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TABLE OF CONTENTS

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RENEWABLE ENERGY SOURCES IN SLOVAKIA: POSSIBILITIES OF CONSUMPTIONOPTIMIZATION IN RESIDENTIAL BUILDINGS

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Abstract - Renewable energy sources (RES) have an important place in the Slovak energy sector. The current growth in the share of energy from the RES since 2005 was the result of growth in gross total RES consumption and GDP growth. The share of RES in the final gross energy consumption in the Slovak Republic (SR) in 2019 reached a level of almost 16.9%, while Slovakia at the European level has committed to increase the share to 19.2% by 2030. Slovakia currently does not have sufficient RES support, especially at the national level. That is why we see reducing energy needs as one of the most optimal solutions. We consider industry and buildings to be key sectors here. This article focuses on the issue of reducing energy demand in the sector of residential buildings. The estimated share of the building sector in the final energy consumption in the SR is approximately 40%, while 70% of the energy consumed in buildings is used for heating and cooling. There are approximately 1 million residential and family buildings in Slovakia. More than half of all buildings are energy inefficient. If we can reduce the energy demand in this area and eliminate it, then we can meet the optimized demand much more easily with a combination of RES without enormous increases in capacity. A significant reduction in the energy demand of buildings can be ensured through a deep renovation of buildings, through which we can reduce the energy consumption of the building by more than 60%. According to our calculations, the energy savings potential of nonrenovated residential buildings represents savings between 7,155-8,347 GWh. The current pace of building renovation in Europe and SR is very low and insufficient to achieve the goal of climate neutrality by 2050; therefore, it needs to be increased.

Keywords: Renewable Energy Sources, Energy Demand, Residential Buildings, Deep Renovation, Slovak Republic.

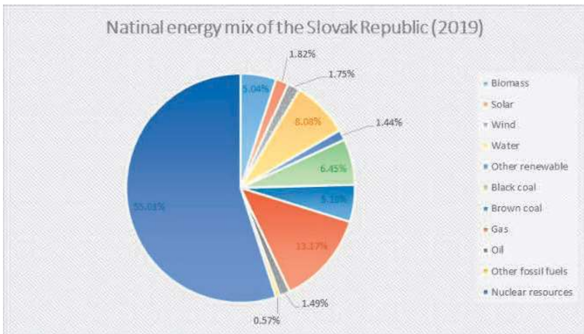
I. INTRODUCTION

With the growth of living standards and the world's population, the overall demand for energy in the world is constantly increasing. Energy security is a key issue for every national economy. Energy is present in every area of life. It provides us with heat, light, and provides fuel for transport. However, high production / high-energy consumption has its negative effects: air pollution, global warming, CO2 emissions, waste of fossil resources, and deforestation. (Maga, et al., 2010).

II. THE CURRENT STATE OF RES ISSUE IN SLOVAKIA AND ITS POSITION WITHIN THE EU

Renewable energy sources are naturally renewable resources. They are available either indefinitely or renewed faster than their consumption rate. Renewables are an important part of the country's energy mix. The energy mix represents an overview of the shares of individual energy sources in the total electricity produced. The production of energy from RES represents ways to use these theoretically unlimited natural resources and contribute to reducing environmental pressure, and thus to reduce the negative impact on human health. Their use, in addition to their environmental benefits, also increases self-sufficiency and energy security, as well as the diversification of energy supplies. This reduces the country's dependence on volatile oil and gas prices, as the energy produced from RES comes from its own territory. Certain risks of using RES result from the nature of these resources. The production of electricity from solar and wind energy is characterized by fluctuations in production, which negatively affects the safety and reliability of the operation of the electricity system. Another risk is a significant increase in electricity prices. In addition to these risks, there are also environmental negative impacts adversely affecting the landscape, habitats and ecosystems, watercourses, etc. These negative effects can be partially eliminated by careful planning and analysis of all adverse effects. The positives of the use of RES outweigh the negatives and the use of RES is one of the priorities of the energy policy of the Slovak Republic (SEA, 2020a). The potential of renewable energy in Slovakia is relatively well mapped. From the sunshine map, you can get information about where and what energy can be used. The potential of geothermal energy is also mapped quite accurately. A similar map exists for wind energy and wind conditions (Rojko, 2020). In addition, individual types of RES can be used in every region in Slovakia. There is no single energy mix for all areas. In essence, every single resource that is available on a given site can be meaningfully used.

Graph 1 shows the National Energy Mix of the Slovak Republic for 2019, which shows the production of electricity in the country. It can be seen from the graph that more than 55% of the energy produced comes from nuclear sources processed by the Mochovce and Jaslovské Bohunice nuclear power plants.



Graph 1: National energy mix of the Slovak Republic (2019)

Source: The authors, according to data from OKTE, Inc.

The Slovak Republic depends on the import of primary energy sources and almost 90% of them are forced to import (nuclear fuel 100%, natural gas 98%, oil 99%, and coal 68%) (MoE SR, 2019). In 2019, the Slovak Republic committed to achieving carbon neutrality by 2050. This led to the adoption of the Integrated National Energy and Climate Plan, which updates the Energy Policy of 2014 and defines the targets for 2030 (SEA, 2020a). The main quantified energy and climate targets by 2030 are across the EU, to achieve a reduction in greenhouse gas emissions of at least 40% compared to 1990 (each country individually according to local conditions). The binding target at the EU level is to achieve a share of energy from RES witha gross total energy consumption of at least 32%, with a share of RES in the transport of at least 14% in each member state, a national contribution to the energy efficiency of at least 32.5% and electricity interconnections of at least 15% (SR currently meets this requirement) (MoE SR, 2019). Optimal use of renewable resources is one of the key factors in achieving a low-carbon economy, with emphasis on the development of RES, especially in heat production. The planned target for 2030 is 19.2%. However, the currently adopted measures of the Slovak Republic in the field of energy efficiency show a value of 30.3%, in contrast to the EU target of 32.5%. The industry and building sectors will be the key sectors in achieving this goal. An overview of energy and climate goals within the EU and the Slovak Republic is given in **Table 1**.

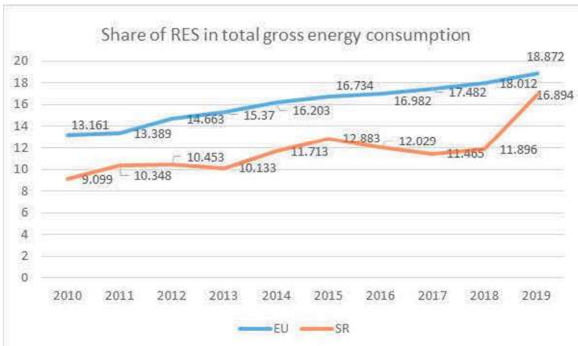
The total investment costs for achieving the RES targets are estimated at 4.3 billion euros. These investment costs include the electricity and heating sectors. They are based on the estimated increase in installed capacity for electricity, respectively, heat from RES, and investment intensity per unit of output (MoE SR, 2019).

Targets EU a SR	EU 2030	SR 2030
Greenhouse gas emissions (as of 1990)	-40%	Not established for member states
Emissions in the ETS sector (as of 2005)	-43%	
Non-ETS greenhouse gas emissions (as of 2005)	-30%	-20%
Share of renewable energy sources (RES) in total	32%	19.2%
The share of RES in transport	14%	14%
Energy efficiency	32.5%	30.3%
Interconnection of electrical systems	15%	52%

Table 1: Energy and climate targets within the EU and Slovakia
Source: MoE SR, 2019

2.1. Renewable energy sources in the Slovak Republic

Renewable energy sources have an important place in the Slovak energy sector. The share of energy from renewable sources has been growing since 2005. In the period 2005-2017, the total share of energy produced from renewable energy sources increased to 11.8%. The increase in the share of renewable energy sources was the result of a growth in gross total RES consumption, which increased by more than 28% during this period (SEA, 2019a). The share of RES in total gross energy consumption in Slovakia in 2019 reached a level of almost 16.9%. With this share, almost one year in advance, the Slovak Republic reached its obligations to the EU, which amounted to 14% by 2020. The European share of RES in the final gross energy consumption in 2019 reached the level of almost 19%. **Graph 2** shows the total share of RES in total gross energy consumption in the EU and the Slovak Republic in the years 2010 to 2019.



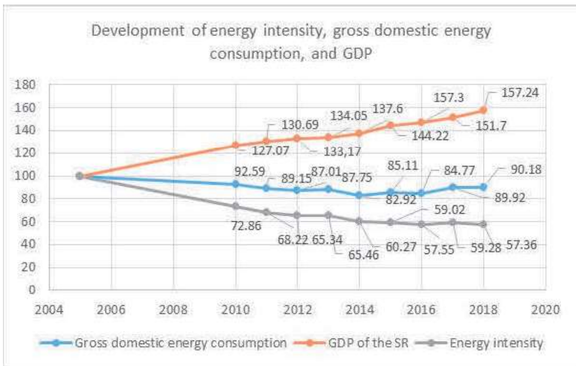
Graph 2: Share of RES in total gross energy consumption in the EU and the Slovak Republic in 2010 - 2019 [%]
Source: Authors according to the data of the European Commission, 2020

Slovakia does not have sufficient support for renewable energy sources, especially at the national level. Since 2013, it has stopped accepting applications for the connection of renewable sources over 10 kW to the distribution network due to concerns about network stability and security of supply. On the other hand, the Ministry of the Environment and the Slovak Innovation and Energy Agency supported the Green Households project and, through the project worth 41 million euros, supported between 2015 and 2018 to 18,502 household renewable energy installations with a total installed capacity of 141 MW (namely: solar collectors for 6,974 households, 5,242 heat pumps, 3,673 photovoltaic systems and 2,613 biomass boilers) (Melichár, J. 2019).

2.2. Energy intensity in the sectors of the Slovak economy

Energy intensity for individual sectors is calculated as the ratio of energy consumed in a given sector and GDP generated in a particular sector. Energy savings, in terms of reduced energy intensity in economic sectors, represent a significant potential for improving the country's energy balance. The goal of efficient use of energy is, among other things, to reduce losses in its use, without lowering the standard of living, as well as reducing the requirements for environmental protection (SEA, 2020b). From 2005 to 2018, energy intensity according to final energy consumption had a declining trend in all sectors. During this period, there was a decrease of 42.9% in all sectors of the economy. This positive trend is the result of GDP growth, which increased by about 57.9% over the same period, and a decline in gross domestic energy consumption, which in turn fell by 9.8% over the period under review (SEA, 2019b). This favorable development is the result of the successful renewal of the industry, the introduction of low-energy processes in the industry, and the improvement of the thermal-technical features of companies, buildings, and the replacement of appliances with more economical solutions. Despite this, the Slovak Republic has the seventh highest energy intensity in the EU28. This fact is taught mainly by the structure of the industry in the Slovak Republic, where industry with high energy intensity has a high share. The priority of the Slovak Republic in the field of energy efficiency is to further reduce the energy intensity of the economy with the intention of reaching the level of the European average (MoE SR, 2018).

Graph 3 shows the development of energy intensity, gross domestic energy consumption, and GDP in the Slovak Republic in the years 2010-2018.



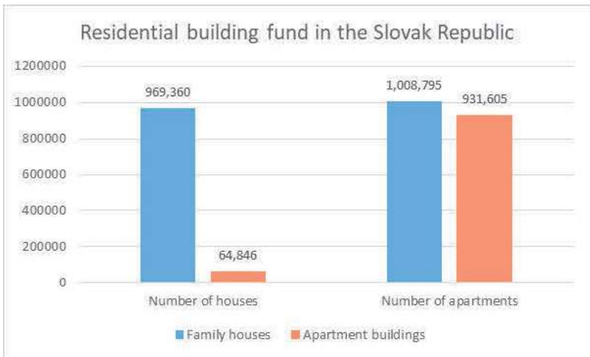
Graph 3: Development of energy intensity, gross domestic energy consumption, and GDP, s.c.15 [Index 2005 = 100]

Source: Authors according to the Statistical Office of the SR and SAE

2.3. Residential building sector in the Slovak Republic

People spend about 80-90% of their total time in buildings. The building sector in Europe is the largest consumer of energy. Almost 50% of the final energy consumption in the Union is used for heating and cooling, of which 80% is used in buildings. Almost 75% of buildings in Europe are energy inefficient, with almost 80% of existing buildings expected to be in use by 2050. The current rate of building renovation in Europe is very low and insufficient to achieve the goal of climate neutrality by 2050 (Filippidou, Jimenez Navarro, 2019). The estimated share of the building sector in the final energy consumption in the Slovak Republic is about 40%, while in buildings 60-80% of the energy consumed is used for heating and cooling, depending on the geographical location, when 6-9 months a year must be heated. Additional energy is used in buildings for hot water, lighting, ventilation, cooking, and operation of electrical appliances. Energy consumption in buildings is influenced not only by the technical characteristics of buildings and appliances but also by the behavior of their users. Buildings are classified into energy classes according to their energy intensity.

There are approximately 1 million residential buildings in Slovakia. These are composed of residential and family houses of which there are approximately 1.9 million housing units. The exact number and distribution of residential buildings are shown in Graph 4. “Their design and technical solutions are different; they differ fundamentally in size, number of floors, and number of apartments. The largest amount of housing construction occurred in the years 1960 to 1983. It follows that their age is more than 30 years, while construction carried out until 1983 achieved very low thermal-technical features resulting from the applicable requirements of the generally established level and technology of construction and knowledge”(MoE SR, 2020).



Graph 4: Overview of the residential building fund in Slovakia
Source: Authors according to the SOBD 2011 and Statistical Office of the Slovak Republic

III. METHODOLOGY

Insufficient support for RES at the national level and the commitment of the Slovak Republic to reach the share of RES at 19.2% by 2030 without their enormous capacity increase, show that one of the most optimal solutions is to actively reduce the energy needs of buildings (except industry). The most important tool for optimizing the energy consumption of buildings is the deep renovation of buildings. Deep renovation is a major renovation of a building and a major renovation of the technical equipment of a building, which achieves the classification of the building into the energy class required for the category of building, which takes into account the life cycle of individual building elements. The building element means in particular the technical system of the building or the building structure forming part of the building envelope (Act no. 555/2005, Coll.). The long-term building stock renovation strategy (2020) distinguishes three standards for the intensity of building renovation: partial renovation (energy savings achieved range between 3-30%); light and medium forms of renovation (savings reach 30-60%) and deep renovation (above 60%). The building sector as such provides a relatively large potential for energy savings. In this paper, we focus on the residential building sector and its potential for energy savings, in the event that all currently non-renovated buildings are restored to the highest possible standard (deep renovation), where we anticipate possible energy savings of 60-70%.

The documents of the Ministry of Transport and Construction of the Slovak Republic: Long-term strategies for the renovation of the building stock are the basis for processing an overview of the residential sector of buildings and data that characterize buildings, their average floor area, and their average heat consumption for heating; results of statistical processing of the Census of Population, Housing and Dwellings 2011 (SODB 2011) and its updating on the basis of data on buildings from the Technical and Testing Institute of Civil Engineering, n. about. (TSÚS); and the INFOREG information system, which registers energy certificates issued for new and significantly refurbished buildings. Given the overall availability of the data used in this paper and ensuring their consistency and relevance, we have taken all data from the reference year 2019.

Data of the number of renovated and non-renovated residential and family houses were obtained from the above-mentioned documents, which are listed in **Table 2**.

	Apartments in apartment buildings	Apartments in family houses
Scope of restoration in 2019	632,301	431,864
Renewal share in 2019 in %	67.87	44.97
Balance	299,304	576,931

Table 2: Renovated apartments in apartment and family houses (2019)
Source: Authors according to MoTaC SR data, 2020

Other data obtained from the mentioned documents were detailed information about family houses. "The total floor area of family houses per apartment is approximately 1.5 times to 2 times the area per apartment in the apartment building. No detailed data on the energy consumption of existing single-family homes are available. From the available evaluations, it is possible to assume an average annual energy consumption for heating of 165 kWh / (m2.a)" (MoTaC SR, 2020).

Due to the thermal properties of the perimeter, cladding, and construction technology, it is possible to divide apartment buildings into five groups, which were also affected by the requirements for the properties of building structures in the individual construction periods. These differ in the level of thermal technical properties of packaging building structures, the share of their area in the building packaging, and in the need, respectively actual energy consumption. The average heat consumption for heating in the Slovak Republic calculated according to these five groups of building systems is 114.8 kWh / (m^2.a) (MoTaC SR, 2020). The determination of measurable indicators of apartment buildings was based on available data sources of qualified estimates of the total floor area of apartment buildings (65,421,666 m^2) (Report of the SR, 2013). This total area was divided by the number of apartments in apartment buildings, and we received an average floor area (70 m^2). Subsequently, the average floor area of an apartment in a family house (1.5 times the area per apartment in an apartment building) of 100 m^2 was estimated.

The estimate of total energy savings (ΣH) was calculated as the sum of energy savings in family houses (ΣFH) and apartment buildings (ΣAH) using a calculation model, based on the above-mentioned variables, which are summarized in **Table 3**. The calculation did not consider the annual rate of renewal, as we wanted to point out the total energy potential that is currently found in non-renovated residential buildings. If we had the current rate of renovation (2% of the total volume of apartments in family and apartment houses), then all currently unrestored apartments would be restored in more than 20 years.

60% savings potential:

$$\Sigma H = \Sigma(EdFH \,.\, FaFH \,.\, RFH \,.\, 0{,}6 + EdAH \,.\, FaAH \,.\, RAH \,.\, 0{,}6) \quad (1)$$

70% savings potential:

$$\Sigma H = \Sigma(EdFH \,.\, FaFH \,.\, RFH \,.\, 0{,}7 + EdAH \,.\, FaAH \,.\, RAH \,.\, 0{,}7) \quad (2)$$

	Family houses [FH]	Apartment buildings [AH]	Total
Total houses [H]	969,360	64,846	1,034,206
Total apartments	1,008,795	931,605	1,940,400
Restored by 2019	431,864	632,301	1,064,165
To be restored [R]	576,931	299,304	876,235
Heating energy consumption [Ed] (kWh/(m2.a))	165	114.8	x
Average area [Fa] (m2)	100	70	x

Table 3: Summary of inputs
Source: Authors according to SODB 2011 data, TSÚS and Statistical Office of the SR

IV. RESULTS AND DISCUSSION

At the end of 2019, the share of renovated family houses in Slovakia reached 42.8%. The share of renovated apartment buildings was 67.9%. The total share of renewed dwellings was 54.8% and non-renewed 45.2%. This 45.2% consists of 876,235 flats, which, if restored to the highest possible standard, could achieve energy savings for heating of 60-70%. An overview of the quantified potential of individual savings is given in **Table 4**.

	Family houses	Apartment buildings	Total
60% energy savings (GWh)	5,712	1,443	7,155
70% energy savings (GWh)	6,664	1,684	8,347

Table 4: Potential for energy savings in deep recovery
Source: Authors

Our calculations show that the potential for energy savings in all non-renovated residential properties is at the level of 7,155 - 8,347 GWh.

For a clearer understanding, these results need to be linked to data from 2018, which show that the gross final consumption of renewable energy sources in heat and cold production reached the level of 7,764 GWh, while the expected consumption for 2021 is 8 379.62 GWh. The gross total consumption of renewable energy sources in 2018 reached 16,190 GWh (Enviroportal.sk, 2018).

At the same time, the total share of RES in gross final energy consumption in 2019 was 16.894%, while the share of renewable sources in heat and cold production in the same year was 19.7%. This information confirms the fact that the energy potential for saving non-renovated residential real estate in Slovakia is large enough for the state's energy policy priorities to focus on reducing consumption in the most energy-intensive sectors - the building sector and the industrial sector. We see the greatest usability of RES in the building sector in the use of heat pumps, solar thermal, photovoltaics, agricultural, or wood biomass.

Of course, the rate of building renovation, the achieved renovation rate, sufficient and available financial resources for renovation, technological development as well as changes in population behavior, demographic factors, and many others will have an important impact on energy savings (MoTaC SR, 2020, p. 33).

The average investment costs for the renovation of a family house are in the range of 180 - 220 € / m2, the average investment costs for the renovation of an apartment building are in the range of 150 - 180 € / m2 (MoTaC SR, 2020). If we wanted to express a rough estimate of the investment costs for the renovation of all these residential properties, then the total investment costs would be almost € 16.5 billion.

V. CONCLUSION

Achieving a low level of energy demand in all significantly renovated buildings requires the efficient use of renewable energy sources. Significant energy savings in energy consumption can be achieved through deep recovery. These are for the mostpart used for heating and cooling in residential buildings. We must not forget the fact that in the total number of already renovated apartments and family houses, a large percentage of apartments are only partially renovated. This partial restoration is most often realized only through the insulation of the perimeter and roof cladding and the replacement of the original opening structures. In this way, however, much lower savings on energy consumption in buildings have been achieved than in the case of deep renovation. In addition, already renovated apartments and family houses will require renewal due to the gradual end of the life of building elements and structures, which will, however, bring further energy savings. The share of such real estate in the building sector is very high, which also provides significant energy savings potential in this area. The renewable energy market in Slovakia is expected to grow. Increased demand for energy from RES will significantly contribute to market growth. In its international commitments, the Slovak Republic has committed itself to increase the share of energy from RES and reducing carbon emissions. On the other hand, there is a lot of competition in the form of an emerging gas market. Another limiting factor is the limited supply of energy from various renewable energy sources. Slovakia needs to set more ambitious national targets for reducing greenhouse gas emissions than the current ones and continue to reap the benefits of such more advanced support policies. Euro funds, as one of the most important public resources, can contribute to the necessary energy transformation to protect the climate, biodiversity and support the local economy. At present, the most important thing is how Slovakia will respond to them and be able to use them to its advantage and through the current National Plan for Recovery and Resilience.

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