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Analysis of the Final Energy Use by Sectors in City of Vidin

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Abstract **– According to the initiative "The Covenant of Mayors for Climate and Energy (CoM)" and within the framework of the EU-funded "Positive Energy Areas Project", the Municipality of Vidin should establish a "Sustainable Energy and Climate Action Plan". The city's sustainable energy development plans aim to reduce CO_2 emissions by 40% up to 2030 and develop a comprehensive climate change adaptation strategy at the local level or integrate it into existing plans. The initiative envisages actions both for mitigating climate change and also for climate adaptation at the local level.**

This paper presents the results of the first part of the process for establishing the "Sustainable Energy and Action Plan of the Municipality of Vidin", including the assessment and calculation of the final energy use in the city by the different sectors. The research aims to present the main data sources necessary for CO_2 emissions inventory at the city level and to process, validate, and analyze used statistical data for defining the final energy use by different sectors in one Bulgarian municipality.

The purpose of this assessment is to determine final energy use by different sectors and by types of energy sources. The results from the analysis and evaluation of the final energy use in the sectors "Residential buildings", "Municipal buildings", "Industry", "Tertiary buildings", "Public lighting" and "Transport" will serve to conduct a baseline of CO2 emissions inventory, which is a part of the "Sustainable Energy and Climate Action Plan". These results also could help the local authorities and key energy players to identify and implement the most suitable measures and actions for climate change adaptation and mitigation.

Keywords: final energy use, local energy assessment, emission reduction

I. Introduction

The European Union seeks to play a leading role in limiting the process of climate change. In this regard, the intention is to be fulfilled the goals of the agreement of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 21) Paris and at the same time to be provided clean energy in the EU. In fulfillment of this commitment, the EU has set itself the following mandatory goals for 2030 [1]:

- Greenhouse gas (GHG) emissions reduction by at least 40% compared to 1990;
- Energy efficiency (EE) increasing to at least 32.5%;
- The share of energy from renewable sources (RES) increasing to at least 32% of the gross final energy consumption in the EU;
- Ensuring a minimum level of 15% interconnection between Member States.

Additionally, in March 2023, as part of the REPowerEU plan, the EU raised its 2030 accelerated renewable energy deployment target to 42.5%, with the ambition to reach 45%.

The role of local authorities in the prevention of climate change is crucial. Over half of greenhouse gas emissions are created in and by cities. About 80% of the population lives and works in cities, where up to 80% of energy is used. At the same time, cities are facing increasing difficulties with the consequences of climate change. Thus, local authorities have an important role to play in achieving the EU's climate goals and in developing and implementing local policies for sustainable development.

The "Sustainable Energy and Climate Action Plan (SECAP)", developed under the CoM initiative, is the main document that shows how a city included in this Covenant could meet its commitments by 2030. The SECAP development is based on the findings of the baseline emissions and climate change and adaptation assessment. By inventorying their greenhouse emissions (GHG), cities are able to determine appropriate strategies to achieve the set emission reduction target (of at least 40% by 2030) compared to the baseline [2].

At national level, Bulgaria has developed its national vision for the development of the energy sector until 2030 with a horizon of 2050, in accordance with the current European regulatory documents for energy policy and global trends in the development of new energy technologies. The country's main goals for stimulating the transition to a low-carbon economy, achieving competitive and secure energy and reducing dependence on fuel and energy imports are laid down in the National Energy and Climate Plan (NECP) and other strategic documents. Specific goals are set for different economic sectors, as some indicators and stages in the development until 2050 for the considered sectors are foreseen based on various analyses. For the "Buildings" sector, indicators for total saved energy, renovated area, and saved CO_2 emissions have been set for three periods: 2021-2030; 2031-2040, and 2041-2050. Regarding the sectors "Industry" and "Transport", a forecast of the final energy use is presented, based on two scenarios: with and without measures, for seven 5-year periods. The measures and financial expectations are described in the NECP and the National Recovery and Sustainability Plan of the Republic of Bulgaria. There are no figures presented for the expected final energy use until 2050 in the "Agriculture" sector, although specific measures are laid down and planned in the National Plan for Recovery and Sustainability of the Republic of Bulgaria.

There are still no in-depth analyses of the expected impact in energy, environmental, social, and financial aspects of the implementation of the specific scenarios, actions, and measures planned in the presented sectors.

There is a need for energy modelling and assessment of specific energy transition scenarios at the national and local levels.

The lack of targeted planning for long-term monitoring of the urban energy transition limits its proper development. The economic profitability of the technologies related to the energy transition concept is essential for their implementation. In this aspect, the dissemination of existing energy transition technologies together with the development and monitoring of urban energy transition plans (such as the Long-term Energy Transition Plan 2050 and the Sustainable Energy and Climate Action Plan) are the only valid means to achieve this transition into cities [3].

In line with the European Union's energy strategy [4], the new CO_2 emission reduction target proposed by the Covenant of Mayors for Climate and Energy is at least a 40% reduction by 2030. The reduction target, which should be achieved by the local authority, is determined in comparison with a base year that is determined within the framework of the Sustainable Energy and Climate Action Plan (SECAP).

Local authorities should report the final energy use and emission factors for all emission sources (direct and indirect and non-energy related) by different sectors and energy types. The sub-sector classification is based on the different actors (municipal/public and private) and does not recommend the inclusion of greenhouse gas emissions generated by large industrial power plants (covered by cap-and-trade schemes or similar) [2]. The baseline emission inventory will show where the municipality was at the beginning (in its baseline year), and the successive monitoring emission inventory will show its progress toward the target. The reference emission inventories elaborating will allow the local authorities to measure its "Sustainable Energy and Climate Action Plan" impact and then adjust it if necessary over time. They also contribute to maintaining the motivation of all actors working to reach the municipalities' goal of harmful emissions reduction by giving them the opportunity to see the results of their efforts [5].

II. Methodology for Determination of Energy Baseline

In drawing up the emission inventory baseline within the Sustainable Energy and Climate Action Plan of the City of Vidin, the following key concepts are of paramount importance:

- Local territory description: Geographical jurisdiction/administrative territory;
- Assessment of final energy use: Final energy use covers all energy delivered to end users in the next energy use sectors: Sector "Public buildings"; Sector "Tertiary Buildings"; Sector "Residential Buildings" Sector "Transport"; Sector "Industry" and Sector “Public Lighting [2];
- Assessment of the sources of greenhouse gases from the energy use of the specified sectors.

According to the Guidebook “How to develop a Sustainable Energy and Climate Action Plan” PART 2 – Baseline Emission Inventory (BEI) and Risk and Vulnerability Assessment (RVA) [5] the base year is the reference year against which the emissions reduction target is compared. The municipalities are free to choose the year for which they can obtain the most comprehensive and reliable data.

The 2021 year has been chosen as the baseline year for the City of Vidin, as the year in which there is the most up-to-date and complete data for final energy use by sectors, as well as statistical data on the population from the 2021 National Census.

The following additional data sources were used in the collection of baseline emission inventory information: reporting and strategic documents of Vidin Municipality and Vidin District; information from local energy suppliers - "Electricity distribution networks Zapad" JSC; information databases of “Energy and water regulatory commission”, “Sustainable Energy Development Agency”, “National Statistical Institute”, other researches and publications.

To unify the units for the amount of fuel consumed, the following conversion coefficients for the density of fuels were used (Table I):

TABLE I Density Values Of Different Types Of Fuels *(SourceDepartment for Environment Food & Rural Affairs - Greenhouse Gas Conversion Factor Repository)* [6]

Density values of different types of fuels	
Fuel type	***Conversion factor***
Unit	***l/t***
Gasoline	1,368
Diesel	1,195
Propane-butane	1,957.3
Methane	5,714.29
Oil	1,467

To convert the amount of fuel from natural units (mass or volume) to energy units (calorific value) the conversion values presented in Table II were used.

TABLE II Calorific Values Of The Different Types Of Fuels [7]

Calorific values of the different types of fuels		
Fuel type	***Unit***	***Net Calorific Value, NCV***
Coal	MWh/t	5
Coal briquettes	MWh/t	5.56
Wood	MWh/m^3	3.3[a]
Pellets, eco-briquettes	MWh/t	4.8
Gasol	MWh/l	11.1
Propane-butane	MWh/kg	12.78
Natural gas	MWh/Nm^3	9.3
Gasoline	MWh/t	12,2
Diesel	MWh/t	11.669
Methane	MWh/t	9.372
Oil	MWh/t	12.211
Electricity	MWh/MWh	1

[a] *At wood humidity >30%*

To determine the basic energy final energy use in the city of Vidin, the following data were used:

Sector “Residential Buildings”: data from a survey conducted under the project "Improving the quality of atmospheric air in the city of Vidin" were provided by the Municipality of Vidin. A total of 4,825 residents of the Vidin municipality, using solid fuel for heating, took part in the study. The study was conducted in the period 16.02.2021-05.03.2021. The survey was conducted to cover more than 25% of homes using coal and/or wood for heating. In the municipal Report on the replacement of stoves in the town of

Vidin [8], it is stated that there are 9181 households using solid fuel for heating.

The following statistical data were used to calculate the final energy use of households in Vidin:

- Population for 2021 for the town of Vidin – 35,784 people (Source: Population Census for 2021 [9]);
- Population for 2021 for the municipality of Vidin – 67,794 people (Source: Population Census for 2021 [9]);
- Average number of persons in a household for 2011 - 2.3 [10];
- Number of households in the town of Vidin – 15,558.3 units, calculated by dividing the population of the town of Vidin by the average number of persons in a household; - Number of households heating with solid fuel in the city of Vidin: 9181 units. (Source: Report "Vision for replacing stoves")[8];
- Percentage of households heated with solid fuel – 59%, calculated as the ratio between the numbers of heated with solid fuel households and the total number of households in Vidin.

In order to estimate the use of solid fuels in households in the city of Vidin, the data on the use of fuels by the surveyed households for the Municipality of Vidin, as well as the primary statistical data on the population from the National Statistical Institute were used.

A report on the electricity consumed by household and business users, as well as their number, is provided by ERM Zapad AD – the regional electricity supplier.

From the processing of the surveys, the average household use for the different types of fuels in natural and energy units was obtained. A percentage distribution of the households according to the fuel they use for heating was also made and thus the use of solid fuels by the households in the town of Vidin was determined.

Sector "Public Buildings": For the purposes of the study, an online tool was developed in the form of a survey to collect data on the final energy use of the sector. The Municipality of Vidin has provided a list of all buildings owned by the municipality and state institutions, which includes a total of 88 buildings. The questionnaire was completed for 68 buildings, of which valid data was received for 60 buildings, i.e. the survey covered 68% of municipal and state buildings. The Municipality of Vidin has also provided a Report on the average annual amount of resources for heating public buildings for the period 2019-2021, which includes information on 25 buildings in the city of Vidin.

Sector "Tertiary buildings": For the purposes of the research, a reference was made to the website of the Sustainable Energy Development Agency (SEDA) [11], which includes information from the energy assessment of buildings, including thermal characteristics of the buildings, final energy and primary energy use, as well as class of energy performance characteristics.

Sector "Public Lighting": For the purposes of the study, data was taken from an energy audit of a Public lighting system in the city of Vidin, in which the type of street lighting measurement and control system, the energy consumed for the base year, and energy saving measures were analysed.

Sector "Transport": For the purposes of the survey used data provided by Vidin Municipality regarding Public Transport, Municipal Transport and Private Transport.

For public transport, data on reported annual mileage for the base year, valid international passenger transport licenses are provided by the Municipality. A survey was made on the types of motor vehicles for urban transport and the average fuel use on an annual basis.

For municipal transport, data has been provided by the Municipality of Vidin, regarding the number of vehicles by type and fuel as of 31.12.2021, owned by the Municipality and municipal enterprises, regular mileage per year, km or engine changes per year for tractors, and a survey has been made for average fuel use, l/km, l/motor hours.

Regarding private vehicles, the following information has been provided by the Municipality of Vidin: Number of vehicles by type and fuel as of 31.12.2021, registered on the territory of the Municipality of Vidin. Average mileage for private vehicles is assumed: 12km/day for 365 days.

The average fuel use for all types of motor vehicles is taken according to the values specified in Ordinance No. 3 of 25.09.1989 for normalizing the use of fuels and lubricants for cars and motorcycles [12], as follows (Table III):

TABLE III NORMS FOR USE OF DIFFERENT TYPES OF MOTOR VEHICLES

Norms for use of different types of motor vehicles	
Vehicle type	***Liter per km. mileage/motor hour***
Bus	0.35
Car	0.08
Motorcycle	0.05
Motorcycle	0.04
Truck	0.16
Tower	0.25
Motorcycle with basket	0.07
Wheel tractor	16
Three Wheeler vehicle	0.08

The amount of fuel consumed (FC) in liters by fuel type and vehicle is calculated according to the equation (1):

$$FC = NV * AAM * FUR \quad (1)$$

Where,
NV is the number of vehicles;
AAM is the average annual mileage, km;
FUR is the fuel use rate, l/km.

The amount of energy from fuel consumed is calculated according to the equation (2):

$$FE_{fuel} = (\sum Fuel_{\ in\ litres} / \rho_{fuel}) * LHV_{fuel} \quad (2)$$

Where,
FE_{fuel} - final energy obtained as a result of fuel combustion, kWh/year;
ρ_{fuel} - fuel density, l/t
LHV_{fuel} - fuel calorific value, kWh/kg.

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Local energy sources: The electricity produced by renewable sources is obtained from the "Register of Guarantees" system of the Sustainable Energy Development Agency (SEDA) and includes all installations connected to the electricity grid that sell renewable electricity to suppliers in the territory of the city of Vidin.

No local heat and cold energy sources are available in Vidin.

Standard emission factors and conversion factors of fuels from natural to energy units were used to determine the baseline energy use.

III. Results and Discussion

On the base of the above-described methodology, the final energy use for all the mentioned sectors was analysed.

Total energy use for all sectors

The total energy use on the territory of the City of Vidin in 2021 is 403,491.5 MWh/year, and the distribution by sectors is presented in Table IV:

TABLE IV Distribution Of Final Energy Use By Sector

Distribution of final energy use by sector	
Sector	***MWh/year***
Public buildings	11,792.08
Tetriary buildings	2,838.46
Residential buildings	17,5629.75
Public lighting	3,159.05
Industry	61,998.23
Transport	148,073.97

From Fig. 1 it can be seen that Sector "Residential buildings" (Households) is the leader in the final energy use with a 43% share of the total final energy use, followed by Sector "Transport" (37%) and Sector "Industry" (15%.)

Fig. 2 shows a high share of electricity (28%), other biomass (27%), and diesel (24%) in the final energy use for the city of Vidin.

Sector “Residential Buildings”

Regarding the determination of the final energy use in the Residential sector, it is clear from the Vision Report on the replacement of heating elements that the number of households using solid fuels is 9,181, which is calculated as 59% of all households in the city (15,558.3). It is assumed that the households using electricity for heating are 41% or 6,379 households.

From the analysis of the surveys of households using solid fuel, the average fuel use per household was calculated in natural units, and from there in energy units, and the percentage distribution of households using different types of fuel was also determined. From the analysis, it can be seen that among the respondents using only solid fuels for heating, households heating with wood have the largest share (45%), followed by households heating with pellets and eco-briquettes (16%) and those heating with coal (14%) (Fig. 3).

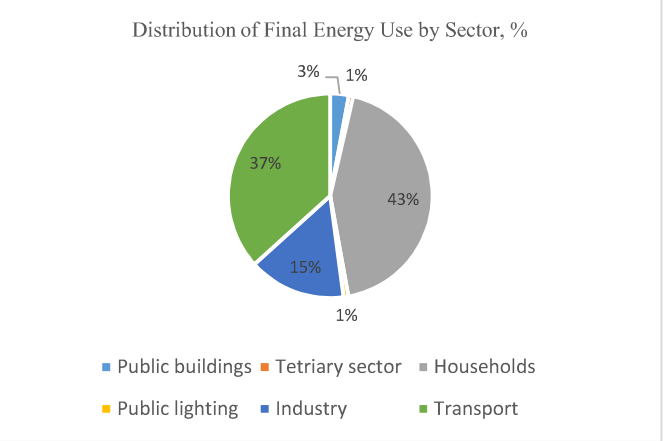

Fig. 1. Distribution of final energy use by sector, %

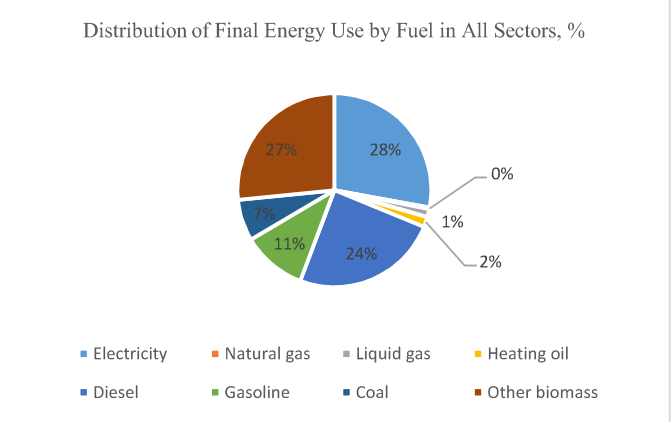

Fig. 2. Distribution of Final Energy use by Fuel in All Sectors, %

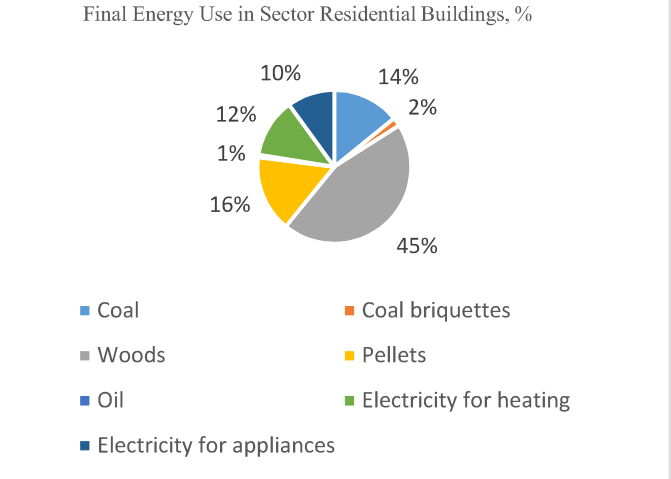

Fig. 3. Final Energy Use in Sector Residential Buildings, %

When determining the final energy use in Sector Residential buildings, this percentage distribution was used, along with the fact that 41% of households in the city use only electricity.

Fig. 4 presents the distribution of energy use for heating in Sector Residential buildings. Woods account for the largest share of heating in residential buildings - 50%, followed by pellets and eco-briquettes - 18%; coal – 16% and electricity for heating – 14%.

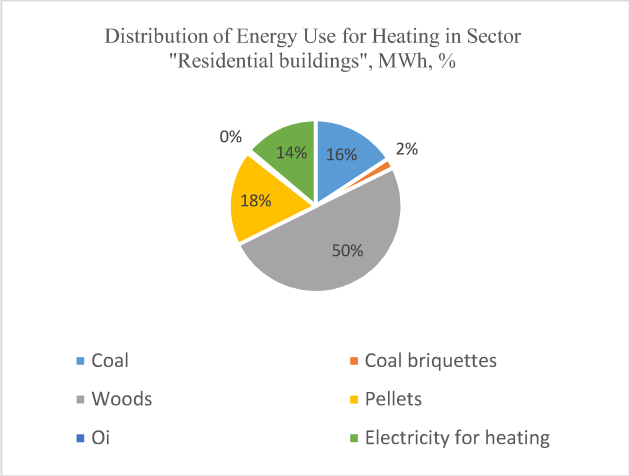

Fig. 4. Distribution of energy use for heating in Sector "Residential Buildings"

Sector "Public buildings"

The final energy use in Sector "Public buildings" constituted 15% of the total energy use in the City of Vidin.

As can be seen in Fig. 5. it is evident that the use of heating oil is dominant - 48%, followed by electricity – 42%. The use of natural gas is 9%. The share of coal and wood is low – 1% in the total energy use of public buildings.

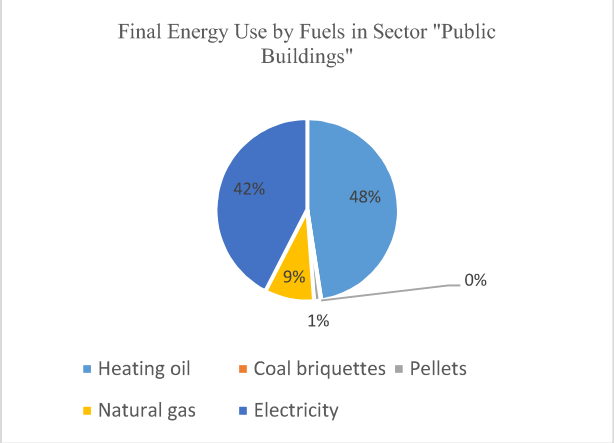

Fig. 5 Final Energy Use by Fuels in Sector "Public Buildings"

Sector "Public lighting"

Sector "Public lighting" in Vidin has an electricity use of 3,159.01 MWh, which is 1% of the municipality's final energy use. The local authorities have already foreseen a measure to modernize the public lighting with new LED illuminators.

Sector "Industry"

The final energy use in the Sector "Industry" is 61,998.2 MWh use of electricity, which constituted 15% of the total final energy use in the City of Vidin.

Sector "Transport"

The data for Sector "Transport" include municipal, urban and personal transport. Energy use in the sector equals 148,074 MWh and represents 37% of the city's final energy use.

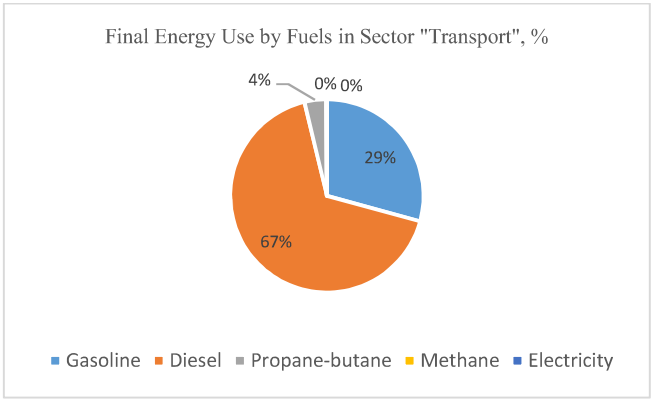

Fig. 6. Final Energy Use by Fuels in Sector "Transport", %

As could be seen in Fig.6 diesel fuel has the largest share of those reported 67%, followed by Gasoline - 29% and propane-butane - 4%.

The City of Vidin is in the process of developing its Sustainable Energy and Climate Action Plan (SECAP) with the goal of a 40% reduction of GHG, as well as Long-Term Energy Vision of the City of Vidin has been developed until 2050 that will achieve the goals of energy savings for all sectors. The projected final energy use for 2030 is based on an estimate of a 10-20% reduction in use in all sectors compared to the baseline from 2021. As results of the calculation of the final energy use it could be seen that, the Sector "Residential Buildings" is the most important for the final energy use and the forecast for reduction of energy use in the sector is based on the implementation of the National Program for Renovation, replacement of inefficient heating systems, as well as the implementation of measures related to behaviour change and replacement of old domestic appliances [3]. The main energy interventions should be focused on reducing energy use in Sector "Residential buildings", followed by Sector "Public buildings".

IV. Conclusion

The main energy sources used in the City of Vidin are coal, wood, and electricity. There is no centralized heating supplier, as well as gas transmission infrastructure built in the city. For the purposes of the emissions assessment, the coal and wood factor is significant. Electricity for heating has no impact on city emissions and is not accounted for in the air pollutant analysis. Having quantitative data about them, however, is important later when planning improvement measures, e.g. to estimate the potential increase or decrease in homes heated by electricity according to future price developments. For example, if a significant increase in the price of electricity is expected, a certain number of residents are likely to switch to fuels such as wood or coal if they are cheaper and technically possible. This fact shows that the processes are dynamic and it is necessary for the local authorities to regularly update the input data and assessments in order to optimize the decisions taken.

For the municipality of Vidin, an estimate for the effective duration of the heating period of 185 days has been accepted. Based on the answers to the surveys - the questions about the way of heating the homes in the municipality of Vidin and the analysis of the energy surveys in the renovated residential buildings, the percentage of solid fuels used by households was determined - 59% use solid fuels for heating and 41% use electricity for heating.

On the basis of these results, it is necessary to make an estimated development scenario until 2030, both without additional measures, projects and activities to mitigate climate change, as well as scenarios with alternative and ambitious measures for deep renovation of buildings, including replacement of the energy source and modernization of the heating installations.

After the assessment of the effect of the baseline scenarios, it will be assessed to what extent the municipal goal of 40% reduction in emissions has been achieved and additional ambitious measures to reach this goal will be discussed. Future monitoring of final energy use by sector relative to the baseline is also needed to assess the actual effect of the implemented measures after 2 years of their implementation.

As Vidin is a regional and municipal centre with an important role in cross-border cooperation and international transport links all decentralized bodies of state institutions in the district are located on the territory of the city. Regular trainings are organized by state institutions (ministries, agencies, etc.,) aimed at raising awareness and increasing the capacity of municipal employees on various topics and application programs in order to be able to stimulate and encourage the local business and citizens to be actively involved in the city's energy planning process and the implementation of the SECAP goals set. To support this a Regional Council on Energy Efficiency was established as a public, expert, advisory and coordination body to the Regional Governor. The council assists the regional governor of the Vidin region in implementing the state policy for increasing energy efficiency in the territory of the region and in the implementation of interaction with the local self-government bodies and the local administration and citizens.

In developing the SCEAP and setting the energy scenarios the local authorities in Vidin should consider implementing the following activities: introduction of energy monitoring systems in municipal buildings; Campaigns to change the energy behaviour of citizens in order to reduce their energy consumption; carrying out surveys and implementation of measures for energy efficiency of multi-family residential buildings on the territory of Vidin Municipality; replacement of the heating installation in municipal buildings and overall modernisation of the heating installations in the buildings and implementation of measures to improve energy efficiency and introduction of systems and technologies for the utilization of renewable energy in the residential building stock

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