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Energy and emission balance of the Małopolskie Voivodeship in 2020

The article presents the energy balance for the Małopolskie Voivodeship in 2020. It shows the production, import, input and output of transformation, own consumption of power plants, combined heat and power plants, network losses and consumption in the economic sectors (industry, waste), transport (road and rail), buildings (residential and tertiary), as well as in agriculture and forestry of the following energy carriers: hard coal, crude oil and petroleum products (including gasoline, diesel, LPG), non-renewable waste, derived heat and electricity. An estimate of greenhouse gas emissions in 1990 and 2020 in the Małopolskie Voivodeship is also presented.

Key words: *greenhouse gas emissions, energy scenarios, energy balance*

1. INTRODUCTION

During the 21st UN Climate Conference in Paris in 2015, it was agreed that all 195 countries would present long-term scenarios to reduce greenhouse gas emissions [1]. In 2021, the European Union announced the ambitious "Fit for 55" package, which assumes reducing greenhouse gas emissions by 55% by 2030 compared to 1990 and achieving climate neutrality by 2050 [2]. This package is much more ambitious than the previous target (adopted in 2014) of reducing greenhouse gases in the EU at a level of 40% by 2030 compared to the base year of 1990 [3].

The Małopolskie Voivodeship was the first in Poland to start developing long-term plans and actions to reduce greenhouse gases. Many steps have been taken to this end, including a detailed estimate of greenhouse gas (GHG) emissions into the atmosphere together with the AGH University of Krakow. The emission of GHG was estimated for 1990 and 2018. The year 2018 was the base year for the Regional Action Plan for Climate and Energy created in 2020 [4]. This plan assumed the implementation of the EU climate goals from 2014 (40% reduction GHG by 2030 compared to 1990).

The Faculty of Energy and Fuels of the AGH University of Krakow has also developed detailed scenarios for reducing greenhouse gas emissions in the Małopolskie Voivodeship by 2050. Four scenarios were created, taking into account the goals included in the Regional Action Plan for Climate and Energy of the Małopolskie Voivodeship (the Małopolska scenario), the National Energy and Climate Plan (the National scenario) as well as new goals under the "Fit for 55" package (the Optimistic scenario) [2, 4, 5]. Additionally, one scenario (Stagnation) assumes no active actions would be taken to reduce greenhouse gas emissions in the voivodeship. The base year for the analyses is 2020. The presented energy and emission balance prepared for 2020 were used to validate the Times-Małopolska model developed and is a starting point for the scenario analyses. The Times-Małopolska

model was developed to support the energy planning process in the Małopolskie Voivodeship. The model was built using the TIMES generator (IEA), widely used to model fuel and energy systems at various territorial scales [6]. The model is used to analyse the development of the energy system of Małopolska province in the medium and long term, including the determination of the optimal technological structure and the energy investment program for the given conditions. The following sectors were analysed in the energy and emission balances and the model: energy, transport, agriculture and forestry, economy (industry), buildings, forests, and land use.

Energy and emission balances are prepared at the national level and have been presented, among others, by the National Centre for Emissions Management (KOBiZE) and Eurostat [7]. However, there are no analyses and results at the voivodeship level in the literature and databases. As part of Air Protection Programs established at the voivodeship level, as well as locally developed (municipal, urban) plans for the supply of heat, electricity and gas fuels or low-emission economy plans, pollutant emissions and consumption of energy carriers are estimated, but they contain differently aggregated data which are often incomplete or outdated.

2. METHODOLOGY

In order to determine the value of the reduction of direct greenhouse gas emissions for the voivodeship, emissions of CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 were estimated for 1990 and 2020. The year 1990 is the base year for goals at the EU, national, and regional levels [2–5]. In 1990, the Małopolskie Voivodeship did not exist, and the areas of the current voivodeship (created as a result of the local government reform of 1999) belonged to the following voivodeships existing in the years 1975–1998: Kraków, Nowy Sącz, Tarnów, Bielsko, Kielce, Katowice and Krosno.

Direct emissions of the following greenhouse gases from sources located in the voivodeship were estimated: CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6. The following greenhouse effect potential was assumed: for CH_4 23, for N_2O 296, SF_6 22200, HFCs 14800 and PFCs 7390.

The energy sector includes emissions and consumption of fuel carriers, as well as energy transformation and losses in the processes of heat, cooling, and electricity production in public power plants, heating plants and CHP, as well as distribution of heating and electricity. The energy and emission balance for this sector was prepared based on data of the National Centre for Emissions Management (KOBIZE), Energy Market Agency (ARE), Central Statistical Office (GUS), Polish Power Grids (PSE), Eurostat, and others [7–16].

The economic sector includes waste management, water and sewage management and industry (including both activities covered and not covered by the EU-ETS). Emissions in this sector come from the storage and biological processing of solid waste, sewage treatment and disposal, waste incineration, industrial production, and the consumption of energy carriers. Emissions were estimated based on data from KOBIZE, GUS, and integrated environmental permits [7, 9, 15–17].

The building sector includes buildings from the tertiary sector: public buildings, non-public (commercial) buildings and residential buildings (single-family and multi-family). Public buildings include publicly accessible cultural facilities, museums, libraries, schools, research institutions, hospitals, medical care facilities, physical culture buildings, and buildings intended for religious activities. Commercial buildings include hotels and other tourist accommodation buildings, office buildings and shops, restaurants, cinemas, etc. Residential buildings are divided into three types: single-family detached houses, single-family terraced or semi-detached houses and multi-family buildings (blocks of flats). Then, these three types of buildings were divided into six groups depending on the year of construction. In both tertiary and residential, energy carriers are used for the following purposes: space heating and cooling, refrigeration equipment for food storage, food preparation equipment, lighting, hot water preparation, other household appliances, and electronics. Emissions and consumption of carriers from this sector were calculated based on data of KOBIZE, GUS, Central Registration of Building Emissions (CEEB) and others [7–9, 17–24].

The transport sector includes public (trains, trams, buses) and private. The following transport categories were considered: buses, special cars (police, military, ambulance etc) and trucks – divided into heavy and light (less than 3.5 tons), motorcycles, passenger cars, trams, passenger, and freight trains as well as regional and long-distance trains. Vehicle categories were divided into the type of fuel used, e.g., passenger cars powered by petrol, diesel, LPG, electric, hybrid, and trains powered by electric and combustion engines (diesel). For each type of vehicle and fuel, the annual mileage, number of vehicles, average number of passengers and goods in the vehicle, average fuel

consumption, etc. were assumed. Energy consumption and emissions were calculated based on the data obtained from: KOBIZE, Eurostat, GUS, city offices of Krakow and Tarnów, Railway Transport Office, General Directorate for National Roads and Highways, expert analyses of the Motor Transport Institute [7, 9, 17, 25–38]. Additionally, the consumption of energy carriers in road transport and their resulting emissions were calculated with the use of COPERT V (EU standard vehicle emissions calculator) [35]. The study does not include aviation emissions.

The agricultural sector includes emissions from field cultivation (including the use of artificial fertilizers), emissions from livestock, and emissions from the use of energy carriers. This sector includes emissions related to the consumption of tractors, harvester, heating of barns and greenhouses etc. Animal methane emissions from enteric fermentation, methane and dinitrogen oxide emissions manure management, greenhouse gas emissions from fertilization and liming of fields, and burning of agricultural residues were estimated. The calculations included domestic cattle, sheep, goats, pigs, poultry, horses, rabbits, and other fur-producing animals. Emissions from the use of energy carriers were also estimated. Data from KOBIZE, GUS, agricultural censuses, breeders' associations etc. were used [7, 9, 17, 39–43].

The forest and land use sector includes emissions related to fuel and energy consumption. Emissions were calculated based on KOBIZE and GUS data [7, 9, 17]. In this sector, CO_2 is also intensively absorbed by forests – the results of absorption estimations are not included.

3. ENERGY BALANCE

The energy balance for the Małopolskie Voivodeship for 2020 was prepared for the following carriers: hard coal, natural gas, crude oil and petroleum products, derived heat, electricity, waste, and renewable energy sources (Fig. 1). The balance also includes the import and local use of fossil fuels, renewable energy sources, and waste [7, 10, 12, 44]. The main energy carriers in final energy consumption are petroleum products (diesel, gasoline), used mainly in the transport sector. However, hard coal is used most frequently in the voivodeship. Almost half of hard coal (51%) is an input for energy transformation, to produce electricity and heat. In the economic sector, the main energy carriers are hard coal and natural gas. The share of renewable sources in the final energy consumption in 2020 was 6%. Most renewable energy sources are used in building sector due to the significant use of PV and biomass boilers. In the Małopolskie Voivodeship, mainly hard coal is mined, which covers approximately two-thirds of the demand for this fuel. The extraction of other fuels is low.

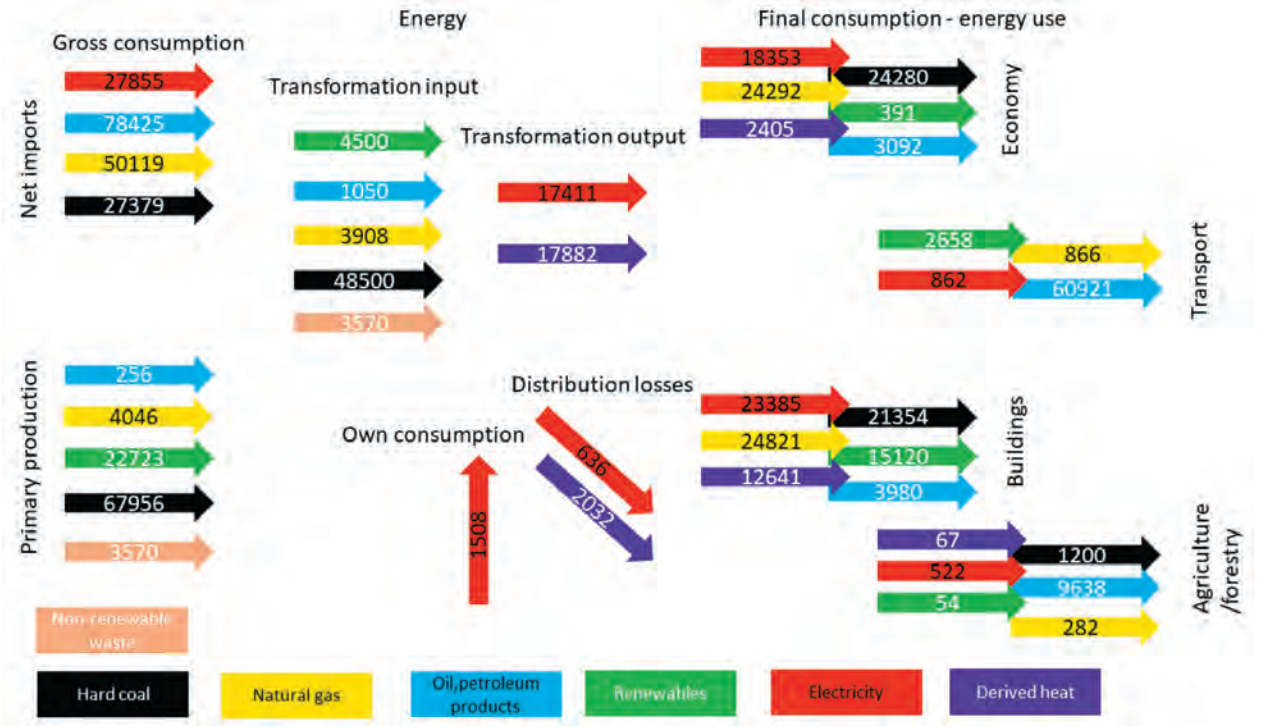

Fig. 1. Energy balance of the Małopolskie Voivodeship for 2020 [TJ].
The "Oil and petroleum products" category includes crude oil, gasoline, diesel oil and LPG

4. EMISSION BALANCE

In 1990, 27,155 kt CO_2e of greenhouse gases was emitted in Małopolskie Voivodeship, while in 2020 19,726 kt CO_2e which is a reduction of 27% (Fig. 2). The largest reduction in emissions during the considered period occurred in the energy sector, where greenhouse gas emissions decreased from more than 10 million tonnes to 4.6 million tonnes. A significant decrease in emissions, that is, by 3 million tonnes, was also observed in the economic sector. A large increase in greenhouse gas emissions is observed in the transportation sector. Between 1990 and 2020, emissions in the transport sector increased significantly from 1,697 to 4,082 kt CO_2e. This is due to the increasing number of vehicles and trips with the use of private passenger cars. In the building sector, greenhouse gas emissions decreased by 13%. In this sector, quite intensive improvement in efficiency (thermomodernisation) and the development of renewable energy sources can be observed. On the other hand, the number of apartments and houses is increasing, as well as the consumption of electricity related to the growth in quality of life. The share of carbon dioxide in total greenhouse gas emissions in the Małopolskie Voivodeship in 2020 was almost 90% (Fig. 3).

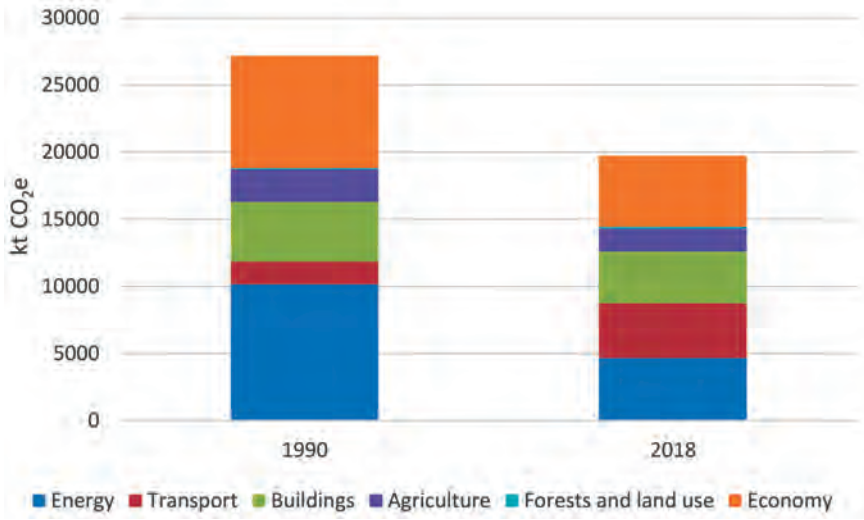

Fig. 2. Greenhouse gas emissions in the Małopolskie Voivodeship in 1990 and 2020 [kt CO_2e]

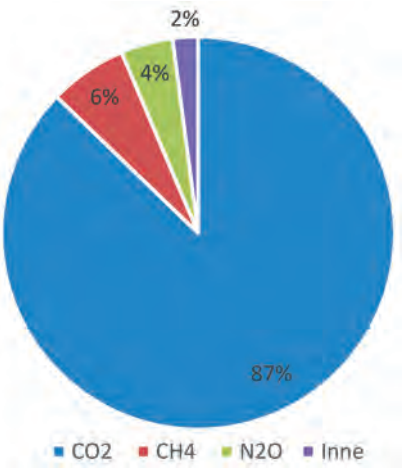

Fig. 3. Mass share (considering the greenhouse potential) of greenhouse gases emitted in 2020 in the Małopolskie Voivodeship

4. SUMMARY AND CONCLUSIONS

The article contains the results of the energy balance for 2020 and the emission balance for 1990 and 2020 for the Małopolskie Voivodeship. The total gross supply of energy carriers was 278,758 TJ. The share of renewable sources in the voivodeship is still low. The highest final energy consumption is observed in the sector including residential, public, and non-public buildings (intended for services). In the voivodeship, the average greenhouse gas emissions per capita in 2020 were 5.78 t CO_2e, lower than the national average for Poland by over 4 t CO_2e. This difference results from large imports of electricity from outside the voivodeship. Greenhouse gas emissions in the years 1990–2020 mainly decreased in the economy and energy sectors while transport emissions are increasing rapidly. The energy and emission balances are the basis for developing energy and climate goals and long-term strategies, and also allow one to observe the progress of the implementation of local policies and goals regarding the reduction of greenhouse gases. Therefore, starting from 2018, the greenhouse gas emission balance in the Małopolskie Voivodeship has been prepared annually (the last one being in 2021).

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