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TIREBOLU MUNICIPALITY

2023 REPORT

CARBON EMISSION REPORT

Stronger Fight Together Against Flood, Heavy Rain and Drought

Town Twinning between Turkey and EU - II (Twinning for a Green Future) Grant Scheme (TTGS-II)

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PREFACE

This greenhouse gas inventory study, prepared within the scope of the "Flood and Drought Combat Project", represents an important step taken by Tirebolu Municipality towards combating climate change. This project, financed by the European Union and carried out under the coordination of Tirebolu Municipality and with our valuable partners from Latvia and Italy, aims to increase the climate resilience of our city and move towards a sustainable future.

This inventory study was prepared in accordance with the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) standards and reveals our city's current carbon footprint with a systematic and scientific approach. Based on 2023 data, the study analyzes greenhouse gas emissions in energy consumption, transportation, waste management and other sectors in detail and provides a solid foundation for our future climate action plans.

The report not only identifies the current situation, but also provides strategic recommendations to increase our city's emission reduction potential and climate change adaptation capacity. As a concrete outcome of sharing knowledge and experience with our international partners, this study highlights the role of local governments in combating climate change and highlights the importance of regional cooperation.

As Tirebolu Municipality, we are committed to using the results of this inventory study effectively in shaping our sustainable urban development policies and achieving our goal of creating a climate-friendly city. We hope that this study will set an example for other cities of similar size and contribute to increasing the capacity of local governments in the fight against climate change.

We would like to thank all our project partners, technical team and all stakeholders who contributed to the preparation of this valuable study.

Bulent KARA
Mayor of Tirebolu Municipality

SUMMARY

This report presents the 2023 greenhouse gas emission inventory of Tirebolu Municipality. The study, prepared within the scope of the European Union-supported "Flood and Drought Combat Project", is based on the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) methodology.

According to the inventory results, Tirebolu's total greenhouse gas emissions in 2023 were calculated as 55,646 tons of CO_2 equivalent. The largest share in the sectoral distribution of these emissions belongs to waste management (52.7% - 29,351 tCO_2e). This is followed by stationary energy (45.9% - 25,550 tCO_2e) and transportation (1.4% - 745 tCO_2e) sectors, respectively. The amount of emissions per capita for the city with a population of 19,750 was determined as 2.8 tCO_2e. For the urban area of 210 km^2, the emission intensity per land unit was calculated as 265 tCO_2e/km^2, and the emission intensity per economic activity was calculated as 213 tCO_2e/million USD.

The report identified significant reduction potentials, particularly in the waste management and energy sectors. In the waste sector, controlling methane emissions, increasing recycling and composting practices; in the energy sector, improving building efficiency and expanding renewable energy sources stand out as priority intervention areas.

The inventory study analyzes the city's water use, waste management, transportation, green areas and energy efficiency data for the period 2020-2024, and offers strategic recommendations to reduce emissions and increase climate resilience. These recommendations will form the basis of the Sustainable Energy and Climate Action Plan (SECAP) development process.

The study aims to strengthen the capacity of Tirebolu Municipality to combat climate change and support sustainable urban development. The report results provide a scientific framework that will guide the future policy and investment decisions of the city administration.

Keywords: Greenhouse Gas Inventory, Climate Change, Sustainable Urban Development, Emission Reduction, Tirebolu Municipality

INTRODUCTION

Global climate change is one of the most urgent and complex challenges of our time. Mitigating its impacts and developing sustainable development strategies for the future requires a multi-layered, multi-stakeholder effort spanning a wide range of influences, from local governments to international organizations.

Cities are key to combating climate change because they account for a significant portion of greenhouse gas (GHG) emissions. This situation increasingly requires inventory studies that present cities' emission profiles in a detailed and comparable manner. City-based GHG inventories make it possible to understand where emissions come from, identify which sectors they are concentrated in, track changes over time, and develop effective policy interventions.

At this point, a methodological framework that is widely accepted on a global scale is needed. The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) is an international standard guide for city-scale Greenhouse Gas Emission Inventories developed in collaboration with C40, the World Resources Institute (WRI) and ICLEI to meet this need. GPC enables cities to comprehensively report all greenhouse gas sources in line with the methodological principles of the United Nations Intergovernmental Panel on Climate Change (IPCC). The main purpose of GPC is to measure, report and monitor city emissions over time in a transparent, consistent, comparable and scientifically sound manner. In this way, greenhouse gas emissions from cities' energy consumption to industrial activities, from waste to transportation and land use can be assessed within a systematic framework.

The GPC classifies city emissions into three different scopes. Scope 1 describes emissions that occur directly within city boundaries; Scope 2 includes indirect emissions from energy consumed in the city but produced outside the city, such as grid electricity, heating, and cooling. Scope 3 includes indirect emissions caused by activities carried out within the city outside the city boundaries. This distinction, on the one hand, prevents double counting by spatially identifying the source of emissions, and on the other hand, clearly shows where emissions are concentrated at the city scale and what cross-border impacts are present.

In addition, the GPC proposes two separate but complementary reporting frameworks for cities to report their emissions: the city-induced framework and the scopes framework. The city-induced framework allows for reporting of GCI emissions from activities occurring within geographical boundaries at two levels: basic (BASIC) and advanced (BASIC+). The basic level takes into account the main emission sources found in almost every city, such as stationary energy consumption, transportation and waste management, while the advanced level also includes industrial processes, agriculture, forest and land use (AFOLU), transboundary transportation and energy transmission-loss emissions. This provides cities with a flexible reporting structure according to data availability and calculation difficulties. The scopes framework aggregates all emissions under Scope 1, Scope 2 and Scope 3, facilitating the compatibility of city-scale inventories with national reporting frameworks and providing multi-layered comparison and aggregation from city to national and even global levels.

In the preparation of this report, the CIRIS (City Inventory Reporting and Information System) tool, which was designed in accordance with the GPC methodology, was used. CIRIS is a comprehensive tool that allows cities to compile, organize and report their RCI inventories in accordance with international standards. This tool helps to structure data, select methodologies, clearly define scopes and present the results in an understandable way, following the basic principles of GPC. Thanks to CIRIS, city administrations can both examine their current emission profiles and create a solid analytical basis that can guide future intervention strategies.

This study comprehensively examines greenhouse gas emissions within the borders of Tirebolu Municipality, located in the South and West Asia geographical region of Turkey. The year of analysis was selected as 2023, thus aiming to present an up-to-date emission profile.

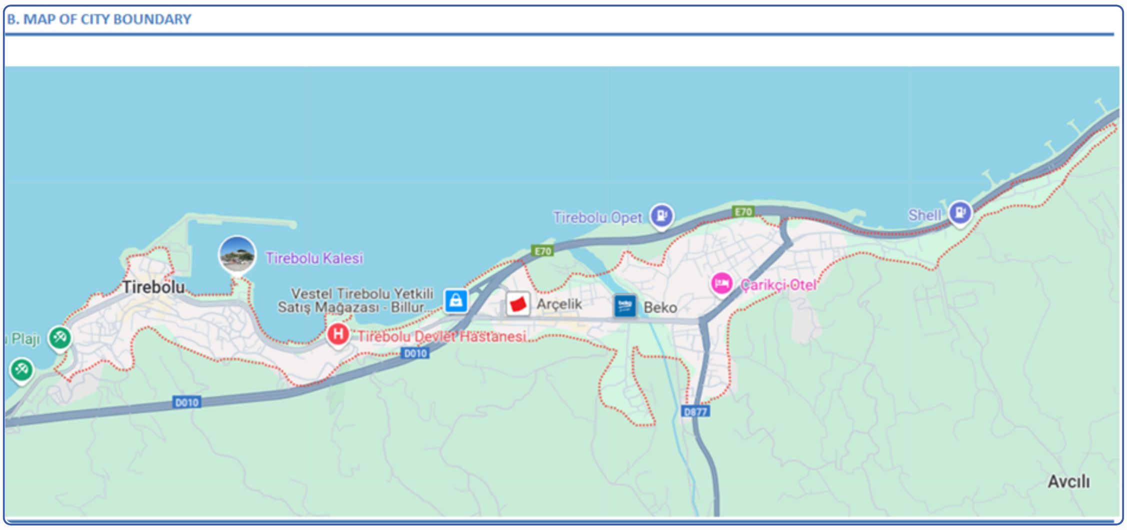
Tirebolu is a settlement located on the Black Sea coastline, which stands out with its historical and cultural heritage as well as its wealth of natural resources. While the city spreads over a surface area of approximately 210 km^2; its geographical location shows topographic diversity with its terrain starting from sea level and rising towards the interior. This diversity shapes both climatic conditions and economic activities. Tirebolu's mild and humid Black Sea climate allows for abundant rainfall throughout the year and lush vegetation. Cool temperatures in the summer and mild temperatures in the winter months keep the city's heating and cooling needs at a relatively balanced level.

Considering its population of 19,750 and the scale of its economic activities, the city has a more modest emission profile compared to large metropolitan areas. The demographic structure has shaped the number of households and consumption habits in a way that matches the needs of local economic activities. The local economy is based mainly on agriculture, regional plant products such as tea and hazelnut production, fishing and, to a limited extent, the service sector. Each of these sectors contains various emission sources, from energy consumption to waste management. For example, agricultural production includes methane and nitrogen oxide emissions from fertilizers as well as fuel use, while fishing activities are associated with emissions from fuel consumption of marine vessels.

Tirebolu’s economic production pattern also reflects the city’s socio-cultural structure. In addition to agricultural activities concentrated in rural areas, small-scale commercial enterprises and public services are more prominent in the town center. This situation points to the potential of local governments to reduce the city’s carbon footprint through practices such as energy efficiency, renewable energy use, waste recycling and improving transportation infrastructure. Thus, the city’s climate strategies can contribute to a sustainable development goal not only in environmental but also socio-economic terms.

The population of 19,750 people living within the administrative borders of the city, which has a surface area of approximately 210 km², was evaluated by taking into account the nature of local economic activities (mainly agriculture and fishing) and climatic characteristics (mild climate, certain number of heating-cooling days). In this context, sectors such as stationary energy use, waste management, transportation and agricultural activities, which are the main determinants of greenhouse gas emissions in the city, were analyzed in accordance with the GPC guide.

The selected reporting level is BASIC, and the inventory of CO_2 emissions at this level was calculated using the CIRIS tool. The data was assessed based on the global warming potential (GWP) values of the IPCC Fifth Assessment Report (AR5), thus ensuring that the methodology is based on current international science. Explaining the methodological choices, making an assessment of the increase or decrease in emissions, and presenting planned future improvements strengthen the holistic approach of this report. Tirebolu Municipality aims to reduce total emissions in future inventories and to place the city's carbon footprint on a more sustainable basis by planning energy efficiency projects, renewable energy initiatives and improvements in waste management.



Picture 1 - Tirebolu District Borders

Table 1. Demographic Information of Tirebolu Municipality

CRITERION	DATA
CITY NAME	TIREBOLU
COUNTRY	Türkiye
AREA	SOUTH AND WEST ASIA (BLACK SEA)
INVENTORY YEAR	2023
HEATING DEGREE DAYS (HDD, °C)	230, 18
COOLING DEGREE DAYS (CDD, °C)	135, 22
LAND AREA WITHIN CITY BOUNDARIES (km^2)	210
POPULATION WITHIN CITY LIMITS	19.750
GDP PER CAPITA TL	355.884,00
ECONOMY TYPE	AGRICULTURE & FISHERIES
CLIMATE	MODERATE, HOT SUMMER

2. CO2 Consumption Inventory and Data Sources

In this section, the data sources that form the basis of the greenhouse gas inventory prepared for the Tirebolu Municipality, the institutions from which they were obtained, the types of data and the frequency of their updates will be discussed in detail. In such inventory studies carried out at the city scale, the use of reliable, accessible and scientifically valid data sets is of great importance. The quality of the collected data directly affects the accuracy of the methodology to be used in inventory calculations and the reliability of the results. Therefore, sources based on international standards (e.g. IPCC guides), national statistical databases, regularly published reports by local governments, technical documents presented by sectoral expert organizations and academic studies form the basis of the data collection strategy.

Table 2. Data Sources Table

Data	Source Name	Source Provider	Last Year
Emission factors for greenhouse gases	IPCC 2006 Guidelines for National Greenhouse Gas Inventories	Intergovernmental Panel on Climate Change (IPCC)	2006
Electricity emission factor	TEİAŞ 2023 Electricity Statistics	Turkish Electricity Transmission Company (TEIAS)	2023
Energy consumption data	Tirebolu Municipality Energy Consumption Reports	Tirebolu Municipality	2023
Wastewater data	Tirebolu Municipality Wastewater Treatment Reports	Tirebolu Municipality	2023
Population and economic data	Turkish Statistical Institute (TUIK) Database	Turkish Statistical Institute (TUIK)	2023
Transportation data	Tirebolu Municipality Transportation Reports	Tirebolu Municipality	2023
Fuel specifications and NCVs	Türkiye Energy Balance Tables	Ministry of Energy and Natural Resources (ETKB)	2023
Climate data	Turkish State Meteorological Service (MGM) Climate Data	Turkish State Meteorological Service (MGM)	2023
Waste data	Tirebolu Municipality Waste Treatment Reports	Tirebolu Municipality	2023

The emission factors used in the inventory calculations are largely based on the IPCC 2006 Guidelines, and these globally accepted standards provide methodological consistency in the calculation of greenhouse gas emissions. The guidelines created by the IPCC are internationally accepted reference points, especially in the selection of emission factors, the determination of emission calculation formulas, and assumptions that can be used in case of data deficiency. In this way, the inventory created specifically for Tirebolu gains a methodological framework that is comparable to global practices.

Energy sector data is enriched through national statistics provided by the Turkish Electricity Transmission Company (TEİAŞ). Electricity statistics published regularly by TEİAŞ every year play a critical role in determining the carbon dioxide emission factors of electricity generation sources. These data provide both transparency and compliance with national average conditions when calculating indirect emissions from the city's electricity consumption. Similarly, fuel characteristics, net calorific values (NCV) and energy balance statistics are obtained through the Turkish Energy Balance Tables of the Ministry of Energy and Natural Resources (MENR). These national sources allow for more accurate modeling of local energy consumption patterns, and therefore precise calculation of greenhouse gas emissions from energy use.

Local energy, water, waste and transportation data have been obtained directly from the regularly published reports of Tirebolu Municipality. Documents such as "Tirebolu Municipality Energy Consumption Reports" and "Tirebolu Municipality Wastewater Treatment Plant Reports" in particular reveal the city's internal dynamics, infrastructure capacity, usage rates and management practices in detail. These local reports stand out as primary data sources reflecting the city's specific characteristics and operational performance. The data in question provides information on a wide range of issues, from electricity and natural gas consumed in residential, commercial and industrial sectors to energy use in municipal buildings, from street lighting consumption to usage rates of different fossil fuel types such as fuel oil, LPG and coal. Thus, it becomes possible to create a comprehensive profile of greenhouse gas emissions from stationary energy.

Data on water and waste management are again obtained from the reports of Tirebolu Municipality and relevant local organizations. Parameters such as total water consumption, groundwater and surface water usage amounts, water loss rates, grey water recovery and electricity consumption of wastewater treatment plants form the basic basis for measuring the extent to which water management practices in the city are sustainable. In addition, data sets provided in the context of waste management include critical indicators such as total waste amount, recycled and composted waste amounts, methane emissions of solid waste storage areas and methane emissions from wastewater treatment plants.

Transportation data, obtained from the Tirebolu Municipality Transportation Reports, play a key role in determining the emissions in the urban transportation sector. Data such as the number of public transportation vehicles, fuel consumption, usage rates, municipal vehicle fleets and private, commercial and hybrid vehicle numbers, the amount of electric vehicle charging stations used and the length of bicycle and pedestrian paths provide a detailed picture of the transportation emission profile. This information is critical in determining the possibilities for the city to move away from carbon-intensive transportation models and encourage more environmentally friendly, low-emission transportation infrastructures.

Population, economic activities and climate data are obtained from national institutions such as the Turkish Statistical Institute (TUIK) and the Turkish State Meteorological Service (MGM) to provide a general picture of the socio-economic and environmental context of the city. Parameters such as population, Gross Domestic Product (GDP) per capita, employment, sectoral distribution (industry, services, agriculture), annual average temperature, annual precipitation, heating-cooling degree days are used as key indicators to assess both the logic of emissions and the effectiveness of possible measures. Such macro data contribute to the contextualization of local emission data and the development of long-term climate action plans.

Data such as the structural characteristics of the city's building stock, age distribution, insulation rate, prevalence of energy-efficient or smart building applications, amount of green space and carbon sink capacity play a key role in urban planning, energy efficiency, green infrastructure development and the design of roadmaps towards carbon neutrality. Regular collection of such data at the local level facilitates city managers to make scientifically based decisions on strategic interventions such as urban transformation, green space protection, afforestation and renewable energy integration.

All data on which the inventory is based have been compiled from locally, nationally and internationally accepted, periodically updated and published, reliable institutional sources. In this way, it is possible to accurately estimate greenhouse gas emissions occurring within the borders of Tirebolu Municipality on the basis of sectors and sources, and to provide effective guidance for future policy, planning and implementation processes.

3. Emission Factors

The Emission Factors Table (Table 3) presented in this section plays a central role in the creation of the greenhouse gas inventory of the Tirebolu Municipality. Emission factors, which are the basic multiplier values used in the calculation of greenhouse gas emissions resulting from various sectors, fuel types and activities within the city borders, allow the inventory study to be structured in accordance with scientific, methodological and international standards. These factors enable comparisons to be made both within the city and at national or global scales by enabling the conversion of activity data into measurable and comparable results in terms of CO_2 equivalent (CO_2e).

Greenhouse gas emission inventories are not only a “data collection” process, but also a holistic study that requires a meaningful and consistent analysis of this data. In this context, the reliability and methodological infrastructure of emission factors are of great importance. The emission factors presented in Table 3 were selected based on the 2006 National Greenhouse Gas Inventory Guidelines of the Intergovernmental Panel on Climate Change (IPCC) and updated by taking into account the Global Warming Potential (GWP) values of the IPCC Fifth Assessment Report (AR5). Thus, the compliance of the emission calculation at the city scale with the principles of scientific accuracy, international comparability and methodological consistency is guaranteed. The use of IPCC guidelines ensures that the numerical multiplier values valid for different sectors and activities are stable, repeatable and comparable.

Emission factors allow for better understanding and management of emission sources in key activity areas such as electricity consumption, fossil fuel use and waste management throughout the city. The applied factors enable the climate impacts of different gases to be addressed on a common scale by converting greenhouse gas emissions to CO_2 equivalent (CO_2e). In this way, it is possible for the city administration to make decisions based on objective, consistent and up-to-date data when determining emission reduction strategies. The Emission Factors Table is one of the key components of the method used in the preparation of the greenhouse gas inventory of the Tirebolu Municipality and is critical for the overall integrity and reliability of the report. The data obtained in this way provides a solid analytical basis for the city’s climate-related policy, planning and action processes.

Table 3. Emission Factors Table (Type CO2e for each activity is GWP 5AR.

Activity	Unit	tCO2e	Data Quality	Definition	Source
Electricity	t/kWh	0,000481	M	EF for industrial electricity (TEİAŞ 2021)	TEİAŞ 2021 Electricity Stats
Electricity	t/kWh	0,000481	M	EF for commercial electricity (TEİAŞ 2021)	TEİAŞ 2021 Electricity Stats
Electricity	t/kWh	0,000481	M	EF for residential electricity (TEİAŞ 2021)	TEİAŞ 2021 Electricity Stats
Electricity	t/kWh	0,000481	M	EF for street lighting electricity (TEİAŞ 2021)	TEİAŞ 2021 Electricity Stats
Electricity	t/kWh	0,000481	M	EF for municipal buildings electricity (TEİAŞ 2021)	TEİAŞ 2021 Electricity Stats
Liquefied Petroleum Gas (LPG)	t/kg	0,003	L	EF for combustion of LPG (IPCC 2006)	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Coal (Bituminous or Black coal)	t/ton	2,49	L	EF for coal combustion (IPCC 2006)	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Electricity	t/kWh	0,000439	M	EF for wastewater treatment plant electricity (TEİAŞ 2021)	TEİAŞ 2021 Electricity Stats
Electricity	t/kWh	0,000439	M	EF for water treatment plant electricity (TEİAŞ 2021)	TEİAŞ 2021 Electricity Stats
Solid waste	t/ton	1,1	L	EF for total solid waste disposal (IPCC 2006)	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Waste water	t/ton	0,112	L	EF for composting (organic waste, CH4 based, IPCC 2006)	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Wastewater CH4 emissions	t/m³	0,007	L	EF for CH4 from wastewater treatment (IPCC 2006)	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Diesel Oil	t/l (litre)	0,00268	L	EF for diesel in public transport (IPCC 2006)	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Diesel Oil	t/l (litre)	0,00268	L	EF for diesel in municipal vehicles (IPCC 2006)	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Natural gas	t/m³	0,001971	L	EF for combustion of natural gas (IPCC 2006)	IPCC 2006 Guidelines for National Greenhouse Gas Inventories

4. Determination of Emissions from Stationary Energy Sources

This section aims to reveal the greenhouse gas emissions originating from stationary energy consumption within the borders of Tirebolu Municipality within the framework of internationally accepted methodological standards (IPCC 2006, GPC). The analysis examines in detail the carbon intensity emerging in the basic components of urban life such as residences, commercial and institutional buildings, manufacturing industry and construction activities by focusing on energy use in different sub-sectors.

During the assessment process, fuel types (natural gas, coal, LPG, electricity, etc.) and areas of use are examined by considering the types of greenhouse gases (CO_2, CH_4, N_2O) emitted from these energy sources; the data obtained are converted into CO_2 equivalent (CO_2e). This approach facilitates understanding the holistic impact of energy demand on the climate at an urban scale, while also allowing different sectors and resources to be compared with each other.

In the collection and calculation of data, sectoral and sub-sectoral classifications structured in line with the GPC methodology are used. Thus, a wide range of emission profiles are clearly presented, from the use of natural gas for heating and cooking in the residential sector to the lighting and cooling needs of commercial buildings, from the process heat and electricity demand of manufacturing industry facilities to the energy consumption of public service buildings. This systematic approach clearly reveals the spatial, sectoral and functional distribution of energy use patterns and related emissions.

In the selection of emission factors and efficiency data, up-to-date, reliable and scientifically based information is used, based on national energy statistics such as IPCC guidelines and TEİAŞ. In this way, the emission results obtained meet high standards in terms of both methodological integrity and international comparability. In addition, transparent documentation of calculations provides a solid basis for future trend analyses, performance monitoring studies and reduction potential assessments.

In the table below we can see the Fixed (Stationary) Energy consumption for Tirebolu district.

Table 4. Stationary (Fixed) Energy Consumption Data

Category	Explanation	Amount	Unit	EF Unit	IF tCO2e	GHGs
RESIDENTIAL - Emissions from fuel combustion within city limits						
Natural Gas in Residences (1.A.4.b)	Residential natural gas consumption for heating/cooking purposes	56.402	m³	tCO2e/m³	0,001971	111,2 tCO2e
Coal in Residential Buildings (1.A.4.b)	Coal used for heating residential buildings	2.566	tonne	tCO2e/ton	2,49	6389,3 tCO2e
LPG in Residential Buildings (1.A.4.b)	LPG consumption for cooking/heating purposes in homes	569.900	kg	tCO2e/kg	0,003	1709,7 tCO2e
COMMERCIAL AND INSTITUTIONAL BUILDINGS - Emissions from fuel combustion within city limits						
Commercial	Natural gas consumption in commercial buildings	643	m³	tCO2e/m³	0,001971	1 tCO2e
COMMERCIAL AND INSTITUTIONAL BUILDINGS - Emissions from grid-supplied energy consumed within city limits						
Commercial / Corporate (I.A.4.a)	Electricity use in commercial/institutional buildings	26.937.951	kWh	tCO2e/kWh	0,000481	12.957,2 tCO2e
Institutional	Electricity use in municipal (institutional) buildings	2.030.278	kWh	tCO2e/kWh	0,000481	976,6 tCO2e
Commercial / Corporate (I.A.4.a)	Electricity used in water treatment plants	1.500.322	kWh	tCO2e/kWh	0,000439	658,6 tCO2e
Commercial / Corporate (I.A.4.a)	Electricity used in wastewater treatment plants	1.190.679	kWh	tCO2e/kWh	0,000439	522,7 tCO2e
Street Lighting	Electricity used for public street lighting	1.526.337	kWh	tCO2e/kWh	0,000481	734,1 tCO2e
MANUFACTURING INDUSTRIES AND CONSTRUCTION - Emissions from fuel combustion within city limits						
Manufacturing industries and construction (1.A.2)	Natural gas consumption in manufacturing industries	6.455	m³	tCO2e/m³	0,001971	13 tCO2e
MANUFACTURING INDUSTRIES AND CONSTRUCTION - Emissions from grid-supplied energy consumed within city limits						
Manufacturing industries and construction (1.A.2)	Electricity consumption in the industrial sector	3.070.131	kWh	tCO2e/kWh	0,000481	1.477 tCO2e

5. Determination of Emissions from Transportation

The transportation sector generally plays a decisive role in the greenhouse gas inventories of cities and provides significant contributions to the total emission profile. Transportation activities within the borders of Tirebolu Municipality are carried out mainly via fossil fuel-based road vehicles, which makes direct and indirect greenhouse gas emissions inevitable. In this context, the Transportation subheading (Table II Transportation), prepared in accordance with the GPC methodology (Section 7), aims to systematically inventory greenhouse gas emissions originating from urban transportation activities.

Within the scope of Table II, the fuel consumption of municipal public transport vehicles and service fleets is defined in detail and the emission values for each activity area are calculated in terms of CO_2 equivalent (CO_2e). Transportation data is compiled with an activity-based (fuel sales approach) method; the consumed fuel quantities (e.g. diesel) are converted into final emission values by correlating them with emission factors selected in line with the internationally accepted IPCC 2006 guidelines. In this way, the effects of other greenhouse gases such as CH_4 and N_2O, as well as CO_2, are evaluated with a holistic view.

This approach provides a clear understanding of the city's transportation profile. For example, the fuel consumption of public transport and the fuel use of municipal service vehicles are calculated separately, making clear the contribution of each vehicle group to urban emissions. Similarly, the data quality assessment (e.g. "L" - low) provides clues for further uncertainty analysis, improving data collection methods or improving the measurement infrastructure.

The transparent and traceable structure of Table II also demonstrates the methodology's compliance with international standards. Clearly indicating the relevant sources (e.g. "Tirebolu Municipality Transportation Reports") and clearly documenting the data collection and calculation processes provide a solid basis for future verification, benchmarking and monitoring studies.

Studies under the title of transportation present greenhouse gas emissions originating from urban vehicle activities in a detailed and objective manner, thus serving as a data-based guide for strategic interventions such as energy efficiency practices, promotion of alternative fuel use or strengthening of the public transportation system. This information supports the steps to be taken within the scope of Tirebolu's climate action plan and provides a critical basis for decision-makers in creating a lower-carbon and sustainable transportation infrastructure.

Table 5. Energy Consumption Data from Transportation

interesting	Explanation	Amount	Unit	EF Unit	IF tCO2e	GHGs
ROAD TRANSPORTATION - Emissions from fuel combustion in urban road transport						
Fuel sales approach	Diesel used by city public buses	116.320	l	tCO2e/l (liter)	0,00268	445,7 tCO2e
Fuel sales approach	Diesel used by municipal service vehicles	111,600	l	tCO2e/l (liter)	0,00268	299,1 tCO2e

Studies under the title of transportation present greenhouse gas emissions originating from urban vehicle activities in a detailed and objective manner, thus serving as a data-based guide for strategic interventions such as energy efficiency practices, promotion of alternative fuel use or strengthening of the public transportation system. This information supports the steps to be taken within the scope of Tirebolu's climate action plan and provides a critical basis for decision-makers in creating a lower-carbon and sustainable transportation infrastructure.

6. Emissions from Waste

Waste management is one of the important and complex components of urban scale greenhouse gas inventories. This section (III WASTE) calculates the emissions originating from solid waste storage, biological processing of organic waste (e.g. composting) and wastewater treatment activities within the borders of Tirebolu Municipality in accordance with the IPCC 2006 and GPC (Section 8) guidelines. The obtained data provide a critical basis for determining emission reduction opportunities and potential improvement areas while shaping the waste management strategies of the city.

Solid Waste Disposal (III.1 SOLID WASTE DISPOSAL): Disposal processes of solid waste produced in the city are notable, especially due to the release of methane (CH_4). Using the amount of stored waste (in tonnes) and the relevant emission factors (EF_Total_Waste), the annual emissions of landfill activities in terms of CO_2 equivalent (CO_2e) are calculated. In this way, the climate impact of interventions aimed at waste separation, increasing recycling rates or implementing methane recovery technologies becomes predictable.

Biological Waste Treatment (III.2 BIOLOGICAL TREATMENT OF WASTE): Biological treatments of organic waste, such as composting, produce additional emissions measured in carbon dioxide equivalent. In this subheading, the amount of organic waste treated and the climate impact of waste treatment activity are determined using IPCC-compliant emission factors (EF_Composting). The results provide guidance for optimizing organic waste management policies and implementing advanced processing technologies.

Wastewater Treatment and Discharge (III.4 WASTEWATER TREATMENT AND DISCHARGE): Wastewater treatment processes lead to methane release as a result of biological decomposition. In this subsection, annual greenhouse gas emissions of the facilities are calculated using the treated wastewater volume (m^3) and emission factors determined by the IPCC guidelines (EF_Wastewater_CH4). The resulting values make visible the potential impact of treatment technologies, methane capture and recovery methods or structural improvements to be made in wastewater management.

The “Data Quality” and related explanation columns of the table provide information about data collection methods, sources, calculation approaches used and uncertainty levels. Thus, the reliability of the findings, their potential for improvement and their change over time can be clearly understood by decision makers and stakeholders.

III WASTE section presents the greenhouse gas emissions resulting from the waste management activities of Tirebolu Municipality in a comprehensive and transparent manner. These data form a solid basis for strategic interventions such as improving waste policies, increasing recycling and composting capacities, promoting methane recovery and developing wastewater treatment technologies. In this way, the city can develop a coherent roadmap to achieve its long-term sustainability goals and reduce its carbon footprint from waste.

Table 6. Energy Consumption Data from Waste

Activity	Waste Type	Explanation	Amount	Unit	EF Unit	IF tCO2e	GHGs
DISPOSAL OF SOLID WASTE - Emissions from solid waste produced in the city and disposed of in urban landfills or open dumps.							
Landfills - Methane commitment	All waste	Total municipal solid waste disposed of in urban landfills	10.988	tonne	tCO2e/tonne	1,1	12086,8 tCO2e
BIOLOGICAL TREATMENT OF WASTE - Emissions from solid waste produced in the city and disposed of in urban landfills or open dumps							
Composting	Organic waste	Organic waste composted in the city (CH4 emissions)	3.626	tonne	tCO2e/tonne	0,112	406 tCO2e
WASTEWATER TREATMENT AND DISCHARGE-Emissions from biologically treated solid waste in the city							
-	All wastewater	CH4 emissions from treated wastewater within the city (on a m^3 basis)	2.408.274	tonne	tCO2e/tonne	0,07	16857,9 tCO2e

7. Data-Based Insights

The calculators presented in this section allow hypothetical estimates to be produced in areas where there is missing or uncertain data in the municipality's greenhouse gas inventory. In particular, issues that are difficult to measure directly, such as fugitive emissions that may occur in low-pressure transmission lines in the urban natural gas distribution network and in lines reaching the final consumers, can be calculated using standard assumptions and average values based on the IPCC 2006 Guidelines. Despite the lack or uncertainty of data, this approach makes a significant contribution to urban administrations in better understanding the general emission profile, determining priority intervention areas and evaluating improvement opportunities in the long term.

Solid waste

Accurately measuring greenhouse gas emissions from waste management activities is critical for determining effective climate action strategies at the local scale. In this context, the "methane commitment" methodology recommended in the GPC standard is used to estimate methane (CH_4) and carbon dioxide (CO_2) emissions released over time in solid waste storage processes. This approach calculates the amount of emissions resulting from the decomposition of stored waste, taking into account parameters such as the default values in the IPCC 2006 guidelines, waste composition, landfill management conditions and methane recovery rates.

In the inventory study conducted for the Tirebolu Municipality, it was assumed that approximately 11 metric tons of solid waste were dumped into a landfill in the "Unmanaged <5 m deep" category in one year. Since such areas lack sufficient technological infrastructure and practices, methane produced as a result of organic waste decomposition cannot be collected effectively and is released into the atmosphere to a significant extent. For example, in this scenario, methane collection efficiency is assumed to be only 27%; the remaining methane escapes into the atmosphere, making it difficult to reduce greenhouse gas emissions.

As a result of the calculations, it was determined that the methane emission from solid waste storage for the year in question was approximately 4 tons in terms of CO_2 equivalent (CO_2e). It was stated that N_2O (nitrogen monoxide) emissions remained at “Trace” (very low level). These data quantitatively reveal the climate impact of the city’s waste management practices and provide an idea about the measures to be taken to reduce the carbon footprint.

These estimated data provide a concrete basis for the Tirebolu Municipality to review waste management strategies, develop methane recovery technologies, and turn to waste separation and alternative disposal methods (composting, anaerobic digestion, etc.). In this way, future policies for reducing carbon emissions can be shaped in the light of scientifically measured and verified data, and the city administration will be able to take more sustainable and climate-friendly steps and reach its long-term goals more reliably.

Natural gas

Methane (CH_4) leaks in natural gas distribution networks constitute a significant component, albeit relatively small, in terms of global warming potential. In the inventory study conducted at the Tirebolu Municipality scale, leaks that may occur during transmission from urban low-pressure natural gas distribution lines to end users were estimated based on the default emission factors recommended by the IPCC 2006 Guidelines for the “developing country” category.

This calculation was made based on natural gas consumption values recorded within the city limits (e.g. 56,402 m^3), and the estimated amount of emissions from leaks was determined as approximately 3 tons of CO_2 equivalent (CO_2e). Although this figure constitutes a small share of the city's total greenhouse gas inventory, it points to the importance of the quality of the infrastructure, leak detection and prevention policies.

The results show that improvements in Tirebolu's natural gas distribution infrastructure can reduce climate impacts.

Modernization of pipelines, increasing periodic maintenance and repair activities, and implementing technologies for early detection of leaks contribute to minimizing these limited but significant emissions from methane. In this way, city administrations can move towards more efficient, safe and climate-friendly practices in energy infrastructure and achieve their long-term carbon footprint reduction goals more quickly.

Waste water

Wastewater treatment and discharge processes constitute an important part of urban greenhouse gas inventories. In this context, depending on the content of wastewater, treatment technologies, population characteristics and geographical conditions, significant amounts of methane (CH_4) and nitrous oxide (N_2O) emissions may occur. In the greenhouse gas inventory study conducted for Tirebolu Municipality, wastewater-related emissions were carefully evaluated by combining default values based on IPCC 2006 guidelines and city-specific data.

Tirebolu is located in one of the coastal regions of Turkey and has a warm and humid climate. With a population of approximately 19,750, wastewater management in the city is shaped under the influence of multifaceted factors such as geographical features, infrastructure status, distribution of income groups and urban-rural settlement structure. The fact that 76% of the population is urban, high-income group and the remaining 24% live in rural areas directly affects many factors from the prevalence of sewage infrastructure to the adoption rate of wastewater treatment technologies.

In addition, assuming that there is no garbage disposal in the city, it is assumed that the organic matter load reaching the sewer system from the residences is transmitted through traditional methods. This situation constitutes an important input that should be taken into account in the design and implementation of wastewater treatment processes, thus closely affecting the city's wastewater management strategies.

Methane (CH_4) Emissions

In wastewater treatment processes, methane is produced as a result of the decomposition of organic matter in anaerobic conditions. In the greenhouse gas inventory prepared for the Tirebolu Municipality, it was determined that the city's wastewater management is largely based on traditional methods, but less controlled infrastructure solutions (septic tanks, latrines, partially managed channel networks, etc.) are used in certain areas. A septic tank usage rate of approximately 9% was assumed, especially in rural areas, and it was determined that the methane emission potential increased in these semi-closed systems.

In the calculations, a BOD (biochemical oxygen demand) value of 38 grams per person per day was taken as the basis, as an assumption adapted to the conditions of Turkey. While this low value indicates that the organic load of the city's wastewater is limited, methane production is still possible in stagnant areas of the sewage system or in areas where anaerobic environments occur. The results obtained revealed that approximately 255 tons of CO_2 equivalent methane emissions occur as a result of the processing of residential and commercial wastewater.

These findings quantitatively demonstrate the climate impact of wastewater treatment methods used in Tirebolu and point to the importance of more controlled, modern facilities that provide aerobic conditions or have methane recovery technologies. In this way, the city administration can review its wastewater treatment policies and take strategic steps to reduce greenhouse gas emissions.

Nitrogen Monoxide (N_2O) Emissions

N_2O is formed as a result of the nitrification and denitrification processes of nitrogen in wastewater. These processes depend on the chemical composition of the wastewater, the level of protein consumption and the treatment technologies used. Calculations made by taking into account the annual protein consumption per capita (37.6 kg/person/year) for Tirebolu and the amount of nitrogen reflected in the sewage assume that there are no advanced wastewater treatment plants providing advanced nitrogen removal in the city.

Under these assumptions, N_2O emissions from wastewater treatment and discharge are found to be around 340 tons CO_2 equivalent. This higher CO_2e value compared to CH_4 is due to the much higher global warming potential of N_2O compared to CO_2. This finding points to a strategic area that can be reduced by improving nitrogen removal processes, increasing denitrification control and introducing more advanced treatment technologies.

Industrial Wastewater

At the Tirebolu scale, no significant industrial wastewater flow was detected during the inventory period or it was observed that industrial activities were limited. Therefore, CH_4 and N_2O emissions from industrial wastewater remained at negligible levels (approximately 0 tons CO_2e). This situation shows that industrial activities have low importance in the greenhouse gas profile of the city or the organic waste load of existing industrial types is limited to a level that does not create significant emissions.

Calculations for the Tirebolu Municipality show that greenhouse gas emissions from wastewater management total approximately 596 tons of CO_2 equivalent. Of this amount, 255 tons are CH_4 and 340 tons are N_2O. The results quantitatively reveal the climate impact of the city's current wastewater treatment infrastructure and practices, providing a scientific basis for future steps.

Modernization of wastewater treatment processes, implementation of methane capture and energy recovery technologies, increasing nitrogen removal rates and improving septic tanks or open channel systems, especially in rural areas, are among the strategic measures to reduce wastewater-related emissions. In addition, continuous monitoring of wastewater quality and improvement of data collection processes will reduce uncertainties and provide a more reliable basis for future inventory studies.

Thanks to this approach, Tirebolu Municipality can manage greenhouse gas emissions in the wastewater sector more effectively and make significant progress towards building a low-carbon and climate-resilient urban infrastructure.

8. Discussions Based on CIRIS Results

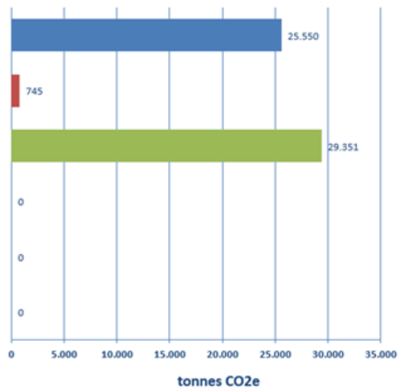
The 2023 greenhouse gas inventory of Tirebolu Municipality shows that the total emissions in the city are approximately 55,646 tCO_2e. This inventory is prepared at the basic (BASIC) level in accordance with GPC standards and covers the stationary energy (residential, commercial/institutional, industrial uses), transportation and waste sectors. The lack of data or the use of notation keys such as “NE/NO” (Not Estimated/Not Occurring) reveal that IPPU (Industrial Processes and Product Use), AFOLU (Agriculture, Forestry and Land Use) and some scope 3 emissions have not yet been fully assessed and that data collection and analysis capacity should be strengthened in the future.

Table 7. Tirebolu tCO2e Calculation Results with CIRIS

SUMMARY

NAME OF CITY:	Tirebolu, Turkey	POPULATION:	19.750
BOUNDARY:	BASIC	LAND AREA (km2):	210
INVENTORY YEAR:	2023	GDP (US$ million):	261

tCO2e	BASIC	Scope 1	Scope 2	Scope 3
	Stationary	8.224	17.326	
	Transportation	745		
	Waste	29.351		
	IPPU			
	AFOLU			
	Other Scope 3			
	TOTAL		55.646	



Intensity indicators	Per capita	Per unit land area (km2)	Per unit GDP (US$m)
Emissions	2,8	265	213

When sectoral distribution is examined, waste management takes the lead with approximately 29,351 tCO_2e, emphasizing the importance of methane and other greenhouse gas emissions originating from solid waste storage and wastewater treatment processes in urban emissions. Emissions from stationary energy are at the level of 25,550 tCO_2e, and electricity consumption of commercial/institutional structures (approximately 15,849 tCO_2e) is particularly striking. The transportation sector has a relatively low share (approximately 745 tCO_2e), which suggests that the city's transportation activities are less carbon intensive than other sectors or that the relevant data set is limited.

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The emission amount of approximately 2.8 tCO_2e per capita is an important indicator that can be compared in assessing the emission intensity of Tirebolu. Land-based emissions (265 tCO_2e/km^2) and GDP (213 tCO_2e/million $) also allow the city to be examined from a spatial and economic efficiency perspective.

These findings guide the development of the SECAP (Sustainable Energy and Climate Action Plan). In particular, improvements focused on waste management, reduction of stationary energy consumption, transition to renewable energy sources, energy efficiency measures in the commercial/institutional sector, low-carbon solutions in transportation (electric public transport, bicycle and pedestrian-friendly infrastructure) and strengthening of missing data areas are strategic priorities to be addressed within the scope of SECAP.

Residential Buildings	8,210	metric ton CO_2e	Scope 1
Commercial and Institutional Buildings	15,851	metric ton CO_2e	Total
Manufacturing Industries and Construction	1,489	metric ton CO_2e	Total
Road Transportation	745	metric ton CO_2e	Scope 1
Solid Waste Produced in the City	12,087	metric ton CO_2e	Scope 1
Biological Waste Produced in the City	406	metric ton CO_2e	Scope 1
Wastewater Produced in the City	16,858	metric ton CO_2e	Scope 1

In particular, improvements focused on waste management, reduction of stationary energy consumption, transition to renewable energy sources, energy efficiency measures in the commercial/institutional sector, low-carbon solutions in transportation (electric public transport, bicycle and pedestrian-friendly infrastructure) and strengthening of missing data areas are strategic priorities to be focused on within the scope of SECAP.

These inventory results obtained for Tirebolu can guide in determining the following strategic priorities within the scope of SECAP:

- **Waste Management Priority: Emissions from waste, which constitute more than half of total emissions, indicate areas for improvement such as methane recovery in solid waste storage areas, development of composting and anaerobic digestion technologies, and increasing recycling rates. In this way, both methane emissions can be reduced and the value of resources that can be restored to the local economy can be increased.**

- **Building and Energy Efficiency: Considering that a large portion of stationary energy emissions are based on electricity consumption, it is understood that energy efficiency measures have significant potential in the city. Measures such as LED lighting, insulation, smart building management systems, heating-cooling optimization and renewable energy (solar, wind) integration in residences and especially in commercial/institutional buildings can be priority actions within the scope of SECAP.**

- **Low-Carbon Solutions in Transportation: Although the current emission share of transportation is relatively low, future plans such as expanding electric public transportation fleets, increasing bicycle paths, encouraging electric vehicle charging stations and developing pedestrian-first transportation models can further reduce the city's carbon footprint in the medium and long term.**

- **Data Collection, Monitoring and Evaluation: Incomplete data on IPPU, AFOLU and other scope 3 emissions creates an opportunity for future improvements. The effectiveness and accuracy of SECAP actions can be increased through stronger data collection mechanisms, collaboration with local stakeholders, sectoral expertise and technical capacity building.**

Tirebolu Municipality’s 2023 emissions inventory is a fundamental reference that guides the city’s climate strategies. These data provide a solid scientific basis for prioritizing, implementing and monitoring policies and measures for a low-carbon and sustainable urban future.

9. Evaluation of Data Relating to Tirebolu Municipality Between 2020-2024

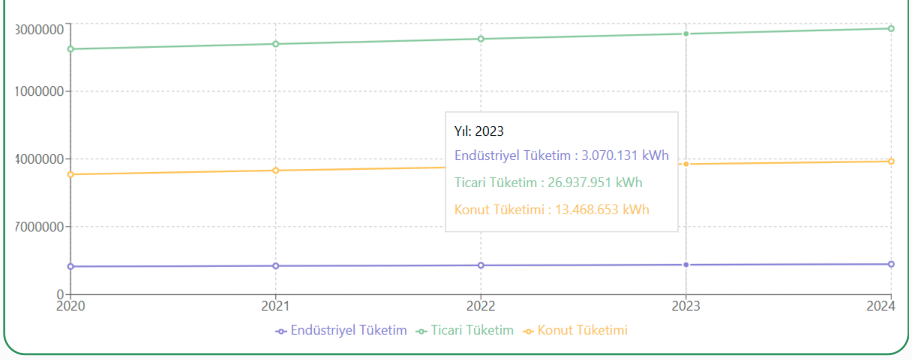
Energy Consumption

The municipality's energy consumption data for the last five years (2020-2024) provide important clues about the transformation of the city's energy usage habits and infrastructure. These data show that, on the one hand, general energy demand is on an increasing trend, and on the other hand, energy supply and fuel types have diversified and transformed significantly over time.

Yıllara Göre Enerji Tüketim ve Demografik Veriler

Yıl	Endüstriyel Elektrik (kWh)	Ticari Elektrik (kWh)	Konut Elektrik (kWh)	Bina Sayısı	Nüfus
2020	2.890.739	25.363.929	12.397.424	3.952	19.750
2021	2.949.734	25.881.560	12.810.402	4.002	20.977
2022	3.009.933	26.409.756	13.182.345	4.035	20.671
2023	3.070.131	26.937.951	13.468.653	4.041	18.773
2024	3.131.534	27.476.710	13.755.753	4.047	18.332

Elektrik Tüketim Trendleri (2020-2024)



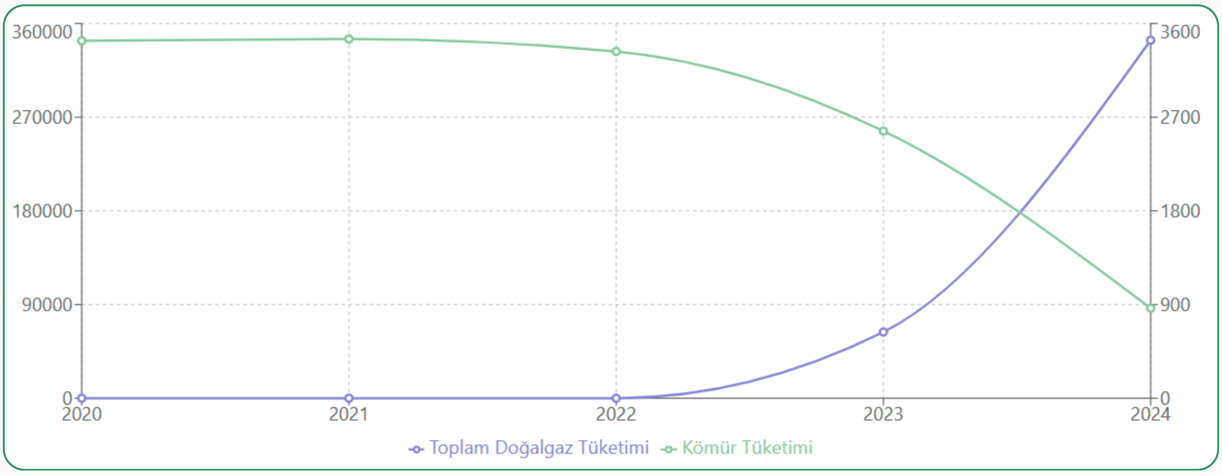
Continuous Increase in Electricity Consumption:

The increase in total electricity consumption, which was approximately 44 million kWh in 2020, to 47.8 million kWh in 2024, shows that economic and social activities in the city are increasingly transforming into an electricity-based structure. This increase indicates the need for sustainable energy efficiency measures in the city's service, commercial and residential sectors. Commercial electricity consumption, which was approximately 25.3 million kWh in 2020, reached 27.5 million kWh in 2024, confirming the importance and energy intensity of commercial activities in the city's economy. The steady increase in electricity consumption per capita in residences from year to year can be evaluated as a reflection of the rise in living standards, the widespread use of electrical appliances and the increasing use of climate control systems.

Inclusion of Natural Gas in the System and Moving Away from Solid Fuels:

While there was no significant natural gas consumption until 2023, the natural gas consumption that started in 2023 and reached 343,926 m³ in 2024 indicates a significant structural transformation in the city's energy supply portfolio. In the same period, the decline in coal consumption from 3,433 tons (2020) to 865 tons (2024) and the dramatic decrease in LPG consumption from 604,350 kg (2020) to 73,500 kg (2024) indicate a shift from solid and high-emission fossil fuels to natural gas, a cleaner fuel. This transformation can be read as an important indicator that the goal of moving away from carbon-intensive fuels and adopting lower-carbon options in energy supply within the scope of SECAP has begun to be implemented in practice.

Yıl	Toplam Doğalgaz (m³)	Endüstriyel Doğalgaz (m³)	Ticari Doğalgaz (m³)	Konut Doğalgaz (m³)	Kömür (ton)
2020	0	0	0	0	3.433
2021	0	0	0	0	3.450
2022	0	0	0	0	3.331
2023	63.550	6.455	643	56.452	2.566
2024	343.926	34.290	3.556	306.080	865



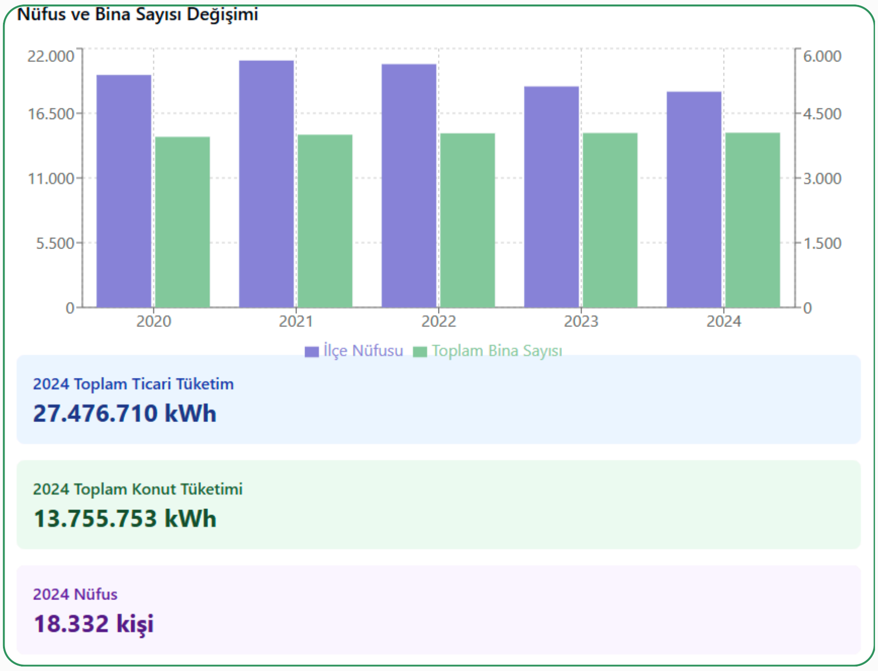
Continuous Growth in Industrial and Commercial Sectors:
The increase in industrial electricity consumption from 2.89 million kWh in 2020 to 3.13 million kWh in 2024 shows that manufacturing and industrial activities in the city are showing a steady increase. The fact that industrial natural gas consumption started with 6,455 m^3 in 2023 and increased to 34,290 m^3 in 2024 during the same period shows that natural gas is increasingly taking place in the energy supply of the industrial sector. This situation reveals that the industrial sector is undergoing a transformation that has the potential to reduce its carbon footprint and to significantly reduce greenhouse gas emissions in the future with energy efficiency technologies, heat recovery and process optimization.

Use of Municipal Buildings and Infrastructure:
The increase in electricity consumption of municipal buildings from approximately 1.8 million kWh in 2020 to 2.05 million kWh in 2024 indicates that the energy demand of urban services is also increasing. However, it is striking that there is still no natural gas consumption in municipal buildings (zero value between 2020-2024), indicating that the transition to this fuel has not yet taken place in local government buildings. This indicates that energy transformation projects (such as the transition to natural gas, heat pump technologies, installation of rooftop solar energy systems) can be planned in the municipal service infrastructure in the future.

Ongoing Demand in City Heating Systems:
The energy consumption of city heating systems increased from 24.1 million kWh in 2020 to 26.06 million kWh in 2024. This increase shows that central heating applications play an important role in the city and that houses need more and more energy to meet their heating needs in the winter months. Increasing the efficiency of these systems, recovering waste heat or integrating renewable heat sources (geothermal, solar thermal) are strategic steps that can be evaluated within the scope of SECAP.

The energy consumption trends observed in the Tirebolu Municipality provide a strategic guide for the city’s future planning. The continuous increase in electricity consumption is directly related to urban growth, increased welfare, and the proliferation of electrical devices; while the integration of natural gas into the system shows that greenhouse gas emissions can be reduced and air quality can be improved by significantly reducing coal and LPG use. Maintaining and expanding this trend will support goals to move away from high-carbon fuels by creating a cleaner energy mix in the city.

The data obtained allow for the strategic shaping of actions to be developed within the framework of SECAP (Sustainable Energy and Climate Action Plan). Applications such as building efficiency, smart grids, demand side management and renewable energy integration can be evaluated to balance the increase in electricity demand. A multi-dimensional approach can be adopted by considering infrastructure investments and awareness campaigns, waste management, heating systems and carbon reduction projects for transportation infrastructure to strengthen the widespread use of natural gas.



Energy consumption dynamics observed in the last five years reveal that Tirebolu has a strong transformation potential in its current energy structure. SECAP actions to be developed under the guidance of this data will accelerate the city's transition to a low-carbon economy, contribute to sustainable development goals and increase climate resilience.

Water and Waste Management

Water and waste management data reveal a city's environmental performance across a wide spectrum, from resource use to waste treatment processes, and the factors affecting greenhouse gas emissions. These data provide a critical basis for developing water resource protection, water loss reduction and waste management policies within the SECAP framework.

Water Management and Treatment Processes:

Municipal water usage data show that total water consumption in the 2020-2024 period has generally followed a stable, even partially fluctuating course. Total water consumption, which was approximately 639,916 m³ in 2020, reached 649,822 m³ in 2024, but this increase remained relatively limited. On the other hand, the increase in the use of groundwater resources is remarkable, rising from 895,883 m³ in 2020 to 905,890 m³ in 2024. This trend reveals that the city's water supply is increasingly dependent on groundwater or at least that the amount of groundwater use maintains a constant and high course. The fact that surface water is not used at all during this period indicates that the city's hydrological and geographical conditions and surface water supply do not play an active role in the urban water supply chain.

Water loss rates ranging from 38% to 45% indicate that improvements need to be made in transmission lines, distribution networks or meter measurements. Reducing water loss not only saves water, but also indirectly affects the amount of wastewater, reducing treatment costs and related emissions. The fact that grey water recovery is zero in the five-year period indicates that the principles of water recycling and reuse have not yet been implemented or data has not been collected in the city. This indicates that water recovery technologies (e.g. grey water use in buildings, water cycles in industrial facilities) should be promoted in the future.

Wastewater Treatment and Energy Intensity:
The commissioning of wastewater treatment plants and the stabilization of the process volume at 1.5 million m^3 as of 2021 indicate that the city has built capacity in wastewater management. However, the fact that the electricity consumption of wastewater treatment plants increased to 1,134,500 kWh in 2021 and is still at 1,188,908 kWh in 2024 emphasizes the energy-intensive nature of treatment processes. The energy consumption of water treatment plants has also increased every year, from 1,413,787 kWh in 2020 to 1,530,328 kWh in 2024. This situation reveals the importance of integrating energy efficiency technologies into water and wastewater treatment infrastructure.

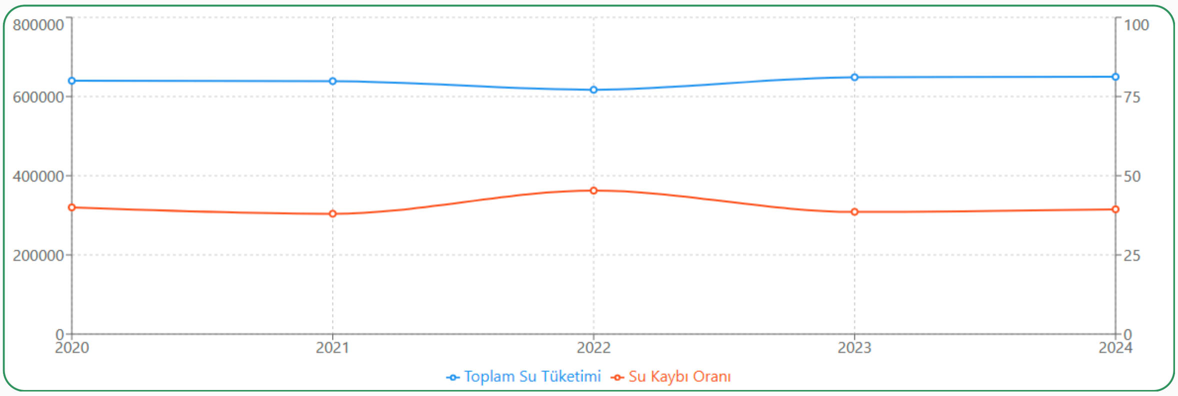
Methane emissions from wastewater treatment plants, which started at 16,533 tons of CO_2e in 2021 and increased to approximately 16,985 tons of CO_2e in 2024, indicate that the organic load and anaerobic conditions in treatment processes must be managed sustainably. Controlling this trend is possible with the commissioning of methane capture systems, biogas recovery and process optimization. In this way, both greenhouse gas emissions can be reduced and the potential for renewable energy production can be evaluated.

Waste Management and Circular Economy Potential:
The fluctuation of the total amount of waste from year to year (11,132 tons in 2020, 12,119 tons in 2024) presents a dynamic related to the urban population, consumption habits and economic activities. The fact that the amount of recycled waste has been zero for five years shows that urban waste is not yet managed with an effective recovery and recycling infrastructure. Although composting of organic waste varies between 3,400-4,000 tons each year, the lack of recycling indicates a significant improvement potential in total waste management.

By increasing the amount of composted organic waste (3,673 tons in 2020, approximately 3,999 tons in 2024), it is possible to increase the organic matter richness of the soil and reduce the need for chemical fertilizers. However, the fact that the recycling share is zero indicates that awareness campaigns, waste separation facilities and appropriate legal regulations are required to prevent materials such as plastic, metal, paper and glass from going to landfill.

The fact that methane emissions from the solid waste landfill are not reported raises questions about the management of the current landfill and the adequacy of methane measurements. With more comprehensive measurement and monitoring systems, emissions from the landfill can be more clearly revealed.

Yıl	Toplam Su Tüketimi (m³)	Su Kaybı (%)	Atıksu Tesis Elektrik (kWh)	Su Arıtma Enerji (kWh)	Metan Emisyonu (ton CO2e)
2020	639.916,53	40	0	1.413.787	0
2021	638.916,53	38	1.134.500	1.442.062,74	16.533,38
2022	617.077	45,3	1.234.006	1.470.903,99	16.814,79
2023	648.716	38,6	1.190.679	1.500.322,07	16.857,92
2024	649.822	39,4	1.188.908	1.530.328,52	16.985,44



Policies and Strategic Directions:

These data facilitate the development of strategic actions on water and waste management within the scope of SECAP. For example, policies such as infrastructure improvements to reduce water losses, promotion of grey water recycling, implementation of methane capture technologies in wastewater treatment plants, and introduction of waste reduction and recycling incentives can significantly improve the sustainability performance of the city.

In addition, the city has a high potential to create green infrastructure, adopt circular economy principles and develop integrated policies in the water-energy-waste sectors. In this way, it is possible to reduce greenhouse gas emissions in both water and waste management processes, increase resource efficiency and place the local economy on a sustainable axis. These orientations provide data and insights that will guide the future climate strategies of Tirebolu Municipality.

Transportation and Vehicles

The transportation sector data includes important indicators reflecting the city's land transportation infrastructure, fuel consumption dynamics of fleets and transportation preferences. These data directly affect the carbon footprint of urban mobility and provide the basis for developing sustainable transportation policies and determining emission reduction strategies within the scope of SECAP.

Public Transport and Municipal Vehicles:
The fact that the number of public transport vehicles (46) in the city has not changed for five years and the annual fuel consumption has remained constant (166,320 liters/year) indicates that the public transport system continues to provide service with a constant capacity. The fact that the daily passenger transport rate of 2,520 has not changed indicates that this system has not experienced a significant increase or decrease in demand or capacity. Modernization, electrification or transition to more efficient fuel technologies of the public transport infrastructure can be effective steps in reducing the city's transport-related emissions.

The fact that the number of municipal vehicles (26) and fuel consumption (111,600 litres/year) remained constant indicates that the municipality has not taken any steps to expand the fleet or change fuel type. Renewing municipal fleets with electric or hybrid vehicles, increasing vehicle efficiency, optimising routes or implementing car sharing models have the potential to reduce emissions from the municipality's own operations.

Increase in Private and Commercial Vehicles:
The data shows that the number of private vehicles increased from 1,010 in 2020 to 1,245 in 2024, and the number of commercial vehicles increased from 942 to 1,120. This trend indicates that individual vehicle ownership and commercial activities (e.g. transportation, distribution services) have increased, thus increasing traffic density and potential emissions over time. The fact that the average daily traffic density within the district has remained constant (1,210 vehicles/day) may suggest that traffic flow has not yet reached its capacity limit or that measurement methods need to be revised.

Alternative Fuels and Electrification Trend:
The increase in the number of hybrid vehicles from 25 in 2020 to 65 in 2024 indicates that low-emission technologies have begun to be adopted, albeit partially, in the city's private vehicle fleet. In addition, the commissioning of electric vehicle charging stations as of 2022 (4 stations) and the fixation of the monthly usage amount as 9,425 kWh indicate that electric vehicles have begun to take their place in urban transportation. Supporting these trends can be accelerated with electric public transportation, incentive packages, expansion of charging infrastructure and awareness campaigns.

Bicycle and Pedestrian Infrastructure:
The fact that the length of the bike path (5 km) and the pedestrian paths (8 km) have not changed for five years indicates that the active transportation infrastructure has not been expanded. However, the promotion of cycling, pedestrian-friendly urban planning and the integration of micromobility vehicles (e-scooters, shared bicycles) can both increase healthy, low-carbon transportation alternatives and help reduce individual car use in the city.

Policies and Strategic Directions:
Insights from transportation data underscore the need to set low-carbon transportation targets within SECAP. The city can replace public transportation with electric or alternative fuel models, reduce individual vehicle dependency by improving bicycle and pedestrian infrastructure, and promote energy efficiency and low-emission technologies in commercial vehicle fleets. It is also possible to direct private vehicle owners to cleaner technologies by increasing the number and capacity of electric vehicle charging stations.

All these steps will reduce the city's transportation-related emissions in the medium and long term, improve urban air quality, reduce traffic congestion and facilitate the transition to a sustainable transportation ecosystem. In this direction, local governments can move forward on the path to sustainable transportation by cooperating with stakeholders (public transportation operators, automotive sector, NGOs, citizens).

Green Spaces and Carbon Sinks

Green areas and carbon sinks are of critical importance in terms of the continuity of ecosystem services within the city, mitigating the effects of climate change and improving the quality of life of local people. When Tirebolu Municipality data is examined, it is seen that there has been a limited increase in the amount of green areas in the last five years (54,600 m² in 2020, increasing to 55,700 m² in 2023-2024). It is noteworthy that this increase is also reflected in the park areas in the city (from 42,800 m² to 43,900 m²), but the overall number of trees has remained constant in the same period (12,000).

The fact that approximately 2,100 trees are planted regularly each year suggests that afforestation efforts are ongoing in the city, but a significant increase in the number of trees has not been achieved. This situation can be explained by the fact that the planted saplings have not yet been fully reflected in the reports, the trees have not yet reached a certain age or a measurable maturity, or the net increase is limited due to losses. At this point, factors such as the effectiveness of afforestation efforts, survival rates of planted trees, maintenance processes, and appropriate species selection may need to be reviewed.

The fact that the forest area (1,380 hectares) has maintained its current level indicates that the forest ecosystems in the region have remained stable. Forests make significant contributions to the city’s climate strategy as long-term carbon sinks. The fact that the carbon sequestration capacity of green areas remains constant at 27,600 tonnes CO_2e/year also reveals that the existing green infrastructure plays a stable carbon sink role, but the capacity increase is very limited.

These data form the basis for strategies such as increasing green areas and carbon sinks, protecting biodiversity, reducing the urban heat island effect and creating ecological corridors within the scope of SECAP. Steps such as strengthening green infrastructure in the city, more careful planning and maintenance of afforestation activities, selecting tree species compatible with local climatic conditions, creating new park areas and improving the ecological functions of existing parks can help improve the city's carbon balance.

In addition, green areas provide many additional services, not only with their carbon sequestration capacity, but also with public health, recreation, biodiversity, water retention capacity and soil erosion prevention. Therefore, green infrastructure and carbon sink management should be integrated not only into climate action plans, but also into sustainable urban planning, social welfare and ecosystem services strategies. This holistic approach will increase Tirebolu's long-term climate resilience and capacity to achieve sustainable development goals.

Renewable Energy and Energy Efficiency

These data show that renewable energy investments in Tirebolu have not yet been implemented or have not reached a measurable level. Local renewable resources such as solar, wind, biomass, geothermal and hydroelectric indicate zero production capacity in the five-year period. This situation reveals that the energy supply in the city is still predominantly based on conventional resources and that no serious breakthrough has been made in renewable technologies.

The absence of energy storage capacity (0 kWh) indicates that technologies that will optimize the balance between clean energy production and consumption have not yet been put into operation. However, especially when renewable energy projects are put into operation, energy storage technologies can contribute to the stable use of intermittent renewable resources by increasing grid flexibility.

Despite this picture, the increase in the number of energy efficient buildings from 290 in 2020 to 360 in 2024 shows that energy efficiency measures are being adopted at least on a building scale in the city. Although this increase is not rapidly growing, the gradual increase in the existing building stock will support the reduction of energy consumption and therefore greenhouse gas emissions in the city. However, the fact that the number of green building certified buildings is zero indicates that the concept of sustainable construction in accordance with internationally accepted standards has not yet become widespread.

The fact that the LED lighting rate remains constant at 94% indicates that a certain standard has been reached in urban lighting, but additional improvements can be made by increasing this rate or introducing additional energy-efficient technologies. Although the rate of 94% is high, bringing it closer to 100% will further reduce energy consumption and therefore emissions from urban street lighting.

From the SECAP perspective, it is clear that Tirebolu needs to make a serious breakthrough in the field of renewable energy. The city can diversify local energy production and reduce carbon intensity by developing renewable energy projects (such as rooftop solar panels, small-scale wind turbines, biomass plants or small river-type hydroelectric power plants) that are suitable for its geographical location and potential resources. In addition, encouraging green building certificates, using sustainable materials in urban transformation projects and spreading passive energy designs will contribute to reducing both energy consumption and greenhouse gas emissions.

Setting concrete targets for Tirebolu in the fields of renewable energy production and energy efficiency, planning and implementing these targets within the framework of SECAP will be an important step towards the city's energy sustainability. In this way, Tirebolu will both increase its energy security in the future and enter a low-carbon development path, thus creating an exemplary local government model in the fight against climate change.

Climate Data and Buildings

The fact that the annual average temperature is 15-16°C and the precipitation is between 1,300-1,500 mm indicates that Tirebolu has a mild and rainy climate. The fact that the number of heating degree days varies between 200-230 and the number of cooling degree days varies between 135-165 indicates that the energy requirements of the buildings require a balanced heating-cooling strategy throughout the year. Within the framework of SECAP, building designs based on climate data, passive air conditioning approaches, insulation materials suitable for the local climate and heating-cooling optimization will help reduce energy consumption and therefore emissions.

Building Stock and Structural Transformation:
The increase in the total number of buildings indicates that urban development is continuing, while the age distribution and insulation rates of buildings are important determinants for future decarbonization strategies. The low rate of buildings aged 0-10 years and the increase in the rate of insulated buildings from only 8% to 11% in the 5-year period indicate that the current building stock is not yet at the desired level in terms of energy efficiency. The high share of old buildings (around 40% aged 31-50, 24% aged 50+) emphasizes the need for renovation projects, comprehensive retrofitting, insulation and heat recovery measures. Such improvements reduce greenhouse gas emissions by reducing energy demand within the scope of SECAP, while also increasing user comfort and building value.

The fact that the number of buildings using smart building systems is very low (5-6 buildings) shows that digitalization and smart technologies are not yet widespread in the city. However, approaches such as smart automation systems, building energy management software, sensor-based lighting and air conditioning control can play a critical role in both energy efficiency and reducing the carbon footprint.

Strategic Approaches:
Economy and Population Size: Increasing GDP per capita can indicate the economic capacity to adopt more sustainable technologies. Local government has the opportunity to decarbonize the economy by investing in cleaner production, green employment and sectors with high environmental standards.

Climate Adaptation and Resilience: Building designs that are suitable for local climatic conditions, rainfall management, green infrastructure and water efficiency policies make the city more resilient to the adverse effects of climate change while reducing energy consumption and emissions.

Building Renovation and Energy Efficiency: Renovation of old buildings that constitute a large part of the existing building stock, widespread insulation, and promotion of smart building technologies may be among the most important steps of SECAP. In this context, incentive mechanisms, low-interest loan programs, tax reductions or technical support may direct building owners to energy efficiency investments.

Data Quality and Monitoring: Resolving inconsistencies in economic data and more systematic and regular collection of building, energy and climate data will be critical to monitoring progress and evaluating the effectiveness of SECAP actions.

The socio-economic structure, climate characteristics and building stock of Tirebolu offer multi-dimensional opportunities for reducing greenhouse gas emissions in the city, increasing energy efficiency and implementing a sustainable urban transformation. The steps to be taken within the scope of SECAP will be designed in light of this data and will contribute to reducing the city's carbon footprint, strengthening the fight against climate change and improving the quality of life of the local people.