Can deep energy retrofitting of multifamily residential buildings reduce the demand for electricity from conventional sources at national level?

Technical analysis

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Introduction

The current study is targeted to the assessment of the opportunities for reducing the energy consumption in Bulgaria through energy-efficient renovation of multi-family residential buildings. It was prepared to support and complement a more wide-ranging study carried out by the European Climate Foundation, devoted to the decarbonization of the electricity sector, comprising Bulgaria, Romania and Greece. The aim of the study hereby is to assess the potential impact of measures concerning the final energy consumption in the building on the decarbonization of the electricity sector.

The methodology of the research is based on the optimal use of the existing reliable and veritable data, mainly from the following sources: the National Statistical Institute (NSI), the data base containing the results from the energy audits performed for the National Program for Energy Efficiency of the Multi-Family Residential Buildings (NPEEMRB), maintained by the Sustainable Energy Development Agency (SEDA), as well as energy audits performed by EnEffect. Additionally, analyses of the World Bank on the characteristics of the residential building stock in Bulgaria and the opportunities for continuing the NPEEMRB, have also been used.

Based on these data, a review of the electrical energy consumption in the residential sector in Bulgaria ia made and the state of the residential building stock is analyzed. As a result, the building segment with the greatest potential for electrical energy savings is identified; consequently, this segment could be aimed at by the forthcoming programs supporting building renovation, should the reduction of electrical energy consumption be set as a priority. The energy consumption patterns in the targeted segment are analyzed and the share and quantity of the electrical energy within the final consumption of households are determined. Thus, based on the available data from the energy audits, the "normalized[1]" savings for building renovation projects reaching energy class C, typical for the current programs, are defined. Applying conservative assumptions, a calculation of the actual savings which are really influencing the national energy balance is made. Then, using a reference building selected for this purpose, the potential actual savings when reaching a higher energy class are calculated, with view to the changes in the EU legislation and the expected development in the Bulgarian legal framework. The potential replacement of electrical energy produced by the conventional Thermal Power Plants (TPP) with electrical energy produced by household PV installations is added to the calculated actual savings. Based on those calculations, the final conclusions about the potential impact of the renovation programs on the national electrical energy balance are presented.

[1] "Normalisation" is a method for the analysis of energy savings, which involves the calculation of the latter based on the amount of energy needed for achieving optimal comfort in all premises of a building. Since it is very common in Bulgaria for the buildings to be underheated in winter, employing this method involves considerable differences between the actual savings (resulting from the real energy consumption providing lowered comfort levels) and the "normalized" ones (reflecting the energy that should be consumed for achieving optimal comfort). As this is the compulsory approach when conducting energy audits, they often fail to yield information about the actual savings resulting from energy efficiency measures.

Not surprisingly, due to the deteriorated energy performance of buildings and the intensified use of electrical energy for heating in the multi-family buildings, which are not connected to the heating network, the saving potential is significant. Only within the building segment chosen, through measures mainly on the building envelope and local energy production using photovoltaic installations, it is possible to save 1765 GWh per year from the current final annual consumption of 3610 GWh per year, or 49%. Additionally, what could be added to these savings are the potential savings from modernization of the heating systems and household appliances, as well as of the systems for domestic hot water and lighting, which are out of the scope of this analysis. From the point of view of the energy system, this obliviates the need of a thermal power station of the scale of TPP "Bobov dol[2]", without taking into consideration the possible savings from multi-family buildings connected to the district heating system, as well as from multi-family buildings built after 1990, multi-family mixed-use[3] buildings, and single-family houses. The potential savings from the settling of households in new nearly zero-energy buildings after 2021 and leaving their current dwellings are also outside the scope of the study, while, with view to the volume of new construction, this could have a considerable effect on the quantity of energy saved.

Analysis of the Energy Consumption in the Residential Sector

Household electrical energy consumption in Bulgaria

Households are the largest end-use consumers of electrical energy in Bulgaria. According to the national energy balance sheet for 2017, drawn up by the National Statistical Institute, the share of electrical energy for the households takes up over 37% of the total electrical energy consumption. The balance of total final consumption of electrical energy is presented in Figure 1.

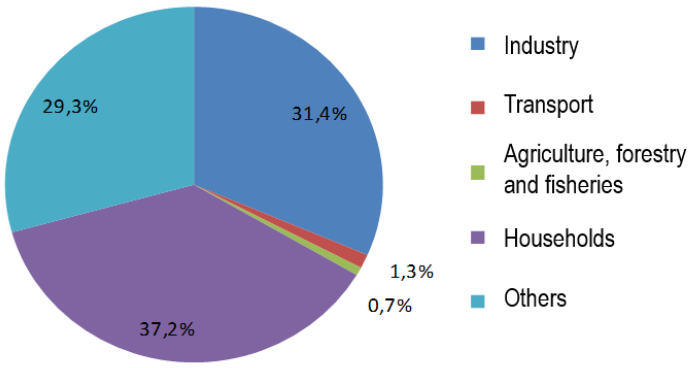


Figure 1. Energy balance of the final consumption of electrical energy in Bulgaria for 2017.

[2] According to the estimates of the Energy and Water Regulatory Commission (EWRC) for the annual net amount of electrical energy for 2018: http://www.dker.bg/uploads/reshenia/2019/res_c-19_19.pdf
[3] Part of the total useful floor area is used for retail or other business activities.

Although a minimal decrease (about 2%) of the share of electrical energy consumption country-wide has been registered in the last decade, reflected in a parallel increase in the share of industry, the former remains unrivaled. At the same time, the statistics reports a trend for an increase in the consumption of the amount of electrical energy by the households, with consumption in 2017 (11138 GWh) being 5.5% higher than that in 2010 (10560 GWh).

Looking at the statistics for the final energy consumption of households, broken down by types of energy products, the consumption of electrical energy for 2017 amounts to 41.3% of the total energy consumption (*Figure 2*). The overview of the statistical data for the previous five years shows that this share has been stabilized at a level ranging between 40,4 % and 42,1%.

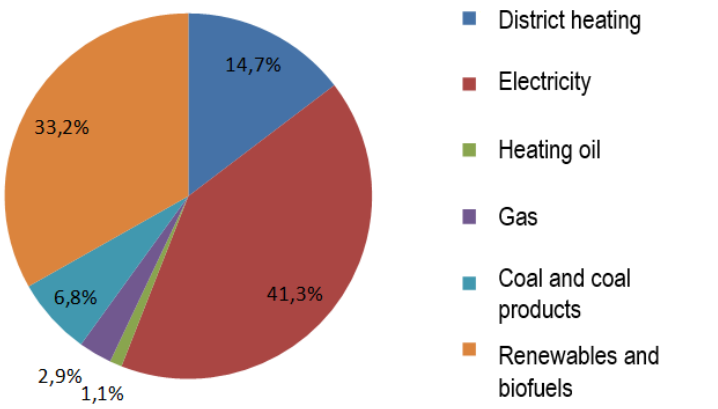


Figure 2. Distribution of the final energy consumption of households, broken down by energy sources for 2017. [4]

The experience gained through a multitude of energy audits of residential buildings in Bulgaria shows that about two thirds, and sometimes even more of the final energy consumed in residential buildings is used for heating. If, however, it is found out during the audits that the normative thermal comfort levels are not met, the so called "normalization" is carried out, recalculating the measured energy consumption against the conditions aligned with the comfort level requirements. It is typical for Bulgaria to maintain temperatures in the buildings lower than the normative ones during the heating season, mainly due to insufficient financial resources. This means that the share of the actual consumption of energy for heating (corresponding to the measured consumption) is smaller than that calculated through the energy efficiency audit. Nevertheless, this share remains the largest one in the buildings' energy balance.

All these figures show the huge potential for achieving a considerable reduction of the electrical energy consumption in Bulgaria through implementing energy efficiency policies and measures in the residential sector. As the main energy saving measures included in the energy renovation of buildings are aimed at reducing the energy consumption for heating, further

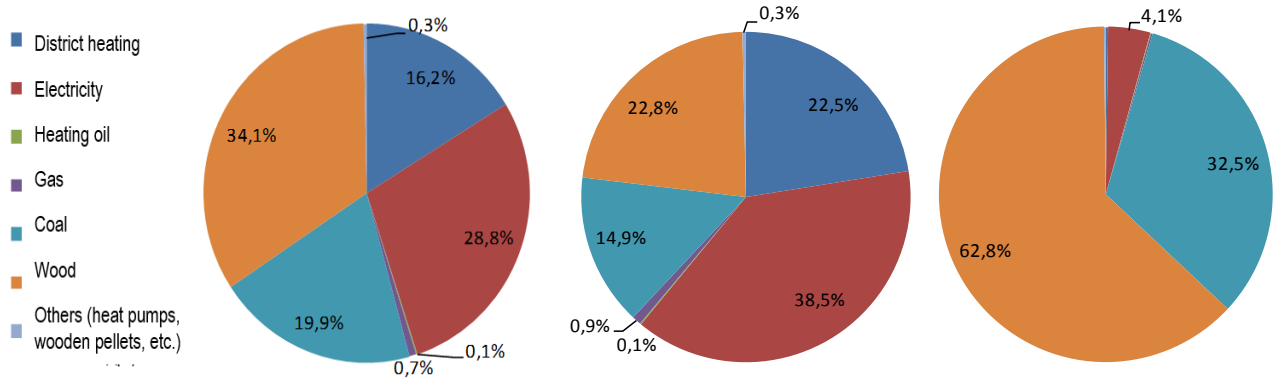
[4] The "Petroleum and petroleum products" category includes the heating oil (naphtha) and liquefied petroleum gas. The category "Coal and solid fuel" encompasses coal and briquettes. The "Renewable fuels" consists only of firewood..

analysis should be performed for determining the share of electrical energy used specifically for heating of the dwellings.

Electrical energy consumption for heating in the residential sector

The data published by the NSI, from the last national census conducted in 2011, show the types of fuel and energy used for heating dwellings in Bulgaria, and are visualized hereby in *Figure 3*. The statistical data is drawn up in accordance with the information collected during the census about the number of dwellings and the main type of resources used for heating.

The heating source used in the largest number of dwellings in Bulgaria is firewood (34,1 %), electrical energy is second (28,8 %), followed by coal (19,9 %). If, however, the data about towns and villages is examined separately, there are considerable differences. In villages, where the dwelling stock could be claimed to consist entirely of houses, and where there are virtually no multi-family buildings, most of the dwellings use solid fuels for heating (62.8% firewood and 32,5% coal), while electricity has a minimal share (4.1%). In towns, on the other hand, the distribution is closer to that for the whole country, which is readily explained by the fact that the number of dwellings in towns (1,884 M) is considerably higher than that in the villages (741 K). The most commonly employed type of heating is electricity (38,5%), but the share of solid fuels is also quite high (in total, 37.7%). The high rate of solid fuels used for heating, accompanied by, in most cases, ineffective means of burning (in old stoves and in buildings in neglected state and inefficient energy performance), leading to high levels of heat loss, is one of the main reasons for the air pollution in a large number of the big cities in Bulgaria. It should be taken into account, of course, that the data is comparatively outdated and probably does not reflect the current state accurately; in any case, the trends are clearly outlined, and it is highly unlikely that significant changes have occurred meanwhile.



a) country-wide *b) in towns* *c) in villages*

Figure 3. Type of fuels and energy used for heating buildings

An interesting comparison could be made while reviewing the data from the previous census, conducted in 2001, in order to find out whether any considerable changes regarding the heating sources used by households in Bulgaria have taken place. At that point, the questionnaires concerned not only the main type of energy resource, but also information was collected separately for the cases when two types of resources had been used. If in those cases the amount of the resources used is redistributed according to their share as individually used energy resources, the result will be the general distribution of shares, comparable to that

of 2011. What such a comparison shows is an increase in the use of electrical energy (from 25.8% to 28.8%) and in the use of coal (from 5.2% to 19.2 %) to the detriment of the firewood (from 51.7% to 34.1%), which is strongly negative in terms of greenhouse gas emissions.

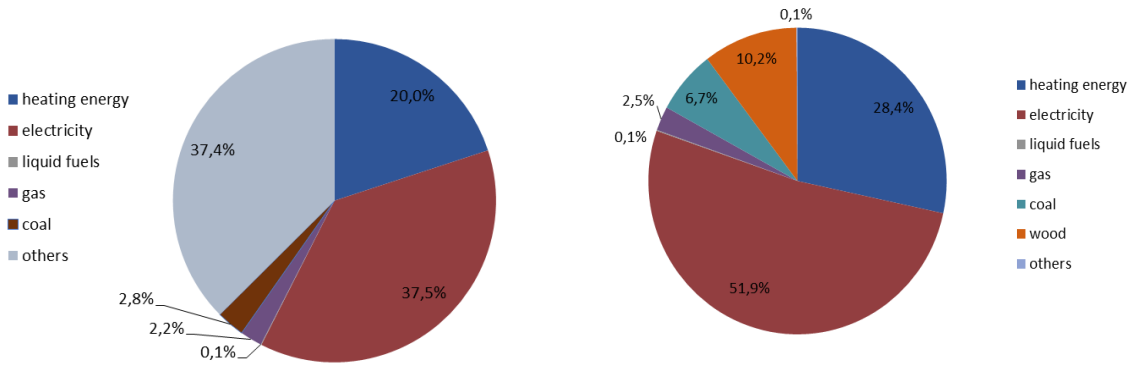
The main conclusion that could be drawn is that the electrical energy is the main energy source used by Bulgarians for heating dwellings in towns, with an increasingly growing share in the households' total energy consumption for heating. Despite the observed increase, the share of electrical energy used in villages remains low. The mix of energy resources in villages is very different from that in towns, with a categorical prevalence of solid fuels. In towns, on the other hand, the residential building stock consists both of multi-family buildings and houses. It could be assumed that the distribution of energy sources in the houses will be, to a significant extent, similar to that in the villages, though the solid fuels are not expected to prevail so drastically over electrical energy. This means that the electrical energy consumption in multi-family buildings would be considerably higher and the potential for electrical energy savings in those buildings would be the greatest. Therefore, it is also very important to determine the specific energy resources mix for heating of multi-family residential buildings.

Electrical energy consumption for heating in multi-family residential buildings

The statistical data analyzed so far do not allow a distinction to be made between the type of electrical energy used for heating, broken down by building types. The national statistics does not provide data that could be used to that end. An assessment of the fuels and energy used in the multi-family buildings could be made only using the database of the Sustainable Energy Development Agency (SEDA), which provides a summary of the data from the audits conducted prior to the renovation of all the 2022 buildings included in the scope of the National Program for Energy Efficiency of the Multi-Family Residential Buildings (NPEEMRB). This information is consolidated at building level, rather than for separate dwellings, comprising not only the distribution of fuels and energy for a certain number of dwellings, but also the amount of energy consumed from each resource type. Unfortunately, the data about the energy consumption levels prior to renovation is aggregated in a way that does not facilitate the determining of the amount of energy used for heating and for other needs. This distribution could be made by taking into consideration the data for the energy savings, broken down by resource types from all energy saving measures concerning the building's heating, and excluding the rest of the measures. Such measures, quite uniformly, are implemented in all buildings renovated under the National Program. Of course, it does matter what the specific measures are and what is the exact amount of saved energy in each building, which is the reason why this statistical sample does not accurately reflect the distribution of energy sources per resource type in the multi-family residential buildings. However, considering the lack of other data, this analysis outlines the situation rather accurately. The results of the analysis of the information from the SEDA database based on the method laid out above are presented in *Figure 4a*.

Within the separate audits, a large share of the energy consumption of the buildings is recorded in the database under the graph "Miscellaneous". Actually, these are buildings in which several different types of heating are used, but the energy auditors have spared the effort to describe separately each type with its respective amount of energy in the audits'

summaries, introducing the total energy in the graph “Miscellaneous” instead. In order to distribute the energy classified under the vague title of “Miscellaneous” into separate resource types, it is accepted to use the distribution for the towns, as shown in *Figure 3b*). The recalculated distribution of energy resources is presented in *Figure 4b*).



a) according to the database *b) after redistribution*

Figure 4. Type of fuels and energy used for heating in dwellings in multi-family residential buildings

Data shows that for multi-family buildings the most common means of heating is undoubtedly the electrical energy – 51.9%. If the buildings connected to district heating networks are left out of the scope of analysis, the share of **electrical energy used for heating in all other buildings increases to 72.5 %.**

Solid fuels are used in 16.9 % of dwellings, despite the fact that most of the multi-family residential buildings are not designed for such type of heating. Burning solid fuels is one of the main reasons for air pollution in towns.

The state of the building stock in Bulgaria

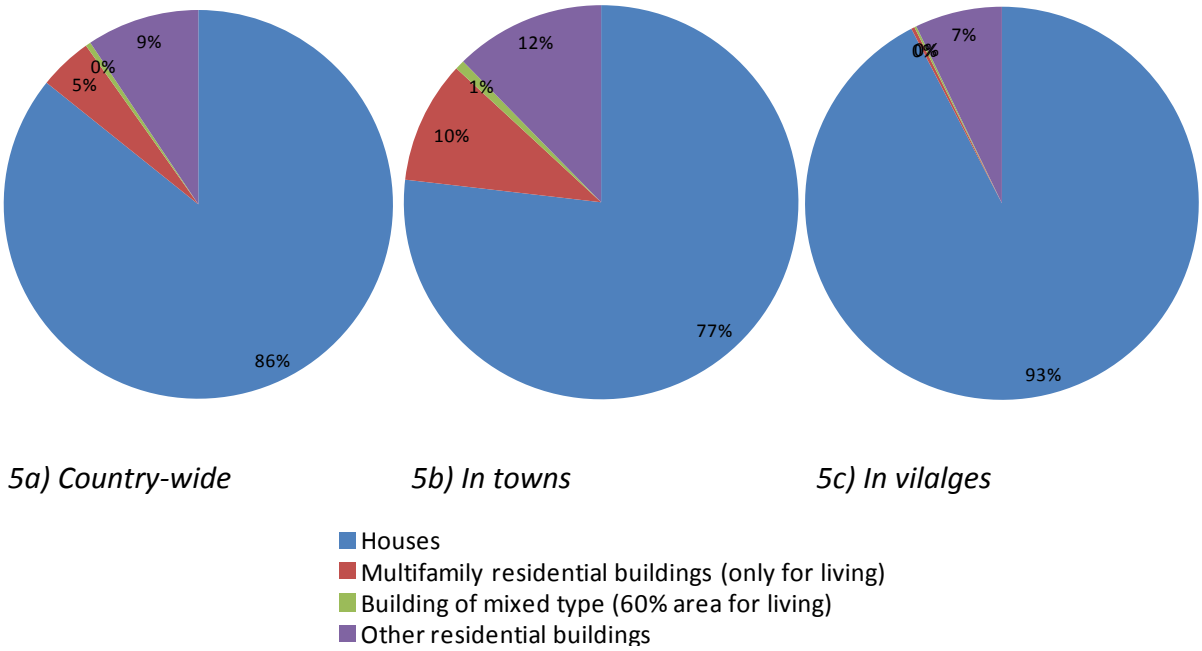
The data issued by the NSI presenting the results of the national census in 2011 are used as the main source of information about the building stock in Bulgaria.[5] These publications present considerably more detailed data, compared to other information sources, including separate detailed reports about the inhabited residential buildings and dwellings. As the main topic of the report hereby is the energy renovation of residential buildings, it is namely the information about the inhabited buildings that is the most important. There is no information about the newest buildings, constructed since 2011, but these buildings are not of interest considering the main object of the analysis hereby.

In Bulgaria, there are over 1.5 million of inhabited residential buildings, 641,000 of which are in towns, and over 864,000 are in villages. According to the classification used by the NSI, the residential buildings are divided into 7 types. Houses are the prevailing type of residential

[5] NSI (2012) Census and Dwelling fund in 2011, Vol. Dwellings fund, Book 1 Buildings. NSI, Sofia.

buildings, their share being about 86% of all residential buildings. This tendency is particularly expressed in villages, where around 93% of all residential buildings are houses. According to the definition laid down by the NSI, the houses are low-rise (one to three floors) residential buildings (detached, semi-detached, terraced houses, row houses etc.), in which all dwellings have their own entrance from the adjacent terrain. The three-floor buildings with one dwelling per floor and a common entrance from the street/the back yard are also included. The number of multi-family buildings in villages is negligible, under 0.5%, but in towns their share amounts to 10%.

According to the definition of NSI, the multi-family residential buildings (blocks of flats and housing cooperatives) are buildings with medium (4 or 5 floors) or high (6 and more floors) floorage and common staircase with entrances to each dwelling. Three-floor houses with two or more dwellings on each floor are also included. The blocks of flats with many entrances and those that are built in connected sections are considered as one building. The percentage of the various building types by number and location is presented in *Figure 5*.



5a) Country-wide *5b) In towns* *5c) In vilalges*

Figure 5. Share of residential buildings in Bulgaria as of 2011.

However, the ratio between the various types of buildings looks quite different when the useful floor area of dwellings in them is considered. Although the number of multi-family residential buildings is many times smaller, in terms of useful floor area their share is almost equal to that of the houses. The total floor area of the dwellings in houses in the country is about 118 million m^2, 54 million m^2 of which are in towns and about 64 million m^2 are in villages. The total useful floor area in blocks of flats is about 117 million m^2, of which over 115.5 million m^2 is in towns and under 1.5 million m^2 – in villages. The information for the useful floor area of dwellings by types of buildings is visualized in *Figure 6*. In percent the floor

of dwellings in multi-family buildings is 47.2% country-wide as opposed to 47.7% of houses. In towns this ratio is 64.7% for multi-family residential buildings and 30.2 % for houses.

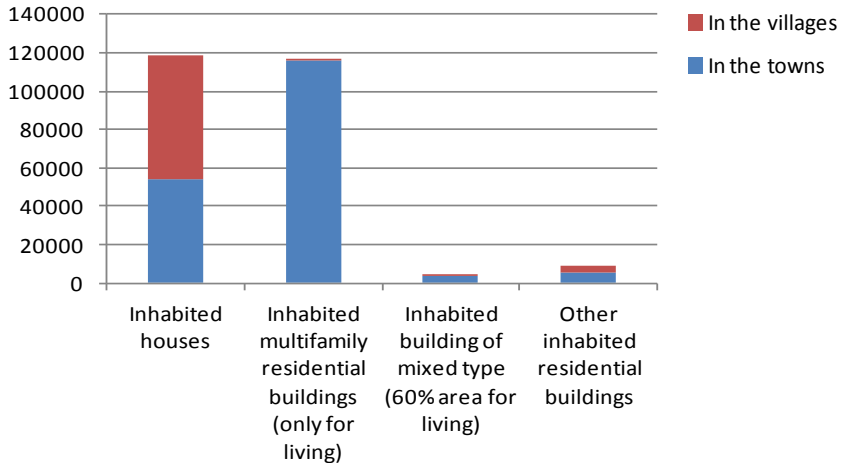
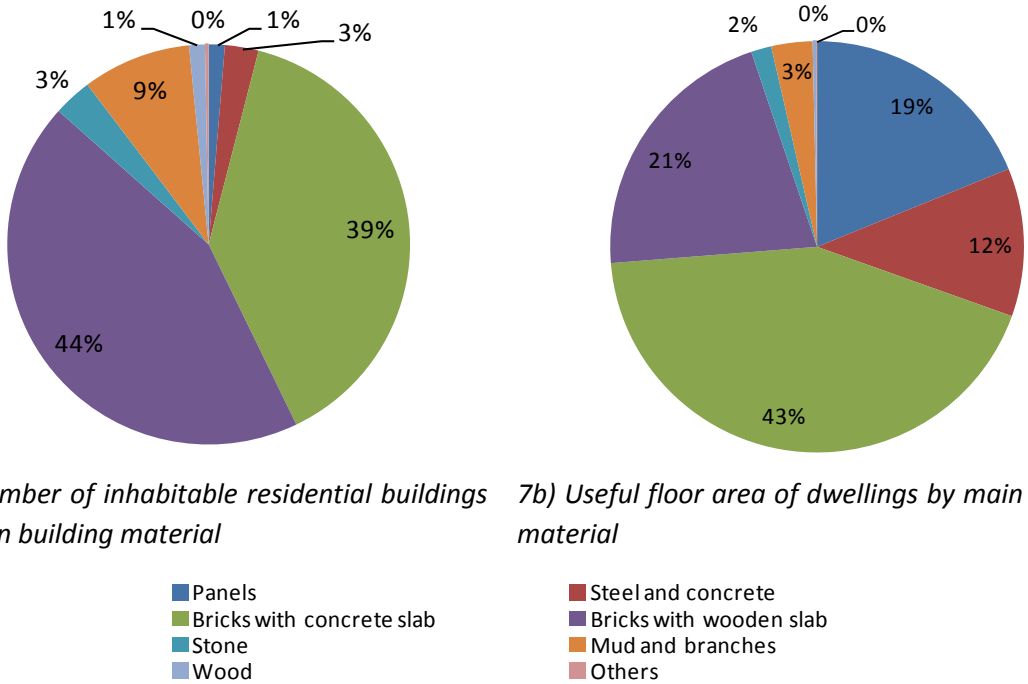


Figure 6. Distribution of the useful floor area in Bulgaria as of 2011.

The type of the building construction plays a significant role in determining whether the building is suitable for renovation or not. The largest number of the inhabitable residential buildings – about 44%, are built with bricks and wooden slab. About 39% of the buildings are built with floors of bricks with concrete slab, while the prefabricated panel buildings, as a number, are just about 1%. The largest total useful floor area is concentrated in buildings with reinforced concrete structure and brick masonry – about 43%, while those with wooden slab, although largest in number, have total useful floor area only about 21%. The floor area of prefabricated panel buildings amounts to about 19% of the useful floor area of dwellings. The data about the inhabitable residential buildings in terms of the main building material used are summarized in *Figure 7*.



7a) Number of inhabitable residential buildings by main building material

7b) Useful floor area of dwellings by main building material

Figure 7. Distribution of the residential buildings and the useful floor area of dwellings depending on the building materials as of 2011.

The World Bank report *Bulgaria: National Program for Energy Efficiency in Residential Buildings. Program Design Report for the Second Phase, June 2018*[6] analyses status of the multi-family residential buildings (prefabricated panels, brick masonry, cast-in-situ monolithic reinforced concrete) built before 1990, whose number is 64 692 in total. Of those, 43 879 are classified as suitable for renovation, and after the deduction of the buildings which have already been renovated under the NPEEMRD (more details to be found in the next section of the current report), the number has been decreased to 41 858. According to the same report, the average total useful floor area per building is calculated to be 4,160 m2 for panels, 2,160 m2 for cast-in-situ monolithic reinforced concrete construction and 1,230 m2 for brick masonry buildings. Data from the report of the World Bank are presented in *Table 1*.

Table 1. Determining the number of remaining multi-family residential buildings, suitable for renovation

Building type	**Total number of multi-family residential buildings with monolithic construction**	**Number of multi-family residential buildings, built before 1990***	**Number of multi-family residential buildings, completed during phase 1**	**Number of remaining multi-family residential buildings to be renovated**
Panels	11,004	9,664	1,419	8,245
Brick	41,910	27,949	135	27,814
Cast-in-Situ Monolithic Reinforced Concrete	11,778	6,266	467	5,799
Total	64,692	43,879	2,021	41,858

** Includes only multi-family residential buildings without business premises.*

According to data outlined in *Figure 4*b) about the shares of different energy resources in the final consumption, it could be assumed that the buildings not connected to district heating networks are about 70% of all multi-family buildings. If we consider these buildings only, the total number of buildings, which should be renovated in order to achieve maximal electrical energy savings, is about 29,300, while the total area is about **57 million m²**. The potential electrical energy savings will be calculated based on this basis, assuming, as it was mentioned above, that the share of electrical energy for heating is **72.5 %**.

National requirements for energy efficiency in residential buildings

In order to analyze the potential savings from the energy efficiency measures, it is necessary to get acquainted with the national requirements for the energy performance of the building components, as well as with the requirements for the integrated energy performance of buildings and the scale of energy consumption classes.

[6] Available at http://documents.worldbank.org/curated/en/329851534930802672/Bulgaria-National-Residential-Energy-Efficiency-Program-Phase-2-Design-Report

As far as the Bulgarian legislation is concerned, energy efficiency requirements were first introduced in 1964, determining the U-values for the buildings' external walls, roofs and floors. Until 1999, the U-values varied depending on the calculated outside temperature, while regarding the facades, the U-values differ depending on the building's construction – whether it is massive, light or very light. It was in 1999 that the required U-values for windows and doors were introduced and the obligatory U-values for facades required adding thermal insulation on external walls. Since 2005, the normative U-values have been treated as reference values rather than obligatory ones. The current U-values have been in force since 2015. The recommended value for external walls is U = 0.28 W/m^{2}K, for a flat roof it is U = 0.25 W/m^{2}K, for a ventilated roof it is 0.3 W/m^{2}K, for floors – U = 0.25 W/m^{2}K, and for windows, depending on the frame material and the window type, it is between U = 1.4-1.9 W/m^{2}K.

The energy efficiency classes are determined depending on the integrated energy performance of the building expressed through the specific annual energy consumption in kWh/m^2. During the period 2005-2009, the integrated energy performance is determined based on the final energy; after 2009 – based on primary energy.

National Definition for NZEBs:

The national definition for Nearly Zero Energy Building (nZEBs) was drawn up in 2015 and is to become compulsory for all buildings after 1st January 2021. According to the National Definition, the nZEB is a building which meets the following requirements:

1. The energy consumption of the building, determined in primary energy, complies with class A from the class scale for the respective building type;

2. The source of no less than 55% of the energy demand for heating, cooling, ventilation, domestic hot water and lighting is supplied from renewable sources, situated in the building or nearby.

Compliance with the energy efficiency requirements:

According to the national legislation, the compliance with the energy efficiency requirements is achieved when the specific annual consumption of primary energy kWh/m2 matches at least the following energy consumption class:

1. "B" – for new buildings and for existing buildings in use after 1.02.2010;
2. „C" – for existing buildings in use before 1.02.2010;
3. „A" – for nZEB;
4. „A+" – for buildings exceeding the national requirements for nZEB.

Energy class	EPmin, kWh/m^2	EPmax, kWh/m^3	RESIDENTIAL BUILDINGS
A+	<	48	A+
A	48	95	A
B	96	190	B
C	191	240	C
D	241	290	D
E	291	363	E
F	364	435	F
G	>	435	G

Figure 8. Energy consumption classes' scale

The energy efficiency of a building is rated in relation to the value of its integrated energy performance, which represents the specific consumption of primary energy per area unit, calculated in accordance with the normative requirements for the micro-climatic levels in the respective building under standard outdoor climate conditions. The energy consumption classes' scale is presented in *Figure 8*.

Here we can state our expert opinion that it was namely in the 1990-s in Bulgaria when we witnessed the lowest quality of the construction of residential buildings. Until 1999, all buildings were designed and build without any insulation on the external walls. The multi-family buildings erected in this period need renovation no less than those built before 1990 and their potential for energy savings is just as high. Unfortunately, there is no available statistical data, which could facilitate the separate review of these buildings, so the sample suggested by the World Bank will be used for further analysis.

Energy renovation of multi-family residential buildings in Bulgaria

History and practices in the energy renovation of multi-family buildings

At this stage, the private initiative for renovating the multi-family residential buildings does not yield significant results. The buildings that had been completely renovated at the initiative of their owners represented a negligible number and, generally, an extremely rare exception. The usual practice is for owners of separate dwellings to have thermal insulation added on external walls adjacent solely to their own apartments and to replace the windows only of certain dwellings. This is neither an effective method in terms of saving energy, nor does it have a positive effect on the overall appearance of towns in Bulgaria.

Four different initiatives, aimed specifically at the energy renovation of multi-family buildings, have been realized so far in Bulgaria. Three of them are:

- From 2007 to 2011: the realization of the MRDPW and UNPD demonstration project *Renovation of multi-family residential buildings* (*2007 -2011*), in cooperation with several Bulgarian municipalities. The total value of renovation works under this project is about BGN 11 million, and about 50 multi-family buildings have been renovated;
- From 2012 to 2015: The realization of the Project *Energy renovation of Bulgarian homes,* by the MRDPW Directorate of Residential Policy, under "Regional Development" Operation Programme 2007-2013. 158 buildings (or building sections) were renovated under this project, initially through granting 50% of the funds and afterwards increasing the grant to 75%. with a total value of the granted funds amounting to upwards of BGN 50 million. The building and construction work for 137 other contracted buildings is transferred to the Energy Efficiency of Multi-Family Residential Buildings National Program (see below), where the grant for its completion is 100%;
- From 2014 to 2020: The renovation of 429 buildings in 28 smaller municipalities, under Priority Axis 2 Support for Energy Efficiency in Urban Centers in the Peripheral Areas under "Regions in Growth" Operational Programme 2014-2020, with total value of the renovations being a bit over BGN 103 million.

Undoubtedly, the most significant and the most wide-ranging initiative of this type is the ***National Programme for Energy Efficiency of the Multi-Family Residential Buildings***. The program was launched in 2015 and the expected completion is scheduled for the end of 2019, with a total number of buildings in its scope amounting to 2022.

Unfortunately, the rules of the Programme did not include a detailed monitoring of the results. In 2019, outside the scope of the Programme, SEDA, pursuant to Art.39, 3 of the Energy Efficiency Act (EEA) started to require that the owners' associations, whose buildings have been renovated for over one year, to deliver a consequent energy efficiency audit, to be used as a basis for issuing a certificate for the results achieved in terms of energy savings and to obtain an updated EPC. Unfortunately, as of the date of preparing this survey, the authors have no data available for such consequent audits. The only source of data that can be subjected to analysis is the full database of the preliminary energy audits, encompassing the projected energy savings estimates.

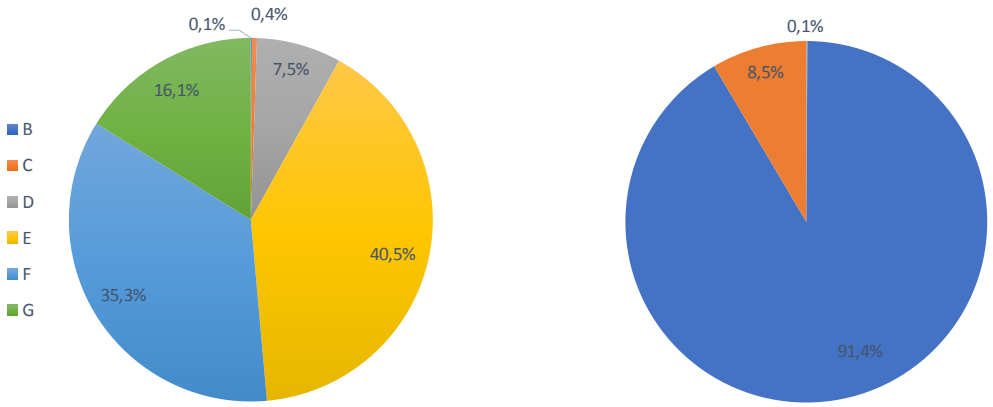
Impact analysis of the implemented energy efficiency measures

As just mentioned, due to the lack of sufficient data from monitoring of the results, the most representative assessment of the effect of the implemented measures is based on the data from SEDA, containing information from the energy efficiency audits carried out before the renovation. In these audits, the energy auditors have recommended the measures taken up subsequently and have provided estimates for the investment needed for achieving the required energy savings.

According to this set of data, the actual measured annual energy consumption in all 2022 buildings is 962.3 GWh per year in total. The "normalized" annual energy consumption, as calculated by the energy auditors, corresponding to the consumption required for the meeting of the normative temperature levels for the building's overall heated space, is 1773,3 GWh

per year or all buildings. In other words, the actual consumption is **approximately a half** of that required for maintaining optimal levels of thermal comfort.

And it is namely the "normalized" consumption that is subjected to assessment in order to determine the energy consumption class of the building; additionally, it is used calculating the projected energy savings.



9a) Before renovation *9b) After renovation*

Figure 9. Energy consumption classes of multi-family residential buildings from the National Programme before and after renovation

Before the renovation, the energy consumption class of most of the buildings is "E" (40.5 %), the second biggest group being buildings with energy consumption class "F" (35.3%), followed by buildings with class "G" (16.1 %). After renovation, 91.4% of the buildings have attained class "C", while class "B" is awarded to 8.5%. What is interesting here is that 2 of the buildings are given class "D" after renovation (*Figure 9*).

The energy efficiency measures in the database are distributed into 12 categories, corresponding to the categories determined in the mandatory summary form in the template for the energy efficiency audit of buildings. The most commonly implemented measures are connected with the improvement of the energy performance of the building envelope, as actually in each renovated building in the scope of the National Programme such measures are implemented. Installing insulation on the external walls is the most common improvement, performed in 2020 of the buildings in total. The statistics for the frequency of the implemented measures is presented in *Figure 10*. Obviously, there are 5 types of measures taken that stand out most prominently. Among them, the measures related to improving the lighting are also implemented frequently, but they concern mostly the replacement of the lighting in the buildings' stairwells and sometimes upgrading them to automatic mode.

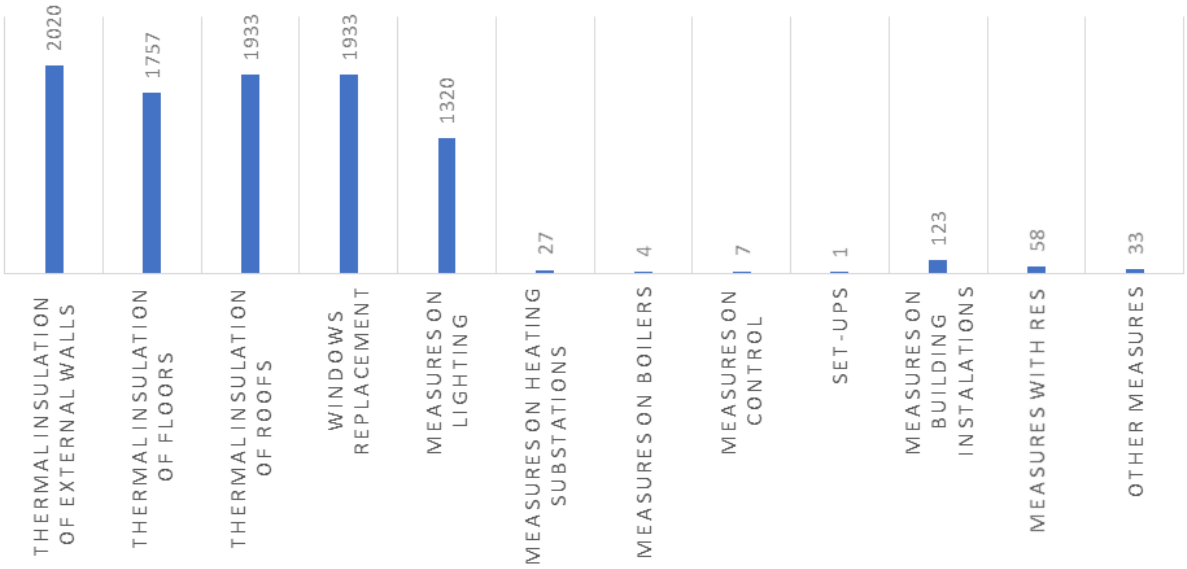


Figure 10. Types of energy saving measures taken under the National Programme

The key indicators for the energy renovation within the National Programme, calculated as average data for all 2022 buildings, are presented in *Table 2* below.

It is notable that, according to the energy auditors' estimates, the investments required to implement the measures amount to BGM 973.5 million while the budget for the Programme was BGN 2 billion, with the full amount contracted. There are several reasons why these values cannot be compared in a straightforward way. Firstly, the National Programme included other eligible costs, which are not directly related to the energy efficiency measures, such as refurbishing stairwells, replacing rainwater pipes and gutters, lightning conductor installations and railings, etc. During the first year of the implementation of the Programme, in some towns (such as Burgas) special additional measures were implemented for rearranging and concealing air-conditioning systems on the facades and installing a common condensate evacuation system. What is more, all ancillary expenses related to the construction – energy and technical audit, design, construction works inspections, authors' and investors' monitoring were also included in the budget.

Table 2. Key indicators for energy renovation of multi-family residential buildings carried out under the National Program

All buildings	**All measures**
Number of buildings	2021
Building area in thousands m^2	10991,5
Investment, in million BGN.	973,5
Annual mean actual specific energy consumption of the buildings before renovation, in kWh/m^2 per year.	87,6

Annual, average "normalized" specific energy consumption of the buildings before renovation, GWh/m^2per year.	161,3
Final energy savings, GW per year.	934,3
Specific final energy savings, kWh/m^2	85,0
Annual, average "normalized" specific energy savings of buildings after renovation, in GWh/m^2per year.	76,3
Savings, in million BGN per year	118,5
Average pay-back period, in years.	8,2
Investment per kWh of final savings, in BGN per Wh	1,04
Specific investment in BGN/m^2	88,57
CO_2, emissions reduction in Kt/year.	308,7
Investment per ton of reduced emission CO_2, BGN/tCO_2	3153,3

Initially the program started with no limitations of the expenditure for separate buildings, and as a result the first renovations were completed at comparatively higher prices. This fact forced the MRDPW to introduce reference prices which could not be exceeded. These referent prices were reduced two more times after follow-up analyses carried out by the Ministry. Furthermore, the MRDPW limited the eligibility of many of the ancillary works with no direct relevance to energy efficiency. The reference prices for implementing eligible measures are summarized in *Table 3*. What could be calculated based on the data presented, is that had all 2022 buildings have been completed in accordance with the latest reference prices for buildings with less than 8 floors, the total investment would amount to less than BGN 1.7 billion. If all ancillary expenditures are excluded, and what is taken into account is only the construction work expenditures, the total investment will amount to about BGN 1.52 billion. The discrepancy between that amount and the estimated value (BGN 0.973 billion) remains considerable. The most significant reason is that the energy auditors seriously underestimate the financial aspect of the energy efficiency audit and do not have detailed knowledge about the market prices; what is more, they fail to evaluate a considerable part of the construction works. Undoubtedly, some of the measures that are not related to energy efficiency, are not evaluated by the energy auditors as well. Thus, it is also likely for the latest MRDPW version of the reference prices to be revised and the values to be refined.

Table 3. Reference prices of the MRDPW for completing the energy renovation under the National Program

Activity	Dimension	26 October 2015		25 January 2016		6 October 2016	
		BGN, without VAT	BGN, with VAT	BGN, without VAT	BGN, with VAT	BGN, without VAT	BGN, with VAT
Expenditures for technical audit and technical passport issue and for energy audit	m^2	12,50	15,00	7,00	8,40	5,00	6,00
Expenditures for project design and for designer-side supervision	m^2	15,00	18,00	8,00	9,60	5,00	6,00
Expenditures for conformity assessment of the investment project	m^2	2,00	2,40	1,25	1,50	0,85	1,02
Expenditures for construction supervision	m^2	7,00	8,40	2,50	3,00	1,75	2,10
Expenditures for construction and installation works - buildings less than 8 floors	m^2	250,00	300,00	140,00	168,00	115,00	138,00
Expenditures for construction and installation works - buildings over 8 floors	m^2	250,00	300,00	140,00	168,00	130,00	156,00
Expenditures for Investor-side supervision	m^2	4,00	4,80	1,25	1,50	0,85	1,02
TOTAL – buildings less than 8 floors	m^2	**290,50**	**348,60**	**160,00**	**192,00**	**128,45**	**154,14**
TOTAL – buildings over 8 floors	m^2	**290,50**	**348,60**	**160,00**	**192,00**	**143,45**	**172,14**

According to the data presented in *Table 2*, the annual energy savings is 934.3 GWh per year, which, as we have already specified, is calculated against the "normalized" consumption before renovation, amounting to 1773.3 GWh per year, i.e. with this assumption, the realized energy savings amount to 52.7 % in total. Consequently, the remaining "normalized" energy consumption after renovation is 839 GWh per year, or energy savings of 47.3 % in total. However, if we compare this value with the actual final energy consumption of the buildings before renovation, which, as specified above, is 962.3 GWh per year, we will see that if all households are heated optimally after renovation, in accordance with the norms, the real energy savings will amount to as little as 123.3 GWh per year, meaning that the energy savings will amount to a mere 12.8 %.

It is reasonable to expect that, if one could achieve better heating for a lower cost, they will improve the thermal levels, if those had not been good enough previously. It could be expected of course that, due to various reasons, this behaviour pattern will not be followed

by all people. Some will retain the heating limitations, others will make partial improvements of the thermal levels, and a certain group will start to heat their dwellings optimally. This means that the actual energy savings, realized under the National Program should be expected to vary within a wide range from 12.8% to 52.7%. The survey questionnaires prepared by the MRDPW and filled in by owners of renovated buildings in 2016 show that the actually achieved reduction in the bills amounts to 24.6%, with a registered increase in the temperatures in premises. Supposing that there is a certain increase in the energy prices and taking into account the improved thermal comfort, we could assume that the actual average savings are nearly 30%. Assuming that the actual savings amount to 30% would mean that people will be using approximately 20% less energy than that estimated by the energy auditors as "normalized" consumption of final energy after renovation. This simple calculation is visualized in *Figure 11*.

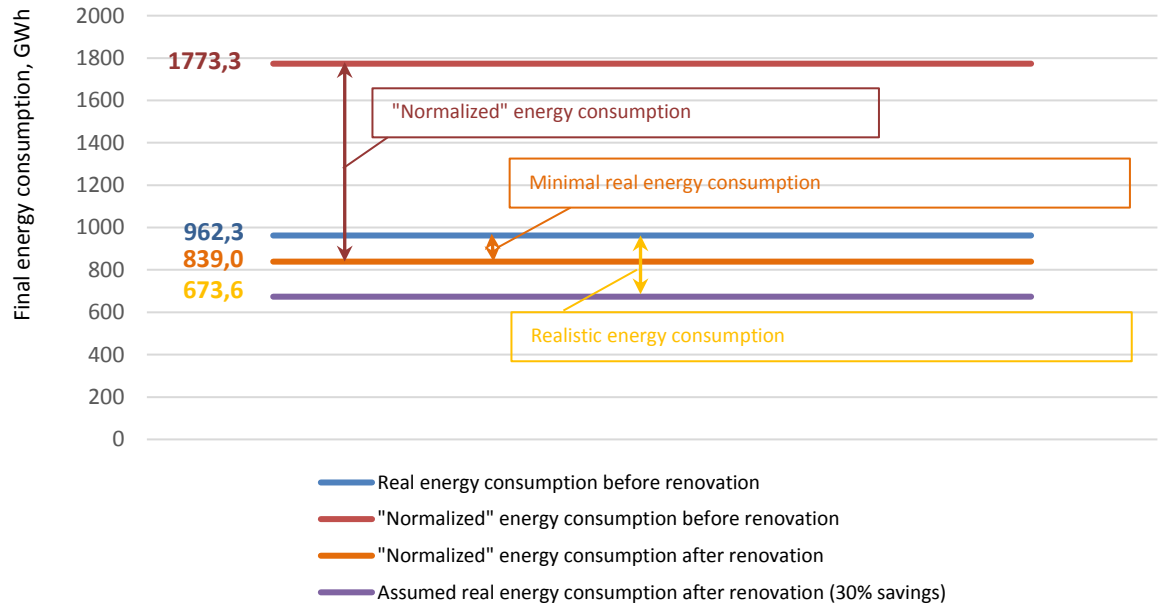


Figure 11. "Normalized" and actual energy consumption in the buildings under the National Programme

In order to analyze the impact of the renovation measures on electrical energy consumption for heating, it is important to consider the statistical reference data that could be extracted from the SEDA database for the separate measures under the National Programme. *Figure 12* shows the specific value of the final energy savings from the different types of measures referenced to the building's useful floor area. What stands out most prominently are two of the measures having the strongest energy saving effect – the external walls' thermal insulation and the replacement of windows. It should be taken into account that this indicator is greatly influenced by the separate enveloping elements and the shape of the building. It is obvious that the buildings within the scope of the Programme, the façade area is considerably bigger than that of the roof and the floor, which could also be expected for the other multi-family residential buildings, not subjected to renovation.

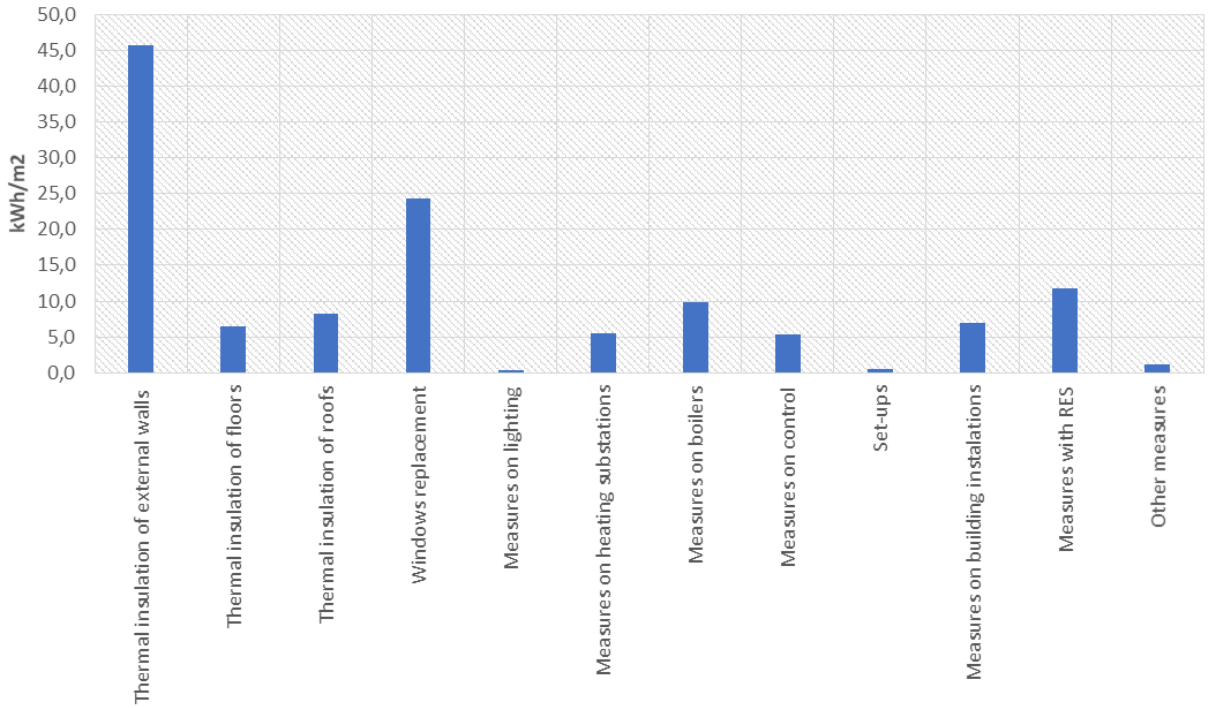


Figure 12. Specific savings of final energy by groups of measures

Most of the names of the different groups of measures suggest by themselves whether the energy savings to be achieved through their implementation relate to the energy consumption for heating or for other needs. There are six measures for which it could be claimed with certainty that they save energy for heating – thermal insulation of external walls, floor thermal insulation, roof thermal insulation, windows replacement, measures for substations and boilers. As of the measures, related to the lighting, it is obvious that they are not meant to deliver heating energy savings, while for the rest of the measures, the information available is insufficient for making valid judgements. We will assume that they are not related to the heating so that our assessment of the amount of energy savings is more conservative. Despite that fact, the realized energy savings by measures show that almost 99% of the overall "normalized" energy savings or, in total, 921.5 GWh/year is connected to heating, while for the other energy needs, the amount of realized energy savings is 12.7 GWh/year in total.

The next two figures – *Figure 13* and *Figure 14*, show the specific average investment for the different measures, referent to the average useful floor area of the buildings and the average buy-back period of the investment by separate measure. What was used in this case is the investments determined by the energy auditors, which, as we specified earlier, are underestimated. Therefore, it is not appropriate to use the resulting values as standpoints for further analyses, but they could serve as a basis for comparing the separate measures in terms of those indicators.

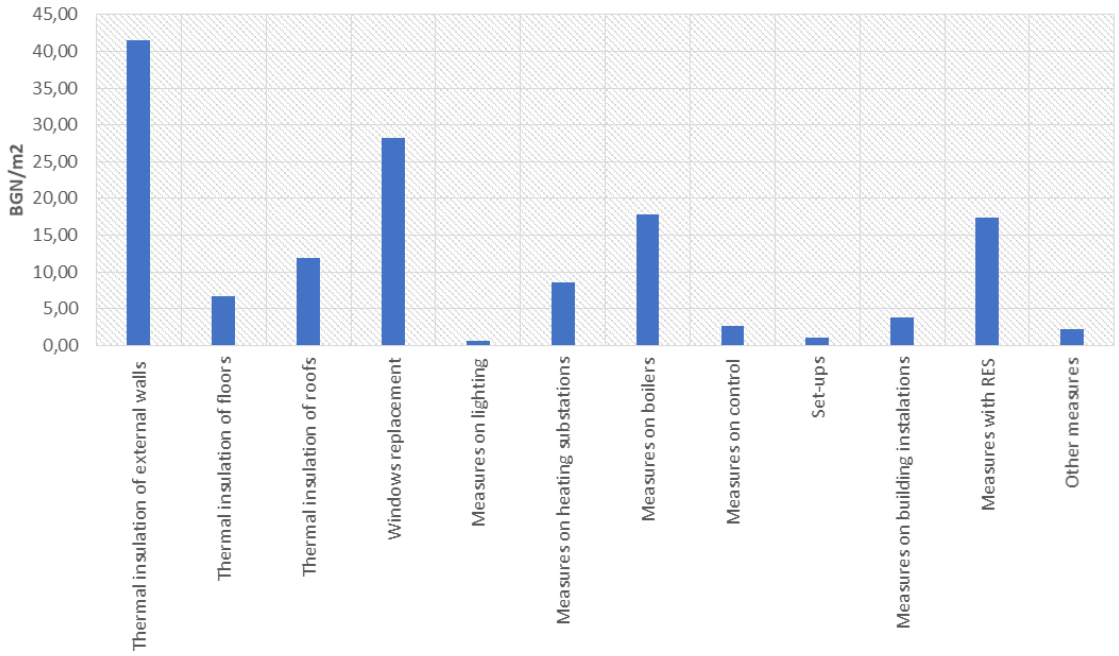


Figure 13. Average specific investments for useful floor area unit by types of measures

As *Figure 12* shows, the biggest investments are mainly for those measures which lead to the highest energy savings. *Figure 14* however shows that the most expensive measure – the thermal insulation of external walls, is more cost effective than most measures and the buy-back period of the investment is shorter than the average buy-back period for all measures.

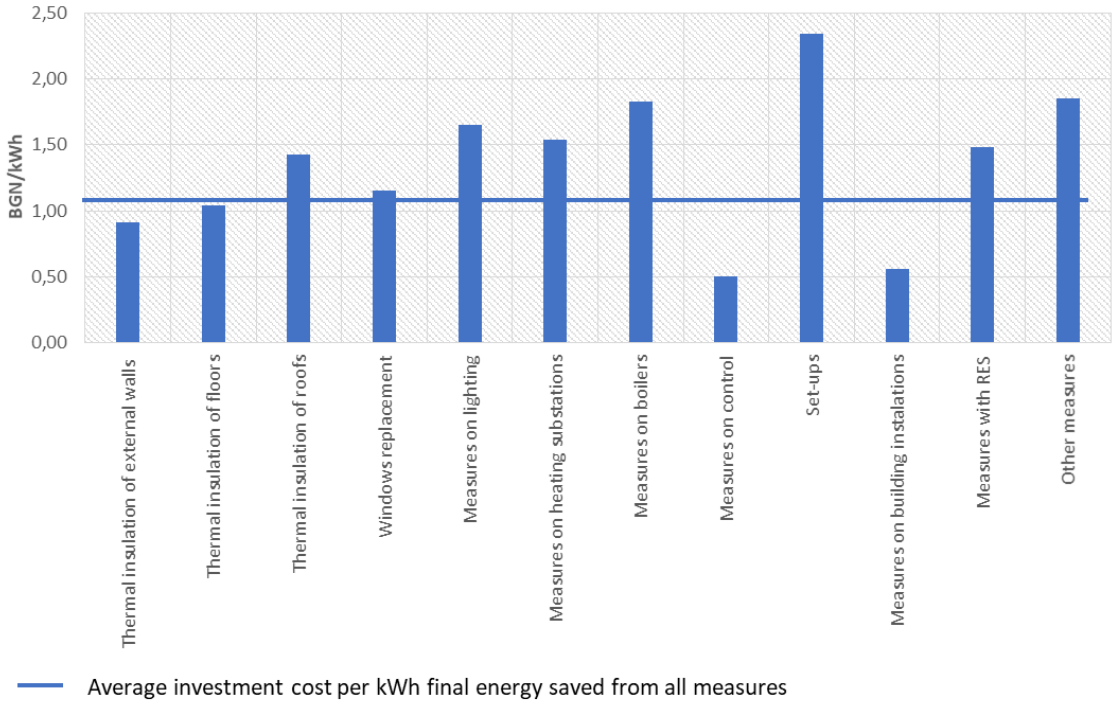


Figure 14. Average buy-back period for different measure types

Of the five most commonly implemented measures (see *Figure 10*), three are the more cost-effective ones with a buy-back period shorter than the average for all measures. The least cost-effective one is the thermal roof insulation. This is due to a great extent to the fact that for many buildings where it is installed externally, the investment includes hydro insulation expenditures which do not lead directly to energy savings, but they are obligatory as they protect the thermal isolation and avoid compromising it.

Another interesting visualization found in the World Bank report cited above shows the relationship between the investment and the useful floor area of buildings (*Figure 15*). In this case the data used is for the real investment for the respective buildings and it is taken from the reports of the Bulgarian Development Bank, published on its website.

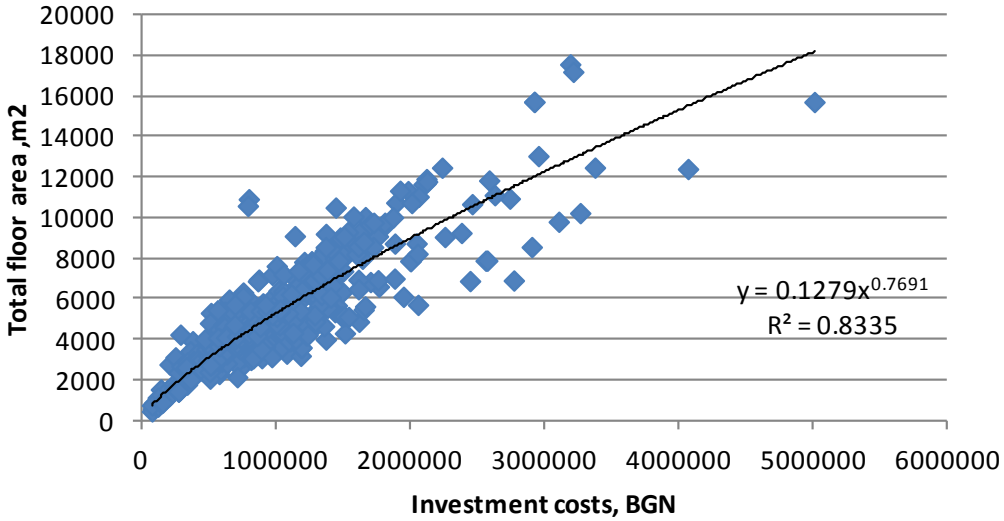


Figure 15. Relationship between the investment and the useful floor area when renovating buildings under the National Program

As expected, it could be seen on the graph that the relationship between the investments and the area of the buildings is not proportional. On the other hand, the deviation of the curve from a perfectly straight line is not too pronounced. It could be considered that if the average investment cost is used to calculate the total investment for another multitude of similar buildings, the deviation would be within the acceptable range for macroeconomic analyses.

Determining the potential for reduction of the electrical energy consumption through energy efficiency renovation of residential buildings

Based on the information presented so far, it is clear that the households use most of the energy for heating and that the share of the electricity used for heating is particularly high in multi-family residential buildings and especially in those which are not connected to district heating networks.

Respectively, the energy efficiency measures leading to reductions in energy consumption for heating will have the highest contribution to the reduction of electrical energy consumption.

At the same time, the efforts should be focused namely on multi-family buildings, which are not connected to district heating networks.

What could be achieved if the renovation continues the way it is carried out up to now and all multi-family residential buildings suitable for renovation fall into its scope?

Let us use the World Bank data from the report cited above as a basis. According to that report, just under 42,000 multi-family residential buildings (see *Table 1*) with a total area of 57 million m^2 need renovation. In order to determine the needed investment, the analysts from the World Bank have justified a price of 166 BGN/m^2. This is the average of the reference renovation prices determined by the MRDPW for residential blocks of flats less than 8 floors (BGN 154,14/m^2, VAT included) and for blocks with more than 8 floors (BGN 172.14 /m^2, VAT included). As we have already seen, applying the proportional specific price per unit of useful floor area is reasonable and will not lead to a significant deviation (*Figure 1*5). According to the World Bank, the realistic renovation rate is 400 buildings per year at 10% annual increase of the rate, with which, as a result, 25.5 years will be needed for the renovation of all buildings. The bank assumes that the annual increase in the cost of investment will amount to 2.5%, and on the basis of that assumption it is calculated that the investment needed for renovation amounts to a total of BGN 21 billion. Considering that there are about 29,300 multi-family residential building not connected to district heating networks with a total area of about 57 million m^2, if it is assumed that the same renovation duration and the same annual increase of the cost of investment as those presented by the World Bank are applied, the investment required for them will be about BGN 14.5 billion.

In terms of energy savings, obviously, it will be the actual savings rather than the "normalized" ones that will have an impact on the national energy balance. Therefore, it is namely their amount that should be determined. For the buildings within the scope of the National Programme (see figure 2), the average specific "normalized" energy consumption before renovation is 161.3 kWh/m^2, and using it, it could be calculated that the total "normalized" energy consumption of the multi-family buildings which are not connected to district heating networks and are not renovated, will be about 9,194 GWh per year. The total actual final energy consumption before renovation, calculated using the specific value of 87.6 kWh/m^2, will be about 4,993 GWh per year. After renovation, the specific "normalized" energy consumption is expected to be about 4,349 GWh per year. The "normalized" energy savings are 4,845 GWh per year. As shown on *Figure 1*1, the realistic savings compared to the actual final energy consumption are up to 30%. This means that the total final energy consumption of the surveyed group of multi-family buildings could be expected to decrease to 3495 GWh per year, or that the actual realized energy savings will amount to 1498 GWh per year. In the analysis regarding *Figure 1*2 we specified that about 99% of the energy savings in the National Program are related to the heating, from which it could be assumed that the actual energy savings for heating will be about 1483 GWh per year.

As it was already clarified during the analysis of *Figure 4*, the share of electrical energy for heating in the buildings which are not connected to district heating networks is about 72,5%, which means that the actual electrical energy savings could be expected to be about 1075

GWh per year. As part of the saved energy, which is not for heating, will also be electrical energy, it could be assumed that the saved energy will be about 1080 GWh per year.

The summarized calculations made so far about the electrical energy savings which could be achieved by applying the existing practices of renovating of multi-family buildings are presented in *Table 4.*

Table 4. Expected reduction of the final electrical energy consumption achieved through renovations of multi-family residential buildings applying the existing renovation practices

All buildings which are not connected to district heating networks	**All measures**
Number of buildings	29 300
Area of the buildings in millions m^2	57
Investment in billion BGN	14,5
"Actual" final energy saved in GWh per year.	1,498
Actual" final electrical energy saved in GWh per year.	1,080
Corrected final total consumption of electrical energy by household in the national energy balance in GWh per year.	10,078

Is it possible to achieve bigger energy savings, ensuring a significant reduction of electrical energy consumption?

The problem of significant amount of the expected energy savings remaining only "on paper" could be solved by applying deep energy renovation. Furthermore, it is the logical policy for the state to follow and apply as a member state of the European Union (EU). It is well known that the EU has set the ambitious goal to achieve zero carbon emissions from heating and cooling of all buildings by 2050. As the buildings existing at present will be the prevailing part of the buildings by that time, the attaining of this goal inevitably involves achieving of maximal improvement of the energy performance of existing buildings. The electrical energy is the resource used for heating which has a CO_2 emission factor a lot higher than the other resources used for heating. What follows from this is that the most significant contribution for attaining this ambitious goal of the EU is the deep renovation of residential buildings with the largest share of electrical energy used for heating.

What should deep renovation involve, what will be the investments for it and the expected savings?

It is obvious from *Figure 1*2 that what has the most serious impact on the reduction of the energy consumption in multi-family buildings is the measures concerning the building envelope. However, when the buildings have a very big share of the electrical energy, achieving "A" class of energy consumption according to the existing scale for residential buildings by the implementation of these measures only is a very difficult and a rather costly task. This is so because the classes are determined according to the primary energy, while the factor for transforming the final electrical energy into primary is a lot higher than that for other

resources (3 for electrical energy as opposed to 1.0-1.3 for the other resources). Usually only the electrical energy consumption for domestic hot water, lighting and equipment is high enough to exceed the eligible maximum for class "A". If measures for reducing the energy consumption for these other needs should be added to the measures for reducing the heating consumption, this will obviously increase the investment cost.

In order to overcome this hurdle, it is possible to refer to other international energy efficiency standards that focus on the physical characteristics of the buildings defining its energy performance. For example, the *Passive House* standard has set a requirement that the final energy for heating and ventilation should not exceed 15 kWh/m^2 per year. Such a value could be achieved if the building envelope components are insulated with thicker insulation materials compared to the reference values determined in the national legislation (see *Table 3*) and if sufficient airtightness is ensured. Of course, the high level of airtightness will significantly limit the natural infiltration of fresh air in the premises. This means that if we want to achieve such a value of the energy performance for heating, it is compulsory to provide mechanical ventilation with heat recovery. Building classical central ventilation system with air ducts will increase the cost of investment. For renovation of multi-family residential buildings, it is more appropriate to use decentralized heat recovery systems, mounted on the external wall.

In order to check what conditions are needed to reach the value determined by the requirement cited from the *Passive House* standard, or a value close to it, we used detailed data and calculations from the energy efficiency audit of a building, which has been renovated under the National Programme, and complemented them with more in-depth analysis. We assume that a renovation as described below can be considered as "deep renovation".

The building is a prefabricated panel block of flats with an area of 4575 m^2, which is not connected to district heating. The mix of energy resources used for heating is as follows: 32% electrical energy; 7% electrical energy with air conditioning systems; 56% energy from firewood and 5% energy from coal. In order to achieve values in the energy balance of the building that are closer to the mean distribution of resources in buildings which are not connected to district heating networks (with a share of electrical energy 72.5%), we recalculated it with the following ratio: 60,2% electrical energy; 12,3% electrical energy with air-conditioning system; 22,5 % energy from firewood and 5% energy from coal. As the actual energy consumption in this specific case is different from the "normalized" value with varying percentage compared to the average for all 2022 buildings, we made additional corrections to the actual consumption so that it corresponds to the average.

In order to determine what the energy consumption in case of "deep renovation" will be, we corrected the thermal insulations thickness in the recommended measures as follows: for walls - 15 cm (U=0,24 W/m^{2}K); for roofs - 20 cm (U=0,19 W/m^{2}K); and for floors – 15 cm (U=0,20 W/m^{2}K). We also added decentralized ventilation with heat recovery, by using a lower recovery rate (70%) than that given by producers (79%), in order to be more conservative in the results. We added the necessary additional energy cost for the functioning of the fans of the ventilation system.

The energy balance of the building is shown in *Table 5*. The presented result for the existing (actual) consumption and for the "normalized" consumption before renovation of the building are according to the energy efficiency audit, used for the renovations under the National Programme, with minimal correction of the mean efficiency coefficient of the heating source, in accordance with the corrected mix of resources used for heating. The actual state before renovation is additionally corrected according to the average rate of deviation from the "normalized" value for all buildings under the National Program.

Table 5. Energy balance of the test building before renovation and when deeply renovated

Group of consumption units	**Existing state before renovation**		**"Normalized state before renovation**		**After "deep" renovation**	
	kWh/m²	**kWh/a**	**kWh/m²**	**kWh/a**	**kWh/m²**	**kWh/a**
Heating	41,7	190 867	104,7	478 936	12,9	58 892
Ventilation	0,0	0	0,0	0	4,0	18 194
Electrical energy for heating water for household needs	15,3	70 133	15,3	70 133	5,5	70 133
Pumps and fans	0,0	0	0,0	0	0,3	1 304
Lighting	2,9	13 399	2,9	13 399	2,9	13 399
Appliances	14,9	68 018	14,9	68 018	14,9	68 018
TOTAL	**74,8**	**342 417**	**137,8**	**630 486**	**40,4**	**229 940**

These calculations show that in this case the specific final consumption for heating and fans achieved in the building in question will be 16.9 kWh/m² per year – a value which is close to that required in the *Passive House* standard. The annual savings realized compared to the actual energy consumption after renovation will be 112,477 kWh per year. However, such an amount will be saved provided that all dwellings in the building are heated in accordance with the optimal conditions determined through the "normalization". In the analysis of *Figure 1*1 we already drew the conclusion that the actual energy consumption after renovation will be about 20% lower than the calculated normalized energy consumption after renovation. In this case the actual amount of energy saved will be 34.6 kWh/m² per year. The electrical energy savings will amount to 25.1 kWh/m² per year.

If we extrapolate these results to the total area of multi-family buildings not connected to district central heating, which have not been renovated (57 million m²), we can see that the actual final energy savings achieved through deep renovation, realized with the measures described above, would amount to 1,974 GWh per year. The actual savings of final electrical

energy will be 1,431 GWh per year. The overall final consumption of electrical energy by households in the national energy balance will decrease to 9 707 GWh per year.

The estimation of the cost of the works and materials for the renovation of the building is prepared by the construction company based on the energy efficiency audit. The same construction company corrected the estimates of works and materials in accordance with the option offered for "deep" renovation and the measures included therein. The increase of the investment cost was estimated by the construction company to be 79%. Taking into account the investment cost for the typical renovation of multi-family residential buildings, proposed by the World Bank - BNG 166/m^2, of which 148.84 BGN/m^2 are the construction works expenditures and 16.16 BGN/m^2 are the ancillary cost for the construction process (audit, design, inspections, etc.), the specific cost of "deep" renovation would amount to 266.5 BGN/m^2. At this cost, and if the same pace and period for renovation as proposed by the World Bank are applied, the costs required for the renovation of all 29,300 multi-family residential buildings will amount to 23.3 BGN billion.

The generalized calculations made for the "deep" renovation option are presented in *Table 6*.

Table 6. Expected reduction of the final consumption of electrical energy in case of "deep" renovation of buildings which are not connected to district heating networks

All buildings which are not connected to district heating networks	**All measures**
Number of buildings	29 300
Area of the buildings in million / m^2	57
Investment in BGN billion	23,3
"Actual" final energy savings in GWh per year.	1 974
Actual final electrical energy savings in GWh per year	1 431
Corrected total electrical energy consumption by households in the national energy balance in GWh per year.	9 707

As the other main resource used for heating in the buildings in question are the solid fuels, the deep energy renovation will also contribute to the reduction of air pollution. Moreover, the high airtightness rates will limit the use of wood and coal burning stoves naturally. Therefore, the building renovation policies and the respective financial instruments should be considered and designed in combination with the policies for overcoming the air pollution problems. The requirement to obliterate the solid fuel altogether could even be an absolute requirement for the owners who want to participate in the public programs for renovation of residential buildings.

In theory, the energy efficiency audits for each individual building must show the exact measures appropriate for that building. In many cases, it is also possible to combine the measures in the building envelope with installation of highly efficient air-conditioning systems, which could effectively replace all other (polluting) heating means. In this respect, the example provided by Burgas should be studied and a certain amount of additional financing

for concealing the air-conditioning systems on the buildings' facades as well as for devising a common system for condensate evacuation could be provisioned. In order to implement the measures concerning the air-conditioning systems, the financial resource could be provided from the REECL credit line for households' energy efficiency, in case it continues to exist.

Potential for installing of small photovoltaic systems

The electrical energy consumption could be reduced even further if small photovoltaic systems of up to 30 kWp for the building's own consumption are installed. According to the *Renewable Energy Sources Act* these installations are subjected to a simplified procedure for joining the high-voltage network. Assuming that on the roofs of one third of the buildings in focus there is enough free space and implementation of such measures is technically possible, about 9700 installations with a total power of 291 MWp could be mounted. With an average productivity of monocrystalline installations for Bulgaria of about 1150 kWh/kWp per year[7], the annual amount produced could be expected to be 334 GWh of electricity, which can be consumed in the buildings and replace the respective amount of conventional energy. With a specific investment of no more than BGN 2/Wp, the cost of investment for that measure would be about BGN 582 million.

Thus, the combination of deep renovation measures for multi-family residential buildings, not connected to district heating networks, and installing small photovoltaic installations of up to 30 kWp on the roofs could contribute to reducing the final energy consumption with 1765 GWh per year.

Survey limitations and further electricity saving potential

At first glance, these savings may not seem very significant, since they amount to about 16% of current household electricity consumption. However, there are several factors to consider:

- The analysis covers only multi-family buildings, which are not connected to district heating network – those which have the highest savings potential and for which data is available. They represent about 70% of all multifamily buildings that perform only residential functions. This account does not include mixed-use residential buildings (buildings where part of the area is for commercial use), as well as the non-monolithic multi-family buildings. If all multi-family buildings in the country are taken into account, the proportion of buildings from which the final amount of energy saved is derived remains below 50%.
- If we extrapolate the actual energy consumption before renovation in the reference building to all multi-family buildings not connected to district heating networks, and take into account that 72.5% of households use electricity for heating, then the total final annual electricity consumption for this group of buildings will be around 3610 GWh/year. This figure represents about 32% of total household electricity consumption. Given that less than 50% of multi-family buildings are included in the scope of the analysis and all houses are excluded, the resulting value for annual final energy consumption seems realistic.

[7] Source: https://re.jrc.ec.europa.eu/pvg_download/map_index.html#!

- The total area of houses country-wide is approximately equal to that of multifamily buildings. Although the share of the heating with electrical energy in these buildings is low, electricity is used as a source of energy for all other needs. In addition, specific energy consumption is higher in homes than in multi-family buildings. This explains the relatively large remaining share of electricity needed, which, however, also has the potential to generate savings.
- The measures considered are mainly related to saving energy for heating. This means that no electricity savings for DHW, lighting and appliances are reported. Typically, in multi-family buildings, the share of these energy consuming devices in the annual final energy consumption is about 20-30% before renovation and after "normalization" of energy consumption, and about 40-50% compared to actual consumption at reduced temperature comfort levels. This potential for savings is the subject of other policies.
- If no renovation of the buildings is carried out, with the gradual increase in the standard of living, the consumption of energy for heating in the buildings concerned will increase, providing better thermal comfort of the households. On the contrary, if the buildings are renovated, the heating energy consumption will remain at the levels obtained in the calculations above, since the expected energy savings are set at the current comfort level before renovation and provided that after the renovation the comfort will be "normalized". This means that there are hidden savings that can quite realistically reach about two thirds of the current estimates, i.e. they are about 7-8% more compared to the current electricity consumption of households.

In order to evaluate and compare the cost-effectiveness of previous building renovation practices and deep energy renovation, a financial analysis of the costs and benefits of the entire life cycle of buildings should be made. The financing method and the percentage of the grant should also be taken into account; another thing that needs to be determined is the set of options which are most beneficial for homeowners. Such financial analysis is not the subject of this study. Another study by the Building Performance Institute Europe, the Technical University of Vienna, EnEffect and Za Zemyata presents an in-depth analysis on this topic.[8]

Conclusion

In confirmation of the initial hypothesis, the renovation of the residential building stock has significant potential to exercise tangible impact on the energy balance and the design of the Bulgarian electricity supply system. Although information is not readily available for all segments of the building stock and in-depth analysis requires further efforts in data collection and management, the execution of the National Program for Energy Efficiency of the Multifamily Residential Buildings (NPEEMRB), and more specifically, the database of completed energy audits of 2022 buildings, allows us to calculate the potential electrical

[8] BPIE (2016) Accelerating the renovation of the Bulgarian building stock. Налично на: http://www.eneffect.bg/images/upload/Novini/Accelerating-the-renovation-of-the-Bulgarian-building-stock_EN.pdf

energy savings in a certain building stock segment and to align them to the structure of the energy demand and supply as reported by the National Statistical Institute (NSI).

More specifically, after a review of the total building stock, the analysis is focused on the monolith-structure multifamily residential buildings (with no commercial premises) eligible for renovation, which are not connected to a district heating system, as they are most prone to use electricity as the main heating sources. Representing less than a half of all multifamily buildings, they are accountable for domestic electricity consumption of 3610 GWh/year. Overcoming the limitations of the standard approach in energy audits requiring calculation of the theoretically necessary rather the actually spent energy, the analysis determines the actual savings that have a real bearing on the country's energy balance. Then, on the basis of a selected reference building, the potential actual savings through reaching a higher energy class are calculated, aided by electricity supply by PV systems situated on the available roof space (1/3rd of the roof area). As a consequence, it is determined that only through measures in the building envelope and by using the potential for onsite PV electricity production in this particular segment, it is possible to achieve electricity savings of 1765 GWh/year – an amount which is comparable to the net electricity production of "Bobov Dol" TPP or to the electricity purchased by the National Electric Company from Maritsa-East 2 in 2018. The total potential savings are much bigger, as this calculation excludes measures in the heating systems or the appliances.

Throughout the analysis, estimations of the costs for the analysed existing and suggested future measures are offered. Based on the current and previous research works, it is firmly believed that a life-cycle cost optimality approach would yield convincing results supporting policy measures for renovation of the residential buildings towards ambitious energy efficiency classes at much lower intensity of the public spending compared to the current practice. However, further research is needed in this direction.

In any case, a clear policy recommendation stands out as a result of the performed analysis: the renovation of the residential building stock needs to be taken into account as a factor influencing the design of the electrical energy supply structure. This has to be reflected in the national Energy and Climate Plan as per the requirements of the Regulation (EU) 2018/1999 on the Governance of the Energy Union, providing the still missing bottom-up sectoral analysis of the energy demand and energy saving potential. In addition, the National Long-term Renovation Strategy, due on 20th March 2020, should consider and potentially prioritize the segments of the building stock with highest potential to influence the phase-out of the most inefficient supply-side energy capacities.

Center for Energy Efficiency EnEffect, November 2019