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Scenario-Based Assessment of Climate Neutrality Pathways in Cēsis Municipality, Latvia

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This document presents an assessment of future energy demand and CO_2 emissions in Cēsis municipality, Latvia, 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 a slight population increase (0,5 % per year), which leads to relatively stable or slowly increasing 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 Cēsis'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 Cēsis 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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Contents

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

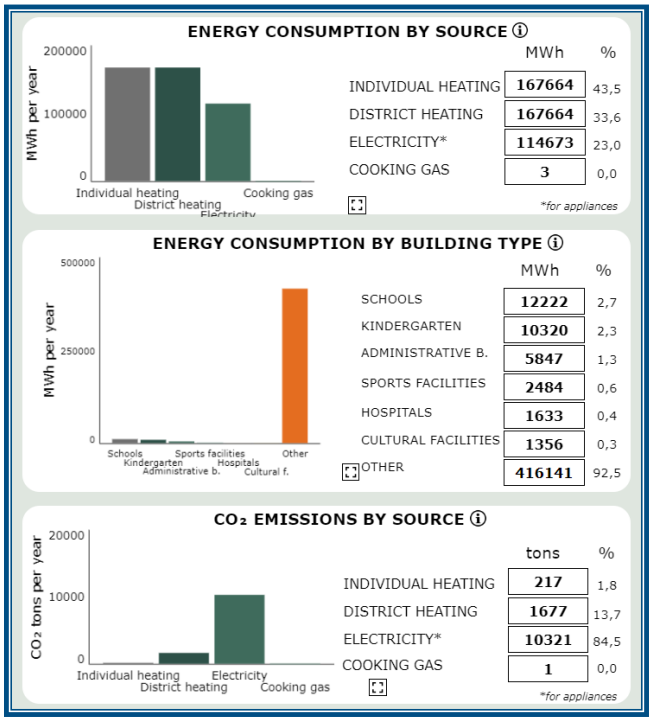
In Cēsis municipality, the total area of municipal buildings in the baseline year is 1 848 654 m². The largest share by area is made up of school, kindergarten and other building groups. The total energy consumption in municipal buildings in 2021 was 498 516 MWh, which accounted for 44,3 % of energy consumption in Cēsis municipality.

By 2050 an additional 7172 m² of administrative buildings is expected to be constructed, thus increasing energy consumption by 801 MWh (0,2 %).

In energy consumption, the largest share is individual heating with 43,5 % of the total energy consumption, followed by the district heating supply (33,6 %) and electricity consumption for appliances (23 %). 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 181 kWh/m²/year and electricity consumption is 62 kWh/m²/year (weighted average across the entire building stock).

Total CO_2 emissions in municipal buildings related to energy use in the Baseline year were 12 194 tons of CO_2. The largest source of CO_2 emissions is electricity for appliances (84,5 %), followed by district heating (13,7 %) and individual heating (1,8 %). Due to the construction of administrative buildings, emissions are expected to rise by 21 tCO_2/year (0,2 %) by 2050. Overall, CO_2 emissions in municipal buildings make up 8,6 % of total CO_2 emissions in the municipality.



1.2. Policies

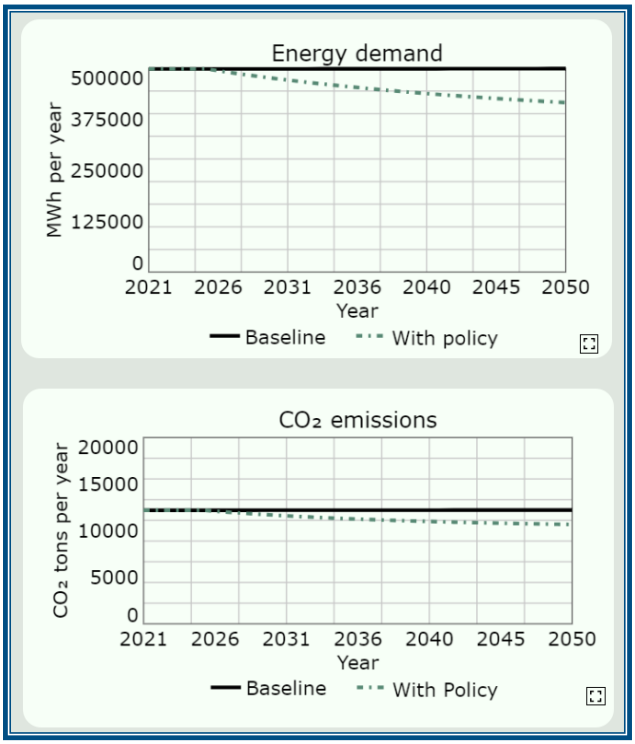
In the municipality buildings sector, several policy measures were proposed:

- **Replacement of windows** (*Implementation speed (IS)* 10 %/year, *Expected savings (ES)* 15 %)
- **Wall insulation** (*IS* 10 %/year, *ES* 40 %)
- **Replacement of light bulbs** (*IS* 10 %/year, *ES* 80 %)
- **Increased use of natural light** (*IS* 10 %/year, *ES* 5 %)
- **Ventilation optimization** (*IS* 10 %/year, *ES* 10 %)
- **Optimal use of appliances** (*IS* 10 %/year, *ES* 10 %)
- **RES-E generation** (*Solar photovoltaics installed capacity* 10 kW, *Heat pump air installed capacity* 10 kW, *Heat pump ground installed capacity* 10 kW)

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

In total, the selected policies achieved 83 207 MWh in energy savings and 1549 tCO_2 in emission savings in 2050 compared to the baseline scenario (16,7 % and 12,7 % reductions respectively). Additionally, the RES-E policy introduced 289 MWh/year of renewable energy in the policy scenario.

After the policy implementation start year in 2025, both energy consumption and emissions continue to decrease in a relatively constant rate of around 3296,7 MWh/year (~0,7 %) and 61,2 tCO_2/year (~0,5 %) respectively.


Energy demand
MWh per year
500000
375000
250000
125000
0
2021
2026
2031
2036
2040
2045
2050
Year
Baseline
With policy
CO₂ emissions
CO₂ tons per year
20000
15000
10000
5000
0
2021
2026
2031
2036
2040
2045
2050
Year
Baseline
With Policy

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

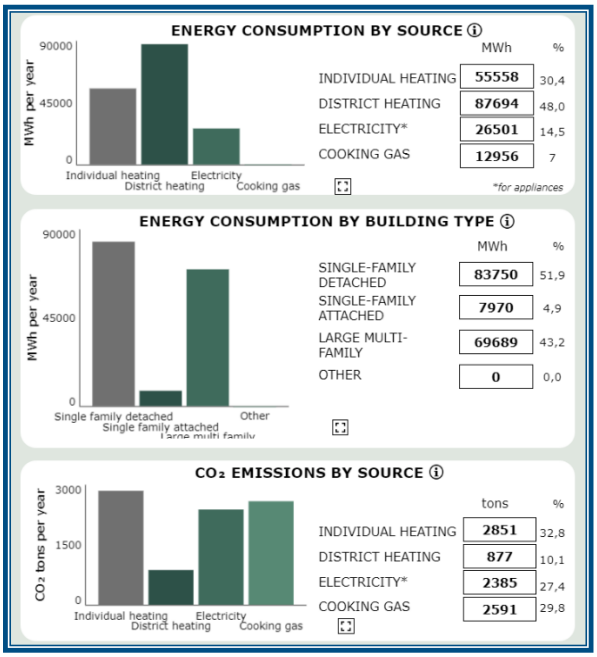
In Cēsis municipality, the total area of residential buildings accounted in calculation is 976 572 m². This area is made up of single-family detached, single-family attached and multi-family houses. In 2021, the total energy consumption in residential buildings was 182 709 MWh, accounting for 16,2 % of total energy consumption in Cēsis municipality.

Of the total energy consumption, district heating systems make up 48 % or 87 694 MWh and energy for individual heating – 30,4 % of total energy demand. Electricity consumption for appliances makes up 14,5 % or 26 501 MWh. It should be noted that electricity for appliances does not include electricity used for heating, rather it is included in individual heating.

Since the baseline scenario does not predict the construction of new residential buildings or the demolition of existing ones, the energy consumption of the baseline scenario is unchanged with the existing assumptions.

The average specific energy consumption for space heating and hot water preparation in the residential sector is 138 kWh/m²/year per year, and electricity consumption is 27 kWh/m²/year (weighted average across the entire building stock).

The amount of CO_2 generated in the household sector in the Baseline year were 8705 tons/year, which is 6,1 % of the municipality's CO_2 emissions. The largest source of CO_2 emissions in residential buildings is individual heat supply, which is responsible for 32,8 % of total CO_2 emissions.



2.2. Policies

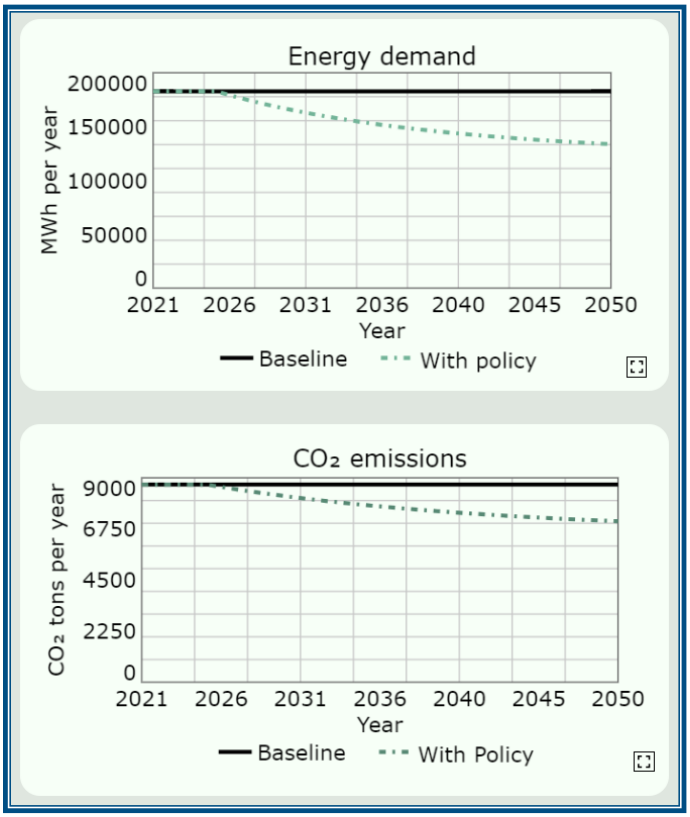
To reduce energy consumption and emissions, a comprehensive renovation and electrification strategy was tested, starting in 2025:

- **Renovation of single-family houses** (*IS* 5 %/year, *ES* 40 %)
- **Renovation of multi-family houses** (*IS* 10 %/year, *ES* 40 %)
- **Renovation of other houses** (*IS* 10 %/year, *ES* 40 %)
- **Electricity saving measures** (*IS* 5 %/year, *ES* 30 %/year)
- **Renewable and low carbon technologies** (*Solar photovoltaics installed capacity* 20 kW, *Heat pump air installed capacity* 20 kW, *Heat pump ground installed capacity* 20 kW)

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

In total, the selected policies achieved 48 975 MWh in energy savings and 1617 tCO_2 in emission savings in 2050 compared to the baseline scenario (26,8 % and 18,6 % reductions respectively). Additionally, the Renewable technologies policy introduced 577 MWh/year of renewable energy in the policy scenario.

After the policy implementation start year in 2025, both energy consumption and emissions continue to decrease in a relatively constant rate of around 1959 MWh/year (~1,1 %) and 64,4 tCO_2/year (~0,7 %) respectively.



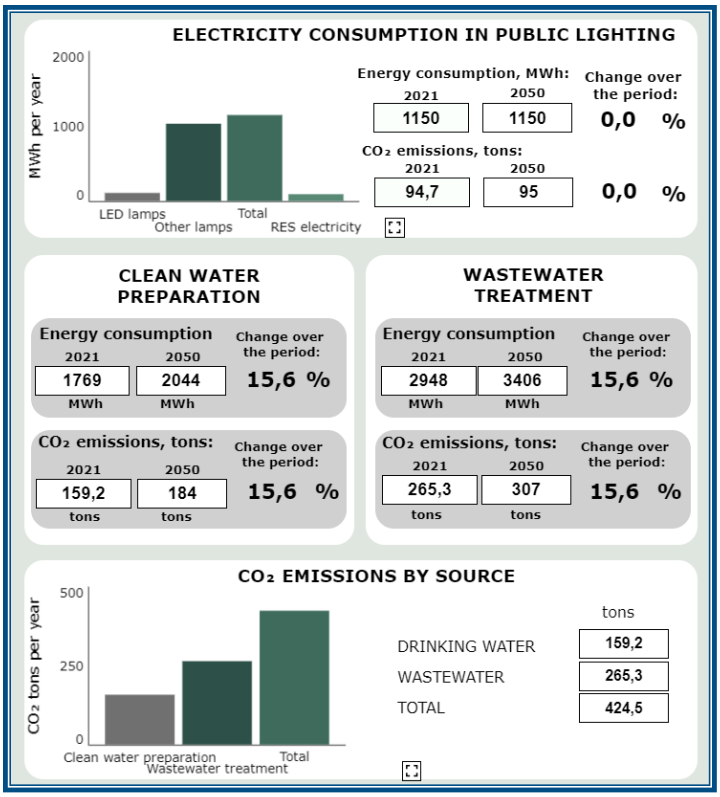
3. PUBLIC INFRASTRUCTURE

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 Cēsis municipality, the expected total electricity consumption in the Public infrastructure sector in the baseline year is 5867 MWh/year, which is 0,6 % of the municipality's total energy consumption. Due to constant population growth, the amount energy used for clean water preparation and wastewater treatment is expected to increase by 15,6 %, bringing the total energy consumption of the sector to 6600 MWh per year in 2050; with wastewater treatment accounting for 51,6 %, drinking water preparation – 31 % – and public lighting – 17,4 % of the total energy consumption.

The amount of CO_2 generated in the Public Infrastructure sector in the baseline year is 519,2 tons/year and it is expected to increase to 586 tons/year (15,6 %) in 2050 due to population growth.



3.2. Policies

The following policy measures were implemented in the public infrastructure sector:

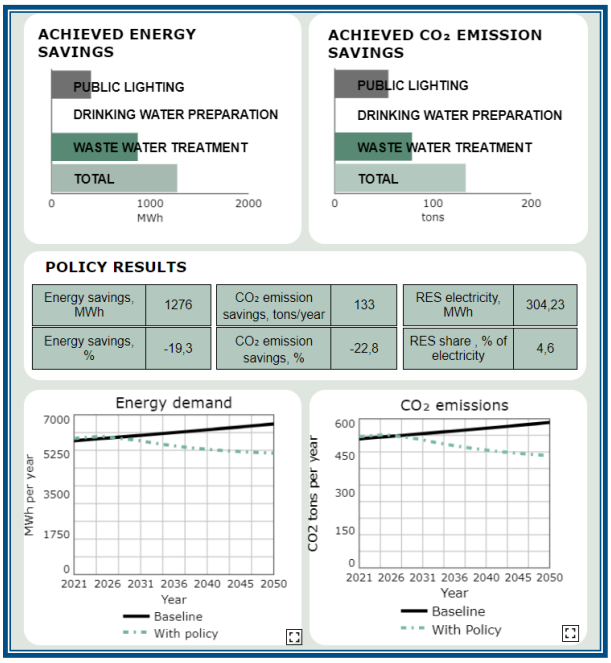
- **Replacement of inefficient light bulbs in public lighting** (*IS* 5 %/year)
- **RES usage in public lighting** (*IS* 5 %/year)
- **Wastewater treatment energy efficiency improvement** (*IS* 0,5 %/year)
- **Wastewater generation decrease** (*IS* 5 %/year)

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

In total, the selected policies achieved 1276 MWh in energy savings in 2050 compared to the baseline scenario (19,3 % reduction). The largest reduction in energy consumption is achieved through improving wastewater treatment energy efficiency, resulting in a 13,2 % decrease. Replacement of inefficient light bulbs in the public lighting system result in a decreased energy demand by 6,1 %. The policy on RES usage in public lighting does not affect total energy consumption; instead, it increases the share of renewable electricity.

As after implementing policies , CO_2 emissions drop by 133 tCO_2, a (22,8 % decrease). The RES usage policy introduces 304,2 MWh/year of renewable energy, which comprises around 4,6 % of the sector's energy demand.

In the policy scenario both energy demand and CO_2 emissions initially are higher than in the baseline scenario, reaching peaks of 6059 MWh/year and 537 tCO_2/year in 2025, after which they start to decrease, falling below baseline projections in 2027 and continuing to decrease until 2050.



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

4.2. Policies

In Cēsis 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 CO_2 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.

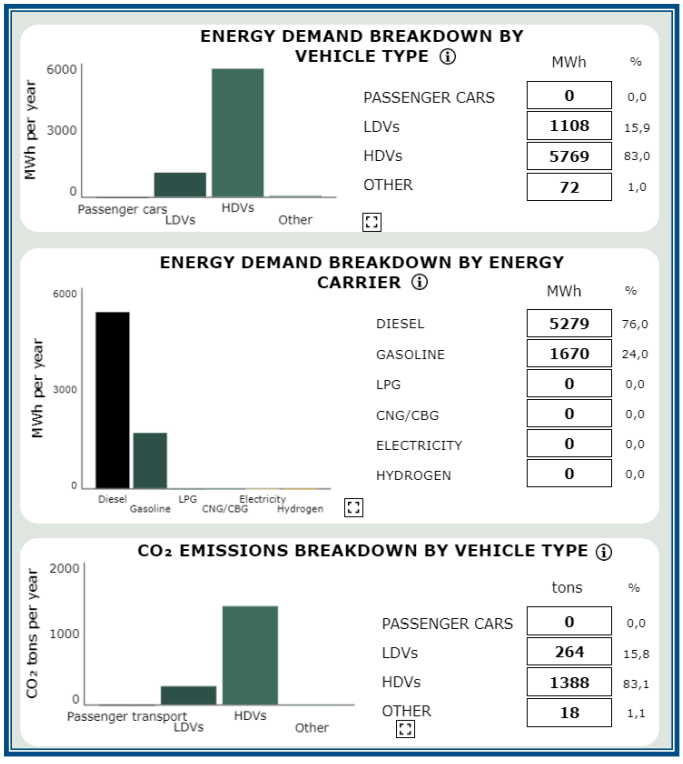
5.1. Current situation

Municipal vehicle fleet

The municipal vehicle fleet consists of 55 LDVs, 38 HDVs un 14 other vehicles. 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 6949 MWh per year, which is equivalent to 0,6 % of the municipality's total energy consumption.

In terms of fuel consumption, diesel fuel accounts for the largest share (76 %), followed by gasoline (24 %). By vehicle type, the most significant energy consumer is HDVs (83,1 %), followed by LDVs (15,8 %) and other vehicles (1,1 %). Total CO_2 emissions related to the municipality's vehicle fleet amount to 1669 tons of CO_2 per year, or approximately 1,2 % of the municipality's total CO_2 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.



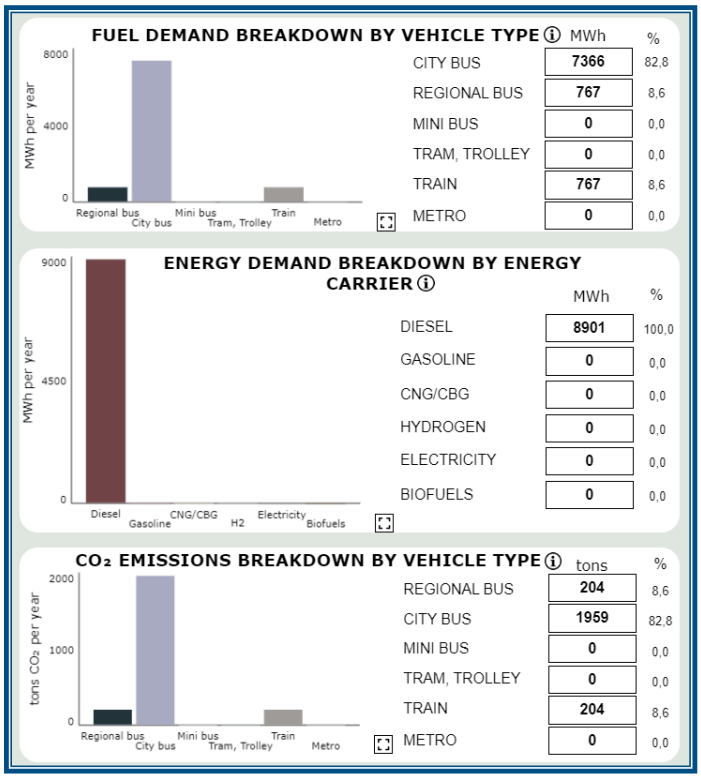
Public transport

According to existing data, 78,4 million passenger kilometres per year are performed by public transport and that number will reach 90,6 million by 2050. 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 7702 MWh per year in 2021 or 0,8 % of the municipality's energy consumption. Of this, the largest share is made up of city bus (82,8 %), followed by train (8,6 %) and regional bus (8,6 %). Diesel dominates in terms of fuel consumption with 100 %. Total CO_2 emissions related to energy consumption in public transport amounted to 2049 tons of CO_2 in 2021 or approximately 1,7 % of the municipality's total CO_2 emissions.

The baseline scenario assumes no changes in the public transport vehicle fleet or usage patterns, and no policy measures are applied. Changes in energy consumption are driven solely by exogenous assumptions, including a gradual increase in population. As a result, public transport energy demand increases over time.

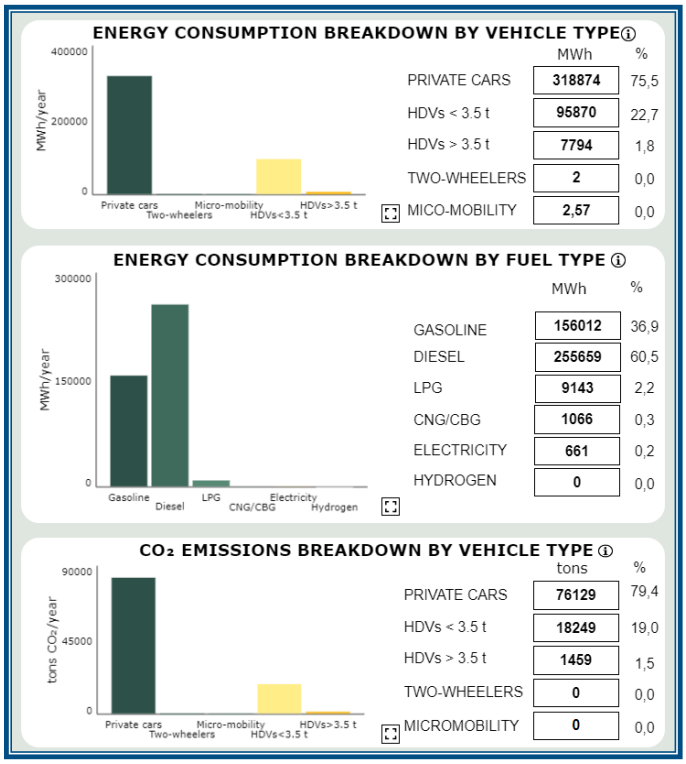
The projected energy consumption in 2050 is 8901 MWh, with associated CO_2 emissions of 2368 tons, corresponding to an increase of 15,6 % compared to the base year.



Private transport

According to existing input data, private transport demand in the municipality is approximately 664,3 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 422 542 MWh per year by 2050 and reach 37,5 % of the municipality's total energy consumption. Of this, the largest share is made by up private cars (75,5 %), followed by HDVs below 3,5 tons (22,7 %) and HDVs above 3,5 tons (1,8 %). Energy demand of other transportation modes, namely two-wheelers and micro-mobility tools, is negligible. Looking at the type of fuel, the two main types of fuel are diesel (60,5 %) and gasoline (36,9 %). Electricity accounts for a small proportion – 661 MWh per year or 0,2 % of total energy demand. Total CO_2 emissions in the private transport sector amount to 95 838 tons of CO_2 per year, or approximately 67,5 % of the municipality's total CO_2 emissions in baseline year.

The baseline scenario assumes no changes in private transport usage patterns and no policy interventions. Changes in energy consumption and emissions are driven solely by exogenous assumptions, including a gradual increase in population. As a result, energy consumption increases by approximately 11,3 % and emissions by 12 % in 2050 compared to the base year.



5.2. Policies

Municipal vehicle fleet

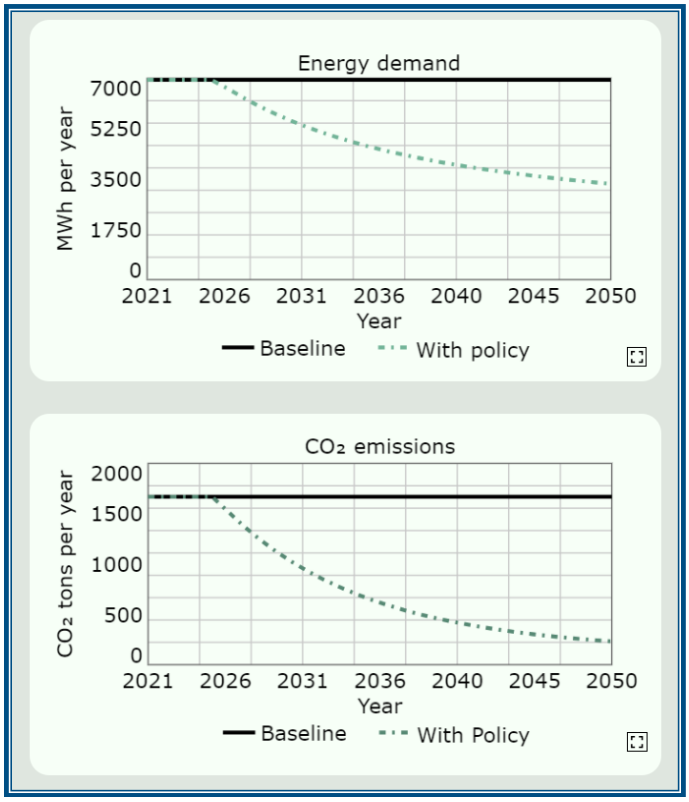
In this sector, several policy measures were proposed:

- **Other vehicle fleet decarbonization** (*Target technology choice Electric vehicles* - 100 %)
- **Fleet modernization and driver awareness training** (*IS* 0,5 %/year)
- **Fleet management improvement** (*IS* 0,5 %/year)

For the fleet decarbonization policy the start year was 2030. For fleet modernization and fleet management improvement policies the start year was 2025. For all policies the implementation end year was 2050.

In total, the selected policies achieved 3618 MWh in energy savings and 1437 tCO_2 in emission savings in 2050 compared to the baseline scenario (52,1 % and 86,1 % reductions respectively).

The biggest decrease in energy demand and emissions was achieved via vehicle decarbonization, which led to 39 % energy demand decrease and 82,3 % emission decrease due to a gradual replacement of all vehicles using internal combustion engines with electric vehicles.



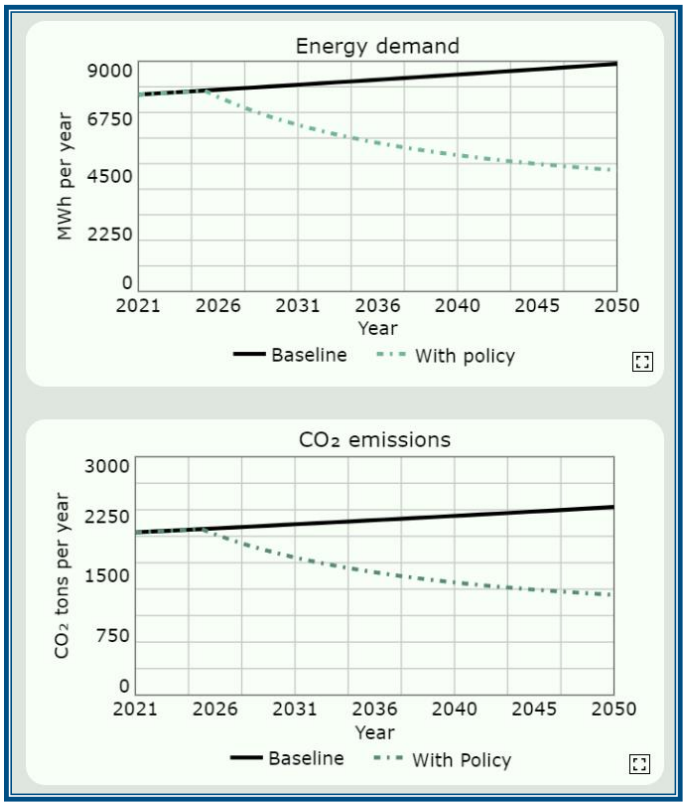
Public transport

In this sector, the following policy was tested:

- **Operational efficiency and route optimization** (*IS* 2 %/year)

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

In total, the selected policy achieved 4159 MWh in energy savings and 1106 tCO_2 in emission savings in 2050 compared to the baseline scenario (46,7 % reductions).



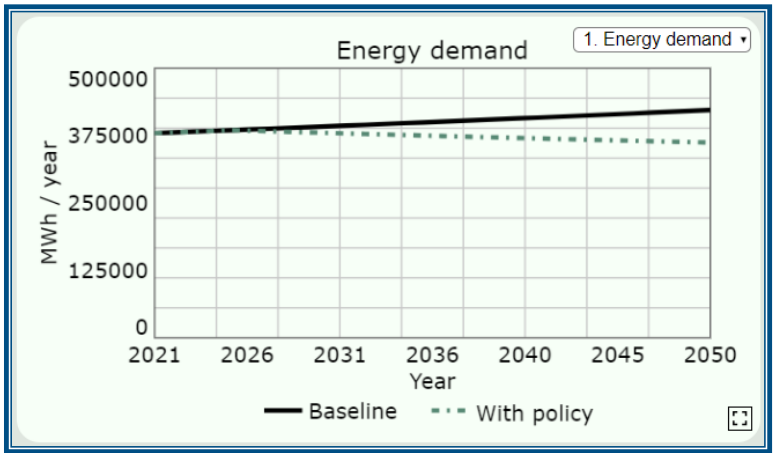
Private transport

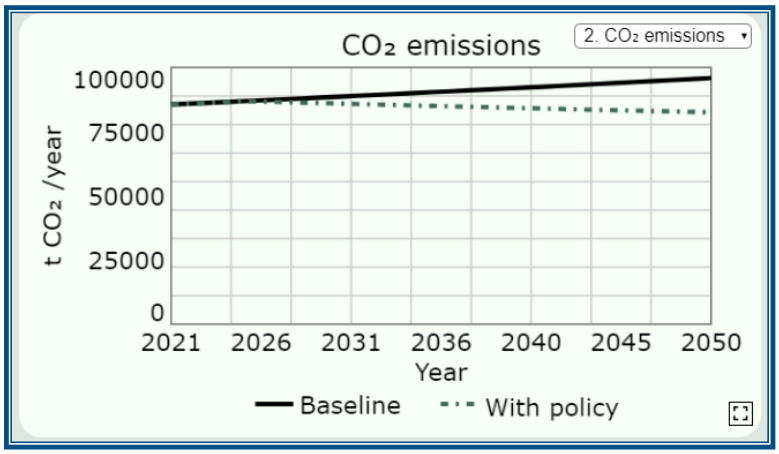
In this sector, two key policies were implemented:

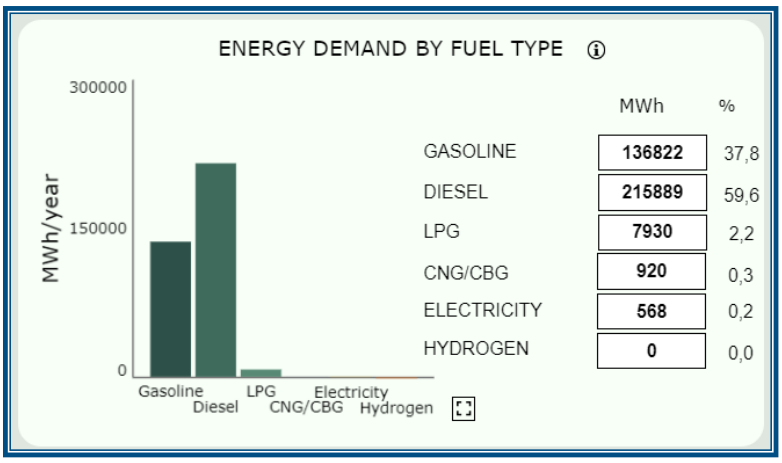
- **Car sharing** (*IS* 0,5 %/year)
- **Freight transport demand reduction** (*Daily distance reduction IS* 0,5 %/year, *Travel frequency reduction IS* 0,5 %/year)

For both policies the implementation start year was 2025 and the implementation end year was 2050.

In total, the selected policies result in a reduction of approximately 60 413 MWh in energy demand and 13 303 tons of CO_2 emissions by 2050 compared to the baseline scenario, corresponding to reductions by 14,3 % and 13,9 %, respectively. Because of freight transport (which mostly uses diesel fuel) demand reduction, the share of gasoline in energy demand has increased to 37,8 %, while diesel share has decreased to 59,6 % compared to the baseline scenario.







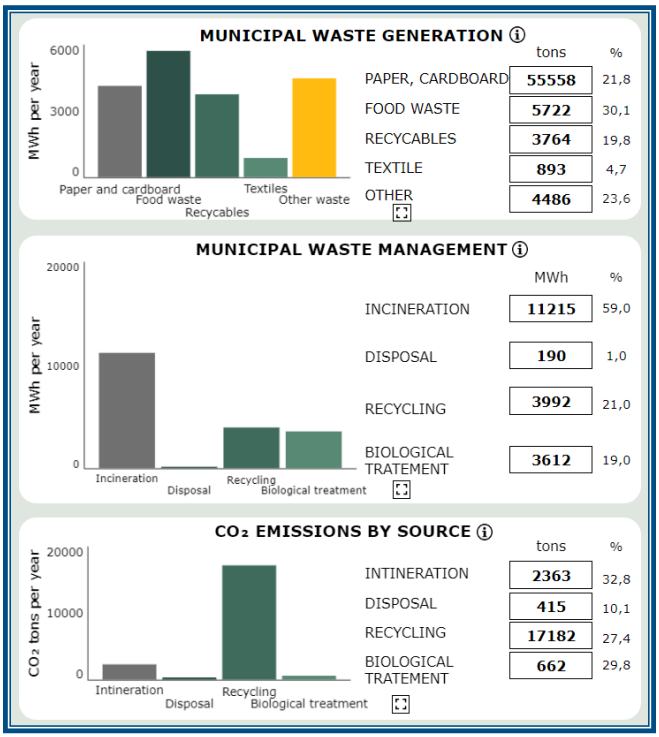
6. WASTE MANAGEMENT

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 (400 kg/capita/year) and the structure of municipal waste. Based on these assumptions, the amount of municipal waste generated in Cēsis municipality in the base year is 17 947 tons and the GHG emissions related to waste management constitute 18 116 tons CO_2eq. The waste management sector accounts for approximately 14,5 % of the municipality's emissions

The baseline scenario assumes an annual 0,5 % increase in the municipality's population, however an annual 0,3 % decrease in waste generated per habitant is assumed. Consequently, by 2050, the total amount of waste generated is expected to increase by approximately 5,9 % and GHG emissions are expected to increase by approximately 13,8 % compared to the baseline year reaching 19 009 tons of generated waste or 20 622 tons CO_2eq, respectively.



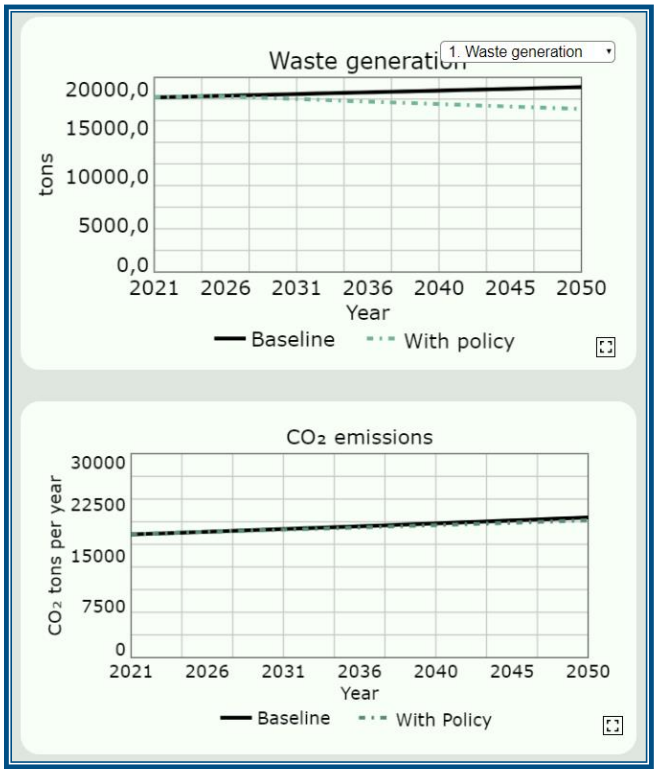
6.2. Policies

In this sector, the following policy was tested:

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

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

In total, the selected policy reduced the amount of waste generated by 1183 tons and achieved 406 tCO_2eq in emission savings in 2050 compared to the baseline scenario (11,8 % and 2 % 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 CO_2 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

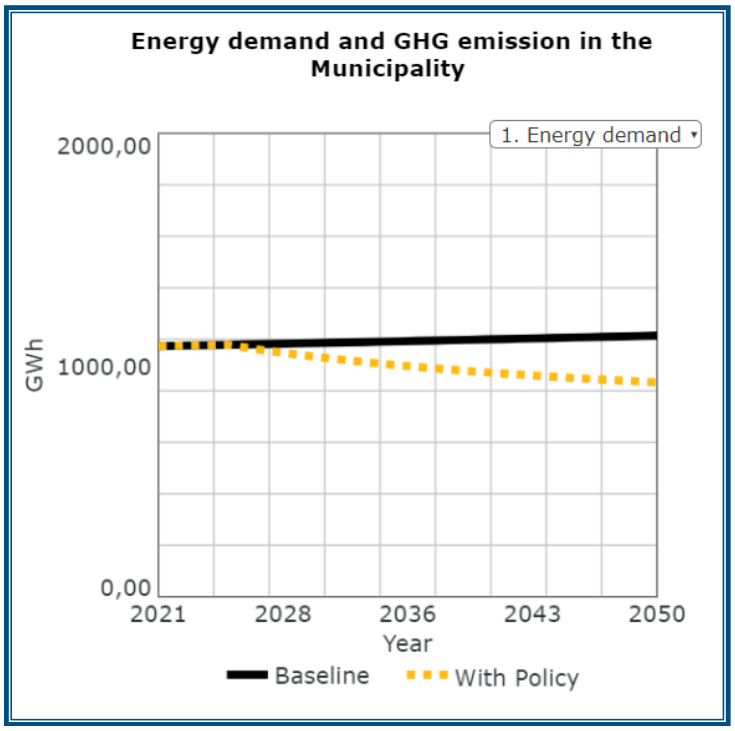
In Cēsis municipality, Local energy production energy demand and GHG emissions are not included in the baseline inventory and projection.

7.2. Policies

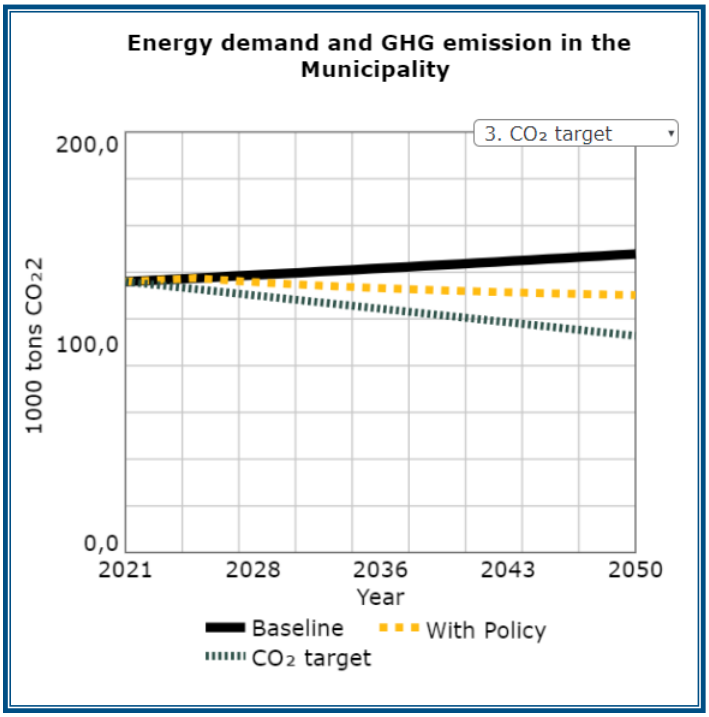
In Cēsis municipality, Local energy production energy demand and GHG emissions were not included in the baseline inventory and projection; thus, no policy analysis was conducted.

8. RESULT OVERVIEW

The results of the simulation show that in the baseline scenario energy demand in the municipality increases by approximately 0,15 %/year over time due to population increase and economic and activity growth assumptions. As illustrated in the figure below, total energy demand rises over time, reaching 1127,02 GWh in the baseline scenario by 2050. The implementation of the selected policy package causes a gradual energy demand decrease, resulting in an energy demand of 925,37 GWh by 2050. This corresponds to energy savings of 201 648,6 MWh, or 17,9 % compared to the baseline projection.



The selected policy package leads to moderate emission reductions – CO_2 emissions decrease from 142 thousand tons in the baseline scenario to approximately 122,4 thousand tons in the policy scenario by 2050, resulting in annual emission savings of 19 552,4 tons (13,8 %). As shown in the figure below, while the policy scenario lowers emissions compared to the baseline trajectory, emissions remain above the long-term CO_2 target (20 % reduction by 2050), indicating that additional mitigation measures would be required to fully achieve the municipality's climate objectives.


Energy demand and GHG emission in the Municipality
3. CO₂ target
200,0
100,0
0,0
1000 tons CO22
2021
2028
2036
2043
2050
Year
Baseline
With Policy
CO₂ target

9. CONCLUSIONS

The results of the scenario analysis for Cēsis municipality demonstrate that the implementation of a comprehensive policy package leads to meaningful reductions in both energy demand and greenhouse gas emissions by 2050, despite moderate population growth and increasing activity levels.

Overall, total energy demand is reduced by approximately 17,9 % (201 649 MWh) compared to the baseline scenario, indicating that energy efficiency improvements and demand-side measures are effective in offsetting growth-related increases in energy consumption. At the same time, CO_2 emissions decrease by 13,8 % (19 552 tCO_2), showing that the selected policy mix contributes to decarbonisation, although at a more moderate level compared to energy savings.

The results highlight that the building sector represents one of the most important areas for energy demand reduction. In particular, **residential buildings** achieve significant savings of 48 975 MWh (26,8 %), driven by deep renovation and electrification measures. **Municipal buildings** also contribute notably, with 83 207 MWh energy savings (16,7 %), supported by building envelope improvements and energy management measures. These results demonstrate that long-term renovation strategies are essential for reducing energy demand in the municipality.

The transport sector emerges as the main driver of emission reductions. Private transport alone achieves reductions of 13 303 tCO_2, while additional savings are observed in municipal and public transport through fleet decarbonisation and operational improvements. However, compared to other case studies, the absence of large-scale electrification or modal shift policies limits the overall emission reduction potential in this sector.

In the **public infrastructure sector**, energy savings of 1 276 MWh (19,3 %) are achieved, mainly through improvements in wastewater treatment efficiency and lighting systems. Although this sector represents a relatively small share of total energy consumption, it contributes to steady and reliable reductions.

The waste management sector shows limited emission reduction potential under the selected policy, achieving only 2 % emission reductions, which indicates that more ambitious waste-related measures would be required to significantly reduce emissions in this sector.

It should be noted that **other sectors** and **local energy production** were not included in the modelling, which limits the overall reduction potential and may underestimate both energy demand and emission reduction opportunities at the municipal level.

Despite the achieved reductions, the results indicate that the implemented policy package is not sufficient to fully meet long-term climate targets, as emissions remain above the desired reduction trajectory by 2050. This suggests that additional measures—particularly in the transport and energy supply sectors—would be required to achieve deeper decarbonisation.

Overall, the analysis demonstrates that energy efficiency improvements in buildings and targeted transport measures provide the most significant contribution to emission reductions, while a broader and more ambitious policy mix, including supply-side interventions and sector coverage expansion, would be necessary to achieve climate neutrality in Cēsis municipality.

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

Sector	Indicator	Results
Municipal buildings	Energy savings	83 207 MWh (16,7 %)
	Emission reduction	1549 tCO_2 (12,7 %)
	Renewable generation	289 MWh
Residential buildings	Energy savings	48 975 MWh (26,8 %)
	Emission reduction	1617 tCO_2 (18,6 %)
	Renewable generation	577 MWh
Public infrastructure	Energy savings	1276 (19,3 %)
	Emission reduction	133 tCO_2 (22,8 %)
	Renewable generation	304,2 MWh
Other sectors	Energy savings	–
	Emission reduction	–
Municipal fleet	Energy savings	3618 MWh (52,1 %)
	Emission reduction	1437 tCO_2 (86,1 %)
Public transport	Energy savings	4159 MWh (46,7 %)
	Emission reduction	1106 tCO_2 (46,7 %)
Private transport	Energy savings	60 413 MWh (14,3 %)
	Emission reduction	13 303 tCO_2 (13,9 %)
Waste management	Waste generation reduction	1183 t (11,8 %)
	Emission reduction	406 tCO_2eq (2 %)
Local energy production	Energy savings	–
	Emission reduction	–
	Renewable generation	–
Peak emissions from imported electricity	tCO_2	–