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Energy saving potentials of Moscow apartment buildings in residential districts

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ABSTRACT

This study estimates the energy savings potentials of Moscow apartment buildings through different renovations concepts. Also the reductions of the district level energy demands resulting from the possible building level energy savings were estimated. The principles of these energy chain analyses are also described.

Most of the apartment buildings in the Soviet Union were constructed between 1960 and 1985, and as a result the urban housing stock today consists mainly of a few standard building types. Energy efficiency of buildings is typically poor. A typical residential district was selected for the analyses. The energy consumption of a typical Russian building was estimated by calculating heating of living spaces, heating of domestic hot water, and the consumption of electricity. The energy consumption of the selected building stock was based on the calculated consumptions of the type buildings. The present state of the district level was studied first, including energy chain analyses. Then the energy savings potentials for three different renovations concepts were estimated. In addition, non-technical barriers to energy efficient renovations are discussed.

1. Introduction

Energy strategy of Russia for the period up to 2030 states that Russia must improve its energy efficiency and reduce energy intensity of its economy to the level of countries with similar climatic conditions such as Canada and the Scandinavian countries [1]. In addition, it is required that Russia's living standards must correspond with those of the developed countries.

According to national statistics service the share of dilapidated and emergency-state housing is around 3% of the total area of the Russian housing stock [2]. However, it is estimated that more than 290 million m^2 or 11% of the Russian housing stock needs urgent renovation and re-equipment, 250 million m^2 or 9% should be demolished and reconstructed [3]. Some 58–60% of the country's total multi-family apartment buildings are in need of extensive capital repair [4].

In 2005; the Russian residential, public, and commercial buildings were responsible for 144.5 Mtoe (million tonnes of oil equivalent), i.e. 1680 TWh, of final energy use (34%) and for 360 Mtoe, i.e. 4186 TWh, of primary energy (55% of overall primary energy consumption). The technical energy efficiency potential of the buildings was assessed at 68.6 Mtoe, i.e. 797,820 GWh [5]. Residential buildings are evaluated to have the largest energy savings potential out of all building types. The largest part (67%) of the energy savings could be implemented through the more efficient utilization of district heating in space and water heating. An estimated 60% of the Russian district heating network is in need of major repair or replacement [6]. The investment needs for rehabilitating the district heating systems is Russia are estimated at US$ 70 billion by year 2030 [7].

The majority of Moscow housing stock is built after World War II [2] and need modernization. Sustainability should be taken to account when renovating these buildings. Thus, energy efficiency of buildings and districts is one of the core issues. Before deciding any renovation solutions, the energy consumption levels need to be estimated. After the estimation, different renovation concepts can be compared with the current situation. This paper describes the principles of the energy analysis process, estimates the present state energy consumptions of a typical Moscow apartment building and a typical district (neighbourhood), and then analyses different building level energy renovation concepts.

Often technical solutions exist for energy renovations of buildings but other obstacles hinder or delay their realization. These non-technical barriers to energy efficient renovations of Moscow residential districts are also described in this paper.

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2. The Moscow housing stock

Construction in Russia [2] state that the total Russian housing stock in terms of total residential floor area was 3177 million m^2 in 2009. Total area of the housing stock per capita was 22.4 m^2.

According to the statistics from 2004, 95% of the Moscow dwelling space is built after World War II, from which 52% of the residential buildings were built during 1946–1975 and 43% in 1976 or later. According to Rosstat [2], there were 39.801 residential buildings in Moscow in 2009. The amount of residential buildings equals 3,835,000 apartments and the total floor area of 214 million m^2. The average floor area of an apartment in Moscow was 55.8 m^2 and the average number of residents per apartment was 2.8. The figures do not account for administrative expansion of Moscow implemented in summer 2012.

2.1. Typical apartment buildings in Moscow

It is important to understand the general situation in the target place before conducting energy analysis. In 2004 United Nations published Country Profiles on the Housing Sector Russian Federation [3], which helps to form an overview of typical building solutions in Moscow and in Russia. First of all, the industrialization of construction started in the Soviet Union in the 1950s, after which the precast concrete large-panel construction developed quickly. Most of the apartment buildings were constructed between 1960 and 1985, and as a result the urban housing stock today consists mainly of a few standard building types. [3]

In general, there are three basic categories for residential panel buildings [3]:

- First generation is five-storey buildings often called *khrushchevky*. Khrushchevky have been built between 1959 and 1969 and about 10% of residential buildings belong to this category. Typically their state is quite poor nowadays and they are situated in fairly attractive areas, not far from city centres.
- Second generation buildings were constructed between 1961 and 1975. The number of storeys varies but nine-storey buildings are the most common. The buildings are long and there are usually five to nine staircases in each. The external walls are different lightweight concrete structures without separate thermal insulation material. The housing norms of 1963 regulated their design and construction. The dwellings in this category are more comfortable than those in the first-generation buildings.
- Third generation buildings were built mainly after 1975 in the suburbs. Large elements and prefabricated modules were used. These buildings are nine-storey or higher, tower type blocks of flats or long, narrow buildings with four to seven staircases. The external walls are usually 32–35 cm thick expanded-clay lightweight concrete.

Natural ventilation is a typical solution in Russia [8]. District heating networks supply heat to about 80% of Russian residential buildings and about 63% of the hot water used by Russia's population [6].

Energy efficiency of these apartment buildings is typically poor. The thermal insulation of the precast panel walls does not meet modern standards, and may cause moisture and mould problems. Moreover, the surroundings like streets, courtyards and parks are usually poorly maintained. The limited variation in the urban housing stock results in suburbs of large uniformity, where individual wishes or needs are rarely met. [3]

There is one more issue that should be considered when studying Russian buildings. It is quite difficult for researchers from outside of Russia to find and correctly interpret Russian data. According to Opitz [9], the central government has a desire to conceal important production and financial facts, which means that the clarity and consistency in published statistics is often rare, and a lot of interesting information is simply unavailable to the general population. Moreover, the statistical reports published in several forms by Goskomstat (the State Committee on Statistics) were incomplete and often inconsistent. The accounting methods and definitions varied among sources and even within the same source in different years. Opitz [9] states that the data almost seem designed to confuse. The data used for this paper was gathered from several sources, and cross-checked when appropriate sources were found.

2.2. The selected housing district

A typical residential district was selected to be analyzed in the project. The selected district mostly represents 4-th Microrayon of Zelenograd, Moscow (longitude 37° east and latitude 55° north). Zelenograd is located about 35 km to the North-West from Moscow City centre. The district dimensions are approximately 1 × 0.5 km. It represents a typical residential district of Moscow and Moscow region with high-rise apartment buildings constructed for the most part in 1960s and 1970s. The district is heated with district heating. Renovation of such buildings and districts may be needed in the near future.

The apartment buildings in the area can be divided into groups according to the building series: II-57, II-49, AK-1-8, II-18 and Mr-60, which are apartment buildings build between 1966 and 1972. Each building series represents a specific building design [8]. There are also other apartment buildings, schools, kindergartens, shops, a bank in the area, but since this project concentrates on modernization of buildings, these newer buildings from the 90s and from the beginning of 2000 are excluded from these energy calculations. The more detailed data about the older apartment buildings is presented in Table 1 and these buildings were the main target of the first calculations of this study. After the initial analysis the most common building type II-18 was selected for further analyses.

In total there are approximately 13,800 residents in the buildings that are included in the calculations. The total floor area of the studied buildings is 327,600 m^2. The number of residents is estimated based on the assumption that the average occupancy rate per flat is 2.7 persons [3].

3. Principles of the energy analyses

The main objective for the energy analyses was to form an overview of average energy consumption, energy production quantities, and energy efficiency in Moscow, Russia. The energy analysis is important, because it helps to recognize the best ways of how to improve the energy efficiency of entire districts and energy systems. The key questions are: "How the energy is currently produced for buildings and districts?", "What are the most efficient ways to reduce energy consumption and how much can it be reduced?", "What is the environmental impact of energy production and how emissions caused by it can be reduced?" and "What are the life cycle energy costs of different alternatives?".

The general methodology of energy analyses is presented in Fig. 1. At first the state of the art was studied for both old apartment buildings and the entire residential district in the Moscow region. This means that the typical apartment building parameters were identified, and an example district was selected for the calculations. Most of the buildings in the example district are built between 1966 and 1972. A few different typical apartment building types was studied: their monthly energy consumption levels were calculated, and then from those results the energy demand of the entire district was calculated including also the energy demands for