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Carbon driven energy equilibrium at the municipal scale – Energy Equilibrium

GoA 2.1 - Test and validate Energy Equilibrium platform

D 2.1 *Evaluation report on Energy Equilibrium pilot platform in the BSR municipalities*

Contributing Partners

IMP PAN

RTU

Municipalities: Gulbene, Tukums, Taurage, Tomellila, Mikołajki Pomorskie, Wejherowo

ZEBAU

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1 Introduction, goals, partnership, etc

The partner municipalities – as well as the entire European Union – faces the challenge of planning and implementing activities in the field of energy security. The transition of municipalities powered by primary (fossil) energy sources to renewable energy sources poses a great challenge to the local governments. It is their main concern that the energy supply is constant and safe. The accession of the municipal partners to the Energy Equilibrium (EE) project provides the opportunity to use, test and apply the solutions proposed by the EE project simulation platform. This practical tool could be the basis and tool for making the best decisions (from economic and ecological points of view) for individual municipalities. Each commune has its own energy situation, pollution sources, energy security and environmental threats, thus making decisions in the field of energy strategy important priority, but also a challenge.

This project aims to address the challenges posed by the variability and non-controllability of temporarily and seasonally generated renewable energy (RES). The primary goal is to develop sufficient energy storage infrastructure to transform RES supply potential into secure energy source.

Generally, energy storage systems might be divided into three groups: short-term solutions, middle-term solutions and long-term solution. The short-term solutions (from millisecond till few minutes), includes various electrical battery systems, are mainly applied by grid regulation institutions for grid stabilization and are out of scope for municipal activities. Main interest for the municipal administration is to provide cheap heat/energy and to assure the supply security. Therefore, at the focus of administration are long term energy storage solution such as: biomass, biogas/biomethane and finally green hydrogen technologies (which seems most expensive although probably not avoidable in the zero-emission future). Hydrogen can be later used to generate other fuels, including methanol, ethanol or ammonia. The middle-term solutions (peak shaving) which also include battery systems might have wide application e.g. in systems for charging of electric cars. Some of these issues are addressed by Energy Equilibrium simulation platform, to be used by municipalities looking for locally appropriate solutions, in order to implement EU strategies, including latest - REpowerEU. This strategy focusses on investments and implementation of new RES (including PV, heat pumps, biomethane and green hydrogen). These implementations should be proceeded by thermal modernisation of existing buildings.

The Energy Equilibrium project is a partnership between various municipalities, regional authorities, and energy experts, with a shared aim to facilitate the transition to zero-emission economy. It was these partner municipalities: Gulbene, Tukums, Taurage, Tomellila, Mikołajki Pomorskie, Wejherowo, which were involved in data collections and testing of EE platform in order to simulate the outcome of various strategies/scenarios of energy transition. Their expectations, results of simulations, challenges and conclusions are summarized in this report. All project partners are thankful for their hard work.

Chapter 2 of report contains municipalities profiles and main characteristics (full available data you can find in the project GoA 1.5 report). Besides, the summary of municipal expectations from the tested EE project platform are presented in chapter 3 of the report (all expectations you can find in Attachment 1). Pilot/scenarios descriptions and obtained results of simulations (done by municipalities are shown in Chapter 4, followed by challenges and conclusions. Attachment 2 presents “Analysis of the feedback received from the municipalities on Energy Equilibrium platform application”.

2 Municipality profiles & descriptions, main energy characteristics

There are six municipalities (both rural and urban) being partners in Energy Equilibrium project:

Municipality/ nationality	Population [thousand}	Kind of municipality	Heat demand of public infrastructure(2022) [GWh]	Electricity demand of public infrastructure(2022) [GWh]
Gulbene (LV)	19.1	Rural	11.7	3.2
Tukums (LV)	43.9	Rural	13.8	6.2
Taurage (LT)	37.3	Rural	59.7	3.8
Tomellila (SE)	13.7	Rural	5.8	2.85
Mikołajki Pomorskie (PL)	3.4	Rural	0.72	0.44
Wejherowo (PL)	46.4	Urban	6.9	8.0

2.1 Gulbene municipality

The administrative area of the Gulbene municipality (1,870 km^2) comprises the town of Gulbene and 13 parishes located in the north-east part of Latvia in the Vidzeme Region. One third is agricultural area and there are above 1,600 active companies. There has been a general decline in the population (presently, 19.1 thousand) and the total number of inhabited households in the Gulbene municipality. The general structure of housing in 2022 consists of 55% apartment blocks (multi-family dwellings) and 45% single-family dwellings.

Main energy characteristics

There are a total of 105 public buildings under the municipality governance. The total heating area of these buildings is slightly growing during last several years (in 2022 it was 110,107 m^2), 52% of the municipal building stock has been thermally modernized. In 2022, the average specific **heat consumption** was 91.4 kWh/m^2/year and 126.8 kWh/m^2/year, in renovated and non-renovated buildings, respectively.

There are three **district heating** (DH) grids in the municipal region covering ~60% of municipal building consumption and ~18,7 % of total heat demand (33.2 GWh in 2022). The total length of the district heating network is 20.4 kilometres. Biomass is the main heat source used in the local heating systems. In 2022, 5,238 tonnes of wood pellets and 5,123 m^3 of firewood were used to heat 28 municipal buildings, 62 multiapartment houses, four individual houses and 46 industry and commercial sector buildings connected to the DH grids.

Total heat consumption by the municipal buildings

	Number of objects	Total heating area, m²	Total heat consumption, GWh
District heat	51	55979	6.17
Individual heat	54	54128	5.58

In 2022, the **total electricity consumption of municipal infrastructure** objects was ~3.2 GWh (with above 90 GWh of **total electricity consumption of the whole city**). The municipal buildings and facilities are the largest consumer (among municipal infrastructure) at 2.4 GWh. The total electricity consumption of municipal buildings increased by 34% in the period from 2018 to 2022. Public street lighting consumed a total of 505 MWh in 2022, a significant decrease compared to 623 MWh in 2018. The operation of water supply and wastewater systems accounted for 182 MWh of demand.

In 2022, 106 thousand litres of diesel and 29 thousand litres of petrol were consumed for **municipal transport**, which is 22 thousand litres more than in 2021. In addition, 2 MWh of electricity was consumed for municipal transport needs.

The total installed capacity of **renewable power plants** in Gulbene municipality in 2022 was 9 MW. In the period from 2018 to 2022, the total installed capacity of biomass CHP (4.38 MW), biogas CHP (0.9 MW) and hydropower (2.83 MW) remained unchanged over the years. However, the total installed capacity of wind energy fell from 0.5 MW in 2018 to 0.25 MW in 2022. On the other hand, solar PV recorded a significant increase from 0.05 MW to 0.64 MW. The total amount of electricity generated from RES (in private hands) in Gulbene municipality has risen from 37.4 GWh in 2018 to 40.2 GWh in 2022 (which correspond to 53.3% of total energy consumption).

There exists a modest **battery system** owned by the Gulbene Municipality. The system has a capacity of 9,072 kWh. Some private companies show interest in the technology implementation. The Gulbene Municipality has established small heat storage system (~50 kW) within individual boiler house fuelled by pellet.

Expectations from EE project platform

- *"I hope that more or less all the functions will work and we can test Energy Equilibrium platform with our existing data input."*
- *"examples of use in practice."*
- *"in the village, the heating equipment must be replaced with a new one, the existing one is in service. Which heating device to choose? Annual consumption 1400Mwh"*
- *"is it justified to install acclimation equipment?"*

2.2 Tukums municipality

The administrative area of the municipality of Tukums (2,450 km^2) comprises the town of Tukums and ten parishes located in West Latvia in the Kurzeme Region. On 1 July 2021, the municipality of Tukums was enlarged when the municipality of Engure, the municipality of Jaunpils and the municipality of Kandava were merged to form the municipality of Tukums. The population in Tukums municipality has decreased from 44.4 thousand in 2021 to 43.9 thousand in 2022. The general structure of housing in 2021 consists of 34% apartment blocks (multi-family dwellings) and 66% single-family dwellings. The total number of households remained unchanged from 2021 to 2022 and totalled 17.3 thousand households.

Main energy characteristics

There are 118 public buildings under the municipality governance with total heating area (in 2022) 175,389 m^2. Only 34% of the municipal building stock has been renovated and an average specific **heat consumption** in renovated buildings in 2022 was 103.9 kWh/m^2/year, while in non-renovated buildings it was 147.6 kWh/m^2/year.

72 objects, representing 80% of the total heating area of the municipal buildings, are connected to **district heating**. These buildings consumed a total of ~13.8 GWh in 2022, mainly in heating season (October till April) and only 102 MWh from May to September. The rest, 44 municipal buildings (with total heating area of 3,522 m^2) is supplied from individual/local mainly gas boilers; annual heat consumption in 2022 was 46.78 GWh. A total of 63,9 thousand m^3 of natural gas, 2,236 m^3 of firewood and 190 tons of wood pellets were used to heat these municipal buildings in 2022.

The **total installed capacity of district heating and local boiler houses** amounts to 48.96 MW, with biomass (wood chips, wood pellets, and firewood) as prevailing fuel (corresponding to 47.9 MW), followed by natural gas (0.82 MW) and propane gas (0.25 MW). Overall, in 2022 total heat production reached 47.6 GWh, a slight decrease from 50.1 GWh recorded in 2021.

There is not much data on **electricity consumption** in Tukums municipality but in 2018 it amounted to 91.6 GWh. The largest consumption sector was households' sector, with 30% of total electricity consumption. Industry consumed 29% of electricity. Municipality infrastructure accounted for 5% of total electricity consumption. The **total electricity consumption of municipal buildings** increased from 3.24 GWh in 2018 to 4.88 GWh in 2022. Public street lighting consumed a total of 969 MWh in 2022. The electricity consumption of municipal transport has decreased over the period. Other consumers such as water supply and sewerage, industrial and municipal household electricity consumption accounted for 372 MWh in 2022.

In 2022, 105 thousand litres of diesel and 5 thousand litres of petrol were consumed for **municipal transport**, which is 35 thousand litres more than in 2021. In addition, 0.42 MWh of electricity was consumed by municipal transport.

In 2022 the total **installed capacity of RES** in Tukums municipality was 9.2 MW; 4.28 MW was related to solar PV, followed by biomass CHP with a total capacity of 2.87 MW, biogas CHP (1.5 MW), and hydropower (0.69 MW). Majority of the produced electricity in 2022 came from biogas CHP (10.7 GWh), followed by biomass CHP (3.1 GWh). Solar PV accounted for 1.1 GWh of produced electricity. No significant energy storage is installed in the region yet.

Expectations from EE project platform

- *“Database of components with specifications, datasheets, and usage examples.”*
- *“Ease the work of energy specialists by reducing the time spent on data processing.”*
- *“Provide platform users with the option to choose their language.”*
- *“Dynamic reports and customizable dashboards will enable users to swiftly obtain the required data in various formats, such as graphs, tables, and charts.”*
- *“By modelling scenarios, it is easier to understand the potential energy gain from the implementation of a project.”*

2.3 Taurage municipality

The administrative area of the Taurage County (1,179 km^2) comprises the town of Taurage and seven parishes: Batakiai, Gaurė, Lauksargiai, Mažonai, Tauragė parish, Tauragė City, Skaudvilė and Žygaičiai located in the Western part of Lithuania. Half of the area is related to agriculture and there are nearly 1,200 active companies. There has been a general decline in the population (presently, 37.3 thousand) but the total number of households in the municipality increased slightly to 19 thousand. The general structure of housing in 2021 consists of 41% apartment blocks (multi-family dwellings) and 59% single-family dwellings.

Main energy characteristics

In 2022, the **total heating area of public buildings** (11,982) was around 2,966 thousand m^2. Only ~21% of the municipal buildings has been renovated. The average specific heat consumption in renovated buildings in 2022 was 45 kWh/m^2/year, while in non-renovated multi-apartment buildings it was 68.4 kWh/m^2/year, without hot water production.

In Taurage municipality there are two **district heating** providers. The total length of the district heating network is 27.8 kilometres. In 2022 the total installed capacity of DH biomass boilers in was 32.27 MW, while the majority, namely 54.18 MW, is fuelled by heavy oil, oil shale and diesel. However, the heat generated in DH is mostly produced by biomass boilers (~75.7 GWh in 2022), while only 803 MWh was produced from fossil fuels. Taurage DH company plans to install 2,000 m^3 thermal water-based storage.

Households accounted for the highest share of total **heat consumption** in 2022 i.e. 75%. The municipal buildings connected to the DH system consumed 8.662 GWh in 2022, a slight decrease compared to 9.3 GWh in 2021. Municipality infrastructure accounted for 16% from total heat consumption of objects connected to district heat supply. 1181 municipal buildings (with a heating area of ~1,286 thousand m^2) have an individual/local heat supply system and consume 4.29 GWh of heat produced from biomass (wood, wood waste, wood pellets, wood briquettes), which is the main source (85%) of heat in local heating systems. A decline was observed in the consumption of biomass and peat, while the consumption of natural gas, LPG and liquid furnace fuels increased slightly between 2018 and 2022.

A slight increase in **total electricity consumption** was observed in the Taurage municipality, mainly in households and industrial sector. The largest consuming sector in Taurage municipality is households, which consumed 38% of total electricity consumption in 2022, followed by the industrial sector, which accounted for 32% of total electricity consumption, and the commercial sector, which accounted for 27%. No data is available on electricity consumption in agriculture and forestry sector. In 2022, the **total electricity consumption of municipal infrastructure** objects was 3.76 GWh, with municipal buildings and facilities being the largest consumer at 2.77 GWh. The total electricity consumption of municipal buildings increased by 1% in the period from 2018 to 2022. Public street lighting consumed a total of 899 MWh in 2022, a significant decrease compared to 1.23 GWh in 2018.

In 2022 the **municipal public transport** consumed 14.59 GWh of energy in the Taurage municipality. The majority, namely 14.45 GWh, was related to diesel consumption, while 146 MWh to electricity. The diesel consumption has increased significantly, from 94 thousand litres in 2018 to 114 thousand litres in 2022. The electricity consumption of municipal public transport has risen significantly from 59 MWh in 2020 to 146 MWh in 2022. There is no specific data on the fuel consumption of private passenger cars, with the total number of passenger cars in the Taurage municipality increasing.

In 2022 **total installed capacity of RES** in Taurage municipality was 56.12 MW. A vast majority of total capacity (50.54 MW) is related to wind energy. There are hydropower plants with a capacity of 3.01 MW, PV plants with a capacity of 2.37 MW, and biogas CHP (in water treatment plant) with a capacity of 0.2 MWe. The total amount of electricity generated from renewable power plants in Taurage municipality has decreased from 135 GWh in 2019 to 114 GWh in 2022 mainly due to weather conditions. Up to now, no energy storage is planned by municipality.

Expectations from EE project platform

- *“How to improve performance of the heating and the transport sector?”*
- *“How to assess the effect of battery use in the transport sector?”*

2.4 Tomellila municipality

Tomelilla municipality is located in the county of Skåne in Southern Sweden. Its area is 397 km^2 with prevailing agricultural use (250 km^2). The municipality population has increased from 13.56 thousand in 2018 to 13.8 thousand in 2022. The total number of households also increased by 164 to 6.4 thousand in 2022.

Main energy characteristics

There are twenty-five municipal buildings with a total heating area of 45.8 thousand m^2. In 2022 the average specific **heat consumption** in renovated buildings was 150 kWh/m^2/year, while in non-renovated buildings it was 130 kWh/m^2/year.

The four main sectors – households, municipal infrastructure, commercial and industrial sectors - consumed 39.7 GWh of heat in 2021, where household sector alone consumed 17.5 GWh, followed by commercial sector with 13.5 GWh. Municipal infrastructure consumed 6.4 GWh. The municipal infrastructure (only municipal buildings) connected to the district heating system experienced a decrease in heat consumption from 7.6 GWh in 2018 to 5.8 GWh in 2022. Four municipal buildings (with total heating area of 16.8 thousand m^2) have an individual/local heat supply system and their heat consumption was 1.6 GWh.

There is one **district heating** system in Tomelilla municipality with length of the network equal 37 km. Biomass and biogas is the main heat source used in the local heating systems.

The total **electricity consumption** in Tomellila municipality decreased from 173.7 GWh in 2018 to 171.2 GWh in 2021. In 2021 the largest consumption sector - households, was responsible for 38% of total electricity consumption. Industry, accounted for 15%, agriculture 33% and commercial activities 12% of total electricity consumption. Municipality infrastructure consumption was only 2% of whole consumption and slightly decreased in the period from 3.16 GWh in 2018 to 2.85 GWh in 2022.

In 2022, the majority of energy to meet **municipal transport** needs was provided by fossil fuels such as petrol (21.28 thousand litres) and diesel (8.86 thousand litres). The total consumption of fuels in the municipality has increased considerably in municipal transport. However, a considerable decarbonization trend is observed in municipal transportation. In 2022, municipal transport consumed 2.5 MWh of electricity, 36.8 million litres of HVO and 27.46 tonnes of biogas.

The total **installed power of RES** increased from 30.63 to 35.93 MW from 2018 to 2022, respectively. The wind energy capacity remained constant at 29 MW, whereas PV capacity increased from 1.6 to 6.9 MW from 2018 to 2022, respectively. In 2021 wind installations generated nearly 50 GWh and PV modules contributed 3.7 GWh. Besides, 100 MWh of electricity was produced from biomass CHP which uses wood chips.

Expectations from EE project platform

- *“I expect to learn how to use the platform in the context of Tomelilla, with challenges that municipalities in Europe face today, e.g. new EU-directives or lack of capacity/ energy production in the region.“*
- *“I have found previous pilots useful and interesting, but sometimes a bit too difficult to follow or understand the parameters. I hope that there are clear explanations to all the parameters that you fill in, and maybe an explanation of how different values affect the end result. This does not need to be included in the platform per se, but could be clarified in a manual or in the introduction of the platform.”*
- *“That the tool is easy to use for local authorities.”*
- *“A better understanding of the energy system in Tomelilla”*
- *“That the model is useful also for part of a local authority or an area we want to work with.”*
- *“We have a lot of wind turbines that will be too old quite soon, which means that we will reduce our energy production (at least when it comes to wind turbines), therefore we want to explore options for new investments in windmills and replacing the current*

turbines. Region Skåne wants the region to have a self-sufficiency rate of 50 % until 2030, which is a high goal considering that the current self-sufficiency rate in the region is 15 %. It will be interesting to explore how the platform could help us in Tomelilla simulate different scenarios where we reach the self-sufficiency goal. "

- *"Information on distributed sun panels system, battery and hydrogen storage"*

2.5 Mikołajki Pomorskie municipality

There are 18 villages in the Mikołajki Pomorskie rural commune in Pomerania region, which make up 16 village councils and covers an area of 91 square kilometres, inhabited by about 3,700 people living in 1,028 houses and flats. Approx. 1,400 citizens live in Mikołajki Pomorskie (38%) alone.

Main energy characteristics

In 2021, about 75% of dwellings (with average usable area of 81 m²) are equipped with individual heating systems. It is estimated that 49.9% of houses have not undergone thermal modernization at all (annual heat consumption ~375 kWh/m^2; calculations based on hard coal usage).

In the commune there are seven very small local boiler houses operated by the Commune Mikołajki Pomorskie (2022). The boiler house (with boiler 200 kW fuelled with fina coal) in **Cieszymowo** heats 10 dwellings and a community centre with a total floor space of 733.9 m²; annual heat consumption 408 GJ (154 kWh/m^2/year). The boiler room in the **Health Center** in Mikołajki Pomorskie (with 62 kW boiler fuelled by fine coal) provides heat for the clinic and the flats with total heating area 355.3 m²; annual heat consumption 160 GJ (123.8 kWh/m^2/year). The boiler house at the building of **Commune Office** heats a total of about 680 m² of office spaces. The boiler (25 kW) burns light fuel oil; annual heat consumption 218 GJ (89.7 kWh/m^2/year). The boiler house with a boiler (50 kW) fuelled by hard coal serves the **cultural centre and the fire station**; annual heat consumption 235 GJ. Apart from the above boiler houses, there are two boiler houses at the **primary school** in Mikołajki Pomorskie. One of the boiler rooms with two pellet boilers with a capacity of 150 kW and 100 kW and the other boiler room with two boilers for fine coal, each with a capacity of 125 kW, heating a total area of 3,072.3 m²; annual heat consumption 1,233 GJ. (111.6 kWh/m^2/year). Another boiler (60 kW) fuelled by fine coal provide heat for the **municipal kindergarten** with a heating area of 494.8 m²; annual heat consumption 286 GJ (159,6 kWh/m^2/year).

There is a growing interest in RES adoption by the commune in which there are three wind farms (51 MW). So, it would be important to establish a reliable energy storage system to mitigate the effects of fluctuating **RES production**. Total annual electricity consumption in municipality (2022): 3.43 GWh, including 1.97 GWh by households, and 415.0 MWh by the municipality infrastructure (households: 24 kWh/m^2/year, municipal buildings: 20 kWh/m^2/year).

Expectations from EE project platform

- *"The tool should provide reliable info for local authorities, they must be sure that the results will be consistent with expectations. There can be no question of testing solutions as the authorities should provide the necessary energy needed for the proper,* *reliable and continuous operation of the water and sewage infrastructure and buildings belonging to the municipality."*

- *"The proposed solution should be acceptable: financially sound, ecological, reliable and stable."*
- *"These should include biogas plant which should be built in our commune, taking into account ecological, practical and economic reasons."*
- *"It would be much easier to use this platform in my native language."*

2.6 Wejherowo municipality

Wejherowo is an urban commune located in the Pomeranian Voivodeship and covers the area of the city of Wejherowo with an area of 27 km^2. The city is the capital of Wejherowo County and the administrative centre of the surrounding rural commune. It is located on the Reda River on the border of the Kashubian Lake District. The municipality of Wejherowo is an element of the Small Kashubian Tri-City established in 2001 (Wejherowo - Reda – Rumia) and a part of the Gdańsk agglomeration (Tri-City: Gdańsk, Gdynia, Sopot + 27 nearby communes).

Currently, the Wejherowo municipality is inhabited by approximately 46,450 people. According to data from 2022, the city's housing resources exceed 19 thousand dwellings. More than 80% of the dwellings are located in multi-family buildings, with ~75% of the total population.

The commune owns the following buildings:

1. Municipal residential buildings - 59 buildings with an area of 16.54 thousand m^2.
2. Residential buildings of Wejherowo Social Housing Society (WTBS) – 7 buildings with an area of 9.92 thousand m^2.
3. Municipal utility buildings - 18 buildings with an area of 51.96 thousand m^2.
4. In addition to private buildings or buildings owned by enterprises or other institutions, within the municipality there are also facilities owned by the district office and military facilities related to the country's defence.

Main energy characteristics

The heated area of all residential buildings located in the municipality is estimated at 1,158 thousand m^2, where ~787.1 thousand m^2 relates to multi-family buildings, and ~371.1 thousand m^2 to single-family buildings. A large group of heat consumers are public and commercial services sector facilities, with the heated area estimated at 392.89 thousand m^2. The industrial sector buildings in the municipality constitute a small group of buildings with an area of approximately 27.2 thousand m^2. The level of thermal modernization in these buildings varies. Most (over 90%) of the multi-family buildings of housing cooperatives operating in the city and ~50% of housing community buildings have already been thermally modernized.

Approximately 40% of the remaining municipal residential buildings have been thermally renovated up to these days, although they are still characterized by high specific **heat consumption** of 150-196 kWh/m^2/year. Some residential buildings, from the 19th century, are under protection of the conservator of monuments, so, the effectiveness of their thermal renovation is limited by regulations and technical limitations. In the case of newer public buildings, specific heat consumption rates of 70-80 kWh/m^2/year were achieved. Municipal buildings that have not undergone thermal renovation are characterized by varying heat consumption - depending on the period of their construction and the sources of heat supply. For buildings connected to the heating system, the heat consumption rate is 120 kWh/m^2/year, while for municipal facilities with ineffective individual sources it is even 270 kWh/m^2/year.

44 buildings owned by the municipality are connected to **district heating (DH) grid**, including 27 residential buildings and 17 public buildings. Heat consumption in municipal buildings was as follows: residential buildings: 2.3 GWh and 1.9 GWh in 2021 and 2022 year, respectively; public buildings: 5.2 GWh and 4.8 GWh in 2021 and 2022 year, respectively.

In the entire Wejherowo municipality, DH provide 38% of the heating needs of buildings. The remaining part (62%) of heating needs is covered by individual sources. The total heat consumption supplied by DH system to all heat consumers located in the municipality amounted to 92.25 GWh and 89.55 GWh in 2021 and 2022 year, respectively. The district heating system provides heat energy to approximately 550 buildings with an area of ~769.4 thousand m^2.

Main fuel is coal - 26%, natural gas - 31%, electricity – 2%, renewable energy – 1.5%, heating oil – 1% and liquid gas – 0.5%. The district heating system is operated by District Heating Enterprise Ltd. (OPEC Gdynia). It works based on the NANICE heating plant. The heat sources are five coal-fired boilers with a total capacity of about 40 MW (two boilers WR10: 2x11.63 MW; two boilers WR5: 2x5.815 MW; one boiler WR 8M: 1x8 MW) and a cogeneration unit 14.9 MW (7.9 MWe+7.03 MWt; Rolls-Royce cogeneration engine type B36:40V16AG). The heating network is 53 km long, has 431 nodes, and 68% of its length is made in pre-insulated pipe technology. The total amount of heat produced in the network was 110.5 GWh/year in 2021 and 106.8 GWh/year in 2022. The total amount of electricity produced in the network from CHP units was 32.99 GWh and 23.36 GWh in 2021 and 2022 year, respectively. Fuel consumption at OPEC company was following: natural gas – 7,401 and 5,287 thousand m^3/year in 2021 and 2022, respectively; coal – 17,2 and 17,64 tonnes/year in 2021 and 2022, respectively. Network losses (includes losses in the heat transmission network and in group heat nodes) amounted to 16.2% in 2021 and 15.4% in 2022.

Total **electricity consumption** in the Wejherowo municipality was 71.48 GWh in 2021 and decreased slightly to 71.05 GWh in 2022. Residential buildings owned by the municipality consumed, approximately 800 MWh of electricity, and public buildings - approximately 1.3 GWh, each above mentioned year. Energy consumption for public street lighting ranged from 5.3 to 5.5 GWh/year.

Municipal transport within the city is organized by the Municipal Transport Company (MZK) using buses. Currently, in year 2022 MZK is equipped with 32 buses, including 30 diesel buses and two electric buses. The consumption of diesel oil by bus fleet amounted to 839 and 826 thousand litres in 2021 and 2022 year, respectively. Electric buses consumed approximately 231 MWh of electricity in 2022. From 2024 on, it is planned to replace the rolling stock with hydrogen buses (the first hydrogen bus has already been tested on the city streets).

Expectations from EE project platform

- *“Possibility to gain access to a reliable and easy-to-use tool supporting the municipality in making decisions and developing action plans aimed at accelerating the local use of renewable energy sources in the region and conducting a low-emission economy while maintaining the reliability of heat and electricity supplies to consumers.”*
- *“Possibility to test various alternative variants of the commune's energy development, taking into account economic criteria.”*
- *“Determining the possibilities of implementing modern heat and electricity production technologies in the municipality, taking into account the requirements of Poland's energy policy and the requirements of European directives.”*
- *“Possibility to verify the municipality's heat and electricity supply scenarios developed every 4 years in local documents required by the Polish Energy Law (“Heat, electricity and gas fuel supply plans for the Wejherowo municipality”).”*
- *“Checking the impact of various external factors on the possibility of reducing energy demand on the part of consumers (thermal renovation of housing stock and public utility facilities).”*

3 Municipality expectations from simulations

The municipalities taking part in the tests and validation of Energy Equilibrium platform expressed their expectations in relation to the platform and its functionalities. Here we summarize them:

- *relations to new EU-directives or lack of capacity/energy production in the region,*
- *better understanding of local energy system,*
- *which heating device to choose in the village,*
- *examples of use in practice,*
- *clear explanations to all the parameters that you fill in, and maybe an explanation of how different values affect the end result,*
- *easy to use for local authorities, the residents and companies,*
- *all the functions will work,*
- *platform in native language for school principals, commune mayor or local entrepreneur,*
- *Local authorities must be sure that the results will be consistent with expectations.*

Partners expressed their wish to study scenarios which are close to their needs:

- *possibility to test "repowering": parameters and cost of repowering,*
- *implementation of the Energy Performance of Buildings Directive, reduction of energy use by 3% per area/year and by 1,9 % per year (baseline 2021),*
- *reliable and continuous operation of the water and sewage infrastructure and buildings belonging to the municipal resource.*

Partner priorities in relation to energy production and storage technologies:

- *new investments in windmills and repowering of the current turbines,*
- *investment in biogas/biomethane installation should be enabled,*
- *distributed sun panels system, battery and hydrogen storage,*
- *PV solar systems and storage,*
- *larger installation of energy storage technology,*
- *wind turbines and for ecological, practical and economic reasons, a biogas plant.*
- *acclimatization equipment,*
- *scenarios where we reach the self-sufficiency goal.*

4 Pilot description and results

4.1 Gulbene municipality

Gulbene municipality performed three simulations related to green transport, apartment building renovation, PV, energy and heat storages as well as heat pump implementation.

<table>
<tr><th>Scenarios</th><th>Sector</th><th>Description</th></tr>
<tr><td>(1) Green transport (50 % on electricity, 25% on hydrogen and 25% on Biofuel).</td><td>Transport</td><td>All public transport in Gulbene Municipality will drive on RES (50 % on electricity, 25% on hydrogen and 25% on Biofuel).
Gulbene Municipality together with public transportation company will build one Lithium-Ion Electricity storage and one PV plant with 2MW capacity for electrical bus charging.
Other energy characteristics of Gulbene were unchanged.</td></tr>
<tr><td colspan="3">Results
After scenario implementation the average RES share in Gulbene will not change significantly - it will stay at 92%.
Calculations shows, that till 2050 all public vehicle fleet reduces from 61 to 56 vehicles.
Graphs show that emissions in public transport sector will decline from 407 to 235.5 kt/year, because of all buses will use RES instead diesel. But public transport share is only 14.4% of all transportation system.
Public vehicle expenses will be almost the same – small increase 1,74M EUR/yr (with diesel buses) to 1,75M EUR/yr (with RES buses) was registered.
To purchase all vehicles, municipality needs investment in the sum of 6,59 M EUR.
According to the simulations, transport does not significantly influence overall energy and emissions balance.</td></tr>
<tr><td>(2) Apartment buildings thermal modernization + PV

and

electric as well as heat storages</td><td>Heating</td><td>80 % of the apartment buildings are renovated with roof PV panel systems implemented.
Some entrepreneurs will build larger solar power plants to produce energy for self-consumption and to sell rest to the network.
Two electricity storage systems will be build (1,000 MWh) and one bigger water tank for heat energy storage (3,000 MWh) for district heating in Gulbene town.</td></tr>
<tr><td colspan="3">Results
The entire system RES share is increasing from 92 % to 94,4 %. Electricity tariff will drop from 238 EUR/MWh to 135 EUR/MWh in 2050.</td></tr>
</table>

- Emissions will stay at 17,7 thousand t.
- Heat energy consumption in apartment buildings will decrease after renovation from 29,7 GWh/yr to 17,6 GWh/yr.
- After making some social actions (information campaign strength 50 %; expertise and knowledge 50 %; implementation and technology 50 %; social factors 30 %; leadership support 60 %; payback time 15 yr) heat energy consumption will decrease to 14,2 GWh/yr.
- Electricity consumption will fall from 2,25 GWh/yr to 1,85 GWh/yr by renovation and to 1,73 GWh/yr by extra social actions.
- Actions in renovation will cost approx. 13,7M EUR, payback time 26 yr.
- District heating tariff will fall from 210 EUR/MWh to 135 EUR/MWh, if we will build water storage in the DH system. In order to build storage systems, it is necessary to invest approximately 765M EUR.

(3) Apartment buildings thermal modernization + PV and electric as well as heat storages and heat pumps	Heating	• 80 % of the apartment buildings are renovated with roof PV panel systems implemented. • Some entrepreneurs will build larger solar power plants to produce energy for self-consumption and to sell rest to the network. • Two electricity storage systems will be build (1,000 MWh) and one bigger water tank for heat energy storage (3,000 MWh) for district heating in Gulbene town. • Gulbene district heating will start to use heatpumps and electricity from PV plant.

Results

- The RES share in Gulbene will increase from 92 to 94,8 %.
- Electricity tariff will drop from 238 EUR/MWh to 119 EUR/MWh in 2050.
- Heat tariff will be the same, because we do not change heat producing technology from fossil to RES. However, we change boiler houses to heat pumps stations.
- Emissions will not change 17,7 thousand t.
- Heat energy consumption in apartment buildings will decrease by renovation from 29,7 GWh/yr to 17,6 GWh/yr.
- After making some social actions (Information campaign strength 50 %; Expertise and knowledge 50 %; Implementation and technology 50 %; Social factors 30 %; Leadership support 60 %; Payback time 15 yr) heat energy consumption will decrease to 14,2 GWh/yr.
- Electricity consumption will fall from 2,25 GWh/yr to 1,85 GWh/yr by renovation and to 1,73 GWh/yr after extra social actions.
- Actions in renovation will cost approximately 13,7M EUR; Payback time 26 yr. In order to build the storage systems, it is necessary to invest approximately 765M EUR.

4.2 Tukums municipality

In order to gain insight, municipal data were examined taking into account various parameters such as sociodemographic, energy economic, sustainability and fuel characteristics indicators. Other sections – buildings, production, storage and transport were examined in a similar way. When moving to the second task, the parameters were changed, and the changes were observed to achieve a 100% share of renewable energy with the lowest system costs by 2050.

<table>
<tr><th>Scenarios</th><th>Sector</th><th>Description</th></tr>
<tr><td>(1) Renovation of multi-apartment residential houses</td><td>Heating</td><td>• The current share of renovated multiapartment residential buildings is 10%.
• The target for the year 2050 is 50%.
• With the existing state support system 40% and increase of energy efficiency diffusion impact factors are assumed as:
- Psychological and Social Factors increased from 10 to 20%, and
- Organizational and Leadership support increased from 10 to 20%.</td></tr>
<tr><td colspan="3">Results
• Reduction of annual heat consumption in apartment buildings from 69.3 to 65.9 GWh per year.
• Reduction of annual electricity consumption in apartment buildings from 5.24 to 4.83 GWh per year.
• Cumulative renovation investment for one apartment buildings 72,500 €
• Current 40% state support adds to the attractiveness of renovation.</td></tr>
<tr><td>(2) Collector Solar Sun in District</td><td>Heating</td><td>• The current installed capacity is 25 MWh
• The target for the year 2050 is 250 MWh
• Operational parameters:
- Full- load hours – 8,760 hr/year
- Technical lifetime– 30 years</td></tr>
<tr><td colspan="3">Results
District Collector Sollar sun
• Total cost of installations 14,9 billion EUR
• System RES share will increase from 19,4 % in 2024 to 61,3 % in 2050.</td></tr>
</table>

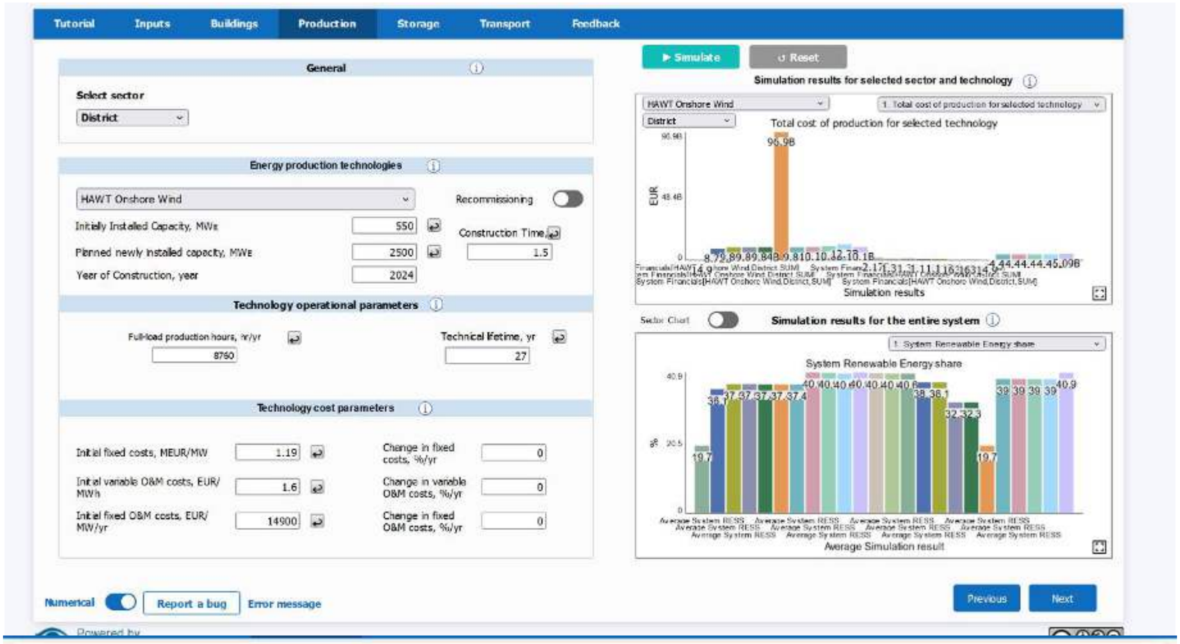

Tutorial
Inputs
Buildings
Production
Storage
Transport
Feedback
General
Select sector
District
Energy production technologies
Collector Solar Sun
Recommissioning
Initially Installed Capacity, MWh
25
Planned newly installed capacity, MWh
250
Year of Construction, year
2024
Construction Time,
0.25
Technology operational parameters
Full-load production hours, hr/yr
8760
Technical lifetime, yr
30
Technology cost parameters
Initial fixed costs, MEUR/MW
0.33
Change in fixed costs, %/yr
0
Initial variable O&M costs, EUR/MWh
0.223
Change in variable O&M costs, %/yr
0
Initial fixed O&M costs, EUR/MW/yr
64.7
Change in fixed O&M costs, %/yr
0
Numerical
Report a bug
Error message
Simulate
Reset
Simulation results for selected sector and technology
Collector Solar Sun
1. Total cost of production for selected technology
Total cost of production for selected technology
34.3B
17.1B
EUR
Simulation results
Sector Chart
Simulation results for the entire system
1. System Renewable Energy share
System Renewable Energy share
61.5
30.8
Average Simulation result
Previous
Next
Total cost of production for selected technology
96.9B
48.4B
EUR
Simulation results
System Renewable Energy share
61.5
30.8
%
Average System RESS
Average Simulation result

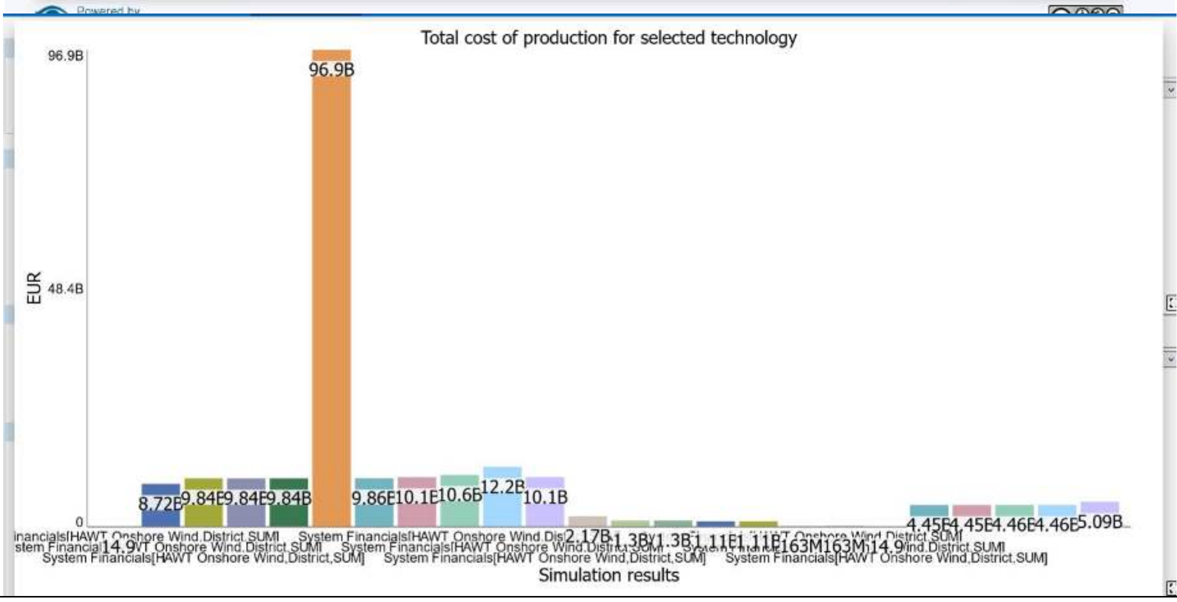
(3) HAWT Onshore Wind in District	Electricity	• The current installed Capacity is 550 MWh • The target for the year 2050 is 2,500 MWh • Operational parameters: - Full- load hours – 8,760 hr/year - Technical lifetime– 27 years

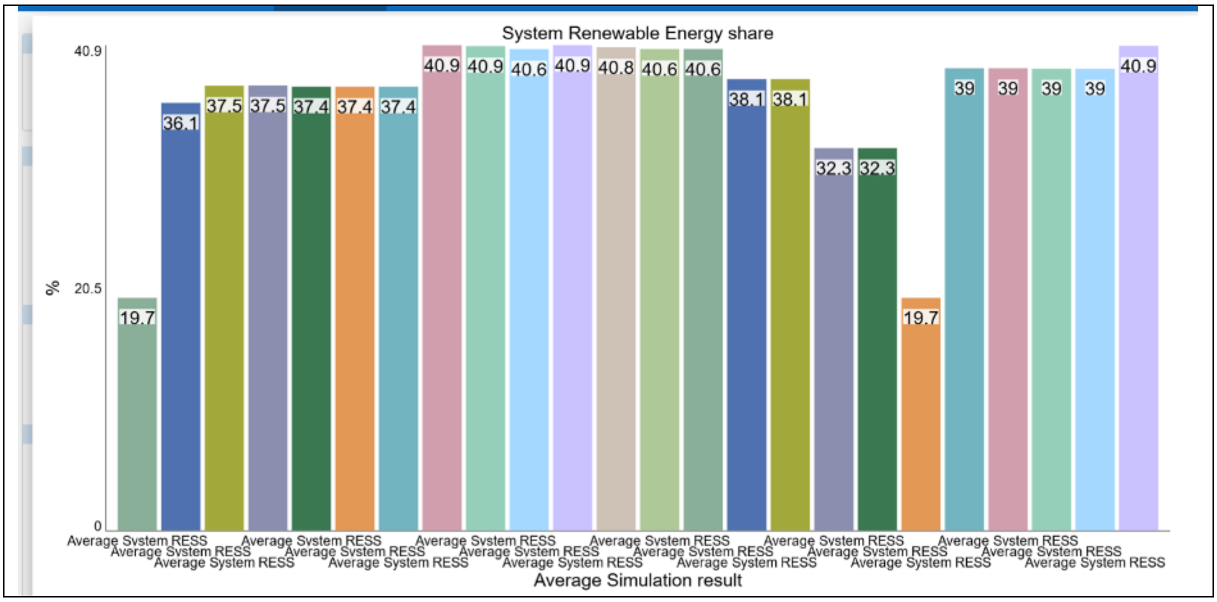
Results

HAWT Onshore Wind in District

- Total cost of installations 5,09 billion EUR
- System RES share will increase from 19,7 % in 2024 to 40,9 % in 2050.







4.3 Taurage municipality

Tauragė County/District Municipality is a leader of the green movement in Lithuania, it has higher green electricity production than consumption. On the other hand, two other sectors – the heating sector and the transport sector - still have space for improvement. The heating sector is strongly related to the efficiency in heat consumption, so renovation of multi-apartment buildings is included in the first scenarios.

Scenarios	***Sector***	***Description***
(1) Renovation of multi-apartment residential houses	Heating	• The current share of renovated multiapartment residential buildings is 10%. • The target for the year 2050 is 50%. • With the existing state support system 40% and increase of energy efficiency diffusion impact factors: - Psychological and Social Factors increased from 10 to 20%, and - Organizational and Leadership support increased from 10 to 20%.
Results • Annual reduction of heat consumption in apartment buildings from 48.8 to 37.4 GWh per year. • Annual reduction of electricity consumption in apartment buildings from 3.7 to 3.21 GWh per year. • Cumulative renovation investment for apartment buildings 159,000 €. • Renovation discounted payback time – about 250 years looks unattractive, however, payback in the case of building renovation is not the only important issue, living standards, a more attractive environment and higher value of household are not less important. • Current 40 % state support adds to the attractiveness of renovation.		

<table>
<tr>
<td>(2) New biomass chips boiler with water tank storage

and

heat pump and PV solution for single-family houses</td>
<td>Heating</td>
<td>• New biomass chips boiler in district heating sector, 5 MW, with water tank storage - this will replace some outdated fossil and other solid fuel installations, which still exist in smaller communities, though main district heating source – boiler-house in Taurage town – is fueled by biomass in the form of wood chips.
• Single-family houses having much larger impact on transfer to RES:
- 0.5 MW heat pumps and 0.4 MW PVs for heating needs replacing solid fuel (coal, firewood) and/or natural gas systems.</td>
</tr>
<tr>
<td colspan="3">Results
District heating system:
• RES to fossil fuel ratio achieved after the implementation of this scenario – increases from 27.4 to 69.9 %. This shows the largest influence for the use of RES in municipality energy sector.
• The changes in energy/heat prices are expected, though the platform does not show it.
• Influence of social actions (info campaigns, capacity building (expertise, knowledge) social factors etc.) has no influence as decisions are made by the DH company regarding system generation efficiency and support availability; and has minor impact on heat tariffs.
• Change in emissions – none as biomass is considered a non-emissions fuel.
• Financing, payback time - available financing is EU, Life funds, soft bank loans, etc.; estimated payback for boilers is 20-25 years.
• Changes in energy demand for district heating system, etc. – close to 25% due to renovation of apartment buildings.
• Influence of storage systems applied on energy/heat tariffs, changes in transportation, other issues important – influence on heat tariffs does not show.
Single family houses:
• Total cost of production 709,000 € (heat pumps) and 1,770,000 € (PV systems).System RES share will increase from 36 % in 2024 to 80.6 % in 2050.
• Total system costs 90,700,000 €.
• Such systems are viable due to state support for both, heat pumps water-to-air and PV plants.
• Electricity storage potential reduction from 2.57 GWh/a in 2024 to 1.29 GWh/a in 2050.</td>
</tr>
<tr>
<td>(3) PV park for charging stations and battery for public transport due to growth of hybrid and electric cars and busses</td>
<td>Transport</td>
<td>• 1 MW PV park for charging needs of electric vehicles in the private sector. The input condition includes 1 % annual growth rate of hybrid and electric cars – final result +250 hybrid cars and +300 electric cars in 2050;</td>
</tr>
</table>

		• Battery for fast charge of public transport (30 busses in 2050) – here 14 more electric busses will replace existing diesel ones.

Results

- Shift from private to public transport 1 %/year. Reduction of diesel private cars – 550. Result is 282 electric and 250 hybrids with electric private cars by 2050.
- No emissions increase. Comparative vehicles emission reduction from 12,1 Mt to 11.7 Mt by 2050. Annual emissions for private vehicles from 600,000 t/a in 2024 to 13,000 t/a in 2050. However, for public transport, though busses were replaced with electric ones, and diesel busses are used for renting purposes only, emissions have increased from 18,200 t/a in 2024 to 35,500 t/a in 2050.
- Reduction of RES share in energy system 32.3% to 27.4% due to use of batteries. Electric storage potential – 24.8 MWh/a in 2024 and 10 MWh/a by 2050.
- Public transport use share increases from 10% to 34% in 2050.
- Reduction of annual expenses for public transport:
  - Fuel 248 thousand €/a to 68.2 thousand €/a;
  - Insurance and Maintenance 247 thousand €/a to 68.4 thousand €/a

4.4 Tomellila municipality

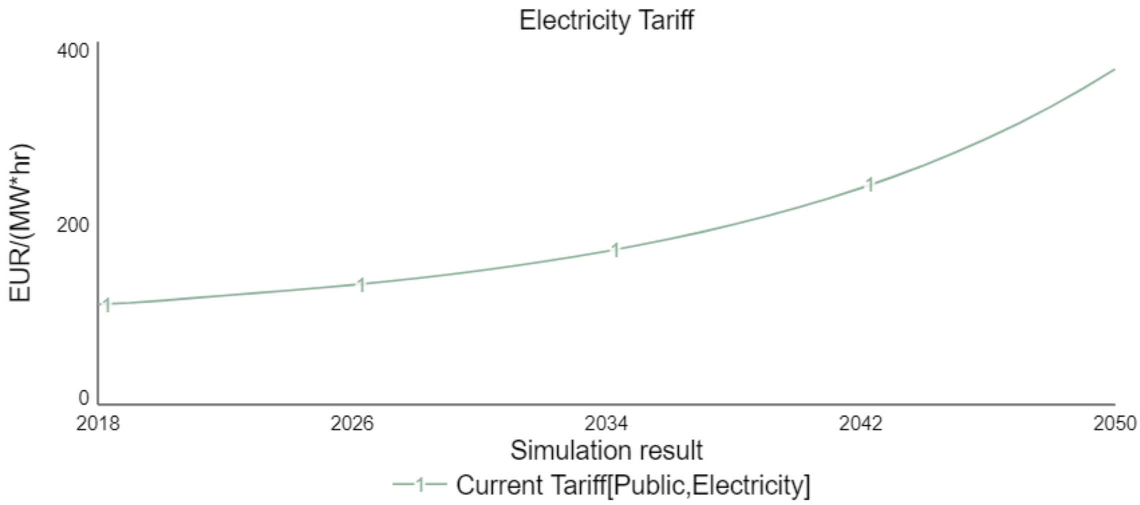
Tomelilla municipality

In Tomelilla municipality, there is 40.7 MW of installed energy production capacity, of which 29 MW is wind power and 11.7 MW is solar power, according to data from the Swedish Energy Agency in 2023. Over the past five years, the installed capacity of solar power has increased significantly, while the installed capacity of wind power has remained the same since 2016. Despite this, Tomelilla municipality has a relatively high number of wind turbines. However, half of these turbines are 16 years or older, and by 2036, 19 out of 22 wind turbines will reach the end of their lifespan (25 years). In 2022, 64.3 GWh were produced in Tomelilla municipality. Wind turbines accounted for 91 percent of electricity production, while solar power accounted for 9 percent. In 2022, 172.2 GWh were used in Tomelilla municipality. This means that the municipality has a self-sufficiency rate of 37 percent, on a yearly basis. Since these energy sources are weather-dependent, the self-sufficiency rate varies over the day and season.

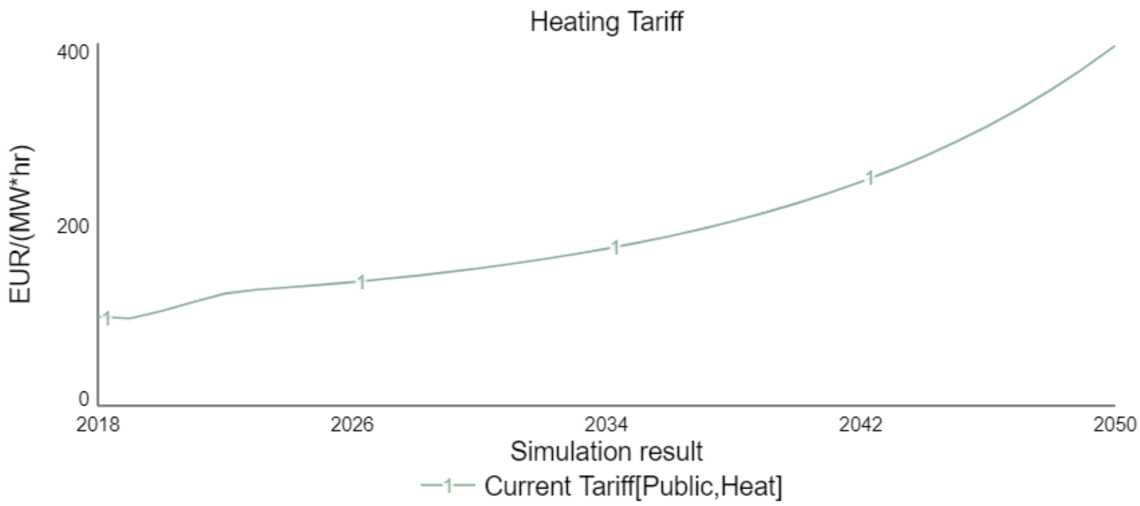
The region Skåne has developed a roadmap for Skåne's electricity supply in 2030. The purpose of the roadmap is to realize the goal of the Effect Commission to increase Skåne's self-sufficiency rate in electricity from the current 15 % (2023) to at least 50 % by 2030, covering all hours of the year. The roadmap highlights the importance of continuing to focus on energy efficiency and emphasizes that flexibility solutions on the user side (control, pricing models, batteries) are crucial for finding a sustainable regional balance between production, distribution, and usage. The roadmap further proposes a sixfold increase in installed electricity capacity in Skåne to achieve the goal of a 50% energy self-sufficiency rate during the most critical hour of the year.

The municipality is therefore faced with different challenges moving forward. First of all, there is the aging process of wind turbines, as well as the slowdown of new wind turbines construction. On the other hand, the region's ambitious goal for 2030 poses additional challenges. The scenarios will explore these challenges.

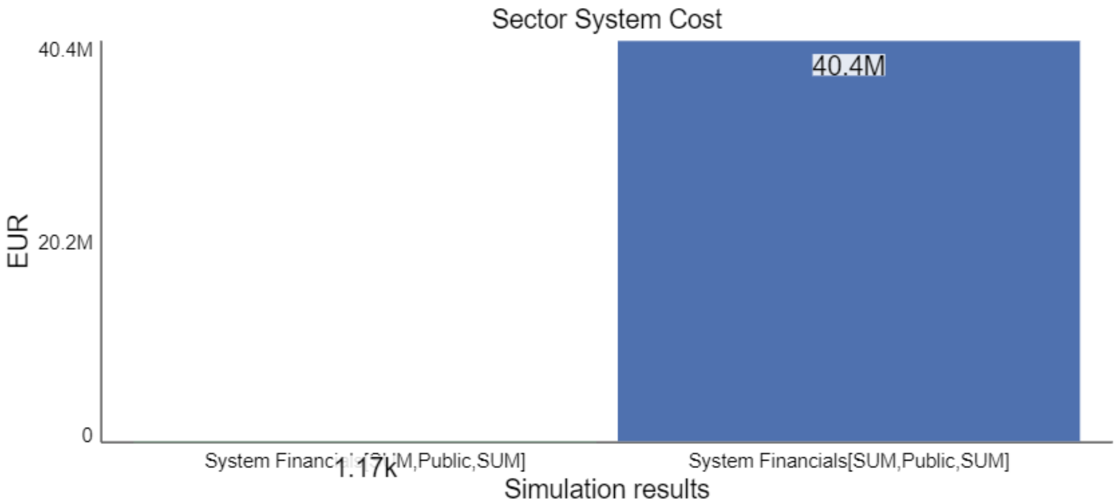
Changes in energy prices:

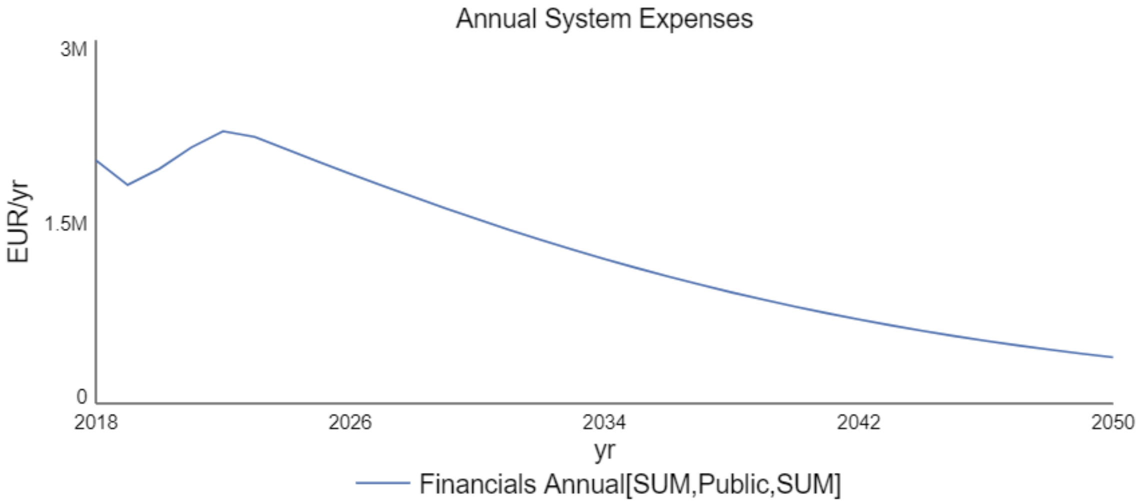


Changes in heat prices:

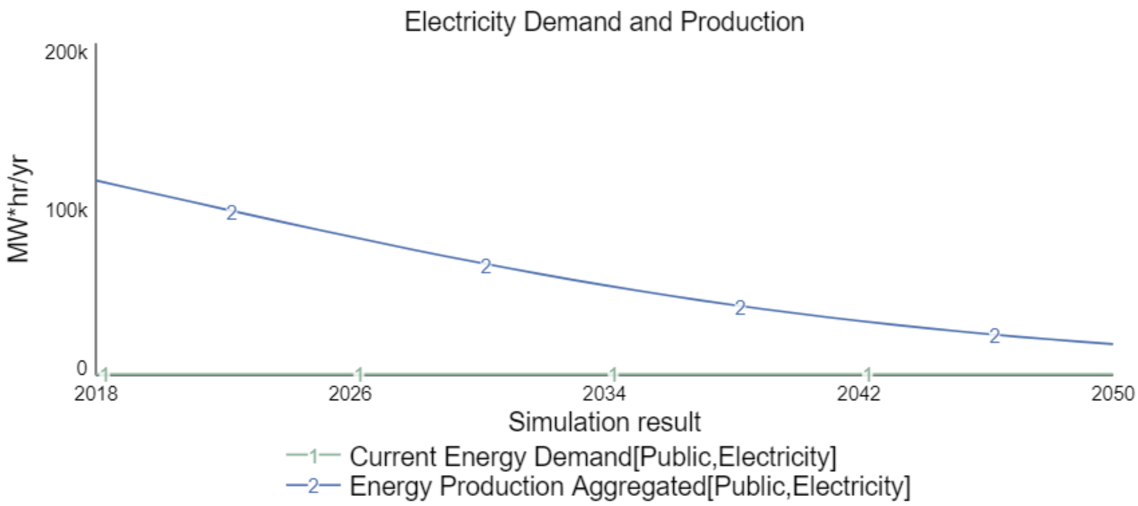


Financing:





Changes in energy demand:



Scenario 1: Achieve a higher sufficiency rate through energy efficiency measures.

<table>
<tr><th>Scenarios</th><th>Sector</th><th>Description</th></tr>
<tr><td>(1) Renovation of single-family households</td><td>Heating</td><td>• The current share of renovated multiapartment residential buildings is 10%.
• The target is to achieve higher self-sufficiency rate in the region. Currently, the share of imported non-renewable heat is high (118/133 GWh/year).
• With the existing state support system 50% and increase of energy efficiency diffusion impact factors:
- Psychological and Social Factors increased from 10 to 20%, and
- Organizational and Leadership support increased from 10% to 20%.</td></tr>
<tr><td colspan="3">Results
• The imported non-renewable heat decreased from 118 to 116 GWh/year.
• The local renewable energy consumed increased from 3,41 to 5,07 GWh/year.
• The cumulative percent change in heat consumption for single family households decreases 0,04 %
• Cumulative renovation investment for single family households was 187,000 €
• Renovation discounted payback time was 740 years.
Reflection:
• The effect of the energy efficiency measures were limited, and might not be the best move forward considering the long payback time.</td></tr>
<tr><td colspan="3">Scenario 2: A new solar park in the municipality</td></tr>
<tr><td>(2) A company is planning to install a solar park in the municipality with a capacity of 80 MW</td><td>Electricity /district sector</td><td>In addition to the 29 MW wind power, 11 MW solar power, and 9 MW boiler biomass woodchips
- 80 MW solar power plant will be added.
The energy balance, before the added 80 MW solar power plant is:
- 7,2 GWh/year imported non-renewable electricity
- 36 GWh/year imported renewable electricity.
- 34 GWh/year local renewable energy consumed.
- No excess energy</td></tr>
</table>

Results The energy balance, after the added 80 MW solar power plant is: • 2,12 GWh/year imported non-renewable electricity • 10,6 GWh/year imported renewable electricity • 84 GWh/year local renewable energy consumed • No excess energy • The electricity storage potential (at its highest) is 89 GWh/year. • The comparative electricity tariff is lower than the base line, and is just under 100 euro/ MWh. • The sector system cost is quite high, 170M Euro. • The share of renewable energy is very high, 99,7 %. Although, it was high earlier as well. The share, before the new solar park, was 96,6 %. **Reflections:** • The installation of the solar power plant increased the local renewable energy consumed significantly and replaces the consumed non-renewable energy. The installation also increased the use of electricity in the district somewhat. • There is a potential for some kind of storage solution.		
Scenario 3: Repower the wind turbines		
(3) Repower the 29 MW wind turbines that exist in the municipality	Electricity/District	• There is currently 29 MW installed wind turbine capacity. However, the installation of new wind turbines has slowed down due to lack of political will and resistance from citizens. Since the wind turbines are growing old, a solution is to replace the current ones with more efficient ones. Input: - Recommissioning 29 MW wind power plants
Results Electricity balance: • 4,67 MWh/year imported non-renewable electricity. • 70,9 GWh/year local renewable energy consumed • 31,3 GWh/year imported renewable energy consumed Renewable energy share (district): • 97 % Sector system cost: • 95,1 million euros • The comparative electricity tariff is lower than the base line, but higher than with scenario 2, with a tariff around 115 Euro/MWh/year **Reflection:**		

- Recommissioning of the wind power plants were less expensive than the 80 MW solar power plant.
- The local renewable energy consumed decreased somewhat but is still high and the largest share of the consumption.
- The non-renewable electricity increased.
- The share of renewable energy share was still high, albeit not as high as it was with the solar power plant.

4.5 Mikołajki Pomorskie municipality

The starting point for further calculations is the existing situation presented in the table below. The main problem of the municipality is that the existing, outdated heating installations (boilers) not only rely on fossil fuels (hard and fine coal) but are also oversized.

Descriptions	Share of RES (electricity) by TSO [%]	Heat Source	Source capacities [kW]	Energy 'in fuel' (2022) [MWh/a]	CO_2 emissions (2022) [t/a]	Current heat demand (2022) [MWh/a]	Total area of buildings [m²]	Specific heat consumption (2022) [kWh/m²/a]
sector: public (coal, Mikołajki)	12.50%	coal boilers	362	473.4	161.8	347.9	2802.6	124.1
sector: public (biomass, Mikołajki)	12.50%	pellet boilers	250	204.8	82.6	183.4	1860.9	98.6
sector: public (Commune Office Mikołajki)	12.50%	light fuel oil boiler	25	67.2	17.9	60.5	680.0	89.0
sector: apartment (Cieszymowo)	12.50%	coal boiler	200	166.4	56.9	113.4	733.9	154.5
sector: single family (village of Mikołajki)	12.50%	small coal boilers	n.a.	8275.0	2828.3	5792.5	31570.0	262.1
sector: single family (rest of municipality)	12.50%	small coal boilers	n.a.	13594.7	4646.5	9516.3	51864.9	262.1

Three preliminary calculation scenarios have been defined for buildings in three sectors, with calculations using the Energy Equilibrium Platform. The presented devices/systems will replace the fossil fuel installations.

Scenarios	***Sector***	***Description***
1) heating microgrid based on a gas heating plant in the village of Mikołajki (biomethane), 2) small biomethane CHP plant in Cieszymowo as a	heating	• Currently there is no district heating system in this municipality, heating is based on individual sources of heat, fuelled mainly by hard/fine coal. Installed other RES capacity: • 0.5 MW (PV, public),

<table>
<tr><td>source of heat for two multi-family buildings,

3) other single-family buildings: biomass boilers (wood chips)</td><td></td><td>• 3 MW (PV, single-family in Mikołajki),
• 10 MW (HAWT, single-family outside),
• 1 MWel and 0.56 MWth (biomethane CHP, apartment),
• 3.11 MW (biomass boilers, single family outside).</td></tr>
<tr><td colspan="3">Results
• Estimated thermal capacity of a heating plant in the village of Mikołajki is 2.3 MW (3060 operational hours at full thermal load).
• Increase of share of renewable energy sources (RES) in total consumption of electricity from 12.5 to 83 % (public), 97 % (single-family), 78 % (apartment).
• Heat price is estimated at 95 EUR/MWh (2026) and 96 EUR/MWh (2034) for public, 100 and 91 EUR/MWh respectively for single-family, 95 and 96 EUR/MWh for apartments.
• It is estimated with the platform that the renovation discounted payback time for single-family buildings (currently, 49.9 % of the usable floor space has not undergone any thermal modernization) is 60 years.</td></tr>
<tr><td>1) rural heating microgrid based on a biomass heating plant in Mikołajki (wood chips),

2) small biomethane CHP plant in Cieszymowo as a source of heat for two multi-family buildings,

3) other single-family buildings: biomass boilers (wood chips)</td><td>heating</td><td>• Currently there is no district heating system in this municipality, heating is based on individual sources of heat, fueled mainly by hard/fine coal.

Installed other RES capacity:
• 0.5 MW (PV, public),
• 3 MW (PV, single-family in Mikołajki),
• 10 MW (HAWT, single-family outside),
• 1 MWel and 0.56 MWth (biomethane CHP, apartment)
• 3.11 MW (biomass boilers, single family outside).</td></tr>
<tr><td colspan="3">Results
• Estimated thermal capacity of a heating plant in the village of Mikołajki is 2.3 MW (3060 operational hours at full thermal load).
• Increase of share of renewable energy sources (RES) in total consumption of electricity from 12.5 to 83% (public), 97 % (single-family), 78 % (apartment).
• Heat price is estimated at 95 EUR/MWh (2026) and 96 EUR/MWh (2034) for public, 100 and 91 respectively for single-family, 95 and 96 for apartment.
• It is estimated with the platform that the renovation discounted payback time for single-family buildings (currently, 49.9 % of the usable floor space has not undergone any thermal modernization) is 60 years.</td></tr>
</table>

1) every public building uses a heat pump, supported by RES installations, 2) other buildings (apartment, single-family) use biomass boilers	heating (public, apartment, single family)	• Heat pumps and biomass boilers will replace the outdated fossil fuel individual installations (almost all fine and hard coal). Installed other RES capacity: • 3 MW (PV, public), • 100 kW (PV, apartment), • 10 MW (onshore wind farm – PPA contract, single-family), • biomass boilers 40 kW (apartment), • biomass boilers 5 MW (single-family). • heat pump outputs 190 kW (public).

Results

- Increase of share of RES in total electricity consumption from 12.5 % (by TSO) to about 97 % for public, 98 % for single-family.
- The fraction of renewable heat produced by the heat pumps, considering both the renewable electricity used and the environmental heat extracted (assuming COP=3) would be 99 %.
- Heat price is estimated at 101 EUR/MWh (2026) and 91 EUR/MWh (2034) for public, 100 and 100 respectively for apartment, 100 and 100 for single-family.
- Annual CO_2 emissions (2026) would be 3.2 t for public, none for apartment and single-family.
- The renovation discounted payback time for single-family buildings is as above (60 y.).

4.6 Wejherowo municipality

When developing the scenarios, a comprehensive approach to the energy management of the municipality and the supply of heat and electricity to all consumer groups was assumed. Therefore, possible directions for the modernization of the existing heating system and expected trends in the development of individual heat sources that currently supply most of the municipality's heat consumers were considered.

When analysing possible directions for the modernization of the heating system, the current activities of the OPEC heating company were taken into account (the construction of a gas-oil heating plant with a capacity of 20 MW planned in the near future (as in scenarios no. 1 and no. 3), as well as plans considered in the longer term assuming the construction of a solar farm with a capacity 1.7 MW and a heat pump with a capacity of 5 MW using geothermal energy (included in scenario no. 2). Additionally, scenario no. 3 assumes the possibility of replacing one of the current coal boilers with a biomass boiler with a capacity of 10 MW.

The construction of new heat sources in the heating system will result in the gradual withdrawal of existing coal-fired boilers. In the scenario analysis, it was assumed that the new sources would result in the replacement of some coal-fired boilers with equivalent power corresponding to the power of the new sources introduced into the system.

In the case of individual energy consumers, real scenarios were adopted for the municipality, considering the actual possibilities and territorial limitations occurring in the city of Wejherowo and the trends in the development of renewable energy sources and other individual sources along with the possibilities of reducing the heat demand on the part of consumers (including the implementation of thermal modernization stimulated by possible national funding). Therefore, the scenarios assume the construction of new individual renewable energy sources on the side of individual energy consumers, including the construction of heat pumps and photovoltaic installations (differentiating the pace of their implementation in scenarios no. 1 and no. 2). In the case of the industrial sector, the possibility of building a biomass (wood chips) heating plant was assumed.

Similarly to the district heating system, the introduction of new individual sources will result in the liquidation of old coal sources, which is considered in the balance of existing heat consumers in each of the separated groups.

In scenario no. 3 (which duplicates the modernization of individual sources from scenario no. 2), the change in energy efficiency diffusion impact factors was additionally considered in order to determine their impact on the thermal needs of individual groups of heat energy consumers and the rate of thermal renovation of facilities.

Table 4.6.1 Comparative indicators for the Wejherowo municipality for the current state

No	Name	Unit of measure	Single family buildings	Apartment buildings	Public	Services	Industrial buildings	Total
1	Total area of the buildings	m²	371097	787133	51963	340923	27200	
2	Initial share of renovated buildings	%	30	50	67	10	10	
3	Share connected to district heating	%	2.14	70.61	100.00	44.70	5.20	
4	Building energy consumptiom - heat	MWh/year	48 700	83 900	4 619	58 200	5 370	200 789
5	Building energy consumptiom - electricity	MWh/year	7 060	20 010	1 025	15 280	16 820	60 195
6	System Renewable Energy share	%	15.6	4.12	3.67	25.7	22.7	14.2
7	Emissions - heat (cumulated for period to 2050)	tons						2 870 000
8	Emissions - electricity (cumulated for period to 2050)	tons						166 000
9	Annual system Expenses - for 2024	EUR/year						40 600 000
10	Annual Vehicle Emissions - Private - 2024	t/year						122 000
11	Annual Vehicle Emissions - Public - 2024	t/year						11 000

In order to compare the results obtained as a result of the simulation in individual scenarios, a table illustrating the basic indicators for the municipality in its current state is provided below.

Scenario 1.

Energy sector or group of energy consumers	Type of investment	Financing of renovation	Energy efficiency diffusion impact factors	Impact on existing sources and other comments
District Heating System	Construction of a new gas heating plant with a capacity of 20 MW.			It replaces some coal-fired boilers with a capacity of 20 MW.
Single family buildings	Construction of photovoltaic installations in single-family residential buildings with a total capacity of 750 kWp (150 buildings - 150 installations of 5 kWp each).	• bank loans - 20% (interest rate 10%) • subsidies - 20% • self-financing - 60% • loan terms - 10 years	10% for each factor	Approximately 5% of buildings, i.e. 150 buildings.
Apartment buildings	1) Installation of heat pumps in multi-family buildings with a total capacity of 1.5 MW (15 buildings - 15 installations of 100 kW each). 2) PV installations 150 kWp (15 installations of 10 kWp each).	• bank loans - 30% (interest rate 10%) • subsidies - 20% • self-financing - 50% • loan terms - 15 years	10% for each factor	Approximately 2% of buildings, i.e. 15 buildings. Heat pumps replace some of the individual coal sources with an equivalent power of 1.5 MW.
Public buildings	Construction of photovoltaic installations in public buildings with a total capacity of 250 kWp (5 buildings - 5 installations of 50 kWp each).	• bank loans - 10% (interest rate 7%) • subsidies - 80% • self-financing - 10% • loan terms - 15 years	10% for each factor	Approximately 30% of buildings, i.e. 5 buildings.
Services	1) Construction of photovoltaic installations in buildings of the service sector with a total capacity of 125 kWp (25 buildings - 25 installations of 5 kWp each). 2) Installation of heat pumps with a total capacity of 500 kW (5 buildings - 5 installations of 100 kW each).	• bank loans - 30% (interest rate 7%) • subsidies - 10% • self-financing - 60% • loan terms - 10 years	10% for each factor	Heat pumps replace some of the individual coal sources with an equivalent power of 0.5 MW.

Industrial buildings	Construction of a biomass (wood chips) boiler room with a total capacity of 200 kW.	self-financing - 100%	10% for each factor	It replaces some coal-fired boilers with an equivalent power of 0.2 MW.
Transport	Purchase of electric buses. Purchase of hydrogen buses.			

Results

- The simulation showed that the share of buildings undergoing renovation in the public services sector increased by approximately 18 % (to 84 %), however, in the remaining groups the increase was much smaller and ranged from 1.5 to 5 %.
- Renovation discounted payback times for buildings vary. Investment outlays are paid back the fastest in the case of public utility facilities (after about 4 years) and industrial buildings (6 years). Residential buildings are characterized by a payback period of 20 years (multi-family buildings) to 36 years (single-family houses), while service sector facilities – about 22 years.
- The assumed rate of thermal renovation will not significantly affect the heating needs of the entire commune: the heat demand will decrease from the current level of 200.8 GWh/year to 199.4 GWh/year, i.e. only by approximately 1%. The balance of electricity consumption remains practically unchanged.
- The cumulative renovation investment for the analysed variant amounts to 52.85M Eur.
- Average energy tariff for sectors is varied and reach the highest values in the case of public buildings (100 % connected to the heating system), which reflects the exceptionally high prices of district heating.
- The share of renewable energy in the commune will increase from the current level of 14 to above 33 %.
- Emissions are expected to be reduced by approximately 18 % for heat, but emissions from electricity production will remain virtually unchanged.
- A significant reduction in emissions can be expected in the transport sector (65 %).
- Total system cost for scenario no. 1 – 812M EUR.

Table 4.6.2 Main results for scenario 1

No	Name	Unit of measure	Single family buildings	Apartment buildings	Public	Services	Industrial buildings	Total
1	Share of renovated buildings	%	31.7	54.7	84.4	11.4	11.5	
2	Cumulated renovation investmentt	EUR	2 550 000	11 200 000	15 300 000	12 500 000	11 300 000	52 850 000
3	Renovation discounted payback time	year	36.3	20.3	3.88	21.9	6.06	
4	Building energy consumptiom Heat	MWh/year	48 600	82 500	4 620	58 200	5 440	199 360
5	Building energy consumptiom Electricity	MWh/year	7 070	19 900	1 030	15 300	16 900	60 200
6	Average energy tariff for sector		heat / electricity	heat / electricity	heat / electricity	heat / electricity	heat / electricity	
	2024	EUR/MWh	135 / 111	127 / 114	156 / 125	133 / 125	128 / 125	
	2038	EUR/MWh	168 /117	117 / 122	166 / 156	118 / 165	158 / 125	

	2050	EUR/MWh	137 / 130	106 / 123	190 / 155	112/ 165	131 / 125	
7	Total system cost	EUR						812 000 000
8	Total cost of production for selected technologies	EUR	6 330 000	64 800 000	213 000	2 996 000	4 950 000	79 289 000
9	System Renewable Energy share	%	28.4	37.9	5.31	34.3	26.1	33.3
10	Emissions - heat (cumulated for period to 2050)	tons						2 350 000
11	Emissions - electricity (cumulated for period to 2050)	tons						166 000
12	Annual system Expenses - for 2050	EUR/year	3 360 000	5 440 000	10 300	3 910 000	349 000	13 069 300
13	Annual Vehicle Emissions - Private - 2050	t/year						42 700
14	Annual Vehicle Emissions - Public - 2050	t/year						3 860

Scenario 2.

Energy sector or group of energy consumers	Type of investment	Financing of renovation	Energy efficiency diffusion impact factors	Impact on existing sources and other comments
District Heating System	1) Construction of a solar collector farm with a capacity of 1.7 MW. 2) Construction of a 5 MW heat pump using geothermal energy.			It replaces some coal-fired boilers with a capacity of 6.7 MW.
Single family buildings	Construction of photovoltaic installations in single-family residential buildings with a total capacity of 1.5 MWp (300 buildings - 300 installations of 5 kWp each).	• bank loans - 30% (interest rate 5%) • subsidies - 20% • self-financing - 50% • loan terms - 10 years	10% for each factor	Approximately 10% of buildings, i.e. 300 buildings.
Apartment buildings	1) Installation of heat pumps in multi-family buildings with a total capacity of 4.0 MW (40 buildings - 40 installations of 100 kW each). 2) PV installations 800 kWp (40 installations of 20 kWp each).	• bank loans - 30% (interest rate 10%) • subsidies - 20% • self-financing - 50% • loan terms - 15 years	10% for each factor	Approximately 5% of buildings, i.e. 40 buildings. Heat pumps replace some of the individual coal sources with an equivalent power of 4.0 MW.
Public buildings	Construction of photovoltaic installations in public buildings with a total capacity of 500 kWp (10 buildings - 10 installations of 50 kWp each).	• bank loans - 10% (interest rate 5%) • subsidies - 80% • self-financing - 10% • loan terms - 15 years	10% for each factor	Approximately 60% of buildings, i.e. 10 buildings.
Services	1) Construction of photovoltaic installations in buildings of the service sector with a total capacity of 250 kWp (50 buildings - 50 installations of 5 kWp each). 2) Installation of heat pumps with a total capacity of 1.0 MW (10 buildings - 10 installations of 100 kW each).	• bank loans - 30% (interest rate 5%) • subsidies - 10% • self-financing - 60% • loan terms - 10 years	10% for each factor	Heat pumps replace some of the individual coal sources with an equivalent power of 1.0 MW.
Industrial buildings	Construction of a biomass (wood chips) boiler room with a total capacity of 500 kW	self-financing - 100%	10% for each factor	It replaces some coal-fired boilers with an equivalent power of 0.5 MW.

Transport	Purchase of hydrogen buses			

Results

- The share of buildings undergoing renovation in the public services sector increased by approximately 18 % (to the level of 84 %), however, in the remaining groups the increase was much smaller and ranged from 1.5 to 5 % (practically as in scenario 1).
- Renovation discounted payback times for buildings vary. Investment outlays will pay off the fastest in the case of public utility facilities (after about 3 years). The longest payback period is typical for single-family buildings - approximately 35 years.
- The assumed rate of thermal renovation will not significantly affect the heating needs of the entire commune: the heat demand will decrease from the current level of 200.8 GWh/year to 199 GWh/year, i.e. only by approximately 1 %. The balance of electricity consumption also remains practically unchanged (as in scenario 1).
- Cumulative renovation investments for the analysed variant amount to 52.8M EUR.
- Average energy tariff for sectors are varying and reach their highest values in the case of public buildings (100 % connected to the heating system), which reflects the exceptionally high prices of district heating (as in scenario no. 1).
- The changes assumed by scenario 2 enable increasing the share of renewable energy in the energy balance of Wejherowo from the current level of 14 % to approximately 35 %.
- Emissions are expected to be reduced by approximately 12 % in the case of heat and the level of emissions related to electricity production will remain virtually unchanged.
- Similarly to scenario no. 1, a significant emission reduction can be expected in the transport sector (65 %).
- The energy development variant of the municipality implemented according to scenario no. 2 will not significantly improve the energy balance of the city of Wejherowo and will only increase the use of renewable energy sources in its energy balance by 4 %.
- Total system cost for scenario no. 2 – 883M EUR.
- The results indicate that a more dynamic development of thermal modernization should be planned and the implementation of renewable energy sources should be planned to a much greater extent.

Table 4.6.2 Main results for scenario 2

No	Name	Unit of measure	Single family buildings	Apartment buildings	Public	Services	Industrial buildings	Total
1	Share of renovated buildings	%	31.8	55.4	84.4	11.5	11.5	
2	Cumulated renovation investmentt	EUR	2 560 000	11 200 000	15 200 000	12 600 000	11 300 000	52 860 000
3	Renovation discounted payback time	year	34.8	17.4	3.2	20.0	6.04	
4	Building energy consumptiom Heat	MWh/year	48 600	82 100	4 620	58 200	5 440	198 960
5	Building energy consumptiom Electricity	MWh/year	7 070	19 900	1 030	15 300	16 900	60 200
6	Average energy tariff for sector		heat / electricity	heat / electricity	heat / electricity	heat / electricity	heat / electricity	
	2024	EUR/MWh	135 / 111	125 / 114	156 / 125	132 / 125	129 / 125	
	2038	EUR/MWh	168 /114	118 / 120	166 / 146	118 / 165	144/ 125	

	2050	EUR/MWh	137 / 133	106 / 123	190 / 146	111/ 165	131 / 125	
7	Total system cost	EUR						883 000 000
8	Total cost of production for selected technologies	EUR	6 580 000	72 100 000	425 000	5 983 000	6 610 000	91 698 000
9	System Renewable Energy share	%	28.9	41.1	6.95	35.4	29.0	34.7
10	Emissions - heat (cumulated for period to 2050)	tons						2 520 000
11	Emissions - electricity (cumulated for period to 2050)	tons						166 000
12	Annual system Expenses - for 2050	EUR/year	3 300 000	5 340 000	13 200	3 930 000	349 000	12 932 200
13	Annual Vehicle Emissions - Private - 2050	t/year						42 700
14	Annual Vehicle Emissions - Public - 2050	t/year						3 780

Scenario 3.

Energy sector or group of energy consumers	Type of investment	Financing of renovation	Energy efficiency diffusion impact factors	Impact on existing sources and other comments
District Heating System	1) Construction of a new gas heating plant with a capacity of 20 MW. 2) Construction of a new biomass (wood chips) boiler with a capacity of 10 MW.			It replaces some coal-fired boilers with a capacity of 30 MW.
Single family buildings	Similarly to scenario No. 2	Similarly to scenario No. 2	• Expertise and Knowledge - 20% • Psychological and Social Factors - 20% • Other factors as in scenario No. 2	Similarly to scenario No. 2
Apartment buildings	Similarly to scenario No. 2	Similarly to scenario No. 2	• Expertise and Knowledge - 20% • Psychological and Social Factors - 20% • Other factors as in scenario No. 2	Similarly to scenario No. 2
Public buildings	Similarly to scenario No. 2	Similarly to scenario No. 2	• Expertise and Knowledge - 20% • Psychological and Social Factors - 20% • Organisational and Leadership Support - 20% • Other factors as in scenario No. 2	Similarly to scenario No. 2
Services	Similarly to scenario No. 2	Similarly to scenario No. 2	• Expertise and Knowledge - 20%	Similarly to scenario No. 2

			• Psychological and Social Factors - 20% • Other factors as in scenario No. 2	
Industrial buildings	Similarly to scenario No. 2	Similarly to scenario No. 2	• Expertise and Knowledge - 20% • Implementation and Technology - 20% • Other factors as in scenario No. 2	Similarly to scenario No. 2
Transport	Similarly to scenario No. 2			

Results

Scenario no. 3 was tested to determine the impact of an additional RES source (new biomass boiler) introduced into the heating system (compared to Scenario No. 1) and to determine the impact of other external factors (Energy efficiency diffusion impact factors) on reducing the heat demand of consumers.

- The simulation conducted for scenario no. 3 showed that increasing the importance of factors such as "Expertise and Knowledge", "Psychological and Social Factors", "Implementation and Technology" or "Organizational and Leadership Support" translates into the pace and volume of renovation of housing resources and other facilities located in the municipality. The greatest impact is visible here in the case of public buildings, the share of which after the forecast thermal renovation increases to 92 % in a given scenario. The number of buildings undergoing thermal modernization in the multi-family construction sector also increases to a greater extent than in scenario no. 2 (up to 59 %). The smallest impact occurred in the single-family buildings sector (an increase of approximately 2 % compared to the current situation - practically no change compared to scenario no. 2).
- Increased thermal renovation will result in a decrease in the thermal needs of consumers from 200.8 GWh/year to 195.4 GWh/year, however, in the scale of the entire commune, this is only a 3 % decrease compared to the current state.
- Renovation discounted payback time for buildings in scenario no. 3 is similar to the results in scenario no. 2 (from 3 years for public buildings to 35 years for single-family buildings).
- Cumulative renovation investments for the analysed variant amount to 81.36M EUR.
- Total system cost for scenario no. 3 – 875M EUR.
- The results regarding average energy tariffs for sectors are similar to the results from scenario no. 2.
- The share of renewable energy in the city will increase from the current level of 14 % to over 35 %.
- In the case of heat energy production, emissions will be reduced by approximately 12 % compared to scenario 2 and by 23 % compared to the current situation.
- Reduction of emissions in the transport sector – analogous to scenario 2.
- Despite the assumed increased impact of external factors (Energy efficiency diffusion impact factors) and the partial transformation of sources in the heating system towards renewable energy sources, the analysed scenario shows that in the Wejherowo municipality it is necessary to look for solutions that have a much greater impact on its

energy management, both within the heating system and in regarding energy consumers.

Table 4.6.7 Main results for scenario No. 3

No	Name	Unit of measure	Single family buildings	Apartment buildings	Public	Services	Industrial buildings	Total
1	Share of renovated buildings	%	31.8	59.1	91.9	13.4	13.3	
2	Cumulated renovation investmentt	EUR	2 560 000	17 200 000	24 000 000	20 200 000	17 400 000	81 360 000
3	Renovation discounted payback time	year	34.8	17,3	3,2	19,9	6,02	
4	Building energy consumptiom Heat	MWh/year	48 600	79 700	4 200	57 700	5 350	195 550
5	Building energy consumptiom Electricity	MWh/year	7 070	19 700	1 000	15 200	16 800	59 770
6	Average energy tariff for sector		heat / electricity	heat / electricity	heat / electricity	heat / electricity	heat / electricity	
	2024	EUR/MWh	135 / 111	125 / 114	156 / 125	132 / 125	129 / 125	
	2038	EUR/MWh	168 /114	118 / 120	166 / 146	118 / 165	144/ 125	
	2050	EUR/MWh	137 / 133	107 / 124	190 / 146	111/ 165	134 / 125	
7	Total system cost	EUR						875 000 000
8	Total cost of production for selected technologies	EUR	6 580 000	71 100 000	425 000	5 983 000	6 580 000	90 668 000
9	System Renewable Energy share	%	28,9	41,0	7,28	35,4	29,0	35,3
10	Emissions - heat (cumulated for period to 2050)	tons						2 220 000
11	Emissions - electricity (cumulated for period to 2050)	tons						166 000
12	Annual system Expenses - for 2050	EUR/year	3 300 000	5 210 000	13 200	3 890 000	344 000	12 757 200
13	Annual Vehicle Emissions - Private - 2050	t/year						42 700
14	Annual Vehicle Emissions - Public - 2050	t/year						3 780

5 Challenges

The creators of the platform have done a huge job and most of the platform operates great. However, municipalities encountered some challenges when applying the platform to their real needs (some are related to limitations of the model assumption or economic parameters, other to computer system capacity – some improvements of model might be necessary). The challenges mentioned by municipalities are listed below:

- *"Judging by the purchase costs and the fact that buses using RES are not cheaper in operation, there is no financial incentives, it is more a matter of confidence and political will. In the case of Gulbene Municipality almost all heat energy is produced from wood (wood chips in district heating, wood pellets and firewood). We expect that nothing will change to a large extent in the next 10 years, and wood will be used mainly for heating. All the electricity produced in Gulbene district is produced from RES, however, its total amount is too small to cover all the demand (approx. 11.3 GWh/year of fossil fuels is imported)."*
- *"Calculations show that we need more RES (15 MWe) to reach 100 % of RES share in electricity in Gulbene region (91,5 % in 2050). There is no payback time for such a big investment in storage systems (1,000 MWh). If we try to lower the tariff, payback time for renovation will be longer."*
- *"The translation into national languages would be very helpful. Though there are possibilities to use the Google translate application, this is not the best choice, as not all users are using Google Chrome and not all institutions allow using apps. Though most specialists know English, not in all sectors (technical, economic, management), thus it would be good to have all terms to be clear."*
- *"Not all measure units on graphs are clear: K and B, maybe are clear for mathematicians, but not for other professionals. Besides, measure units are also not always clearly seen in the graphs. Titles and figures should be clear."*
- *"There is no need to show all simulations – showing the final result for each estimate would be the better option."*
- *"The use of multi-optional scenarios is complicated and does not always work e.g. growth of public electric buses means a reduction of the inventory of old diesel ones in everyday activities, but they can be used e.g. renting only; the same is true in the change of private electric car parks, however, this cannot be done. Some re-estimates of the full car park can be done automatically with regard to global trends. A similar situation is in the heating sector, where the new biomass boiler (wood chips or pellets) can replace the old boilers, burning fossil or other solid fuels, however, it is not clear how to do this."*
- *"Though there is a possibility to combine storage with generation sources, this combination of the boiler with water tank heat storage had no effect. Does not show the need for water tank storage for biomass boilers, though such boilers need storage for improvement of operation efficiency, especially during peak hours and during fast changes of temperature during winter periods."*
- *"No possibility to assess the effect of battery use in the transport sector."*
- *"Simulation results for the entire system could be in separate window and engulf all measures in all the rest pages."*
- *"I am not sure, whether the results obtained are reasonable in all cases."*

- *"I do not understand why the boiler has such effect on the share of renewable energy in the municipality. I thought that an installation of 80 MW solar park would affect the share of renewable energy more than it did (it did not affect it at all)."*
- *"It was interesting that the information campaign did influence the renewable energy share, albeit small."*
- *"Most of the diagrams did not change with the different scenarios, and I do not know why. The challenge was that I did not have enough knowledge to know why the results were what they were. In the stage of the project, we are in now, I think I need more guidance to understand how different renewable energy sources affect the system."*
- *"Scenario export does not work (changes not included)."*
- *"Results are debatable and unverifiable (in the sense of understanding and checking the built-in algorithms)."*
- *"No biogas and biomethane CHP plant options (correct calorific values (LHV), renewable energy status)."*
- *"No report generator (which makes it extremely difficult to use the Platform)."*
- *"Too many options, sometimes unclearly named – instead of fewer of them, for the real use, but proven."*
- *"Desired list of configurations, sorted by net present cost, as quasi-optimization (for more complex cases, scenarios)."*
- *"The list of heat sources needs to be supplemented, as it does not include many traditional individual sources that currently exist in municipalities and whose description is necessary to determine the current energy balance of the municipality. There are no oil sources (used e.g. in many public utility facilities in rural areas without access to the gas network in Poland), coal boilers (which operate only for heat production and are difficult to enter as CHP Extraction Coal) or heating using tiled stoves (which can be fired with coal or biomass), etc."*
- *"The use of pull-down menus (of course widely used, which is justified in the case of single options) does not allow for a quick review of scenarios/concepts (I suggest designer and developer check out the professional energy programs – quasi-graphic solutions) and it is quite easy to make mistakes, especially for more complex scenarios."*
- *"It should be possible to independently introduce several groups of sources of the same type but differing in e.g. technical condition and lifetime. This is necessary when new sources replace some of the old, ineffective sources that will be taken out of service, leaving some sources of a given group that are characterized by better technical parameters. In any case, it should be possible to isolate from a group of input sources of one type that part of them that will be withdrawn from use as a result of the appearance of new sources."*
- *"This situation also occurs in the case of sources operating in the heating system. It is not clear, for example, how to model a variant when some of the coal-fired boilers in the heating system (whose technical lifetime has not yet ended) are replaced with new sources, and the remaining coal-fired sources remain, but are subject to modernization which involves limiting their installed power)."*
- *"Import of previously exported files does not work properly. After importing the input data, for example, the previously entered areas of individual consumer groups and, in some cases, the data of heat sources are reset to zero."*

- *“Calculations in the "Total energy consumption by sector" section and energy balances in the "Production" part should be refined, as there are inconsistencies and different results regarding total consumption and energy consumed.”*

6 Conclusions

The platform operates well. There are however some improvements which might increase Platform applicability:

1. The EE project model provides valuable insights and resources to address the challenges of energy storage deployment in the municipality.
2. The translation of the Platform language might help to increase its target.
3. More training hours and an EE simulation program manual is necessary.
4. Exemplary calculations should be included in the Platform description/manual to help non-specialist to understand the Platform applicability e.g. how different renewable energy sources affect the system.
5. More information on the social aspect is needed, e.g. what does it means Psychological and Social Factors 10 or 20%.
6. Too many options, sometimes unclearly named – instead of fewer of them, for the real use, but proven.
7. Import of previously exported files does not work properly.
8. Effect of some technologies should be checked e.g. water heat storages.

Attachment 1

The expectations expressed by municipalities taking part in the tests and validation of Energy Equilibrium platform

- I expect to learn how to use the platform in the context of Tomelilla, with challenges that municipalities in Europe face today, e.g. new EU-directives or lack of capacity/energy production in the region.
- I have found previous pilots useful and interesting, but sometimes a bit too difficult to follow or understand the parameters. So for this pilot, I hope that there are clear explanations to all the parameters that you fill in, and maybe an explanation of how different values affect the end result. This does not need to be included in the platform per se, but could be clarified in a manual or in the introduction of the platform.
- That the tool is easy to use for local authorities.
- A better understanding of the energy system in Tomelilla
- I'm only taking part to learn about the project end the model.
- We expect an easy-to-use platform that we can introduce to the residents and companies of Gulbene and neighboring counties.
- I hope that more or less all the functions will work and we can test Energy Equilibrium platform with our existing data input.
- Examples of use in practice.
- The Energy Equilibrium platform is a very well-thought-out solution, taking into account many details. Personally, I have no problem with using it when I am constantly instructed by our partners from Gdańsk. It would be much easier to use this platform in my native language. It will be much easier to present how the platform works to the school principal, commune mayor or local entrepreneur. If we are to implement this professional tool in our area, we must be aware that it must be understandable.

Partners express their wish to study scenarios which are close to their needs:

- We are exploring if it is possible to conduct "repowering" in the municipality. Repowering is the process of replacing older power stations with newer ones that either have a greater nameplate capacity or more efficiency which results in a net increase of power generated. Is it possible to try a scenario where we conduct repowering, that would be great as it is an avenue we are exploring. Parameters that would be interesting to learn are what the cost of repowering would be, how many old wind turbines could be replaced by how many new wind turbines, and what size the new wind turbines would be.
- I have also received a request from the people at the building department that they would like to explore how the platform can be used when municipalities need to implement the Energy Performance of Buildings Directive, which in article 6 says that the buildings should reduce energy use by 3% per area/year, and art. 5 that says that municipality buildings should reduce energy use by 1,9 % per year (baseline 2021). If it is possible to model a scenario based on that directive, that would also be interesting to try out!

- Everything related to sustainable energy generation and storage
- We have not yet put forward a specific scenario plan in the energy management working group.
- In the village, the heating equipment must be replaced with a new one, the existing one is in service. Which heating device to choose? Annual consumption 1.4 GWh
- First of all, the goal is to provide the necessary energy needed for the proper, reliable and continuous operation of the water and sewage infrastructure and buildings belonging to the municipal resource. There can be no question of testing solutions here. Local authorities must be sure that the results will be consistent with expectations.

Partner priorities in relation to energy production and storage technologies ?

- We have a lot of wind turbines that will be too old quite soon, which means that we will reduce our energy production (at least when it comes to wind turbines), therefore we want to explore options for new investments in wind mills and replacing the current turbines. Region Skåne wants the region to have a self-sufficiency rate of 50 % until 2030, which is a high goal considering that the current self-sufficiency rate in the region is 15 %. It will be interesting to explore how the platform could help us in Tomelilla simulate different scenarios where we reach the self-sufficiency goal.
- That the model is useful also for part of a local authority or an area we want to work with.
- Distributed sun panels system, battery and hydrogen storage
- There is currently no answer to this question. We will definitely work together with Gulbene municipality!
- At the moment, PV solar systems are mentioned in various talks about possible energy production technologies to be introduced, but the vision of storage does not appear. It is possible that the Energy Equilibrium platform could help convince thermal energy producers and municipal representatives to decide on a larger installation of energy storage technology in the future.
- Is it justified to install acclimation equipment?
- I don't know of any energy storage technology that would be a good solution for our commune. When it comes to production technology priorities, I am thinking about wind turbines (due to poor energy storage solutions). Next (despite great difficulties), I think that for ecological, practical and economic reasons, a biogas plant should be built in our commune.
- Currently, the most available solutions for the commune are photovoltaic solutions, but this solution (in my opinion) has its weaknesses.

Attachment 2

Analysis of the feedback received from the municipalities on Energy Equilibrium platform application

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