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

Policy Brief

While reviewing the summary of the draft National Energy and Climate Plan of Bulgaria, one couldn't help noticing that energy efficiency is quoted among the national energy priorities, targeting *"increasing energy efficiency through the development and application of new technologies to achieve modern and sustainable energy system"*. Obviously, this statement implies that energy efficiency is an important element for the balancing of the energy system, with direct implications to the energy supply-side. Further on, energy efficiency is rightfully associated with *"achieving energy savings in final consumption and energy generation, transmission and distribution activities, and improving the energy performance of buildings"*.[1]

Starting with these good omens, the draft plan provides brief information on the expected development of a long-term national strategy to support the renovation of the national building stock with interim indicative targets for 2030, 2040 and 2050, indicative description the financial means to implement the strategy, and effective mechanisms to promote investment. It should be noted here that the EU is pushing the strategy to identify measures facilitating cost-effective transformation of the existing stock into nearly zero-energy buildings (nZEB). According to data by the National Statistical Institute for 2017, the total useful floor area of the country is slightly above 289 million m^2. On the other hand, the most common class of energy consumption of the buildings applying for National Programme for Energy Efficiency in the Multifamily Residential Buildings (NPEEMRB) is "E". If it is assumed that just 10% of these residential areas will be renovated within the period 2021-2030 to energy consumption class "C" (as per the current regulations), this will realize about 3555 GWh of annual primary energy savings. If the buildings are renovated up to class "B" (as indicated by the 2017 Renovation strategy), the savings will amount up to about 5000 GWh/year, and if upgraded to nZEB level (as per the ambition of the EU) – up to about 7745 GWh/year. Such savings equal about 3.5% of the country's current gross energy consumption and obviously would make a significant contribution to the 25% energy efficiency target.

Having in mind these general estimations, the question below seems quite natural:

"If building renovation is happening anyway, isn't it possible that the generated savings replace some of the most polluting and costly power generation facilities?"

[1] Available at: https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_bg_necp.pdf

Yes, it is, the in-depth analyses show – even though not precisely in this scale. But if we only try to estimate the possible savings just from the most obvious suspect – the monolithic multifamily buildings built before 1990 that are not connected to the district heating network, the annual savings of electricity for heating only through measures in the building envelope and using part of the RES potential can reach the amount of electricity produced by Bobov Dol TPP or purchased by NEC from Maritza-East 2 TPP in 2018. Note - we only consider the potential of less than 50% of all multifamily buildings subject to renovation….

It's worth sparing a thought, isn't it?

AIM OF THE STUDY

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 is 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.

METHODOLOGY

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.

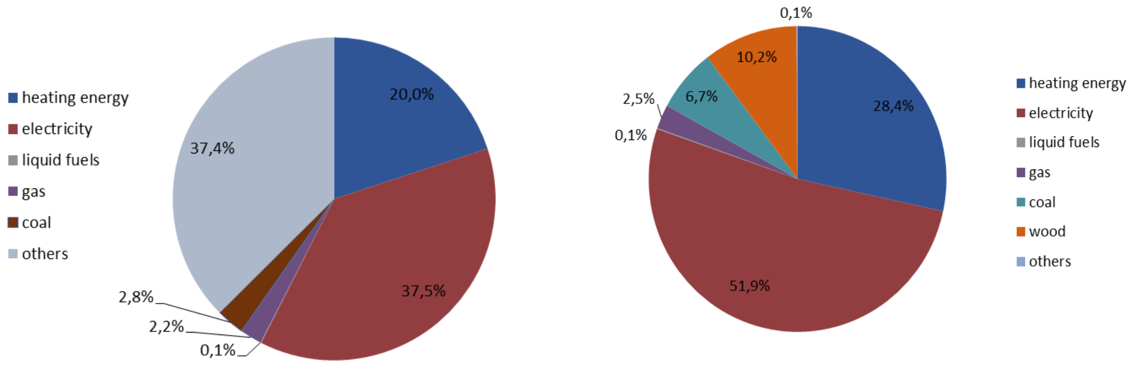
Based on these data, a review of the electrical energy consumption in the residential sector in Bulgaria is made and the state of the residential building stock is analyzed. As a result, the building segment with the greatest potential for electrical energy savings is identified: the monolithic multifamily buildings built before 1990 that are not connected to the district heating network. 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" savings for building renovation projects reaching energy class C, typical for the current

> ***"Normalisation"*** *is a method for 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.*

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 sources with electrical energy 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 programmes on the national electrical energy balance are presented.

MAIN ASSUMPTIONS

Data from the energy audits undertaken within the NPEEMRB show that for those 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 %.**



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

Figure 1. Type of fuels and energy used for heating in dwellings in multi-family residential buildings – before and after redistribution of the fuels in the “Miscellaneous” (“Others”) graph

The World Bank report *Bulgaria: National Program for Energy Efficiency in Residential Buildings. Program Design Report for the Second Phase, June 2018*[2] defines the number of the multifamily buildings suitable for renovation as 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.

Table 1. 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

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

Brick	41,910	27,949	135	27,814
Cast-in-Situ 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 1b*), 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**, with total area of about **57 million m^2**. The potential electrical energy savings are calculated based on this basis, assuming, as it was mentioned above, that the share of electrical energy for heating is **72.5 %**.

ACTUAL ENERGY SAVINGS

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 2*, 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 3,495 GWh per year, or that the actual realized energy savings will amount to 1,498 GWh per year. As 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 1,483 GWh per year.**

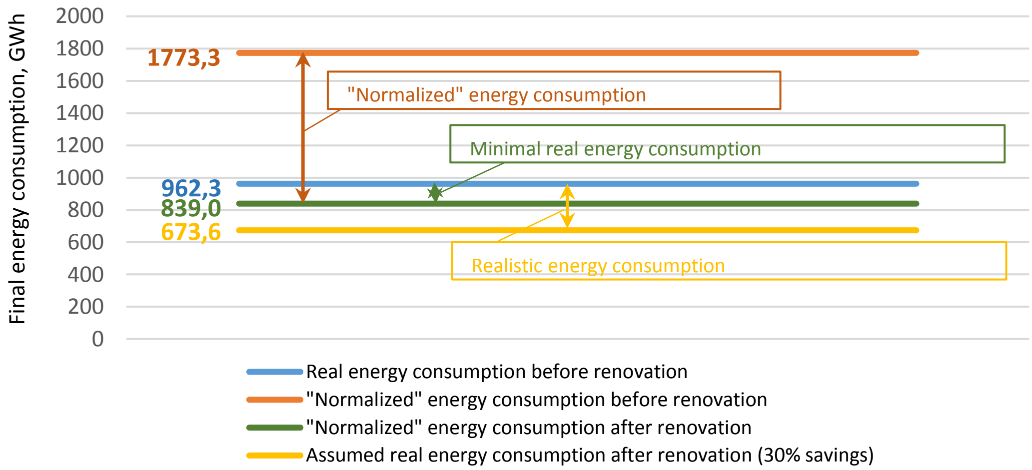


Figure 2. "Normalized" and actual energy consumption in the buildings under the National Programme

As it was already described, 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 "normalized" 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 **total saved electricity will be about 1080 GWh per year**.

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 EU member state. 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 optimal improvement of the energy performance of the existing buildings.

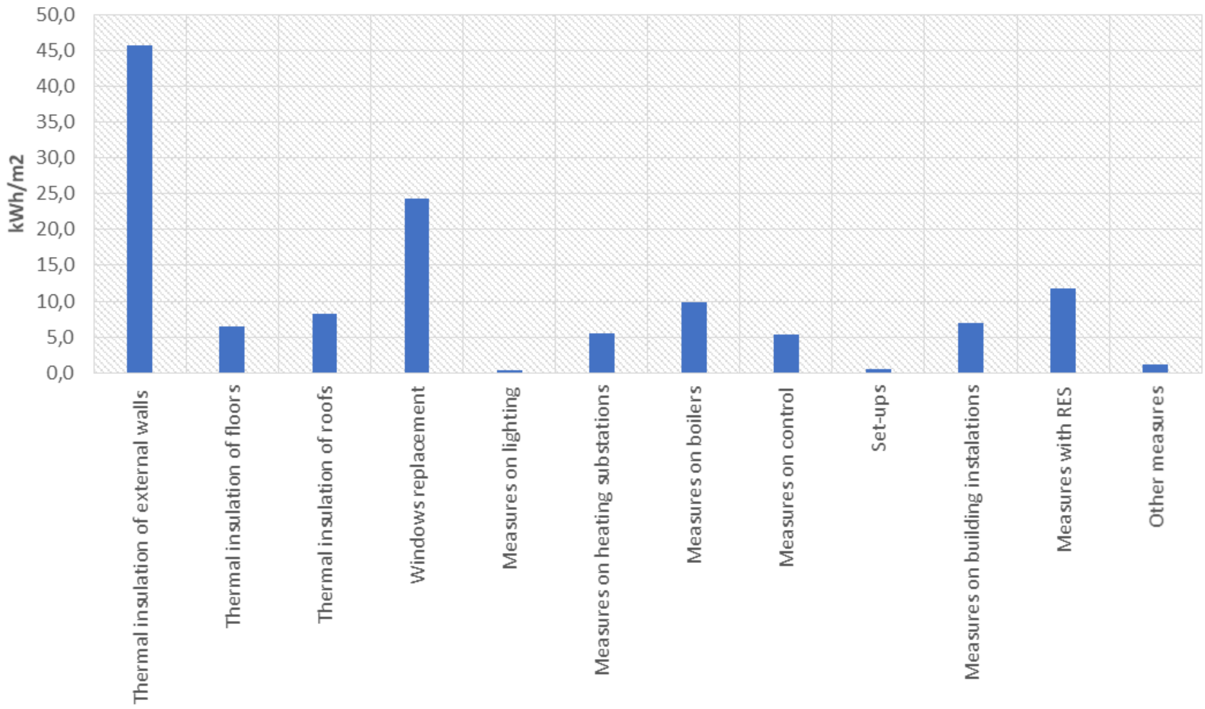


Figure 3. Specific savings of final energy by groups of measures

It is obvious from *Figure 3* that the most serious impact on the reduction of the energy consumption in multi-family buildings is exercised by measures concerning the building envelope. If the building envelope components have better energy characteristics and if sufficient airtightness is ensured, this would definitely lead to significant energy saving. 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. Installing centralized ventilation system with air ducts may increase the cost of investment and induce inconvenience to residents, so the calculation assumes installation of decentralized heat recovery systems, mounted on the external wall.

In order to check what conditions are needed to reach the most ambitious international standards (while at the same time comparable to the national nZEB definition), we used detailed data from an energy efficiency audit of a building renovated under the National Programme, and complemented the calculations with more in-depth analysis. We assume that a renovation as described below can be considered as "deep retrofit".

THE TYPICAL CASE

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^2K); for roofs - 20 cm (U=0,19 W/m^2K); and for floors – 15 cm (U=0,20 W/m^2K). 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 2*. 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 2. Energy balance of the reference building before renovation and after deep renovation

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 DHW	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/m^2 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/m^2 per year. The electrical energy savings will amount to 25.1 kWh/m^2 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 m^2), 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.**

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.

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[3], 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%.
- 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, their share 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 thermal comfort levels. This potential for savings is a subject of other policies, but should not be underestimated.

[3] 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. This explains the relatively large remaining share of electricity needed, which, however, also has significant savings potential.
- 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.
- The natural process of households moving from old to new, more efficient dwellings and the associated reduction in energy demand for heating must also be kept in mind. In view of the effective requirement for the construction of nZEBs from 2021 on and the significant volume of new construction in Bulgaria, the potential savings can be even greater than those from renovation of existing buildings. However, to stimulate this process, the development and implementation of long-term housing policies at national and local level is needed.

CONCLUSIONS AND RECOMMENDATIONS

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. This is fully confirmed by the current analysis, solely focused on the monolith 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 their 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.

For further reference, please check the in-depth technical analysis supporting the current policy brief at www.eneffect.bg.

Center for Energy Efficiency EnEffect, November 2019