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# ANALYSIS OF GHG EMISSIONS BY SECTORS IN CITY OF VIDIN

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***Abstract***

*The publication presents an analysis of the baseline inventory of greenhouse gas emissions by sector in city of Vidin, based on the assessment of final energy use in the sectors, according to the methodology for developing a Sustainable Energy and Climate Action Plan (SECAP) in the framework of the Covenant of Mayors. The GHG emissions inventory enables local governments to understand the emissions contribution of different activities; to determine where to direct mitigation efforts and to create strategies to reduce GHG emissions and track their progress.*
*The article presents the results of the analysis of the base inventory of emissions in the city of Vidin, including the description of the methodology and key factors affecting emissions in the sectors "Residential buildings", "Public and Tertiary buildings", "Transport", "Public lighting" and "Industry", considering possible strategies and measures to reduce carbon footprints, including the amount of emissions gases. This analysis aims to provide a basis for developing sustainable policies in the municipality aimed at achieving the goal of reducing greenhouse gas emissions by 40% by 2030 by identifying and planning climate change mitigation and adaptation actions.*

***Key words**: baseline GHG inventory, climate change adaptation and mitigation actions, energy use by sector, GHG emissions, Sustainable Energy and Climate Action Plan.*

## INTRODUCTION

Climate change will remain the one of the main challenges of the coming decades, shaping the future of the global society and world economy through its huge impacts and the need of our response. The harmful impacts of global warming are increasing in scale and frequency, with devastating effects on people, nature, and economic systems across the globe. The urgent need for stronger action to tackle climate change comes at a time of multiple global crises. In these terms the global emissions rebounded in 2021-2022 and reached a new high in 2022.
A number of scientific studies have been conducted and various actions and initiatives have been taken to address this problem. Kijewska & Bluszcz in 2016 have analyzed the level of differentiation of European Union member states in terms of emissions of four greenhouse gases and identified groups of similar countries based on these criteria. William F. Lamb et al. (2021) provide a sector-by-sector summary of key trends and challenges that collectively shape prospects for a rapid and deep transition and for avoiding dangerous climate change. Csalódi et al. (2022) assess the relationships between time series of GDP per capita and total $CO_2$ emissions of countries around the world, discussing the sector's contribution to climate change. Magazzino et al. (2022) examine various drivers of greenhouse gas emissions such as population, economic development, forest density and agricultural practices. Reavis et al. present disclosure and emissions opportunities for the 100 largest global food and drink companies and highlight the urgent need to set truly ambitious, science-based climate targets (Reavis et al., 2022). Minx et al. present a comprehensive and synthetic dataset of global, regional and national greenhouse gas emissions by sector for 1970-2018 with an accelerated extension to 2019 (Minx et al., 2021). Han et al. have explored knowledge structure and boundary trends regarding the IOA model applied to CF research using scientometric visualization analysis (Han et al., 2022). Moiceanu & Dinca have analyzed Romania's GHG emissions under the EU and Romania legislative framework by performing a projected GHG analysis using data from Eurostat and the Romanian National Institute of Statistics (Moiceanu & Dinca, 2021). A number of scientists in Bulgaria have published their research in the field of increasing the energy efficiency of buildings and industrial systems (Iliev et al., 2021; Genbach et al., 2018; Kolev et al., 2017; Komitov et al., 2020; Valchev &

Mihaylov, 2020; Zlateva et al., 2020), but no publications related to the study of GHG emissions by sectors were found.

The European Union is extremely responsible when it comes to activities to deal with the consequences of climate change and also activities to adapt to its adverse effects. All 27 EU countries have committed to making Europe the first climate-neutral continent by 2050.

To achieve this, they have committed, firstly, to reduce emissions by at least 55% by 2030 compared to levels of 1990. In February 2024, the European Commission presented its assessment for a 2040 climate target for the EU (European Parliament Commission Staff, 2024). The Commission recommended reducing the EU's net greenhouse gas emissions by 90% by 2040 relative to 1990. Moreover, the European Green Deal is the key response to the climate challenges, which sets targets for climate neutrality until 2050. It is a strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource -efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use.

As stated in the 100 Climate-Neutral and Smart Cities by 2030 Info Kit for Cities (European Commission, 2021c) the targets of the European Green Deal (namely reducing emissions by 55% by 2030 and becoming the first climate neutral continent by 2050) will be impossible to achieve without cities in the vanguard of concerted efforts. It's obvious that local authorities play a key role in achieving the national energy and climate goals and are leading actors in the implementation of local sustainable energy policies. The greenhouse gases emission commitments are considered that could be fulfilled being the cornerstone of the European deal on climate change (Di Paolo et al., 2023).

Reaching and indeed exceeding national or EU GHG reduction targets, such as those proposed by the EU Green Deal, is not an easy task (Rivas et al., 2021), specially for the small and medium sized municipalities.

It is still relatively difficult for the Bulgarian small municipalities to conduct energy modelling and analysis of final energy consumption, due to lack of capacity and difficult adoption of different energy planning tools. However, various materials and initiatives have been developed for the benefit of municipalities in terms of tools for energy planning and monitoring.

The energy planning process encompasses a number of elements – institutional arrangements, exemplary guidelines, modelling and forecasting methods, specific methodologies using various scenarios and communication programs. There are well-established planning approaches, but the energy transition creates a need to reassess some aspects of the planning process, especially those related to the construction of an attractive vision and predictability for investments in municipalities (EnEffect, 2023).

Municipal energy planning and energy system modelling, on the other hand, is a research field that has traditionally been de-emphasised in favour of national energy system modelling (Johannsen et al., 2021).

Covenant of Mayors on Climate and Energy provides a framework for energy planning at municipal level and aims to complement national energy and climate plans with a specific initiative to support cities. The initiative aims to gather local authorities to voluntarily commit to implementing sustainability policies in their territories. Local authorities are provided with a harmonized data compilation, methodological and reporting framework to turn greenhouse gas reduction ambitions into reality. One of the possible assessment tools included within the Covenant of Mayors is the GHG emissions inventory, which quantifies the GHG emissions released to the atmosphere (Marchi et al., 2023).

The key enabling factor for higher climate ambition in cities is the development of local mitigation actions in line with the results of the baseline emissions inventory; focusing on implementing actions in the most emitting sectors of activity (Rivas et al., 2021).

There is a possibility for Joint SECAP plan, especially in the case of small municipalities in EU countries that lack a national framework for climate planning, which can contribute significantly to building a climate-adaptation strategy (D'Onofrio et al., 2023).

By reducing GHG emissions in their jurisdictions, the local authorities can tackle the root cause of climate change (Papp, 2023).

The Covenant of Mayors includes both climate mitigation and adaptation aspects and is built around three pillars:

- Actions to mitigate climate change (at least 40% emissions reduction target by 2030 compared to baseline - initially);
- Actions to adapt to climate change;
- Access to secure, sustainable and affordable energy (Bertoldi, 2018a; 2018b).

If the local government has been a signatory of Covenant of Mayors recently, they should comply with "Fit for 55" and the commitment should be 55% reduction by 2030 which can be found quite bold for a lot of cities. If they are members before 2021 the commitment is 40% reduction by 2030.

Municipality of Vidin, as one of the six follower cities in MAKING-CITY project, and has committed to develop a Sustainable Energy and Climate Action Plan, which on the base of comprehensive final energy use analysis and GHG emission inventory defines the main goals, actions and measures for the development of municipal policy for climate change mitigation and adaptation.

The commitment of the Municipality of Vidin is to develop Sustainable Energy and Climate Action Plan in which to present its vision for climate change mitigation - at least 40% emission reduction target by 2030 compared to the baseline year - 2021 and adaptation to climate change (Making-city Consortium, 2023). By developing of Sustainable Energy and Climate Action Plan (SECAP) for a municipality of Vidin they will be offered numerous advantages and benefits, making it a strategic and responsible choice. Vidin's target of reducing emissions by 40% is consistent with the project's goals and is aligned with the near baseline year - 2021.

The plan of Vidin addresses the impacts of climate change by reducing greenhouse gas emissions by identifying climate change mitigation actions the city can significantly decrease a municipality's carbon footprint, contributing to a cleaner and healthier environment.

Moreover, by setting clear goals and strategies for emissions reduction the SECAP of Vidin will play a crucial role in mitigating climate change. The goals will align with the global efforts to limit global warming and help the municipality to meet international climate agreements like the Paris Agreement.

The energy vision of the city of Vidin until 2030 and until 2050 will help to reduce GHG emissions, increase energy efficiency and improve the quality of life of the local population, while at the same time ensuring sustainable economic development for the city.

## MATERIALS AND METHODS

In the preparation of the GHG emissions baseline inventory within the framework of the Sustainable Energy and Climate Action Plan of the city of Vidin, was adopted the methodology of the Handbook "How to develop a Sustainable Energy and Climate Action Plan" Part 1 - The process of development of SECAP, Step by Step towards Low Carbon and Climate Resilient Cities by 2030, which aims to support local authorities in European Union Member States joining the Covenant of Mayors for Energy and Climate.

On the base of the above-mentioned document in the process of establishment of the $CO_2$ emission baseline inventory within the Sustainable Energy and Climate Action Plan of the city of Vidin, the following key concepts are of utmost importance:

- Local territory analysis: Geographical jurisdiction/administrative territory;
- Assessment of final energy use which covers all energy delivered to end users in all energy consumption sectors: "Municipal buildings"; "Tertiary buildings"; "Residential Buildings"; "Transport"; "Industry";
- Assessment of the sources of greenhouse gases from the energy consumption of the specified sectors.

For each of these sectors, the types of energy sources and the annual quantities used were determined on the base of data collection from different sources.

Sector "Municipal buildings" - The Municipality of Vidin 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. The Municipality of Vidin has also provided a Report on the average annual number 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 Agency for Sustainable Energy Development (SEDA), which includes basic data for the buildings, including total area, energy consumption, availability of a certificate of energy characteristics, etc.

Sector "Residential Buildings" - For the purposes of the research, data were taken from a survey on the project "Improving the quality of atmospheric air in the Municipality of Vidin", which aims to reduce emissions of fine dust particles FPC10 from domestic heating, by means of free replacement of solid fuel appliances (wood and coal) of households with alternative types of heating appliances. A total of 4,825 residents of the Municipality of Vidin took part in the survey conducted for the purposes of the project. The survey was conducted in the period 16.02.2021 - 05.03.2021 and covers the population that uses solid fuel for heating. The survey was conducted to cover more than 25% of homes heated with coal and/or wood.

From the municipal Report on the replacement of stoves in the city of Vidin, it is clear that there are 9181 households using solid fuel for heating.

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

- Population for 2021 for the city of Vidin – 35,784 people (Population Census for 2021).
- Population for 2021 for the municipality of Vidin – 67,794 people (Population Census for 2021).
- Average number of persons in a household for 2011. 2.3 (National Statistical Institute).
- Number of households in city of Vidin – 15,558.3 units, calculated by dividing the population of city of Vidin by the average number of persons in a household:
- Number of households heating with solid fuel in the city of Vidin: 9,181 units. (Municipality of Vidin, 2021).
- Percentage of households using solid fuel for heating – 59%, calculated as the ratio between the number of households heated with solid fuel and the total number of households in Vidin.

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

Sector "Industry" - the final energy use in the industry sector was calculated on the basis of data provided by (Electric Distribution Networks Zapad AD, 2023), which cover the amount of electricity transferred to the company's customers. The amount of electricity for the sectors Public buildings and Street lighting has been removed from the reference for business users on the territory of the municipality.

Sector "Transport" - for the purposes of the survey for used data provided by the Municipality of Vidin 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.

A survey was made on the types of motor vehicles for urban transport and the average fuel consumption 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 of Vidin and municipal enterprises, mileage per year, km or engine changes per year for tractors, and a survey has been made for average consumption of fuel, l/km, l/m.h.

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.

To determine the average fuel consumption for the various vehicles, the values from Ordinance No.3 of 25.09.1989 on normalizing the consumption of fuels and lubricants for cars and motorcycles were taken.

At the moment of development of the SECAP of the city of Vidin, no other non-energy sources of

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GHG are available.

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

Local heat/cold production (LPT/C)*, divided into: At the time of the research, there are no local sources of heat or cold energy in the city of Vidin.

Base year selection - the year 2021 has been chosen as the base year for the Municipality of Vidin, as the year in which there is the most up-to-date and complete data on energy consumption by sector, as well as statistical data on the population from the 2021 National Census. To unify the units for the amount of fuel consumed, the following conversion coefficients for the density of fuels were used (Table 1).

Table 1. Density values of different types of fuels (Department for Environment Food & Rural Affairs - Greenhouse Gas Conversion Factor Repository 10)

| 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 2 were used.

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 (Minister of Transport, Ordinance No. 3 of 25.09.1989, 1989), as follows: (Table 3). The amount of fuel consumed (FC) in litters 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):

$$FEfuel = (\sum Fuel\ in\ litres/\rho fuel) * LHVfuel \quad (2)$$

where:

- *FEfuel* - final energy obtained as a result of fuel combustion, kWh/year;
- *ρfuel* - fuel density, l/t;
- *LHVfuel* - fuel calorific value, kWh/kg.

Table 2. Calorific values of the different types of fuels (Minister of Energy. Regulation on the methodologies for the determination of the national energy efficiency target)

| 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%*

Table 3. 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 |

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

## RESULTS AND DISCUSSIONS

The total $CO_2$ emissions by energy source, calculated on the base of the final energy use in City of Vidin are presented in Table 4.

Table 4. Distribution of greenhouse gas emissions by energy source for 2021

| Type of energy source | Final energy consumption | GHG emissions, t CO2 | Share of total emissions |
|---|---|---|---|
| | MWh/y | t $CO_2$/y | % |
| Electricity | 112,363.31 | 54,608.57 | 48% |
| Natural gas | 1,216.2 | 267.57 | 0% |
| Liquefied Gas (LPG) | 5,370.6 | 1,557.4 | 1% |
| Liquid fuel for heating | 6,918.2 | 2,006.291 | 2% |
| Diesel | 99,010.69 | 28,713.1 | 25% |
| Gasoline | 43,479.34 | 12,609.01 | 11% |
| Coal | 27,942.5 | 10,059.31 | 9% |
| Biomass | 107,190.5 | 4,287.622 | 4% |
| Total | 403,491.54 | 114,109 | |

As it can be seen from Figure 1 the largest contribution to GHG emissions, in the base year 2021, is the consumption of electricity (48%), liquid automotive fuels, respectively diesel (25%), gasoline (11%), coal (9%). Emissions from biomass use are 4% of total emissions from energy use.

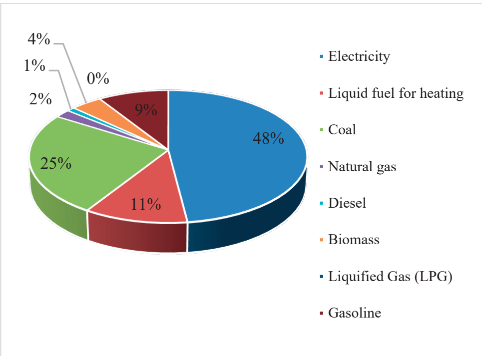


Figure 1. Distribution of GHG emissions by type of energy source for 2021

The distribution of GHG emissions by sector is presented in Table 5.

Sector "Residential buildings" is the sector with the highest percentage of final energy consumption (44%) and contribute significantly to GHG emissions (30%). This emphasizes the importance of targeting actions for energy efficiency measures and emissions reduction strategies in residential buildings.

The sector with the highest share of GHG emissions (38%) is the Transport sector, which also represents second place in the final energy use with 37%. While industry accounts for 15% of final energy consumption, it contributes a relatively higher percentage (26%) to GHG emissions, due to the main energy source - electricity. Municipal buildings sector accounts for 3% of final energy use and 4% of $CO_2$ emissions. Sector "Tertiary buildings" and sector "Street lighting" represents 1% each of final energy use and $CO_2$ emissions (Figure 2).

Table 5. Distribution of final energy consumption and GHG emissions by sector

| Distribution of final energy consumption by sector | | | Distribution of final energy consumption by sector | Distribution of GHG emissions by sector |
|---|---|---|---|---|
| | MWh/y | % | t $CO_2$/y | % |
| Municipal buildings | 11,792.1 | 3% | 4,294.2 | 4% |
| Tertiary sector | 2,838.5 | 1% | 1,379.5 | 1% |
| Residential buildings | 175,629.8 | 44% | 33,834.5 | 30% |
| Street lighting | 3,159.1 | 1% | 1,535.3 | 1% |
| Industry | 61,998.2 | 15% | 30,131.1 | 26% |
| Transportation | 148,074.0 | 37% | 42,934.3 | 38% |
| Total | 403,491.5 | | 114,109.0 | |

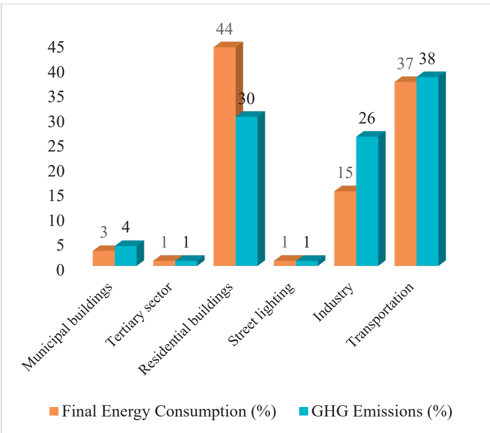


Figure 2. Distribution of final energy consumption and GHG by sector

Figure 2 highlights the need for a multi-faceted approach to assess final the energy use and GHG emissions. Efforts should be directed towards residential buildings energy efficiency, sustainable transportation solutions, and cleaner industrial practices to achieve a more balanced and sustainable energy consumption.

The following sections focus on sector-by-sector greenhouse gas emissions to provide a more in-depth analysis of the energy sources used and their GHG emissions share.

An analysis of the final energy use and GHG emissions in the building sector, including residential, municipal and tertiary buildings is shown in Table 6.

Table 6. Distribution of final energy consumption by fuel in the building sector

| Energy source | Final energy use | Distribution of GHG emissions | |
|---|---|---|---|
| | MWh/y | t $CO_2$/y | % |
| Electricity | 47,176.6 | 22,927.85 | 62,4% |
| Natural gas | 1,032.3 | 227.11 | 1% |
| Liquid fuel for heating | 6,918.2 | 2,006.29 | 5% |
| Coal | 27,942.5 | 7,265.06 | 20% |
| Biomass | 107,190.5 | 4,287.62 | 12% |
| Total | 190,260.29 | 36,713.93 | |

As can be seen in Figure 3, electricity contributes the largest share (62.4%) of $CO_2$ emissions in the buildings, followed by coal (20%) and biomass (12%). Liquid fuels represent 5% of the emission sources in the building sector and are used mainly in Municipal buildings. Natural gas is used in a small part of municipal buildings and is a responsible for 1% of the $CO_2$ emissions.

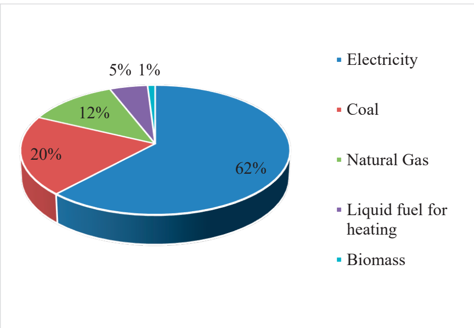


Figure 3. Distribution of greenhouse gas emissions in the building sector by type of energy source for 2021

Sector "Residential buildings" occupy the largest share of GHG emissions in the city of Vidin (Table 7). In turn, the main sources of emissions in the "Residential buildings" sector are electricity consumption (54.8%); coal (30%) and biomass (13%), and liquid fuels contribute 1% of emissions in the sector.

Table 7. Distribution of final energy consumption by fuel in sector "Residential buildings"

| Energy source | Final energy use | Distribution of GHG emissions | |
|---|---|---|---|
| | MWh/y | t $CO_2$/y | % |
| Electricity | 39,333.9 | 19,116.28 | 56% |
| Liquid fuel for heating | 1,313.4 | 380.88 | 1% |
| Coal | 27,931.4 | 10,055.31 | 30% |
| Biomass | 107,051.1 | 4,282.042 | 13% |
| Total | 1756,29.8 | 33,834.51 | |

Electricity, coal and biomass are the main sources of energy in the residential sector (Figure 4). The significant GHG emissions associated with electricity and coal underline the need for strategies to reduce the carbon footprint of this sector. The introduction of energy efficient measures and low emission heating technologies for households can help reduce GHG emissions and sustainably manage the energy needs of residential buildings.

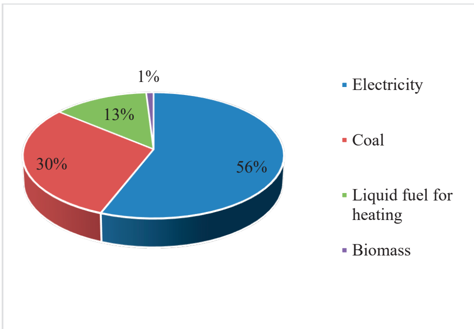


Figure 4. Distribution of greenhouse gas emissions in Sector "Residential buildings" by type of energy source for 2021

The analysis of energy use in Municipal buildings, it can be seen that the largest share of GHG emissions is contributed by electricity (57%), followed by liquid fuels (38%) and natural gas (5%) - Table 8 and Figure 5.

Table 8. Distribution of final energy consumption by fuel in sector "Municipal buildings"

| Energy source | Final energy use | Distribution of GHG emissions | |
|---|---|---|---|
| | MWh/y | t $CO_2$/y | % |
| Electricity | 5,004.3 | 2,432.072 | 57% |
| Natural gas | 1,032.3 | 227.11 | 5% |
| Liquefied Gas | 5,604.9 | 1,625.41 | 38% |
| Coal | 11.1 | 4.003 | 0.09% |
| Biomass | 139.5 | 5.57 | 0.13% |
| Total | 11,792.1 | 4,294.18 | |

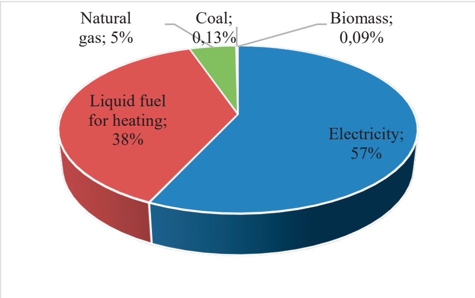


Figure 5. Distribution of greenhouse gas emissions in Sector "Municipal buildings" by type of energy source for 2021

Table 9 provides information on the three sectors - "Tertiary Buildings", "Street Lighting" and "Industry", in terms of their final energy consumption and greenhouse gas emissions in tonnes of carbon dioxide per year.

Table 9. Final energy use and GHG emissions in sectors "Tertiary buildings", "Street lighting" and "Transport"

| Sector | Final energy use | GHG emissions |
|---|---|---|
| | MWh/y | t $CO_2$/y |
| Tertiary Buildings | 2,838.5 | 1,379.49 |
| Street Lighting | 3,159.1 | 1,535.3 |
| Industry | 61,998.2 | 30,131.14 |

Sector "Tertiary buildings" represent 1% of the final energy use in the city of Vidin, and also accounts for 1% of GHG emissions in the city. In the sector, the most significant energy source is electricity. Sector "Street lighting" accounts for 1% of the final energy use and 1% of GHG emissions, respectively.

Table 10 provides information for the energy sources used in Sector "Transport" and its associated greenhouse gas emissions in tons $CO_2$ per year:

Diesel has the largest share of total GHG emissions in the "Transport" sector (67%), making it a major source of pollution in this sector.

Gasoline follows with a significant share of 29% in total emissions. Liquefied petroleum gas (LPG) and other energy sources (electricity, natural gas/methane) have lower share in the total emissions from "Transport" sector (4%) (Figure 6).

Private motor vehicles have the highest final energy consumption and generate the highest amount of $CO_2$ emissions (42,466.06 t/year). Urban transport and municipal vehicles use a small amount of energy and generate relatively low emissions but should not be neglected in climate change mitigation actions.

Table 10. Final energy consumption and GHG emissions in the Sector "Transport"

| Sector Transport | Final energy use | Conversion factor | Distribution of GHG emissions | |
|---|---|---|---|---|
| | MWh/y | g $CO_2$/kWh | GHG emissions t $CO_2$/y | % |
| Electricity | 29.4 | 486 | 14.29 | 0% |
| Natural gas | 183.9 | 220 | 40.46 | 0% |
| Liquefied Gas (LPG) | 5,370.64 | 290 | 1,557.49 | 4% |
| Diesel | 99,010.69 | 290 | 28,713.1 | 67% |
| Gasoline | 43,479.34 | 290 | 12,609.01 | 29% |
| | 148,074.0 | | 42,934.34 | |

Private motor vehicles have the highest final energy consumption and generate the highest amount of $CO_2$ emissions (42,466.06 t $CO_2$/year). Urban transport and municipal vehicles use a small amount of energy and generate relatively low emissions but should not be neglected in climate change mitigation actions.

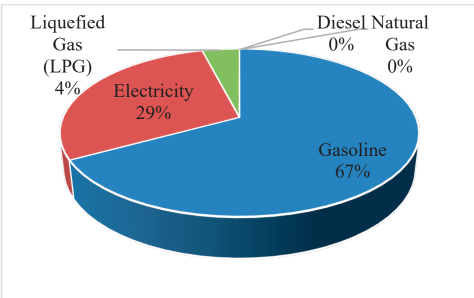


Figure 6. Distribution of GHG emissions in Sector "Transport" by type of energy source for 2021

A summary table (Table 11) is presented to provide an overview of the Vidin's final energy use, as well as greenhouse gas (GHG) emissions across different sectors. on the basis of the presented data, the potential for final energy savings and emission reduction was analysed, as the long-term vision for development of the city of Vidin was defined until 2030 and until 2050, which considers the medium- and long-term goals and priorities of the regional policy, laid down in the strategic documents at different territorial levels in the country: regional, regional, national level.

Table 11. Summary of final energy use and GHG emissions and 2030 targets by sector

| Sector | Distribution of final energy consumption by sector | | Distribution of GHG emissions by sector | | Final energy usage reduction targets | | GHG emissions reduction targets | |
|---|---|---|---|---|---|---|---|---|
| | MWh/ y | % | t $CO_2$/ y | % | t $CO_2$/ y | MWh | t $CO_2$/ y | % |
| Municipal buildings | 11,792.1 | 3% | 4,294.2 | 4% | 2,830.1 | 24% | 3,044 | 71% |
| Tertiary sector | 2,838.5 | 1% | 1,379.5 | 1% | 709.6 | 25% | 344.87 | 25% |
| Residential buildings | 175,629.8 | 44% | 33,834.5 | 30% | 17,563.0 | 10% | 1,5902.22 | 47% |
| Street lighting | 3,159.1 | 1% | 15,353 | 1% | 315.9 | 10% | 767.65 | 50% |
| Industry | 61,998.2 | 15% | 30,131.1 | 26% | 3,719.9 | 6% | 7,532.79 | 25% |
| Transport | 148,074.0 | 37% | 42,934.3 | 38% | 29,614.8 | 20% | 19,749.8 | 46% |
| Total | 403,491.5 | | 114,109.0 | | 54,753.3 | 13% | 47,341.32 | 40% |

## CONCLUSIONS

To estimate carbon dioxide emissions, a comprehensive analysis of all significant energy consumers in the city of Vidin by sector was implemented.

It was established that the municipality of Vidin lacks a mechanism for energy planning and modelling. There is a lack of tools for analysis and monitoring of energy consumption in the sectors. It was recommended that an energy monitoring system be included in the municipality's strategic energy documents, with the aim of analysing the final energy consumption by sector and evaluating the effect of the implemented measures.

The analysis shows that the residential, transport and municipal sectors are key areas of focus: residential and transport together contribute significantly to final energy consumption and greenhouse gas (GHG) emissions. In addition, municipally owned buildings should serve as an example of increasing energy efficiency.

Based on the analysis, it will be recommended that the Municipality of Vidin focus on the following priority actions to mitigate climate change: reducing final energy consumption in the building sector by increasing the energy efficiency of buildings and municipal infrastructure and modernizing heat sources; increasing the share of renewable energy sources in final energy consumption, modernizing public, municipal and private transport, creating a favourable business and industrial environment by increasing the competitiveness of local enterprises, creating a better urban environment by building and expanding parks and green alleys in a city, increasing the administrative capacity for energy transition.

The goal of the implementation of the above-mentioned priorities is to achieve the main energy goals of the city: reduction of greenhouse gas emissions by 40% by 2030 and reduction of annual final energy consumption by 13% by 2030.

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