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Retrofit Strategies for the Existing Residential Tower Blocks in Northern Cyprus

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Abstract: This paper presents a study to investigate the actual building energy use and measures to improve the energy efficiency of residential tower blocks in the Turkish Republic of Northern Cyprus (TRNC). One of the main concerns is that, the TRNC is burdened with the legacy of poorly built housing stock accumulating over the last few decades. There are no strict measures or benchmarks for building energy performance, nor an official roadmap for regulating 'retrofit strategies' to improve energy efficiency. The aim of this study is to develop and test potential retrofit strategies aimed at optimising the energy performance of the existing residential tower blocks in the TRNC. This research adapts a quantitative research design primarily using computer software simulations in a case study approach. To capture the existing energy consumption, physical characteristics of selected case studies are incorporated into the energy simulation analysis. In this case study approach, three prototype residential tower blocks are analysed related to occupants' energy use patterns. To accomplish this, the study first examines three prototypes of typical residential tower blocks built in the 1970's, 1990's and 2010's. The modelling software used is REVIT 2017 with 'Green Building Studio' as a plug-in for energy performance analysis and simulation. This paper reports on the preliminary simulation results that demonstrate that the 73% of the total heat loss from the buildings is due to air infiltration, un-insulated external walls, and windows (resulting in high annual energy demand for cooling), particularly in the south-east facing flats.

Keywords: Energy Efficiency, Energy Performance, Retrofit, Northern Cyprus

Introduction

This research project is undertaken in Famagusta, Turkish Republic of Northern Cyprus (TRNC). Understanding the importance of energy performance of the existing building stock constitutes a thorough cultural and societal challenge. It plays a crucial role in the efforts to reduce the negative environmental impacts of inefficient construction activity. Energy and carbon reductions from the existing building stock take high priority in both, the construction and residential sectors (Salat, 2009). The main objectives for energy saving targets are cost savings and reduction of carbon-dioxide emissions. However, in the TRNC, two critical features of the housing sector are the absence of regulatory bodies to oversee the process of construction and the fact that the majority of housing stock is poorly built by privately owned construction companies (Yapicioglu and Wright, 2014). Hence, without institutional structures within the country to oversee building initiatives, it becomes almost impossible to bring the building sector into European Union standards (Ulucay, 2008). The study aims to investigate the current energy consumption patterns (heating and cooling demand) of three different prototypes of existing residential tower blocks (RTBs) and explore the potential energy saving outcomes of implementing energy efficient technologies in retrofit strategies. The study also intends to propose cost-effective retrofit strategies that would bring about significant energy savings and carbon reductions to the residential sector in TRNC. The main question is: What are the feasible and efficient retrofit strategies for upgrading energy performance of three sample prototypes of RTBs?

In this study, adoption of cost-effective retrofit strategies has extended to take into account and demonstrate how the location of buildings and the type of construction materials become vital components in energy consumption supported with the critical insights of occupants' energy use variation. For this research, initially, three residential tower blocks were investigated and evaluated in terms of their orientation, floor plan designs, building age and materiality. Then, three high potential of deep retrofit strategies were selected and then evaluated in detail via employing energy analysis simulation packages.

Architectural prototypes of three distinct construction periods and technologies of existing RTBs are modelled using REVIT 2017 with a supporting plug-in 'Green Building Studio' energy simulation software package. The main variables focused on as having major impact on heating and cooling demand are: the demographic structure of households, plan organization of the building, and the construction materials. Results are obtained for each retrofitting schemes' feasibility by analyzing in energy use intensity and life cycle energy use. This paper presents and discusses the initial findings of the residential tower block 3 (RTB3) in order to respond to the scope of the research.

Background - Location and Climate

According to the Koppen-Geiger climate classification, Cyprus has climate characteristics that are typical Mediterranean. The Koppen-Geiger climate data shows that the overall climate of Cyprus is a Subtropical (Csa) type climate and partly Semi-Arid (Bsh) type climate in the north-eastern part of the island (Kottek, 2006). That is to say, the climate characteristics of Cyprus are hot and dry during summertime (see Figure 1).

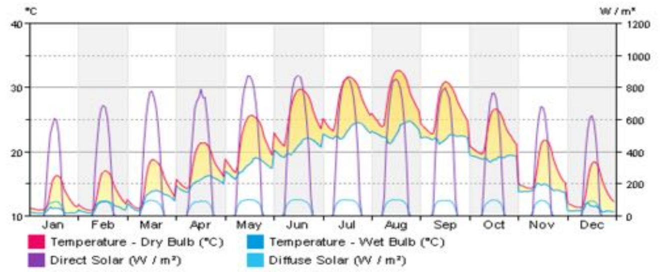


Figure 1: Diurnal weather averages of the research context.
Source: Autodesk - REVIT2017 'Green Building Studio' energy analysis report - weather data, (2017).

The climate of Famagusta, the location of the study, shows mild characteristics of Mediterranean climate (The Cyprus Meteorological Service, 2013). Maximum Dry Bulb Temperature (DBT) may reach up to 42 Celsius in summer, which occurs in August and minimum DBT may drop down to -6 Celsius in winter that happens in January. Mean Minimum DBT changes between 6.8 Celsius and 22.3 Celsius while Mean Maximum (Hadjinicolaou, 2010). DBT varies between 16.3 Celsius and 33.3 Celsius. The prevailing winds come from north-east but the most consistent directions for wind are south-west and west (ibid). Hence, the hot and dry summers and wet moderate winters are the main climate characteristics and have direct impact on the demands of annual heating and cooling demand, due to the requirement for summer cooling as well as winter heating.

Methodology

The study adopts a ‘quantitative’ research design primarily using computer software simulations for future energy performance predictions. The study focuses on a case study approach in order to carry out analysis on three of the most common residential tower blocks prototypes in three different regions of Famagusta; including no man’s land of ‘Varosha’ territory, the ecological land of the city centre, and the urban agglomeration area. This approach helps provide a good representation of the common drivers in the property market with different levels of retrofit strategies and representative samples from three main construction periods of the 1970’s (RTB1), 1990’s (RTB2) and 2010’s (RTB3). These three different RTBs correspond to three different construction phases with respect to type, age, design and materials. The RTBs are chosen from privately owned construction companies specialised in mass housing development projects (mainly owner-occupied dwellings). For the buildings built in three distinct periods, these are described by three new variables defined to include energy consumption patterns of occupants, thermal performance of buildings and thermal comfort level of occupants. The input parameters required for the modelling include the building geometry and properties of the construction materials, specifications of the building components and the outdoor air temperature of the built environment, and occupants’ energy consumption. The periods of construction are determined by building techniques influenced by the building regulations of each phase; the choice of materials for windows, roofs, walls and other building elements. Energy simulations of the thermal performance of the buildings are conducted using meteorological data of a typical year in Famagusta. The building geometry was created for its initial existing state, every floor and apartment with correspondent thermal zones and subdivisions (see Figure 2 a,b,c&d), indicating clearly which zones and spaces are not heated like balconies, and storage areas.

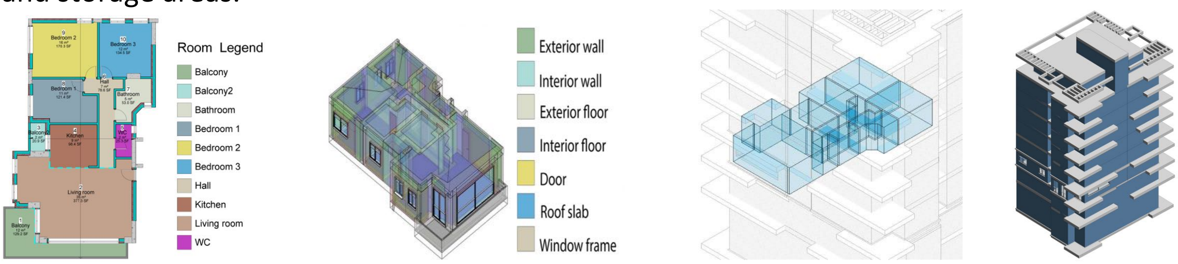


Figure 2 a,b,c&d: Floor plan organisation and the analytical energy simulation model of the tested apartment unit. Source: Autodesk - REVIT2017 ‘Green Building Studio’ energy analysis result, (2017).

Thermal specifications of construction materials are made according to the benchmarks of the British Construction Codes and Practices – Law 1959, which is the most recent data set available at the time of undertaking the research for this study.

Table 1: Thermal transmittance values of the external walls of the RTB3.

cast-in-situ concrete large panel wall	U= 0.8-1.2W/(m2K)
brick wall (without insulation)	U= 1.6-2.0W/(m2K)
autoclaved aerated concrete large block wall	U=0.8-1.2W/(m2K)
aluminium framed single/double glazed windows,(without insulation) with a tow had	U=2.5-3.0w/(m2K)

Source: State Planning Organisation of the TRNC, Building Construction and Parcel Statistics, (2010).

Case Study Building - RTB 3- Alasya Park Apartments - 2010's residential tower blocks

The estate was designed in 2010 and completed in 2013 (see Figure 3 a,b&c). It is fully managed by privately owned construction company and all flats are ultra-modern when constructed, having lifts, central heating and double glazed windows. It comprises 245 flats over seven 13 storey towers. In this case study building, many changes have occurred including measures carried out by households such as enclosures of balconies: adapting a storage/garage on the ground floor for residential use; extension to the penthouse apartments; where householders were not concerned about the thermal impact of increasing the window to wall ratio of their apartments. Approximately 90% of balconies are glazed or covered by different materials for shading purposes and there are too many external units for air-conditioning systems.

Figure 3 a,b&c: The Alasya Park - large scale en-mass housing estate, the modelled and simulated sample residential tower block.
Source: Image a&b - credits: Author, (2015) - Image: Revit 2017 'Green Building Studio', (2017).

Results and analysis: Retrofitting Advantages - Energy Performance of Prototype Building

In this section, the residential tower block prototype RTB3 is modelled according to building geometry, floor plan organisation, construction material and orientation (south-east) of buildings. In that sense there is communication and collaboration between research, design, and the implementation of energy efficiency retrofitting and challenges come through the building energy performance simulation. For the retrofit strategies, the concepts were modified to ASHRAE 90.1-2010 retrofit package. The materials were selected to meet the U-value and other requirements defined in Table 1. By the performed Building Performance Systems (BPS) dynamic simulations/investigation and optimisation of different building envelope structures, it has been demonstrated that it is possible to significantly reduce heating and cooling loads. Table 2 demonstrates the contextual features of prototype building before retrofitting.

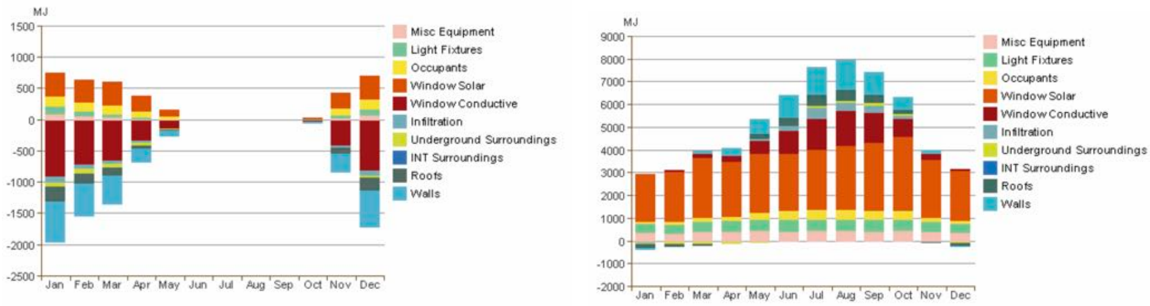
Table 2: The contextual features and simulation benchmarks of prototype building.

Building Performance Factors

Location:	35.1504554748535,33.908374786377
Weather Station:	1253615
Outdoor Temperature:	Max: 35°C/Min: 5°C
Floor Area:	81 m²
Exterior Wall Area:	96 m²
Average Lighting Power:	6.46 W / m²
People:	2 people
Exterior Window Ratio:	0.24
Electrical Cost:	$0.14 / kWh
Fuel Cost:	$0.78 / Therm

Source: Autodesk - REVIT2017 'Green Building Studio' energy analysis result, (2017).

The simulation results of the base case scenario for RTB3 building demonstrated that the 73% of the heat losses come from air infiltration, mainly through exterior walls without insulation, and windows (provoking a high annual energy demand for heating). The results of simulations performed for the upgraded models are shown in Figures 4 a&b. In terms of savings in specific heat losses, the exterior walls without insulation achieved 52% over the existing state, and the windows achieved 44%. This trend was followed by the roofs, the simulation measures have shown that the RTB3 achieved 41% of energy consumption reduction after retrofitting.



Figures 4 a&b: The monthly heating and cooling load of the RTB3.
Source: Autodesk - REVIT2017 'Green Building Studio' energy analysis result, (2017).

The diagram in Figure 4a shows that the specific annual energy demand for heating in the RTB3 can be reduced by 52% by applying the layer of thermal exterior insulation to the building envelope (new U-value 0.14W/m2K) and changing the existing double pane windows to triple pane windows (the existing U-value 2.10W/m2K), and further improvements led to a reduction of 73%, while in upgrading the windows (new U-value 0.7/m2k) in the RTB3, specific annual energy demand for heating can be reduced by 57% only by treating the building envelope, while the application of other measures such as energy efficient lighting use can provide a further 59% savings in the RTB3.
Figure 4b shows that a 30% reduction of cooling load for RTB3 is achievable by improving the building envelope (new U-value 0.15W/m2K), by placing new exterior thermal insulation. Cooling design calculations are carried out to determine the capacity of mechanical cooling equipment required to meet the hottest summer design weather conditions and this was determined as parameters of energy measures during the simulation processes. By further increment of the insulation thickness, a significant decrease in cooling load can be noted for both south-west and south-east facing spaces. It is also remarkable to not that placing a well-ventilated facade achieved significant energy savings for cooling, up to 35% in upgrading envelope of the exterior wall. A similar scenario also can be seen in upgrading insulation of the roof, where there is a slight noticeable increase in cooling design capacity for upgrading U-values of windows, but by installing a ventilated facade savings up to 34% are achievable in the RTB3.

Discussions: Potential energy retrofit scenarios

The building envelope is an important component in the building structure as the interface between the interior of the building and the outdoor environment. Kylili and Fokaides (2015) assert that a feasible solution for achieving energy savings in existing buildings through interfering with the building construction is upgrading exterior wall systems. Besides building physics, energy conscious retrofit scenarios have considered the architectural measures that affect the overall improvement of the actual energy performance of buildings. The presented scenarios are studied globally, apart from sustainable Energy Efficiency Implementation (EEI) measures and local construction practices, and have given models of improvement suitable for this research context. Table 3 shows the typical assumptions of energy consumption and carbon emissions of the 'building form' energy performance measures during pre and post retrofit phases.

Table 3: The energy consumption reduction measures during the pre and post retrofitting.

1 Base Run	2 Design Alternative
Energy, Carbon & Cost Summary	**Estimated Energy & Cost Summary**
Annual Energy Cost **$2.274**	Annual Energy Cost **$1.683**
Lifecycle Cost **$30.967**	Lifecycle Cost **$22.919**
Annual Energy	**Annual Energy**
Energy Use Intensity (EUI) **674MJ/m2/year**	Energy Use Intensity (EUI) **674MJ/m2/year**
Electric **15.414 kWh**	Electric **11.349 kWh**
Fuel **5.209 MJ**	Fuel **4.966 MJ**
Annual Peak Demand **5.3 kW**	Annual Peak Demand **3.6 kW**
Lifecycle Energy	**Lifecycle Energy**
Electric **462.413 kW**	Electric **340.477 kW**
Fuel **156.054 MJ**	Fuel **149.870 MJ**

Source: Autodesk - REVIT2017 'Green Building Studio' energy analysis result, (2017).

The proposed solution for energy consumption reduction of the building is installing thermal insulation terracotta ceramic tile (new U-value 0.14W/M2K), replacement of windows and door glazing (from single to double or triple, low-e glazing), and wood-framed door/window openings that led to a considerable reduction in the heat losses through building envelope. The thickness of additional insulation for the facade and floor (U=0.04W/(m2K) was 100, 200, 300mm, for the roof the change of original 175mm insulation and additional insulation of 50, 150, 250mm, which can reduce the amount of heat that the building absorbs due to partial reflection of solar radiation. (Green Building Studio, 2017).

Three energy saving measures were considered from the upgrading of existing windows (U 1.5W/(m2K)) to the installation of double glazed windows (U 1.2 and 0.7W(m2K)). Two different new door options also were considered (U 1.5 and 1.0W/ (m2K)) (ibid). It is also noted that the base case is RTB3 with its proposed structure and service systems that provide indoor climate according to ASHRAE 90.1 -2010 standard (an acceptable, moderate level of expectation). Along with improved energy efficiency, also indoor climate was upgraded to correspond to ASHRAE benchmark (normal level of expectation) requirements. Additionally, mechanical supply and exhaust ventilation with two types of ventilation heat recovery efficiency was considered: 60% and 80% in the RTB3.

One essential element in the strategies proposed was the glazed enclosure of the balconies, which caused an aesthetic change of appearance of the building envelope, by means of sliding glass elements, which created a thermal buffer zone in the winter. Glazed enclosure of the balconies is proposed in the RTB3, it is evident that the greater effect on reducing the need for heating was achieved by upgrading building envelope, from 53% to 73% savings in order to exterior wall orientation and thickness of insulation materials. At the same time, in the summer time, intensive ventilation is required to prevent the glazed terraces from generating additional heat load. This is partly due to the current natural ventilation systems are not regulated and apartments are mostly under ventilated. Ensuring that ventilation airflows meet indoor climate standard requirements increases global costs, but energy savings cannot be achieved through lower indoor air quality as indoor air pollutants affect resident's health (Jones, 1999). For this reason, a ventilated facade was proposed, which can reduce the amount of heat that the building absorbs due to partial reflection of solar radiation by the covering and the ventilated air gap. It is also remarkable to note that the discount rate is a key variable for the life-cycle cost assessment calculation (LCA). The prices for the energy cost are chosen by the publication of the energy agency in Cyprus (Cyprus Energy Agency, 2015). Table 4 shows the life-cycle parameters of the calibrated case study building. Therefore, the overall energy use saving and life cycle energy use of retrofitting strategies are given in Table 5 (The costs have been calculated as the arithmetic mean of quotes independently by 'Green Building Studio' life cycle assessment plug in adds that indicating benchmarks in building retrofit.)

Table 4: The life-cycle parameters.

Parameter	**Value**	**Unit**	**Reference Scenarios**
Time frame	30	y	Kylili (2016)
Discount rate	3.5	%	Chrysostomou (2015)
Price increase			
Energy cost	3.32	%	Kylili (2015)
Building services	1.46	%	Avgelis (2009)

Table 5: Energy use intensity and life cycle energy use/cost of the RTB3.

Energy Use Intensity		**Life Cycle Energy Use/Cost**	
Electricity EUI:	**140 kWh/sm/yr**	Life Cycle Electricity Use:	**330.570 kWh**
Fuel EUI:	**206 MJ/sm/yr**	Life Cycle Fuel Use:	**484.600 MJ**
Total EUI:	**710 MJ/sm/yr**	Life Cycle Energy Cost:	**$23.396**

Source: Autodesk - REVIT2017 'Green Building Studio' energy analysis result, (2017).

The investigation on the basis of prototype RTB3 shows that with the conditions of parameters of the calculation, the energy use intensity of heating and cooling demand in relation to the cost optimum is about 330.570 kWh/M2 per year. The analysis pointed out that the RTBs older than 30 years are profitable for retrofitting because of their low energetic quality. Because of the high effect on the building envelope materials, which requires the feasibility of the energy conscious retrofitting measures, the input parameters (benchmarks), such as the life-cycle parameters, including the discount rate of the energy price inflation, should be planned carefully.

Conclusions, Limitations and Future Research Direction

Retrofitting and upgrading of the existing residential tower blocks 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 RTBs would have the additional benefits of increasing the property market value and positive social effects, and incentivising house owners' awareness of energy consumption. At the same time, energy efficiency measures of the RTBs can also improve indoor air and indoor environment quality, with added benefit of reducing overheating risk assessment of the building. In addition to direct impact on energy consumption reduction, there will be significant reduction in energy bills. In this study applied in other two prototype RTBs, economic analysis was performed on several potential retrofit scenarios that clearly proved to be feasible, within concerning the existing energy performance of selected case study buildings in Famagusta and its urban agglomeration regions.

Undertaking energy performance analysis of prototype RTBs in TRNC shows clearly that the proposed energy efficient strategies ought to be considered due to the significant savings in energy and associated carbon emissions. To conclude, applying energy efficient retrofit measures to RTBs in TRNC is crucial importance, so the existing housing stock can be treated in a systematic manner to achieve significant energy savings.

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