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ENERGY EFFICIENCY RETROFITS OF RESIDENTIAL BUILDINGS IN UKRAINE. A CASE STUDY

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According to the International Energy Agency, globally buildings are responsible for nearly 40% of total end use of energy [1].

In 1999 the Programme of Residential Buildings of First Mass Construction Series Reconstruction was approved by Cabinet of Ministers of Ukraine [2]. According to this Programme, buildings that were constructed during 60-70ss from panel and brick materials constitute together 72 million m^2 in total living area, i.e. a large part of the total Ukrainian residential buildings stock. Such buildings are characterized as having very poor thermal performance.

According to [3], the thermal resistance (reciprocal to U-value) of thermal envelopr components for newly constructed buildings in Ukraine should be no less than (for the 1st temperature zone): for external walls – 3,3 m^2K/W; roofs – 5,35 m^2K/W; top floor ceiling (adjacent to unheated attics) – 4,95 m^2K/W; windows – 0,75 m^2K/W; entrance doors – 0,5 m^2K/W. The relevant thermal resistances for opaque elements of retrofitted buildings may be taken with coefficient 0,8.

The current reduction needs of buildings' energy use led worldwide to pursuit the goal of low and very low energy buildings, thus appearing different definitions and concepts. Despite these differences all have in common that very low energy houses have a design that enables low energy demand through: well insulated building envelope; compact shape and no thermal bridges; energy efficient windows facing sun allowing use of passive solar gains; good airtightness for controlled ventilation [4]. Hence, these buildings have significant lower energy demand than buildings just meeting the mandatory buildings regulations, which typical criteria are 25-50% better than minimum requirements [4].

A number of voluntary standards for heating energy demand aiming high comfort with minimum consumption have been developed in various countries for residential and non-residential buildings, such as the Passive House standard.

The concept of Passive House has been developed in Germany by the Passive House Institute and is currently considered as the most demanding standard on buildings' energy efficiency [5]. A passive house's annual heating demand must be equal or less than 15 $kWh \cdot m^{-2}a^{-1}$ (assuming a uniform indoor temperature of 20 ºC) or, the heating load must be equal or less than 10 $W \cdot m^{-2}$, the primary energy use must be equal or less than 120 $kWh \cdot m^{-2}a^{-1}$, the airtightness level (n_{50}) must be equal or less than 0.60 h^{-1}.

The Passive House Standard often cannot be feasibly achieved in older buildings due to various difficulties. Refurbishment to the EnerPHit Standard [6] using Passive House components for all relevant structural elements in such buildings leads to extensive improvements with respect to thermal comfort, structural integrity, cost-effectiveness and energy requirements.

For existing buildings the EnerPHit standard was developed by limiting the annual heating demand to a maximum of 25 $kWh \cdot m^{-2} \cdot a^{-1}$, assuming a uniform indoor temperature of 20ºC. The maximum value of the air tightness level (n_{50}) is considered equal to 1.0 h^{-1} [6].

The objectives of this study were as follows: 1) to evaluate the current thermal performance of a typical 5-story building called "Khruschevka", located in Kyiv (Ukraine) and built in 1960s using PHPP9 calculation tool [7]; 2) to assess the impact of the thermal upgrade of walls, top floor ceiling, basement ceiling, windows, and different ventilation strategies on space heating energy consumption.

Table 1 describes the base case construction details.

Table 1 - Base case construction details

Element	Construction	U-value (W/m^2K)
External wall	15 mm interior plaster+380 mm lime sand brick	1,24
Top floor ceiling	220 mm concrete slab+70 mm expanded clay+50 mm sand-cement mortar	1,405
Basement ceiling	22 mm parquet+220 mm concrete slab+50 mm polystyrene+10 mm plaster coat	1,629
Doors	metal	3,704
Glazing	Double glazing 4/12 mm in timber frame	2,96-3,02

The relevant air exchange rate was taken as 0,73 h^{-1}. The ventilation type – only windo ventilation.

The retrofits strategies were designed to achieve progressive improvements of the envelope's thermal performance and airtightness up to the EnerPHit standard (heating demand 25 $kWh/(m^2a)$ and air permeability rate $n_{50}<1.0\ h^{-1}$). For thermal simulation, a "base case" was defined to represent the condition of the existing house.

Two upgrade variants were considered: variant 1 – the upgrade to match the minimum requirements of the current Ukrainian Building Codes [3]; variant 2 – the upgrade to match the requirements of EnerPHit Standard [5].

On this basis, in the next phase of the study, refined retrofits packages were tested using the Passive House Planning Package 9 (PHPP 9), the Excel spreadsheet-based design tool specifically developed by PHI to assist architects and designers plan and verify Passive Houses towards certification. It calculates building components' U-values, heating, cooling and primary energy demand, ventilation rates for comfort as well as the risk of overheating in the warmer season. Furthermore, it compiles climate data from many locations worldwide, including Kyiv (Ukraine).

The results of the calculation illustrate that the improvements from the poorly insulated house (base case or existing building) to one matching the minimum requirements of the current Ukrainian Building Codes (the relevant U-values of the upgrade: the external walls – 0,302 W/(m^{2}K), the top floor ceiling – 0,206 W/(m^{2}K), the basement ceiling – 0,259 W/(m^{2}K), the external doors – 1,919 W/(m^{2}K), the windows – 1,28 – 1,29 W/(m^{2}K) lead to the reduction of heating demand from 173 kWh/m^{2}a to 76 kWh/m^{2}a (according to the annual method). A more significant result is that, by improving insulation of the top floor ceiling (U-value=0,151 W/(m^{2}K)), the basement floor (U-value=0,151 W/(m^{2}K)) and the external walls (U-value=0,147 W/(m^{2}K)), installing energy efficient windows (U-value=1,28 – 1,29 W/(m^{2}K)) as well as using mechanical ventilation with a heat recovery unit (effective heat recovery efficiency 83 %) and increasing air tightness in the path to meet the EnerPHit Standard, annual heating demand drops to 18 kWh/m^{2}a.

The results show the potential of energy savings while retrofitting the existing old buildings in Ukraine.

A special attention should be paid to the reduction of ventilation losses. The ventilation rate is usually given by the building regulations and should provide a good indoor air quality. As the reduction of the ventilation rate is not generally recommended, the only way to reduce the ventilation heat losses is to introduce the heat recovery of the ventilation. In refurbishments of existing buildings, it is not always possible to achieve absence of thermal bridges with justifiable effort as is necessary for Passive House new builds. Nevertheless, thermal bridge effects must always be avoided or minimized as much as possible while ensuring cost-effectiveness. It is important to remark that housing retrofit is case-specific, and evolutive, since the achievement of high performance-based standards, such as EnerPHit, benefits from the steady improvement of construction technology.

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