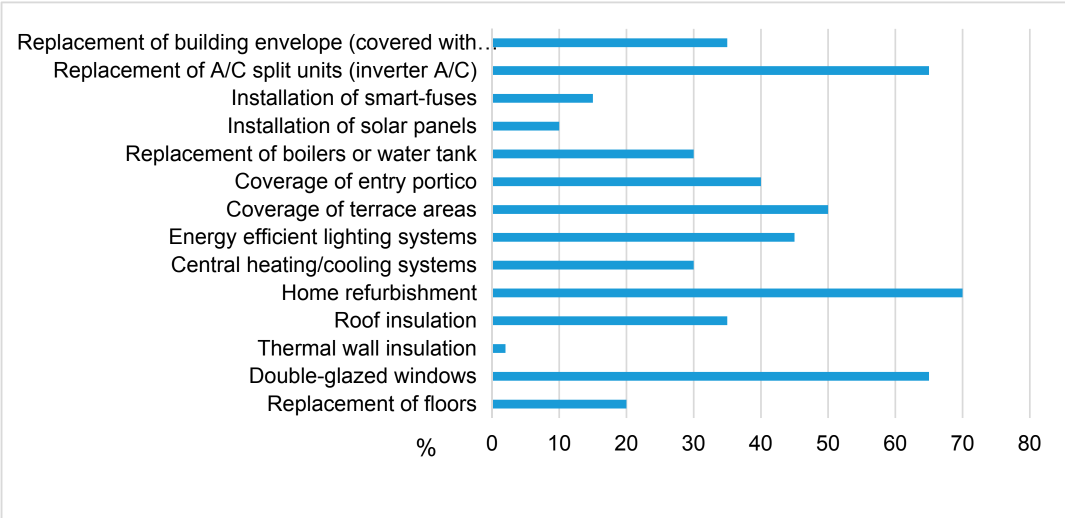

Figure 7. Refurbishment activity patterns.

Today, primary needs have evolved according to the demographic structure of the occupants and their lifestyles, financial capacities and several different occupants' profiles are identified naturally. These householder profiles differ according to which housing estate project is under discussion and what the construction companies' targets were during the design process. However, it should also be remembered that house owners are now much more willing to improve the physical conditions of their dwellings than they were in the past and the trend for refurbishment continues. Consequently, profiling occupants and their behaviour is a much more complex activity when it also considers the refurbishment habits of the occupants. Construction systems and materials are common nominators in the selected buildings and are strictly connected with the choice of construction companies' progress at the time. Therefore, the materiality of buildings is a significant indicator not only of its level of physical obsolescence, but also the rapid construction demand linked to implement poorly built materials at that time.

Several differences occur among apartments, terraced houses, semi-detached and detached buildings due to typology, built-form, distribution and construction systems. The common factor is generally that the housing stock after the great expectations raised by the Annan Plan was not designed to meet today's energy efficient standards especially concerning the control of indoor comfort conditions (heating and cooling demand), and the thermal losses due to poorly-built construction material choices. This means that offering adaptation of retrofit packages for improving energy efficiency in the housing sector would not only bring a relevant reduction in energy consumption in the selected housing estates, but also that households can be strongly involved in reducing their energy costs.

In response to questions concerned with occupants' energy awareness and behaviour in energy use, 60% are aware of challenges of installation of energy efficiency building systems as can be seen in Figure 8. This may be due to the consistent information campaigns communicated via media sources about energy conservation and recycling. The State Planning Organisation statistics in 2015 reported that energy awareness and recycling rates for households have risen approximately 40% in the T.R.N.C. from the previous year rate [36].

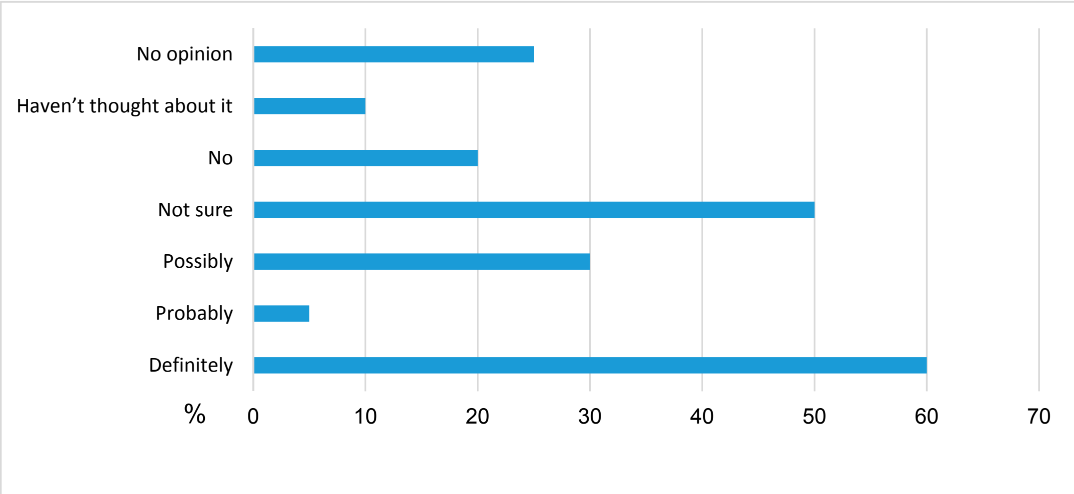

Figure 8. Energy conservation awareness.

In addition, the study also revealed that changes of building components, as articulated by occupants, are on the rise. Even though some buildings have undergone major renovation, the addition of more spaces and the covering of terrace areas account for a high percentage of the renovation activity. Hence, the quality profile of this new-built housing stock changes gradually and only the construction process and renovations differ substantially from the housing stock.

Subsequently, it is quite hard to have a reliable forecast of the renovation trends without having a control mechanism and adaptation packages developed through an investigation of the selected buildings. At this stage, the preliminary findings show that identification of the diagnosis in selected buildings can be useful for understanding what main changes occupants are expecting in the residential sector, and for further investigating their requirements from the construction companies and their involvement in the decision-making process.

Moreover, the study found that the occupant's refurbishment trends affect not only the energy performance of buildings but also increases carbon dioxide emissions in the environment. It is also worth commenting that the impact of the construction activity has produced further problems in the residential sector and this contributes to making an investigation of the potential adaptation packages much more complex. To compensate for this, a useful starting point could be identified as the diagnosis of buildings in the selected mass housing estates. What seems to be clear is that the physical quality of the buildings, the demographic structure of households and the quality of refurbishment activity are perceived as inappropriate in meeting the emerging demand of the residential sector.

7. Discussion

In this case study approach, 70 buildings are analysed, 70 semi-structure interviews with house-owners are conducted, and five retrofitting strategies are considered (Table 3), in accordance with the contribution they make to reducing energy demand.

In these selected housing estates, three main requirements have been associated with refurbishment trends. The first one deals with the covering of terrace spaces in the detached and semi-detached buildings and balconies in the apartments and terraced houses and adding more room spaces as a whole (which is strictly related to the demographic structure of the occupants) to obtain two different kinds of result. First, adaptable spaces allow for the extension of the living room, dining area and entry lobby of the buildings according to changes in the lifestyles of occupants. Second, it allows some spaces to be widened and given a more specialised function, such as ample living spaces for a family or a room. This could be achieved by extending the spatial layout of the existing building. These kinds of interventions are generally integrated to the on-going changes of users' profiles and to the trends of refurbishment activities and do not belong to concerns about reducing energy consumption demand but rather to the idea of improving the quality of living conditions.

Table 3. Structure of the step-by-step applicable "retrofit strategies".

STEPS	RETROFIT STRATEGIES
S1	Replacement of existing windows
S1B	Integration of replacement of existing equipment, heating/cooling system
S1C	Integration of PV and solar collectors on the roof
S2	Building envelope implementation of roof and partially of facades to avoid thermal bridges
S3	Total building envelope implementation
S4 (S1 + S2)	Replacement of existing windows, total building envelope implementation (optional integration or replacement of existing equipment, heating/cooling system)
S4B	Integration of PV and solar collectors on the roof/facades
S5	Volumetric additions, partial replacement of existing windows, partial building envelope implementation (optional integration or replacement of existing equipment, heating/cooling system)
S5	Integration of PV and solar collectors on the roof/facades

The second refurbishment activity involves a general improvement of the dwelling and also of the building as a whole in terms of the replacement of kitchen units or bathrooms, roof insulation, installation of double-glazing windows and addition of shading panels (pergolas) directly to the outside of the building. Most of these activities are an expression of trends of informed high-quality interventions. Therefore, the problem is related to understanding the benefits of "energy-efficiency" during the refurbishment process to meet the requirements of building standards. In most cases, the refurbishment activity is perceived by the occupants as not only improving the quality of living conditions but also a real opportunity to reduce energy consumption in the residential sector. The third refurbishment activity deals with access to fresh water supply, the recycling of rain water and grey water and the connection to the grid which varies depending on the location of each housing estates. Nevertheless, these activities to improve the infrastructure of the buildings may have relevant effect in terms of the utilisation level of the mass housing estates. At the same time, many buildings are being fitted with solar panels.

In Figure 9, with regards to "reasons for taking any of the retrofitting scenarios into an action", saving money came first as a matter of concern where the majority of both samples reported this to be the main reason, along with one or more other reasons such as saving energy, due to habit, and environmental concern. Around a quarter of the samples took these actions only to save money as the one of the main reason, followed by to save energy and due to environmental concern, while around a fifth take these actions out of habit. Considering the f first concern for most households in this study is to save money, it suggests that financial incentives could possibly be effective in encouraging policy uptake and delivery in this particular region.

Energy retrofit for recently-built housing stock: The way forward foreseen here is to put in place effective implementation scenario(s) which are decided upon after the buildings have been undergone a systematic retrofit. These strategies aim to reduce energy consumption for the heating and cooling demand of buildings, as well as improving the indoor comfort conditions of buildings by encouraging the benefits of using energy efficiency technologies in maintenance interventions and reducing the up-front costs of the existing condition of building systems before going under refurbishment. From this study, it was found that the design of retrofitting strategies, while allowing higher residual thermal loads from individually refurbished buildings compared to a standard renovation, reaches 91%, 92% and 87% lower primary energy balance than the existing residential building stock [37].

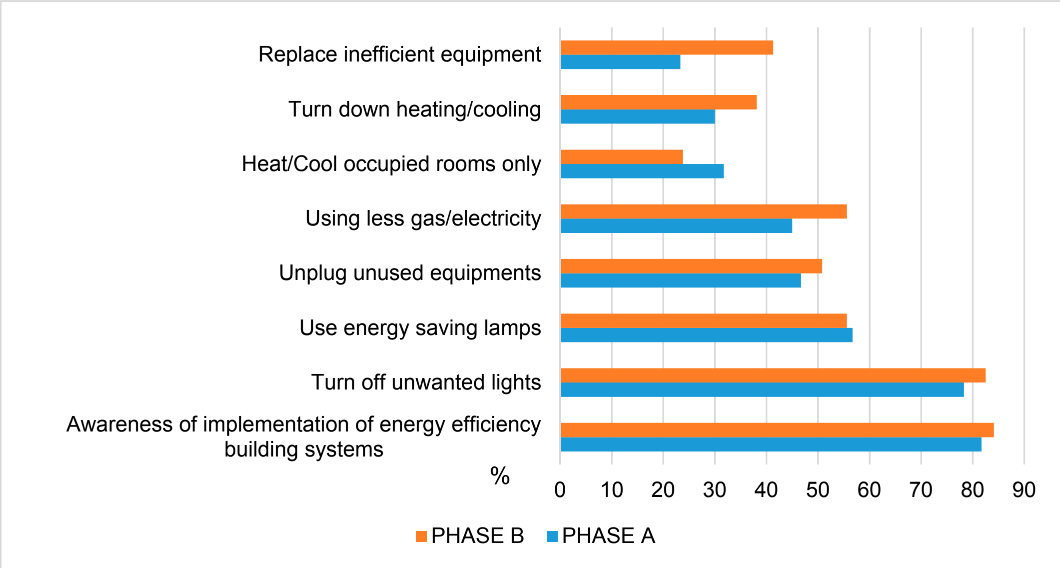

Figure 9. Behaviour patterns in phases A and B.

There is an increase in demand on the property market for energy efficient designed buildings focusing on energy consumption patterns of households with regard to environmental impact as a result of poorly built construction materials and climate change impact. Therefore, a concern for the life-cycle performance of buildings is a central purpose in any refurbishment activity. An analysis of the life cycle of buildings is a pivotal factor in any measurement of performance when assessing the impact on the environment from buildings of any kind. This approach is more feasible to implement, because of the energy efficient alternative when the construction systems have reached the end of its life length and need refurbishment either way, or to advance measures that were not yet due, in order to improve energy efficiency [38].

Under this rendering of the implementation of energy-efficiency technologies lies a further level of case study analysis. This focuses attention on the diagnosis, action and intervention of construction companies, house owners, building contractors, stakeholders, architects and designers in the T.R.N.C. as well as those interested in furthering the promotion of effective retrofitting scenarios with a view to reducing the energy consumption of buildings. By considering the residential sector, the importance of the financial viability of such privately owned construction companies cannot be underestimated. For a large-scale construction company to have an impact, it must be successful and financially viable [39].

It has also to be said that the most common refurbishment activity is the addition of new volumes adjacent to the existing building or open terrace areas on both the ground and first floors. These often unintentionally lead to increase in energy consumption of the buildings. Consequently, the changes on the current market conditions after the Annan Plan lead to the residential sector to becoming aware of the necessary EU objectives in the design process as regards to energy efficiency and also in defining the construction process and its impacts on the built environment.

Therefore, based on the arguments discussed above, it is important to incorporate in the design a process outline of "energy-efficiency", such as retrofitting strategies so that it will have a high market appeal and therefore should be incorporated into the construction phase so that the annual consumption of energy can be reduced as much as possible. It should respond to growing demand of construction activity. For this reason and in the process of the implementation of retrofitting strategies for reducing the energy consumption of buildings, it is apparent that the role of government initiatives, the framework policies of construction companies and house owners should be examined as a way of finding practical routes to implement "retrofit strategies" and purpose design recommendations for the housing sector in the future (Figure 10).

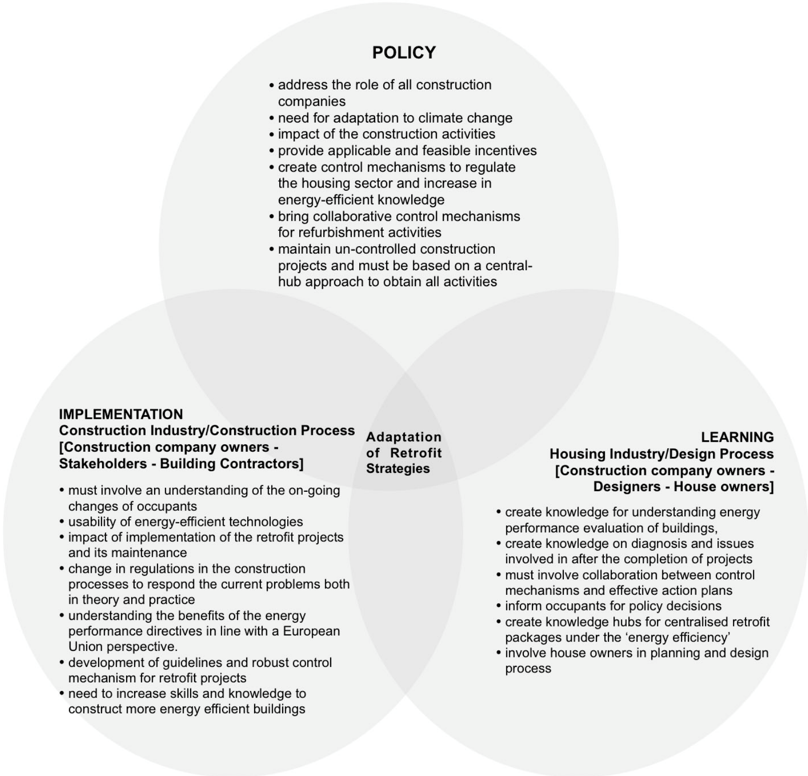

Figure 10. The hypothesised relationship between policy, implementation and learning through research process.

8. Conclusions and Recommendations for Future Research

8.1. Conclusions

From the findings of the study, it can be concluded that the original contribution of this research lies in adoption of the retrofit strategies that systematically integrates energy efficiency standards in order to improve conditions within the residential sector under the combined influence of three variables, namely the construction activities, occupants' behaviour and the energy consumption of buildings. Nevertheless, the majority of households (54%) indicate that they would use energy efficient technologies for their home refurbishment to upgrade energy performance. At the same time, 40% of the households would not implement cost-effective energy efficiency building systems and 6% was not aware of challenges through "systematic" retrofitting. In summary, this study and investigation process analyses the pattern interpretation of the occupants' behaviour and their cultural assessment embedded energy performance of buildings during the implementation of retrofit strategies. In this context, no existing research was identified applying energy efficiency standards of retrofitting to any types of buildings, whether recently built mass housing estate projects or otherwise.

The results of the research contributed to facilitate private construction companies that aim to support retrofit strategies by providing them with new guidelines and policies together with the necessary data about the implementations needed for the improvement of the housing sector in the T.R.N.C. This research does not only enable households to become involved in the process of identifying the applicable retrofit scenarios, but also to improve living conditions and to achieve minimum energy efficiency consumption of buildings. This research has provided the context with the knowledge to realise the main goals: the identification of possible future instruments and incentives that are needed to overcome the weakness in current legislation and thus bring about a more energy efficiency residential building sector.

8.2. Recommendations for Future Research

Retrofitting and upgrading of the existing mass housing estate developments to energy efficiency through testing different retrofitting strategies is of utmost importance but their long-term viability depends on the sustainable, holistic approach where energy related measures are closely linked with functional, construction, and economic demands. The implementation of the preliminary architectural and energy efficiency improvements in the residential buildings would have the additional benefits of increasing the housing space market value and positive social effects, and incentivising house owners' awareness of energy consumption. At the same time, energy efficiency implementations targeted at the selected case study buildings can also improve indoor air and indoor environmental quality, with corresponding to reducing overheating risk assessment of a building. In addition to direct energy consumption reduction, energy use potentialities of retrofitting measures can provide indirect economic benefits to both house owners and privately owned construction companies, particularly in this research context.

Introducing subsidies/implications improves the feasibility of undertaken energy conscious retrofitting strategies, but they become sustainable on their own aspects and design parameters. Undertaken energy performance analysis of prototype models shows clearly that the proposed energy efficient strategies must be feasible. Obtained results must be valid and reliable justification of the significance of the proposed redevelopment project in an institutional level to bring significant potentialities for energy savings. To conclude, optimising energy efficient retrofitting measures for mass and large scale residential developments are of crucial importance, thus the existing housing stock can be treated in a systematic manner to achieve similar energy saving potentials.

Author Contributions: Bertug Ozarisoy and Hasim Altan conceived and designed the concept and outline for the paper; Bertug Ozarisoy conducted the interviews and wrote the paper; and Hasim Altan supervised, and provided sources, comments, and major edits to the paper.

Conflicts of Interest: The authors declare no conflict of interest.

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