



Scenario-Based Assessment of Climate Neutrality Pathways in Raciechowice Municipality, Poland

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This document presents an assessment of future energy demand and CO₂ emissions in Raciechowice municipality up to 2050, using a scenario-based modelling approach. The analysis covers major sectors, including buildings, transport, public infrastructure and waste management, and evaluates the impacts of selected policy measures on energy consumption, fuel structure, and emissions.

The analysed scenario assumes a modest economic development and no population changes, which leads to relatively stable or slowly decrease demand in several sectors. In this scenario, decarbonisation is primarily achieved through energy efficiency improvements, demand reduction, behavioural measures, and integrated sectoral policies. The document highlights the trade-offs between energy demand reduction and technology-led decarbonisation, and provides insights into how different policy choices can shape Raciechowice's long-term energy system and climate outcomes.

NB! The simulations were conducted solely for exploratory and analytical purposes. They do not represent official projections, nor have they been adopted or endorsed by Raciechowice municipality. Rather, these exercises serve as a basis for discussion and reflection among municipal stakeholders and may support future decision-making processes.

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1. MUNICIPALITY BUILDINGS

Energy consumption in municipal buildings refers to the amount of energy used by public facilities owned or managed by local governments, including city halls, schools, libraries, police and fire stations, public works facilities, and recreational centers. These buildings often have diverse functions and require energy for lighting, heating, cooling, water heating, and running various equipment and systems.

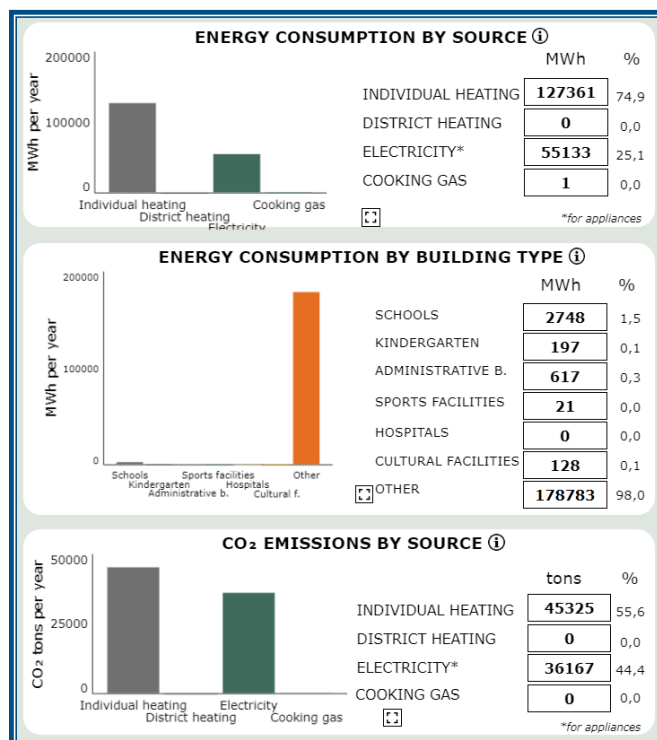
1.1. Current situation

In Raciechowice municipality, the total area of municipal buildings in the baseline year is 427 385 m². The largest share by area is made up of schools, administrative buildings and other building groups. The total energy consumption in municipal buildings in 2021 was 219 953 MWh, which accounted for 73,8 % of energy consumption in Raciechowice municipality. As no building construction or demolition is assumed, both energy consumption and emissions remain unchanged throughout the baseline scenario.

In energy consumption, the largest share is individual heating with 74,9 % of the total energy consumption, followed by electricity consumption for appliances (25,1 %). It should be noted that electricity for appliances does not include electricity used for heating, rather it is included in individual heating.

The average specific heat energy consumption in municipal buildings is 298 kWh/m²/year and electricity consumption is 129 kWh/m²/year (weighted average across the entire building stock).

Total CO₂ emissions in municipal buildings related to energy use in the Baseline year were 81 493 tons of CO₂. The largest source of CO₂ emissions is individual heating (55,6 %), followed by electricity consumption for appliances (44,4 %). Overall, CO₂ emissions in municipal buildings make up 71,3 % of total CO₂ emissions in the municipality.



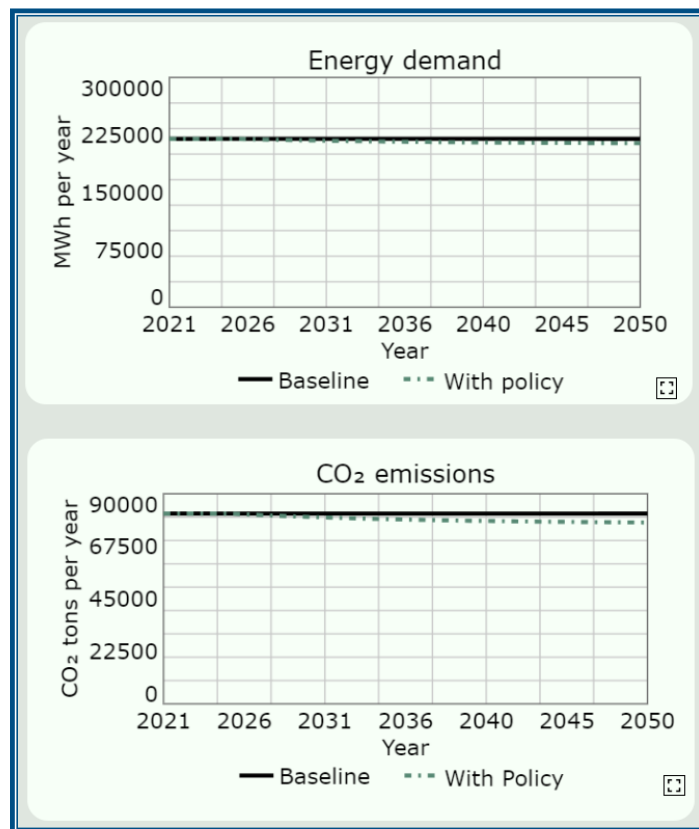
1.2. Policies

In the municipality buildings sector, the following policy was proposed:

- **Replacement of light bulbs** (*Implementation speed (IS) 10 %/year, Expected savings (ES) 80 %*)

The implementation start year for the policy was 2025, while implementation end year was 2050.

The selected policy decreased the energy demand in municipal buildings by 5793 MWh/year and emissions by 3800 tCO₂/year, resulting in 2,6 % and 4,7 % reductions, respectively.



2. RESIDENTIAL BUILDINGS

Energy consumption in residential buildings refers to the total amount of energy used for various activities, including heating, cooling, lighting, cooking, and powering appliances. All residential building stock is grouped according to four types – single family detached, single-family attached, large multi-family, and other.

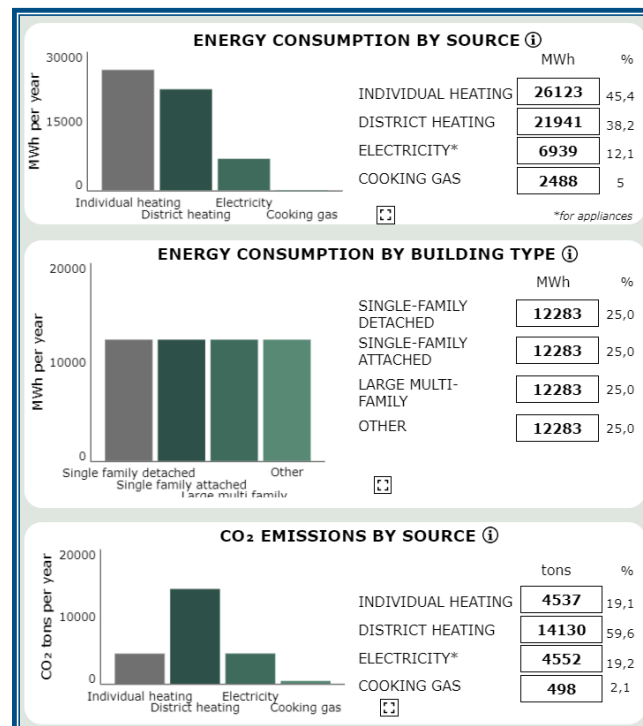
2.1. Current situation

In Raciechowice municipality, the total area of residential buildings in the baseline year is 187 528 m². This area is made up of single-family detached, single-family attached, multi-family and other houses. In 2021, the total energy consumption in residential buildings was 57 491 MWh, accounting for 19,3 % of total energy consumption in Raciechowice municipality.

Of the total energy consumption, district heating systems make up 38,2 % or 21 941 MWh and energy for individual heating – 45,4 % of total energy demand. Electricity consumption for appliances makes up 12,1 % or 6939 MWh. It should be noted that electricity for appliances does not include electricity used for heating, rather it is included in individual heating.

The average specific energy consumption for space heating and hot water preparation in the residential sector is 225 kWh/m²/year per year, and electricity consumption is 37 kWh/m²/year (weighted average across the entire building stock).

The amount of CO₂ generated in the household sector in the Baseline year were 23 716 tCO₂/year, which is 20,7 % of the municipality's CO₂ emissions. The largest source of CO₂ emissions in residential buildings is district heating, which is responsible for 59,6 % of total CO₂ emissions followed by electricity for appliances (19,2 %) and individual heating (19,1 %).



2.2. Policies

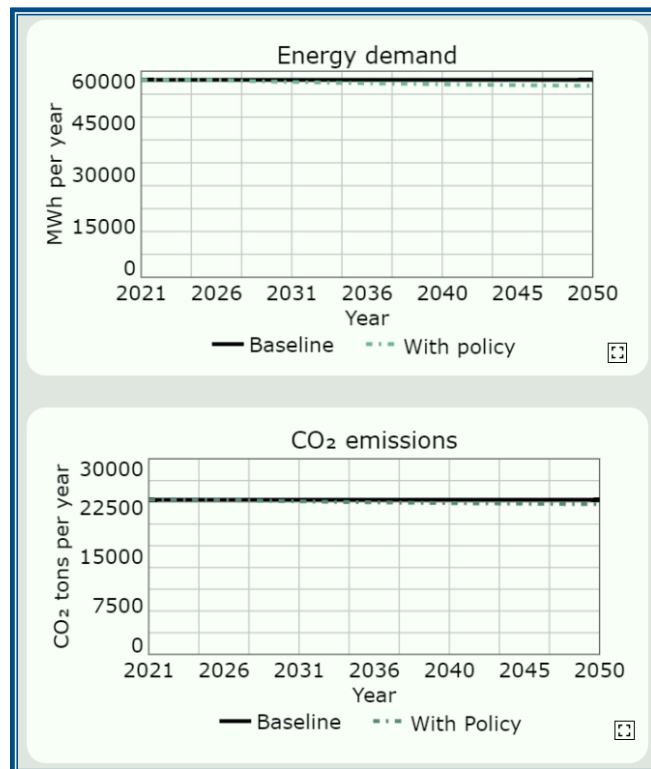
To reduce energy consumption and emissions, a comprehensive renovation strategy in single-family houses was tested, starting in 2025.

- **Renovation of single-family houses (IS 5 %/year, ES 10 %)**

The policy implementation start year was 2025, while implementation end year was 2050.

In total, the selected policy achieved 1737 MWh in energy savings and 674 tCO₂ in emission savings in 2050 compared to the baseline scenario (3 % and 2,8 % reductions respectively).

After the policy implementation start year in 2025, both energy consumption and emissions continue to decrease in a relatively constant rate of around ~0,12 % and ~0,11 % respectively.



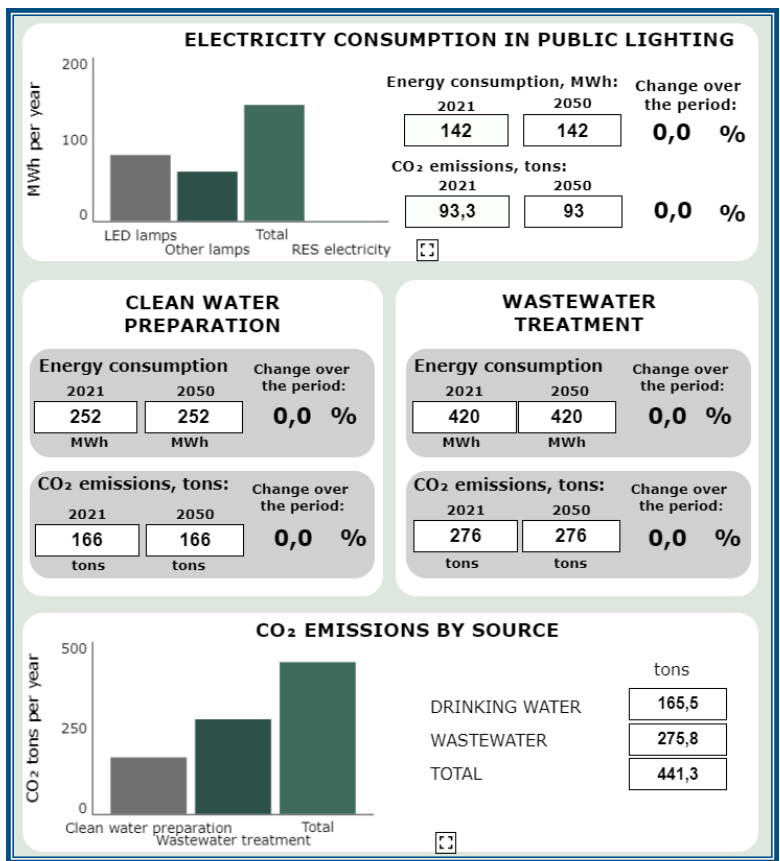
3. PUBLIC INFRASTRUCTURE

The Public Infrastructure sector encompasses essential services and systems that support communities and contribute to their quality of life. This sector includes electricity consumption related to public lighting, clean water preparation, and wastewater treatment, all of which are critical to maintaining public health, safety, and urban functionality.

3.1. Current situation

In Raciechowice municipality, the expected total electricity consumption in the Public infrastructure sector in the baseline scenario is 814 MWh/year, which is 0,3 % of the municipality’s total energy consumption, with wastewater treatment accounting for 51,6 %, public lighting – 17,5 % – and drinking water preparation – 31 % of the total public infrastructure energy consumption.

The amount of CO₂ generated in the Public Infrastructure sector in the baseline year is 535,3 tons/year, which is 0,5 % of the municipality’s total energy consumption. Since no population changes are assumed, public infrastructure energy consumption and emissions remain unchanged throughout the baseline scenario.



3.2. Policies

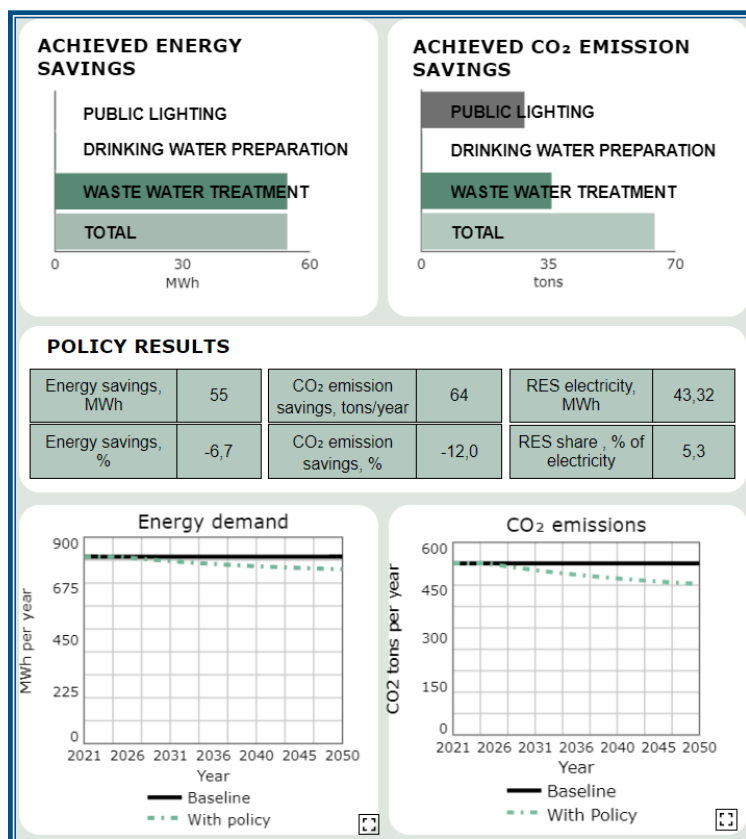
To assess the potential for reduction of emissions, the following public infrastructure-policies were tested:

- RES usage in public lighting (IS 3 %/year)
- Wastewater generation decrease (IS 5 %/year)

For all policies the implementation start year was 2025, while implementation end year was 2050.

In total, the selected policies achieved 55 MWh in energy savings in 2050 compared to the baseline scenario (6,7 % reduction). This reduction in energy consumption is achieved through reducing the amount of wastewater generated, as RES usage in public lighting does not affect total energy consumption; instead, it increases the share of renewable electricity.

As after implementing policies , CO₂ emissions drop by 65 tCO₂, a (12 % decrease). The RES usage policy introduces 43,32 MWh/year of renewable energy, which comprises around 5,3 % of the sector’s energy demand.



4. OTHER SECTORS

In Other sectors, energy consumption from four sub-sectors is considered: Commercial and Tertiary, Industry and Construction, Agriculture and Forestry, and Other. Only emissions related to energy consumption are considered in this sector. The calculations are based on aggregated statistical data on energy consumption in sectors and assumptions about future development trends.

4.1. Current situation

In Raciechowice municipality, Other sectors energy consumption and GHG emissions are not included in the baseline inventory and projection.

4.2. Policies

In Raciechowice municipality, Other sectors energy consumption and GHG emissions were not included in the baseline inventory and projection; thus, no policy analysis was conducted.

5. TRANSPORT

The transport sector in municipalities is a significant contributor to greenhouse gas (GHG) emissions, primarily due to reliance on fossil fuels. Sectors covered include: municipal vehicle fleet, public and private transportation. Only land transport and CO₂ emissions related to fuel combustion are considered. It should be noted that the results for the transport sector are obtained through calculations, not based on actual fuel invoices. Therefore, there may be data discrepancies.

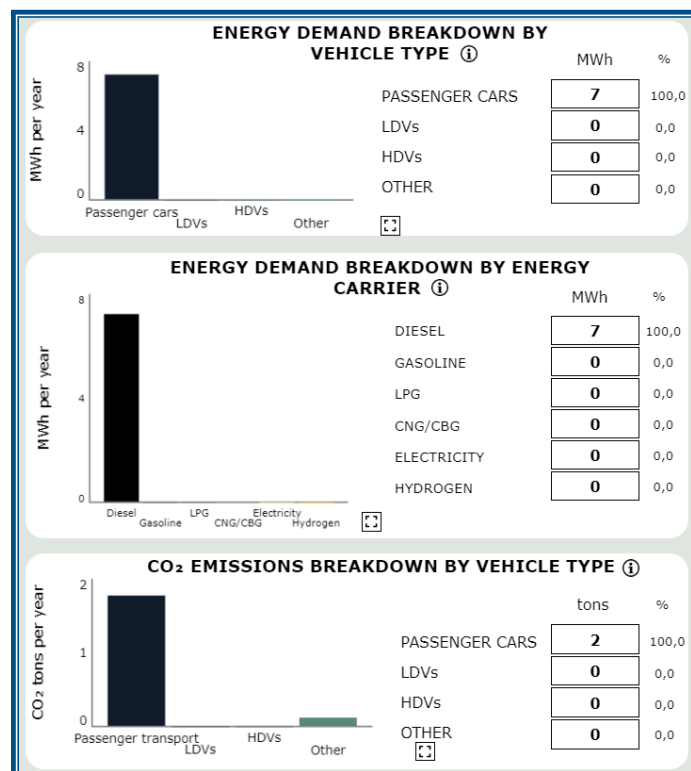
5.1. Current situation

Municipal vehicle fleet

The municipal vehicle fleet consists of 1 diesel passenger car (therefore, diesel comprises 100 % of the fuel consumption). Assuming the average annual vehicle mileage, specific fuel consumption by fuel type and fuel type distribution, it was calculated that the energy consumption of the municipal vehicle fleet is 7 MWh per year, which is negligible in the municipality's total energy consumption.

Total CO₂ emissions related to the municipality's vehicle fleet amount to 2 tons of CO₂ per year, which are also negligible in the municipality's total CO₂ emissions.

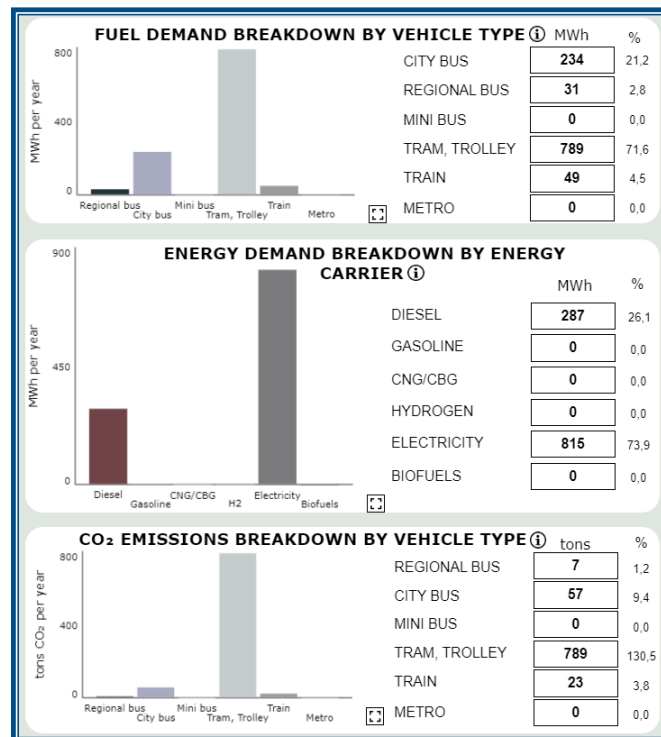
The baseline scenario does not assume any changes in the municipal vehicle fleet, thus energy consumption and emissions are assumed to remained unchanged from the base year.



Public transport

According to existing data, 6 million passenger kilometres per year are performed by public transport. The largest share of this demand is made up of city public transport (90 %), followed by regional public transport (10 %).

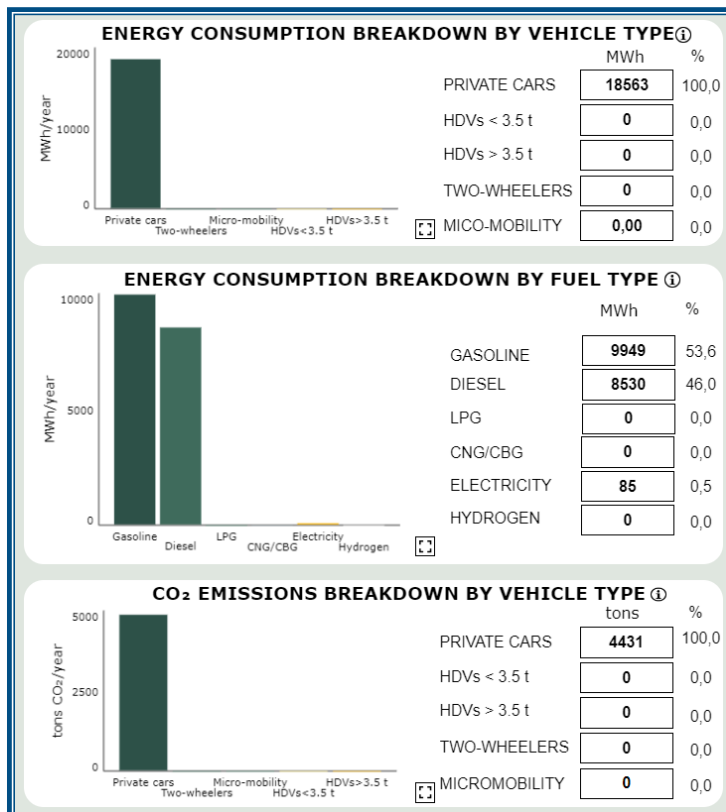
Based on the assumptions made regarding the use of various public transport modes, average occupancy rates, average fuel consumption and type of fuel used, it has been calculated that the energy consumption of public transport is approximately 1103 MWh per year in 2021 or 0,4 % of the municipality's energy consumption. Of this, the largest share is made up of tram and trolley (71,6 %), followed by city bus (21,2 %) and train (4,5 %). Electricity dominates in terms of fuel consumption with 73,9 %, followed by diesel with 26,1 %. Total CO₂ emissions related to energy consumption in public transport amounted to 605 tons of CO₂ in 2021 or approximately 0,5 % of the municipality's total CO₂ emissions.



Private transport

According to existing input data, private transport demand in the municipality is approximately 31,3 million passenger kilometres per year. Based on the assumptions made regarding the use of private vehicles, average fuel consumption and type of fuel used, it has been calculated that the energy consumption in the private transport sector will reach 18 563 MWh per year by 2050 and reach 6,2 % of the municipality's total energy consumption. This energy demand is completely made up by private cars. Looking at the type of fuel, the two main types of fuel are diesel (53,6 %) and gasoline (46 %). Electricity accounts for a small proportion – 85 MWh per year or 0,5 % of total energy demand. Total CO₂ emissions in the private transport sector amount to 4431 tons of CO₂ per year, or approximately 3,9 % of the municipality's total CO₂ emissions in baseline year.

The baseline scenario assumes no changes in private transport usage patterns and no policy interventions, therefore, energy consumption and emissions remain unchanged throughout the whole baseline scenario.



5.2. Policies

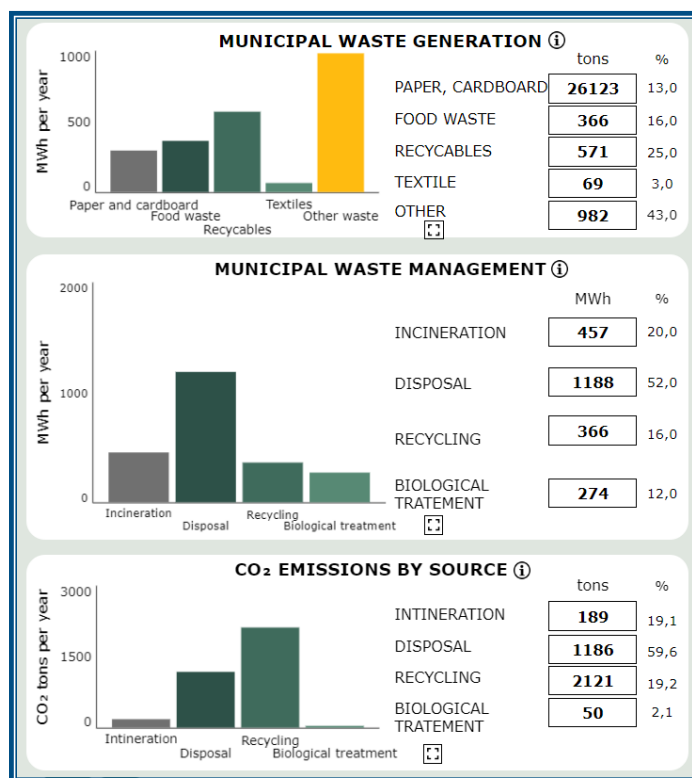
In this sector, no policy measures were proposed or tested, as the municipality has currently no plans to implement additional interventions. Therefore, the baseline scenario remains unchanged, and no simulated energy or emission reductions are projected for this sector.

6. WASTE MANAGEMENT

In the waste management sector, GHG emissions related to waste management are considered. Effective waste management strategies, such as recycling, composting, and energy recovery, help reduce emissions by minimizing landfill waste and promoting circular economy practices. Municipalities can lower their carbon footprint by implementing sustainable waste policies, investing in waste-to-energy technologies, and encouraging community participation in waste reduction efforts.

6.1. Current situation

The calculations of the baseline scenario are based on assumptions about the number of inhabitants, the amount of waste generated per inhabitant (357 kg/capita/year) and the structure of municipal waste. Based on these assumptions, the amount of municipal waste generated in Raciechowice municipality in the base year is 2285 tons and the GHG emissions related to waste management constitute 3546 tons CO₂eq. The waste management sector accounts for approximately 3,1 % of the municipality's emissions.



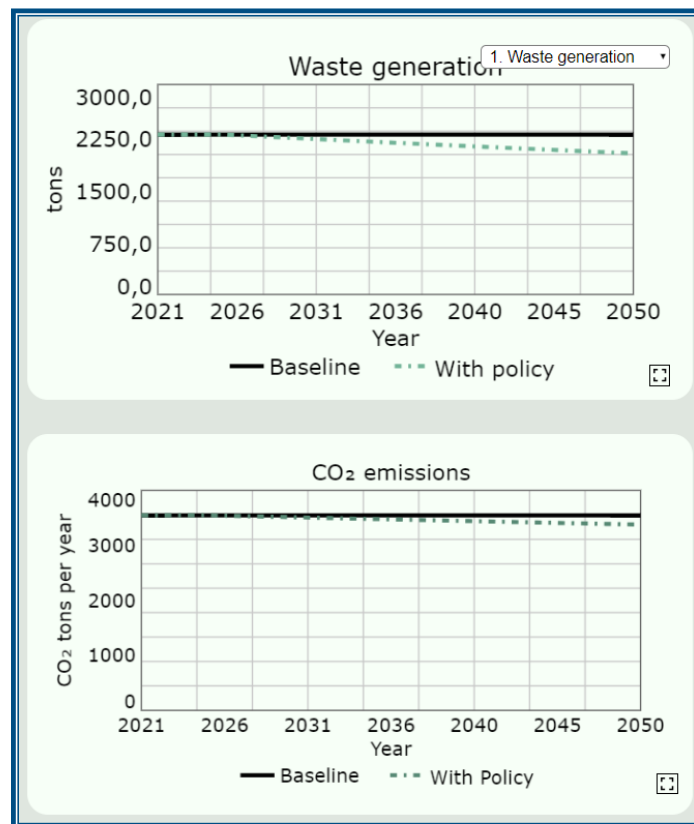
6.2. Policies

To assess the potential for further reduction of emissions, the following policy was tested:

- **Reducing amount of waste generated (15 0,5 %/year)**

The start year for both policies was 2025, while the end year was 2050.

In total, the selected policy reduced the amount of waste generated by 269 tons and achieved 167 tCO₂eq in emission savings in 2050 compared to the baseline scenario (11,8 % and 4,7 % reductions respectively).



7. LOCAL ENERGY PRODUCTION

The Local Energy Production Sector encompasses energy production technologies and their associated environmental impact. This sector includes local electricity and heat generation parameters. The municipality can reduce CO₂ emissions in this sector by reducing heat losses in the system, recovering lost heat and decarbonizing various energy systems.

NB! The local energy production sector differs from other sectors in that it represents energy supply rather than energy demand. The 2050 scenario without energy-production-specific policies therefore reflects the energy demand generated by all other sectors after their respective policies are applied, but before any policies targeting local energy production are introduced.

7.1. Current situation

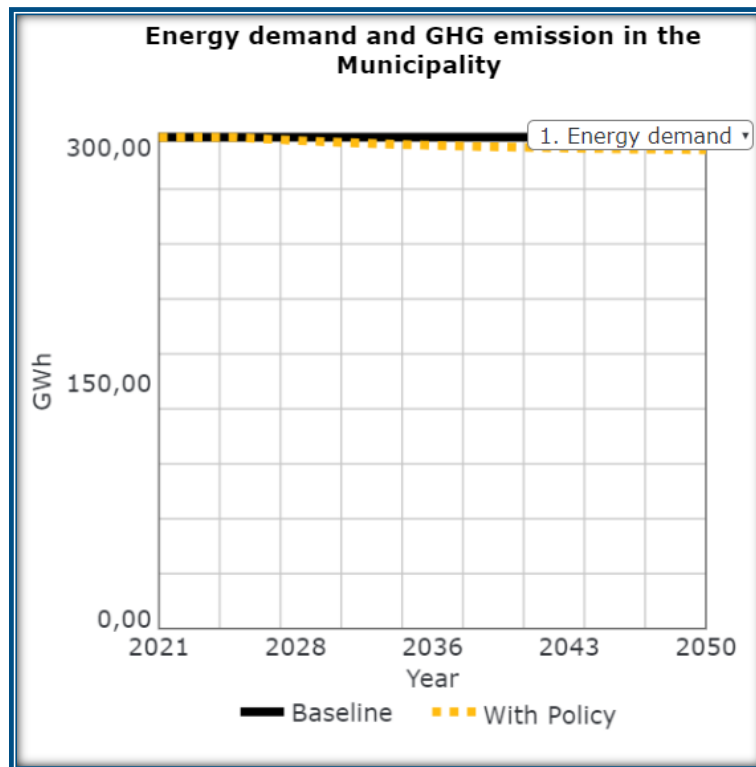
In Raciechowice municipality, Local energy production energy demand and GHG emissions are not included in the baseline inventory and projection.

7.2. Policies

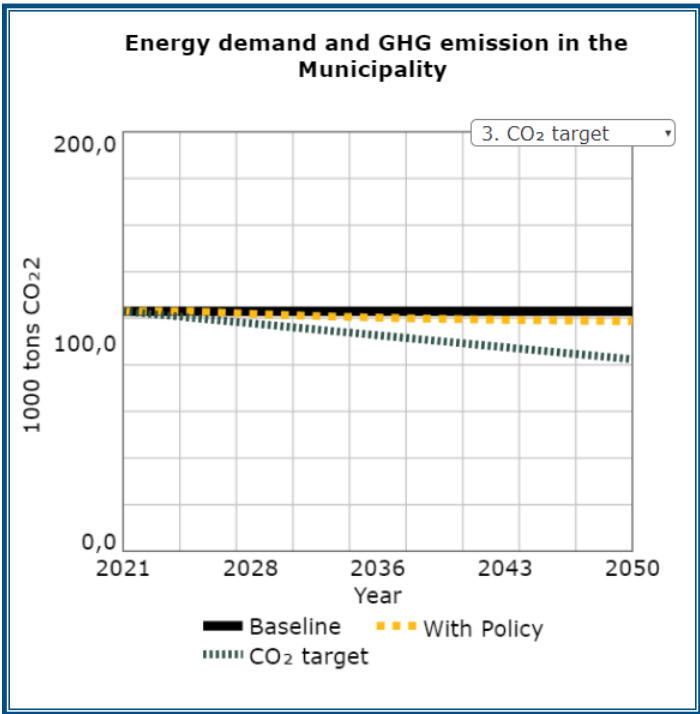
In Raciechowice municipality, Local energy production energy demand and GHG emissions were not included in the baseline inventory and projection; thus, no policy analysis was conducted.

8. RESULT OVERVIEW

The results of the simulation show that in the baseline scenario energy demand is 297,93 GWh/year; as no population changes occur, this value remains unchanged from the baseline year through 2050. As illustrated in the figure below, the implementation of the selected policy package causes a gradual energy demand decrease, resulting in an energy demand of 290,35 GWh by 2050. This corresponds to energy savings of approximately 7584,4 MWh, or 2,5 % compared to the baseline projection.



The selected policy package leads to similarly modest emission reductions – CO₂ emissions decrease from 114,3 thousand tons in the baseline scenario to approximately 109,6 thousand tons in the policy scenario by 2050, resulting in annual emission savings of 4706,9 tons (4,1 %). As shown in the figure below, while the policy scenario slightly lowers emissions compared to the baseline trajectory, emissions remain above the long-term CO₂ target (20 % reduction by 2050), indicating that additional mitigation measures would be required to fully achieve the municipality's climate objectives.



9. CONCLUSIONS

The results of the scenario analysis for Raciechowice municipality indicate that the implementation of the selected policy package leads to limited reductions in both energy demand and greenhouse gas emissions by 2050, mainly due to the narrow scope of applied measures and the absence of structural changes in key sectors.

Overall, total energy demand decreases by approximately 2,5 % (7 584 MWh) compared to the baseline scenario, while CO₂ emissions are reduced by 4,1 % (4 707 tCO₂). These relatively modest reductions reflect the fact that the analysed scenario assumes no population change and only incremental improvements in energy efficiency, without large-scale system transformation or technological shifts.

The results clearly show that **the municipal buildings sector** dominates both energy consumption and emissions, accounting for nearly 74 % of total energy demand and over 70 % of emissions. Despite this, the implemented policy—focused only on lighting improvements—achieves relatively small reductions (2,6 % in energy demand and 4,7 % in emissions). This highlights a significant untapped potential for deeper renovation and heating system transformation in this sector.

The residential buildings sector contributes to emission reductions to a limited extent, achieving 3 % energy savings and 2,8 % emission reductions through renovation of single-family houses. These results indicate that more ambitious renovation strategies and fuel-switching measures would be required to significantly reduce emissions in this sector.

In **the public infrastructure sector**, modest energy savings of 6,7 % (55 MWh) and emission reductions of 12 % (65 tCO₂) are achieved, primarily through wastewater reduction measures and increased use of renewable electricity. While the absolute impact is small, this sector demonstrates stable and predictable improvements.

The transport sector shows no contribution to emission reduction, as no policy measures were implemented. Given that transport still contributes to overall emissions, this represents a major missed opportunity for decarbonisation, particularly through electrification and demand-side measures.

Similarly, **other sectors** and **local energy production** were not included in the modelling, limiting the overall reduction potential and preventing a comprehensive assessment of the municipality's decarbonisation pathways.

The waste management sector achieves minor improvements, with 4,7 % emission reductions, indicating that more advanced circular economy and waste treatment measures would be needed to significantly reduce emissions.

Overall, the analysis demonstrates that incremental and sector-limited policies result in only marginal improvements in energy demand and emissions. To achieve meaningful decarbonisation, Raciechowice municipality would require a broader and more ambitious policy mix, including deep building renovation, transport sector interventions, and inclusion of currently unmodelled sectors.

The results suggest that without structural changes and cross-sectoral policies, the municipality is unlikely to meet its long-term climate targets, and significantly stronger interventions will be necessary to achieve a substantial transition toward climate neutrality.

Table 1. Summary Table of Key Quantitative Results (2050)

Sector	Indicator	Results
Municipal buildings	Energy savings	5793 MWh (2,6 %)
	Emission reduction	3800 tCO ₂ (4,7 %)
	Renewable generation	–
Residential buildings	Energy savings	1737 MWh (3 %)
	Emission reduction	674 tCO ₂ (2,8 %)
	Renewable generation	–
Public infrastructure	Energy savings	55 MWh (6,7 %)
	Emission reduction	65 tCO ₂ (12 %)
	Renewable generation	43,32 MWh
Other sectors	Energy savings	–
	Emission reduction	–
Municipal fleet	Energy savings	–
	Emission reduction	–
Public transport	Energy savings	–
	Emission reduction	–
Private transport	Energy savings	–
	Emission reduction	–
Waste management	Waste generation reduction	269 t (11,8 %)
	Emission reduction	167 tCO ₂ eq (4,7 %)
Local energy production	Energy savings	–
	Emission reduction	–
	Renewable generation	–
Peak emissions from imported electricity	tCO ₂	–