

# Emerging Actions And Energy Strategies For Sustainable Development Of Sakarya City, Turkey: A SWOT Analysis

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## Original article

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# Abstract

**Background:** Turkey has been one of the earliest participants of the international climate policy process, since the Ministerial Conference on Atmospheric Pollution and Climate Change held in 1989. The country has prepared strategy documents, actions plans, sectoral policies and projects to detect and adapt climate change effects. However, any of this has not turned into a main plan to support climate change mitigation on an international scale. The purpose of this paper is to identify local climate change mitigation strategies of Sakarya city, Turkey by strengths, weaknesses, opportunities and threats (SWOT) analysis. For this purpose, relevant information were gathered from Covenant of Mayors, greenhouse gas inventories of the city, National Energy Efficiency Action Plan, online workshop with 44 local stakeholders from private sector and local universities held on 13.10.2020.

**Results:** Transportation sector action plans proposed within SWOT analysis promise to decrease local transportation-based emissions by 27% compared to 2017 and by 26% compared to 2030 business as usual (BAU) Scenario. Buildings sector action plans proposed within SWOT analysis promises to decrease local building-sector based emissions by 20% compared to 2017 and by 33% compared to 2030 BAU Scenario. All mitigation strategies proposed within SWOT analysis promises to decrease local total emissions by 24% compared to 2017 and by 28% compared to 2030 BAU Scenario.

**Conclusion:** The results emphasize the importance of the cross-link between local adaptation and mitigation in terms of energy demand and energy-based emissions on national and international scale. This paper proposes that developing complete greenhouse gas inventories by accurate data within current technologies like the Internet of Things (IoT) and formulating climate change targets accordingly is the key to achieve the adaptation of local mitigation plans. In conclusion, it is emphasized that efforts to monitor, to report and to develop local mitigation legislations will determine the success rate of national sustainable development goals.

## Introduction

The last decade has seen a critical level of global warming between 0.8 and 1.2 degrees Celsius representing alarming anthropogenic degradation of climate system (Intergovernmental Panel on Climate Change Summary for policymakers 2018). The Paris Agreement aims to limit this warming well below 2 degrees Celsius above pre-industrial levels to avoid dangerous degradation levels (Paris Agreement 2015). Recent climate change mitigation studies support that the world must commit to a rapid decarbonisation agenda to reach the goal of Paris Agreement (Kriegler, E et al. 2014, Nukusheva, A et al.2020, Riahi, K et al. 2017, Rogelj, J et al. 2015a, Skjærseth, JB 2021).

Burning fossil fuel resources for electricity and heat is the main driver of climate change (Dmitrii, B et al. 2021, Hanna, B et al. 2020). The records indicate that emissions from these sectors have reached to a historic value, 33.1 Gt CO<sub>2</sub>eq in 2019 (International Energy Agency, CO<sub>2</sub> emissions 2019). However, the latest data show that global energy based CO<sub>2</sub> emissions dropped dramatically in the first quarter of

2020, due to the declines in global energy demand by the pandemic recession in global economic activity and mobility. It is estimated that the lowest value since 2010 will be recorded by the end of 2020, 30.6 Gt, almost 8% lower than the historic value in 2019 (International Energy Agency, Global Energy Review 2020). In this context, structural decline in emissions must be at the top of political agenda to avoid a rebound as the world comes out of the pandemic recession.

The future of energy demand and energy-based emissions are dependent on climate change adaptation actions by all levels of governments from local to national. There is a widespread agreement that adaptation comprises of interactions between social, cultural, economic processes by stakeholders and local governments (Liu, Y et al. 2020). Therefore, in order to mitigate climate change with resilient communities, it is required to understand how action plans work locally (Barnett, J 2010).

Sakarya is a city in Turkey located in the Marmara Region with coordinates 40° 41' 50" N 30° 27' 24" E. The city encompasses a total area of 4.823 square kilometers, an area which had a population of 1,029,650 in 2019 and a population density of 211 inhabitants per square kilometer. The population of the city increased by 18.7% in 2019 and continues to increase due to labor demands in rapidly growing industry sector (Turkish Statistical Institute. Population, Annual Growth Rate and Sex Ratio 2019). Agriculture and industry have an important role in the city's economy. The share of agriculture and industry sectors in employed population of the city were reported 17% and 24% respectively. Sakarya is one of the developing cities of Turkey with 1.6% share in the country's gross domestic product (Republic of Turkey Sakarya Governorship, Briefing II 2019).

Sakarya Metropolitan Municipality (SMM) is a member of Covenant of Mayors which entered into force in 2018 to pursue the efforts to limit greenhouse gas emissions on a local scale and strengthen the national response to the threat of climate change. In this context, reducing emissions at least 40% by 2030 and transition to cleaner and more secure energy future have become urgent goals of the city in the short and medium term. In this paper, urgent action plans to achieve local climate change targets were proposed by conducting a "strengths, weaknesses, opportunities and threats (SWOT) analysis.

## **Materials And Methods**

The SWOT analysis is a technique first presented by Albert Humphrey in the 1960s for decision making for complex strategic situations (Learned, EP 1969). The technique aims to develop action plans to increase strengths and to reduce or eliminate weaknesses by benefiting from opportunities and preventing threats (Dyson, RG 2004).

In this paper, the SWOT analysis technique was used to analyse the energy-based greenhouse gas emissions situation in Sakarya city, Turkey and to develop local action plans for reducing local emissions and contributing the national climate change targets. The strengths, the weaknesses, the opportunities and the threats were identified by gathering the main points of Covenant of Mayors, greenhouse gas inventories of Sakarya city, climate change targets of National Energy Efficiency Action Plan and outcomes of an online workshop with local stakeholders held on 13.10.2020. The workshop provided

different opinions from 44 participants from city universities, local governmental agencies and local nongovernmental organizations. Mitigation activities and priority levels to be implemented within a sustainable energy action plan for the city were determined within the scope of the following working groups: buildings and industry, transportation and renewable energy (Table 1). Greenhouse gas emission assumptions for the targeted year 2030 were made based upon population growth rate, building and service sector growth rate, energy consumption trends in the last decade and legislative changes in the jurisdiction of SMM.

**Table 1. SWOT Analysis Matrix**

Segments	Strengths	Weaknesses	Opportunities	Threats
Transportation	<ul style="list-style-type: none"> <li>-low public transport fees</li> <li>-age profile of the bus fleet</li> <li>-wide transportation network</li> <li>-bicycle infrastructures</li> </ul>	<ul style="list-style-type: none"> <li>-public transport infrastructure</li> <li>- pedestrianization</li> <li>-expertise in transportation planning</li> <li>-public preference level</li> <li>-rail system</li> <li>- public transport line planning</li> <li>- financial resources</li> <li>-passenger information activities</li> <li>-zoning planning</li> <li>- alternative energy sources</li> <li>- bicycle paths</li> </ul>	<ul style="list-style-type: none"> <li>-reduced fuel costs with new technologies</li> <li>-government support for public transportation</li> <li>-geographical structure</li> <li>-urban master transport plan</li> </ul>	<ul style="list-style-type: none"> <li>-comfort of private transportation</li> <li>- legal legislations</li> <li>-challenges in rail transport</li> <li>-local resistance to pedetrization and bicycle projects</li> </ul>
Buildings	<ul style="list-style-type: none"> <li>-vision and infrastructure for smart city plans</li> <li>-municipality support for innovation</li> <li>-heat insulation for current buildings</li> </ul>	<ul style="list-style-type: none"> <li>-financial resources</li> <li>-growth rate of the city</li> <li>- experienced staff members</li> <li>-action plan: no strategy for urban transformation</li> <li>-university cooperation</li> <li>-geographical information system</li> <li>-reconstruction controls</li> </ul>	<ul style="list-style-type: none"> <li>-sustainable design standards for new residential areas</li> <li>-renovation of current buildings with low emission technologies</li> <li>-urban energy transformation</li> <li>-energy efficient lighting systems for current buildings</li> <li>-North Anatolia fault line</li> </ul>	<ul style="list-style-type: none"> <li>-illegal housing</li> <li>-agricultural land</li> <li>-local interest in urban energy transformation</li> <li>-uncontrolled industrial shift from Kocaeli and Istanbul</li> </ul>

-local energy performance certificate regulation

-environmental impact analysis

Renewable Energy

-energy efficient street lighting

-sustainable energy from organic waste materials: one operating integrated solid waste management system

-heat and electricity production from current landfill area

regular waste (electronic, oil, battery and tie) collection

-student awareness

-renewable and low carbon energy transform in residential areas

-investment costs

-rapid growth in urbanization and energy demand

-renewable energy applications in municipal buildings and subsidiaries

-Renewable Energy Trade Agreement

-cooperation between municipality and university

-midterm and long term energy transform strategies with infrastructure companies

-sustainable energy potential from organic waste

-interaction of students with their social environment

-experts in renewable energy from local universities

-growth rate of natural gas demand for heating

-increase in bagless, unpermitted coal demand

-quality of coal available in the market

-experienced staff for special waste collection

-social awareness

To evaluate the impact of action plans proposed in this paper, 2017 was selected as the reference year to compare the emission reduction targets. The direct and indirect greenhouse gas emissions of each sector were calculated by multiplying the final energy consumption by the corresponding emission factor. All CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions were calculated for all fuel types together using the IPCC emission factors in the Fifth Assessment Report (AR5).

# Results

## 3.1. Transportation

Sakarya Greenhouse Gas Emissions Inventory 2019 indicated that transportation sector is responsible for 27.5% of total emissions of the city with an energy consumption record 4,867,923 MWh. Growth rates of greenhouse gas emissions by transportation units were recorded 1% by municipal diesel fuelled vehicle fleet, 2% by municipal electric vehicle fleet, 3% public transport diesel fuelled vehicle fleet, 3% public transport electric vehicle fleet, 1.5% private diesel fuelled vehicles, 1% private diesel fuelled logistical vehicles, 1% private gasoline powered vehicles and 1% private LPG vehicles (Figure 1). Although diesel fuel demand of the city decreased from 2017 to 2019, transportation shares, 1,5 million tCO<sub>2</sub>eq, are still the second in total emissions in parallel with the growth rates of urbanization and industry. SMM aims to decrease transportation-based emissions to 369,288 tCO<sub>2</sub>eq by 2030 within Covenant of Mayors.

Republic of Turkey Ministry of Energy and Natural Resources announced the urgent transportation sector actions as follows (Turkish Republic Ministry of Energy and Natural Resources. National Energy Efficiency Action Plan 2017-2023):

- energy efficient vehicle incentives: low taxation for low emission vehicles, raising social awareness for electric and hybrid vehicles
- comparative analysis of alternative fuel resources and new technologies
- improving pedestrian and bike transport: building new pedestrian and bike paths integrated with public transport nationwide.
- reducing traffic congestion in cities: measures to deter entry into city centers, parking lot cautions, dissemination of smart transportation system applications
- expanding public transportation

This paper proposes urgent local transport action plans for Sakarya city in Table 2 on the basis of SWOT analysis results in Table 1.

Main transport plan of Sakarya city was put into practice in 2011. The city has experienced rapid growth in urbanization, industry and traffic density since then. Therefore, it is urgent to put Action Plan 1 in place in parallel with zoning plans of the city. The owner and implementer of this plan is SMM and the key for the success here is to increase the number of experienced staff in the field.

Public transportation utilization rate of Sakarya city was recorded 9% in 2019. The target of Action Plan 2 is to increase this rate to a minimum record 35% by 2024. The priority actions within this plan is to optimize public transportation routes, establish new public transport lines for urban transformation areas, increase the number of public buses, transfer new technologies and build a rail system. The number of private transportation vehicles in the city are more than the number of public transportation vehicles-1050 private buses, 632 private minibuses and 362 taxis (Sakarya Metropolitan Municipality. Strategic Plan 2020-2024). The very low public utilization rate, 9%, indicates that local people mostly prefer private

transportation vehicles. The results of the workshop indicate that private transportation vehicles provide time savings in comparison with public transport modes. Action Plan 2 proposes to improve public transportation with new public transit modes and reduce at least 50 MtCO<sub>2</sub>eq of transportation-based emissions.

**Table 2. Transportation Sector Action Plans for Sakarya City**

Action Plan 1	reviewing main transport plan and revising public transport plan
Action Plan 2	increasing public transport utilization rate
Action Plan 3	replacing public transport with energy efficient vehicles
Action Plan 4	initiating fast-charging station infrastructure studies
Action Plan 5	increasing bike transport shares
Action Plan 6	increasing pedestrian transport
Action Plan 7	developing low carbon vehicle sharing systems
Action Plan 8	providing economic driving techniques trainings
Action Plan 9	organizing social activities to increase social awareness

Public transportation utilization rate of Sakarya city was recorded 9% in 2019. The target of Action Plan 2 is to increase this rate to a minimum record 35% by 2024. The priority actions within this plan is to optimize public transportation routes, establish new public transport lines for urban transformation areas, increase the number of public buses, transfer new technologies and build a rail system. The number of private transportation vehicles in the city are more than the number of public transportation vehicles-1050 private buses, 632 private minibuses and 362 taxis (Sakarya Metropolitan Municipality. Strategic Plan 2020-2024). The very low public utilization rate, 9%, indicates that local people mostly prefer private transportation vehicles. The results of the workshop indicate that private transportation vehicles provide time savings in comparison with public transport modes. Action Plan 2 proposes to improve public transportation with new public transit modes and reduce at least 50 MtCO<sub>2</sub>eq of transportation-based emissions.

Current technologies entering the transit industry offer great improvements in fuel economy of vehicles. Action Plan 3 targets to achieve considerable reductions in fleet fuel consumption by changing fleet buses and minibuses with new vehicles, more efficient vehicles in the short term and hybrid-electric vehicles in the medium term. It is expected to save 1,157 tCO<sub>2</sub>eq and 42,716 tCO<sub>2</sub>eq transportation-based emissions by low carbon transformation and by hybrid-electric transformation in public transport fleet respectively.

It is a fact that switching from conventional polluting vehicles to electric powered vehicles is a near future trend driven primarily by growing concerns about climate change. However, the transformation is likely to

be time consuming and uncertain in locations where charging process is more difficult. In Sakarya city, fast-charging stations just emerged in some locations like shopping malls, hotels and highway side facilities. Action Plan 4 targets to support infrastructure studies to extend electric vehicle transformation in the city. The success of all the action plans above is depended on public awareness and acceptance. Activities to improve the social infrastructure to develop and/or transform transportation modes are vital for green mobility. Safe and economic training is a powerful social infrastructure tool of transportation to reduce use of fossil fuels and transport-based emissions. Action Plan 8 targets to train all drivers in the city and in particular drivers of public transportation modes. Current researches indicate that efficient driving behaviours can reduce use of fossil fuels by 5% and 10% for moderate driving styles and by almost 20% for aggressive driving styles (Gonder, J et al. 2011). Training passengers and pedestrians is also a powerful tool to extend public transportation modes, bike transport and pedestrian transport. Action Plan 9 targets to organize training activities at schools for raising social awareness of young people of the society and to organize bike events to incentivize local people to cycling.

Sakarya city has a favourable topological structure for cycling. The municipal corporation developed a bicycle share system called SAKBIS which provides 110 bikes and 15 stations in different locations of the city. The results of the workshop indicate that the application received public acceptance and reached over 120 thousand accesses (Sakarya Metropolitan Municipality. Strategic Plan 2020-2024). Action Plan 5 targets to stimulate cycling and discouraging the use of private cars. In this context, urgent actions are determined to improve the physical infrastructure as well as the physical. Building new cycle ways, bike parking and bike stations are the prior actions since cycling is one of the developing transport modes of the city. One of the key outcomes of the workshop is that many local people's perceptions of road safety acts a significant barrier to cycling. Therefore, the next action must be establishment of new bike friendly traffic regulations in the city. Besides, integration of SAKBIS with the other public transport modes is also an urgent action to discourage the use of private cars.

Walking is the oldest transportation mode and the primary for some people (Loukaitou-Sideris, 2020). However, there are significant barriers to pedestrian travel like the lack of access to sidewalks, lack of regulations on pedestrian safety, disintegration of sidewalks to the other public transport modes and disinterest in walking (Anciaes PR, 2016). Action Plan 6 presents urgent local actions to increase pedestrian travel in Sakarya city. Building sidewalks, integrating sidewalks with the other public transport modes and traffic calming are listed as the actions to improve the physical infrastructure. On the social infrastructure side, urgent actions to convey health and environmental messages to demonstrate that walking brings health benefits for all people and environmental benefits in all locations can help to raise social awareness.

Vehicle sharing is an emerging transportation system reducing fossil fuel uses, increasing safety and reducing operating costs (Jones EC, et al. 2019, OECD/ITF 2017). In Sakarya city, only bicycle sharing system, SAKBIS, has been effectively operated. Action Plan 7 targets to increase vehicle station facilities, vehicle fleet size and customer demand in the city in parallel with Action Plan 4 and Action Plan 5. Investigating management models to meet current and future mobility needs, cooperation with private

enterprises to build flexible services and public incentivisation are determined the key actions to increase low and/or zero carbon vehicle sharing systems. However, achieving the targets of Action Plan 7 is depended on the progress of Action Plan 4 and Action Plan 5. It is expected to save almost 43,899 tCO<sub>2</sub>eq transportation-based emissions, if Action Plans 4-7 are successfully and urgently put into practice.

Figure 2 indicates greenhouse gas emissions by transportation sector of reference year 2017 and 2030. From the figure, it can be concluded that transportation action plans proposed within SWOT analysis in Table 1 promises to decrease sector-based emissions by 27% compared to 2017 and by 26% compared to 2030 business as usual (BAU) Scenario.

### 3.2. Buildings

Sakarya Greenhouse Gas Emissions Inventory 2019 indicated that the largest contribution comes from building sector, 57.5% of total emissions of the city. The largest share of emissions by the sector came from industrial buildings to a record 27%. Residential buildings and commercial buildings were responsible for 19.9% and 9.6% of total emissions by the sector. Building outdoor lighting systems and municipal buildings followed industry, residential buildings and commercial buildings with smallest shares of 0.7% and 0.3% respectively (Figure 3). Building based emissions increased from 1,372,910 tCO<sub>2</sub>eq in 2017 to 1,419,701 tCO<sub>2</sub>eq in 2019. One of the sustainable development targets of the city is to decrease these emissions by at least 450,319 tCO<sub>2</sub>eq by 2030.

In Sakarya city, there are 13 small industry areas and 6 organized industrial areas with a total area of 772 Hectares. Besides, new organized industrial areas in Karasu, Ferizli, Kaynarca and Akyazı towns are in the construction phase. Industry based emissions of the city is recorded 1,254,061 tCO<sub>2</sub>eq in 2019 (Sakarya Chamber of Commerce and Industry. 2018-2021 Strategic Plan). It is expected to record larger emissions in the following years, since the sector experiences a rapid growth.

This paper proposes urgent local buildings and industry action plans for Sakarya city in Table 3 on the basis SWOT analysis results in Table 1.

**Table 3. Buildings Sector Action Plans For Sakarya City**

Action Plan 1	energy savings in residential buildings
Action Plan 2	energy savings in non-residential buildings
Action Plan 3	urban transformation
Action Plan 4	energy savings in municipal buildings
Action Plan 5	renovation of outdoor lighting systems

In Sakarya city, the largest share of residential buildings-based emissions came from fossil fuel use for heating- 65% of building based emissions and 20% of total emissions. Heating based energy demands of

the city is larger than cooling energy demands due to climate conditions of the city. Therefore, thermal insulation can make a significant difference in the city's emissions by heating and cooling. Action Plan 1 proposes that thermal insulation for all buildings can reduce heating and cooling based energy demands and emissions of the city almost 533,186 MWh and 121,112 tCO<sub>2</sub>eq at least by 2030. Natural gas is the primary heating energy source of residential buildings in the city. An urgent action by Action Plan 1 is to complete natural gas transformation in all residential buildings in the city. It is estimated that 14.876 tCO<sub>2</sub>eq of building based emissions can be saved by coal to natural gas transformation. The other urgent action of the plan is to renovate lighting systems of residential buildings. Energy efficient new lighting systems can provide 18,005 MWh energy savings and 9,254 tCO<sub>2</sub>eq emission savings by 2030. However, Action Plan 1 underlines that social awareness is the key to succeed expected savings within the actions by the plan. It is likely to make additional 77,163 MWh energy savings and 39,662 tCO<sub>2</sub>eq emission savings by 2030 with social responsibility as well as heating, cooling and lighting savings. Therefore, activities to raise the awareness of local people are also listed within urgent actions to reduce carbon foot print by residential buildings.

Non-residential buildings, commercial buildings and industrial buildings, were responsible for 35% of the city's total building-based emissions. Action Plan 2 offers thermal insulation, renovation of lighting systems and social awareness activities to reduce total emissions by commercial buildings. Although cooling has a larger share in energy demands of non-residential buildings, thermal insulation can still provide 142,911 MWh energy savings and 30,689 tCO<sub>2</sub>eq emission savings. However, energy efficient lighting systems can make a significant change in total emissions of commercial buildings and industrial buildings by 161,671 tCO<sub>2</sub>eq savings. Previous studies held in Sakarya city proves that more than 40% lighting energy saving is possible just using a daylight-controlled lighting automation system in such buildings (Yavuz, C et al. 2010, Yavuz, C et al.2012). Social responsibility is also vital in this sector with a potential of 94,360 MWh energy savings and 57,689 tCO<sub>2</sub>eq emission savings in addition to the savings by thermal insulation and energy efficient lighting energy systems.

Sakarya city lies down on the North Anatolian Fault System. Many earthquakes occurred in the last two millennia along the city and surrounding area (Karabacak, v. et al. 2019). Therefore, the priority of all buildings in the region is to withstand earthquakes (Özmen, C et al. 2007). Action Plan 3 targets to integrate energy efficiency applications with design and construction stages of buildings which do not comply with earthquake regulations. Urban transformation plans including sustainable energy solutions can contribute to sustainability of the city in terms of safety, energy access and climate change concerns.

Sakarya Greenhouse Gas Emissions Inventory 2017 indicates that municipal buildings are responsible for 19,289 tCO<sub>2</sub>eq of total emissions of the city. Although actions to reduce emissions by municipal buildings do not promise significant savings, a potential of 3,906 tCO<sub>2</sub>eq, Action Plan 4 presents that these actions can support action plans to extend social awareness. Therefore, it is suggested to put place in urgent actions of thermal insulation, energy efficient lighting systems and social awareness activities to succeed Action Plan 1 and Action Plan 2.

The share of outdoor lighting of municipal and public buildings in total emissions of the city was recorded 31,184 tCO<sub>2</sub>eq in 2017. Action Plan 5 targets to renovate outdoor lighting systems of all public buildings, since the government encourages corporations to make at least 15% outdoor lighting energy savings in parallel with the growth rate of electricity price of the country. An energy efficient outdoor lighting transformation with 15% energy savings can provide 11,500 tCO<sub>2</sub>eq emission savings to Sakarya city.

Figure 4 indicates greenhouse gas emissions by building sector of reference year 2017 and 2030. From the figure, it can be concluded that buildings sector action plans proposed within SWOT analysis in Table 1 promises to decrease building-sector based emissions by 20% compared to 2017 and by 33% compared to 2030 BAU Scenario.

### *3.3. Renewable energy*

In 2019, total annual electricity consumption and greenhouse gas emissions by electricity generation of Sakarya city were recorded 3,144,306 MWh and 1,869,116 tCO<sub>2</sub>eq. The share of total annual electricity generation-based emissions in total city emissions was 40% (Figure 5). Industrial sector makes the largest contribution with a 58% share and followed by commercial, residential and agricultural sectors.

In Sakarya city, solar and bioenergy technologies are promising to transform energy system of the city into a more sustainable one mainly by renewable energy sources. The annual mean solar radiation of the city is about 1450 kWh/m<sup>2</sup>, lower than Turkey's annual mean record but still a great potential comparing to Germany mean value (Figure 6) (Solar GIS, Solar resource maps of Turkey, Solar GIS, Solar resource maps of Germany). Bioenergy is an important source of sustainable energy in Sakarya city due to its significant potential of forest sources and non-forest sources (solid wastes, animal wastes and agricultural crop residues). In 2019, annual dry biomass potential of field crops and tree pruning wastes are recorded 974,990 tonnes and 28,304,823 tonnes respectively (Sakarya Chamber of Commerce and Industry, 2018-2021 Strategic Plan).

Republic of Turkey Ministry of Energy and Natural Resources 2019-2023 Strategic Plan aims to increase the share of renewables in electricity generation by at least 38.8%. In this context, it is expected to reach a total installed renewable capacity of 56,804 MW by 10,000 MW solar photovoltaic, 11,883 MW wind, 32,037 hydro and 2,884 geothermal and biomass (Turkish Republic Ministry of Energy and Natural Resources. National Energy Efficiency Action Plan 2017-2023). Short term and midterm renewable energy targets of SMM Strategic Plan to increase the installed renewable capacity of the city coincide well with national energy goals.

This paper proposes urgent renewable energy action plans for Sakarya city in Table 4 on the basis of SWOT analysis results in Table 1.

### **Table 4. Renewable Energy Sector Action Plans for Sakarya City**

Action Plan 1	solar photovoltaic energy applications in public buildings
Action Plan 2	solar photovoltaic energy applications in residential and non-residential buildings
Action Plan 3	green electricity tariffs
Action Plan 4	renovation of street lighting
Action Plan 5	electricity from municipal solid waste

In Sakarya city, the share of electricity in total energy demand and total emissions of public buildings are almost 16.8% and 33.1%. Action Plan 1 offers that utilizing renewable energy sources as the primary energy source for electricity generation in municipal buildings and other public buildings can provide significant energy savings and consequently emission savings. It is likely to put urgent actions in place within Action Plan 1, since public buildings have some advantages in parallel with relevant regulations relating to unlicensed electricity generation based on renewables. Current legislation allows unlicensed applications up to 5 MW installed power (Republic of Turkey Energy Market Regulatory Authority, Electricity Legislation 2019). In this context, the prior target is to install 25,000 kWp solar photovoltaic energy systems in municipal buildings and the other public buildings by 2030. To achieve this target, the first action must be to determine primary and proper buildings for solar PV applications by a full feasibility study. Then, resources must be investigated to ensure the rapid transition to solar PV energy in the selected buildings. Finally, tendering schemes must be developed for installation, operation and maintenance stages by typical project experiences. There are several previous studies, regarding the best installation angles (Tirmikci, CA et al. 2019a) and mechanical preferences of PV systems (Tirmikci, CA et al. 2018b) for Sakarya city, that responsible authorities can easily use to find the best system match for the best building. Taking all actions into account the targeted solar PV capacity will provide at least a sum of 30,000 MWh annual mean electricity generation and 15,402 tCO<sub>2</sub>eq emission savings.

Residential and non-residential buildings are responsible for 41% of total electricity consumption and 40.9% of total energy-based emissions of Sakarya city. Action Plan 2 offers a rapid solar PV energy transition for these buildings by utilizing current legislation allowing unlicensed applications up to 5 MW installed power. As in Action 1, doing a full feasibility study, resource investigation and developing tendering schemes are urgent actions for success. However, the city is in the process of urban transformation within relevant legislation relating disaster risk areas. This process to build new residential areas and to transform the risky building stock can be considered as an opportunity for energy transition. In this context, local governments subsidize PV applications at certain capacities in residential and non-residential buildings to speed up the transition. It is aimed to increase the installed solar PV capacity of residential and non-residential buildings by 175 MWp by 2030. The new capacity promises 240,000 MWh electricity generation and 107,940 tCO<sub>2</sub>eq emission savings annually.

Republic of Turkey Energy Market Regulatory Board approved a green tariff of 0.698 TL/kWh which allows end users to source up their electricity from renewable resources. Action Plan 3 targets to increase renewable energy demand on the end customer side by increasing the number of green tariffs. The

priority of the action plan is to extend greenest tariffs from energy suppliers that buy electricity certificate directly from renewable energy generators. Greenest tariffs tend to be more expensive due to the cost and efficiency of renewable energy generation systems. However, the demand for these tariffs are likely to increase in parallel with social awareness actions within local and national sustainable development plans to convince the end users that this price is worth paying. Besides, it is vital to increase the number of mixed tariffs from suppliers that provide end users mixed electricity from mix of renewable resources and fossil fuels. Although mixed tariffs do not promise to stimulate the development of renewables, they can speed the transition to a hundred percent renewable tariffs in Sakarya city where the number of green end users are very few. It is likely to save 514 tCO<sub>2</sub>eq emissions annually by a 1000 kWh of electricity consumption of an end user from a greenest tariff.

Reports indicate that the share of street lighting in total energy demand of SMM is 15.8% which accounts for 31.184 tCO<sub>2</sub>eq/year. Action Plan 4 targets to reduce the street lighting demands by renovating the street lighting systems. The prior action must be to analyse lighting energy demands and to do a feasibility analysis of lighting systems regionally. In the next step, lighting systems must be renovated as per the order of priority given by feasibility reports. It is likely to provide 18.309 kWh energy savings and 9.41 tCO<sub>2</sub>eq emission savings annually by renovation of at least half of street lighting systems in the city.

SMM generates electricity from municipal solid waste with an installed capacity of 3.87 MW at Sakarya Integrated Solid Waste Management Centre (SEKAY). Action Plan 5 offers that increasing the installed capacity of generation from municipal solid waste can be a rapid solution in short term to decrease the carbon foot print of the city in the process of renewable energy transition in all sectors.

Figure 7 indicates total greenhouse gas emissions of reference year 2017 and 2030. From the figure, it can be concluded that all action plans proposed within SWOT analysis in Table 1 promises to decrease total emissions by 24% compared to 2017 and by 28% compared to 2030 BAU Scenario.

## Conclusion

In Sakarya city, the largest contribution to energy-based emissions comes from building sector, 57.5% of total emissions of the city. Transportation sector follows the building sector with a significant share, 27.5%. This paper presents local action plans to reduce the emissions by building and transport sectors and to support energy transformation set out in National Energy Efficiency Action Plan. Action plans were developed by a SWOT analysis with information gathering the main points of Covenant of Mayors, climate change target of National Energy Action Plan and an online workshop with local stakeholders. The calculations derived from proposed action plans indicate that preventive measures by local government can reduce emission per capita dramatically.

The results of SWOT analysis in this paper emphasize that local policies have the key role to build resilient cities against the climate change combat with economies of scale, environmental sustainability and educated society. The first step for local adaptation and mitigation in climate policy is to develop

complete and accurate greenhouse gas inventories. In this context it is meaningful to real-time monitor and analyse emissions with current technologies like the Internet of Things (IoT) which offer a promising method to real-time monitoring. The next step is to formulate climate change targets and actions considering the cross-link between local adaptation and mitigation. Final steps are monitoring, reporting and developing adaptive local legislations accordingly (Fig. 8). In order to successfully implement climate change mitigation policies and activities, it is important to develop clearly stated assessment and reporting requirements and to develop monitoring methods that will provide performance evaluations. On a local scale, efforts to measure the progress in the practices and the cooperation between local government, private sector and local educational institutions will determine the contribution of local stakeholders and the success rate of sustainable development goals.

## **Declarations**

### **Ethics approval and consent to participate**

Not applicable

### **Consent for publication**

Not applicable

### **Availability of data and materials**

The data that support the findings of this study are available from Sakarya Metropolitan Municipality but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Sakarya Metropolitan Municipality.

### **Competing interests**

The author declare that they have no competing interests.

### **Funding**

Not applicable.

### **Authors' contributions**

Concept – CAT, Data Collection &/or Processing – CAT., Literature Search – CAT., Writing – CAT

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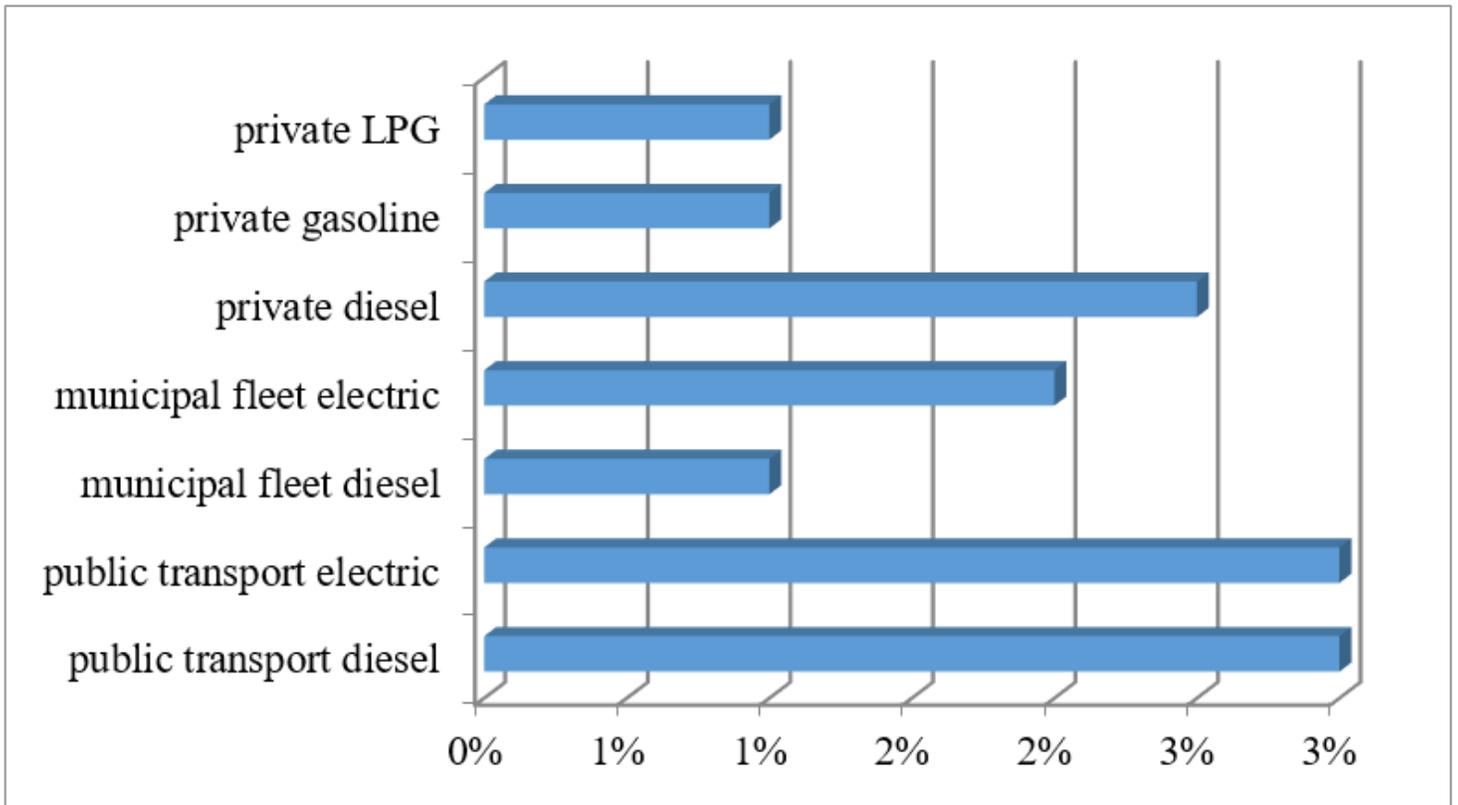
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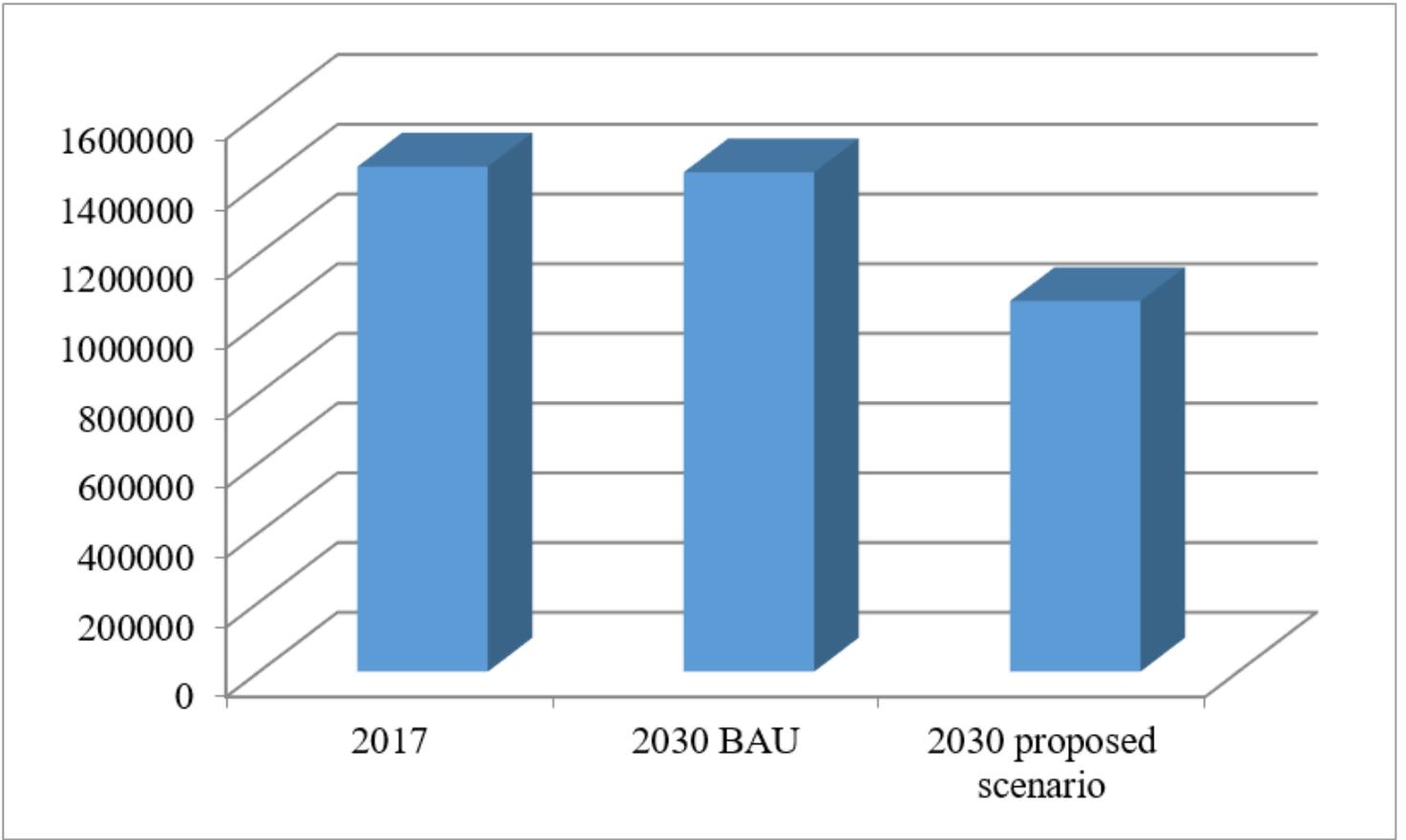
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## Figures



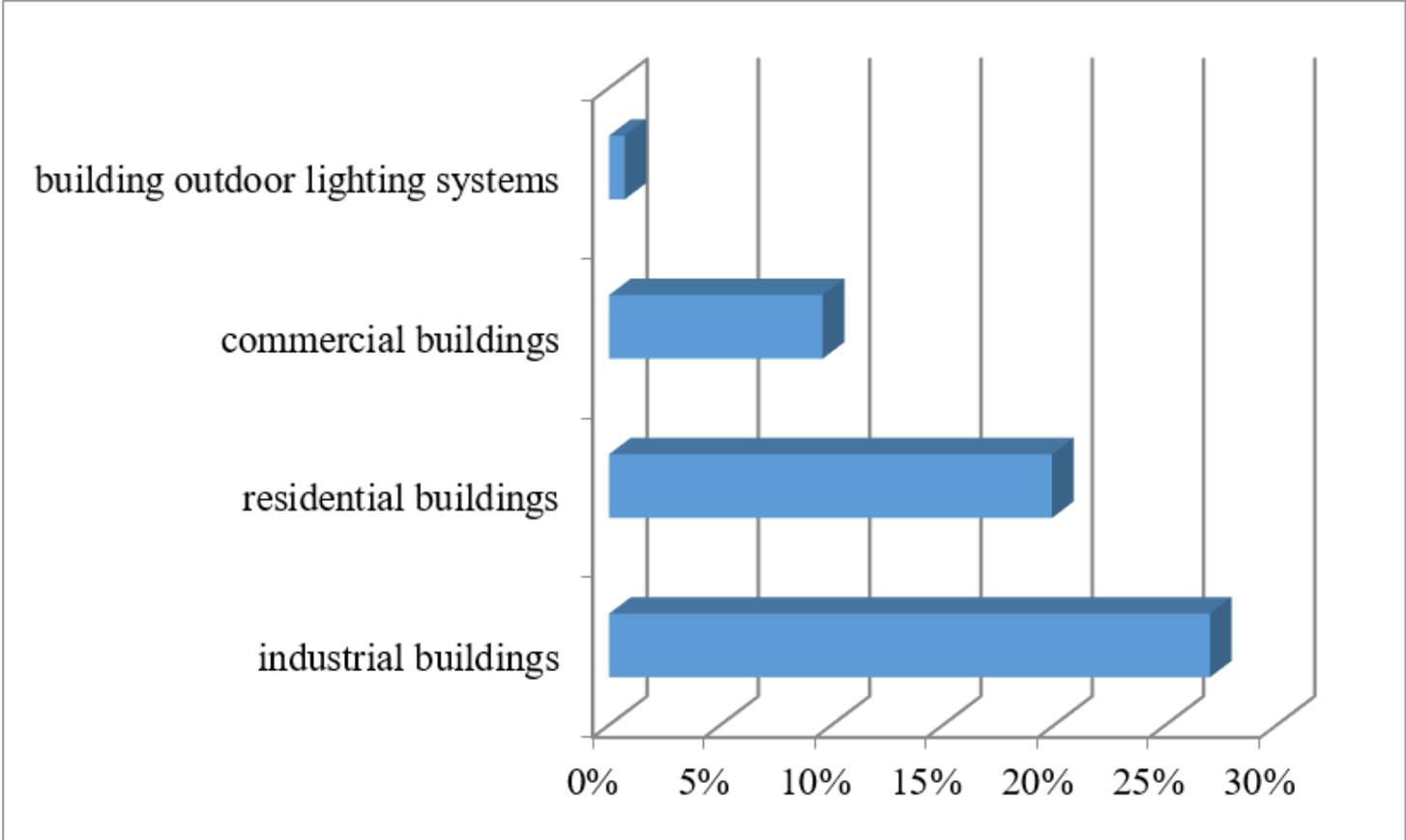
**Figure 1**

Growth rates of greenhouse gas emissions by transport units.



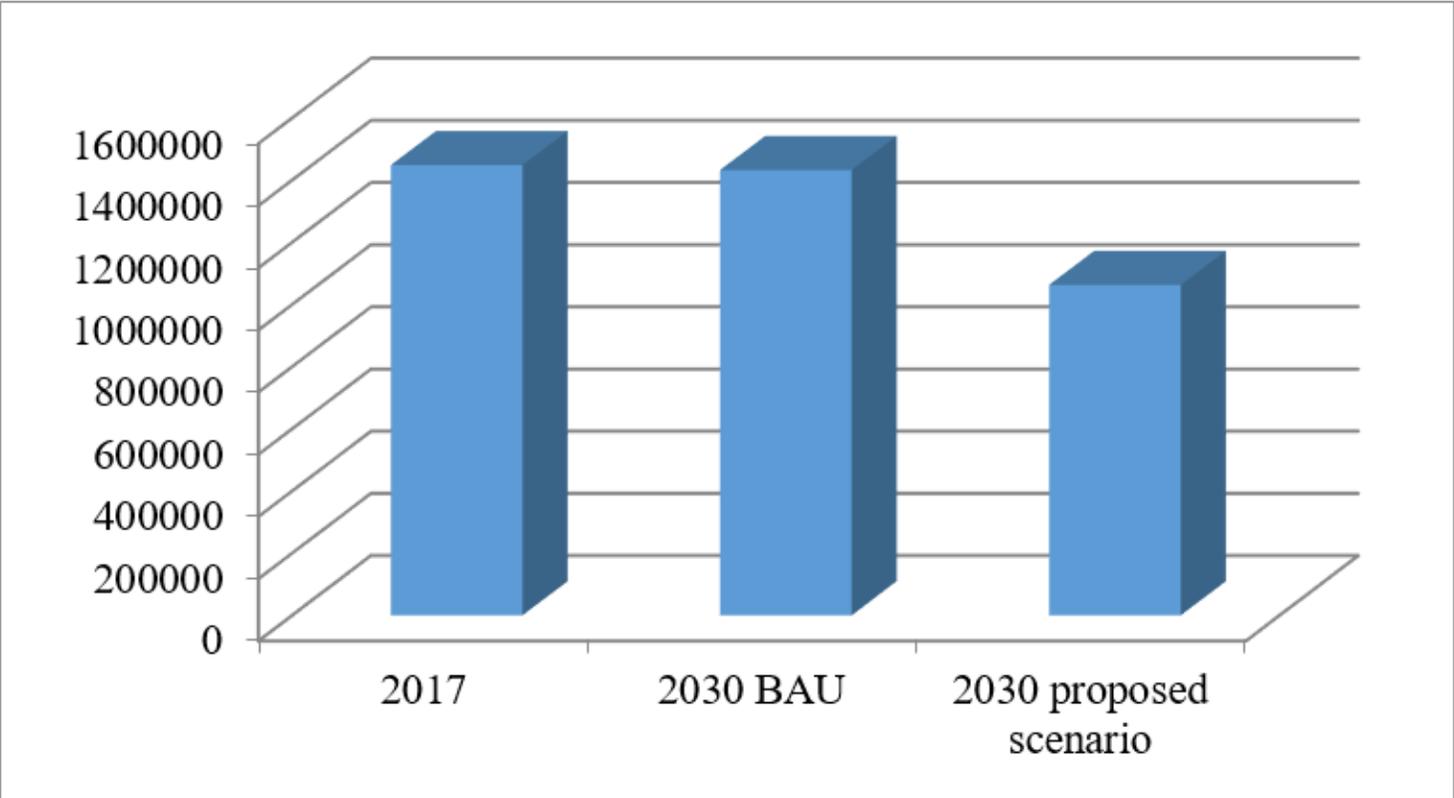
**Figure 2**

Greenhouse gas emissions by transportation sector of 2017, 2030 BAU and 2030 proposed scenario



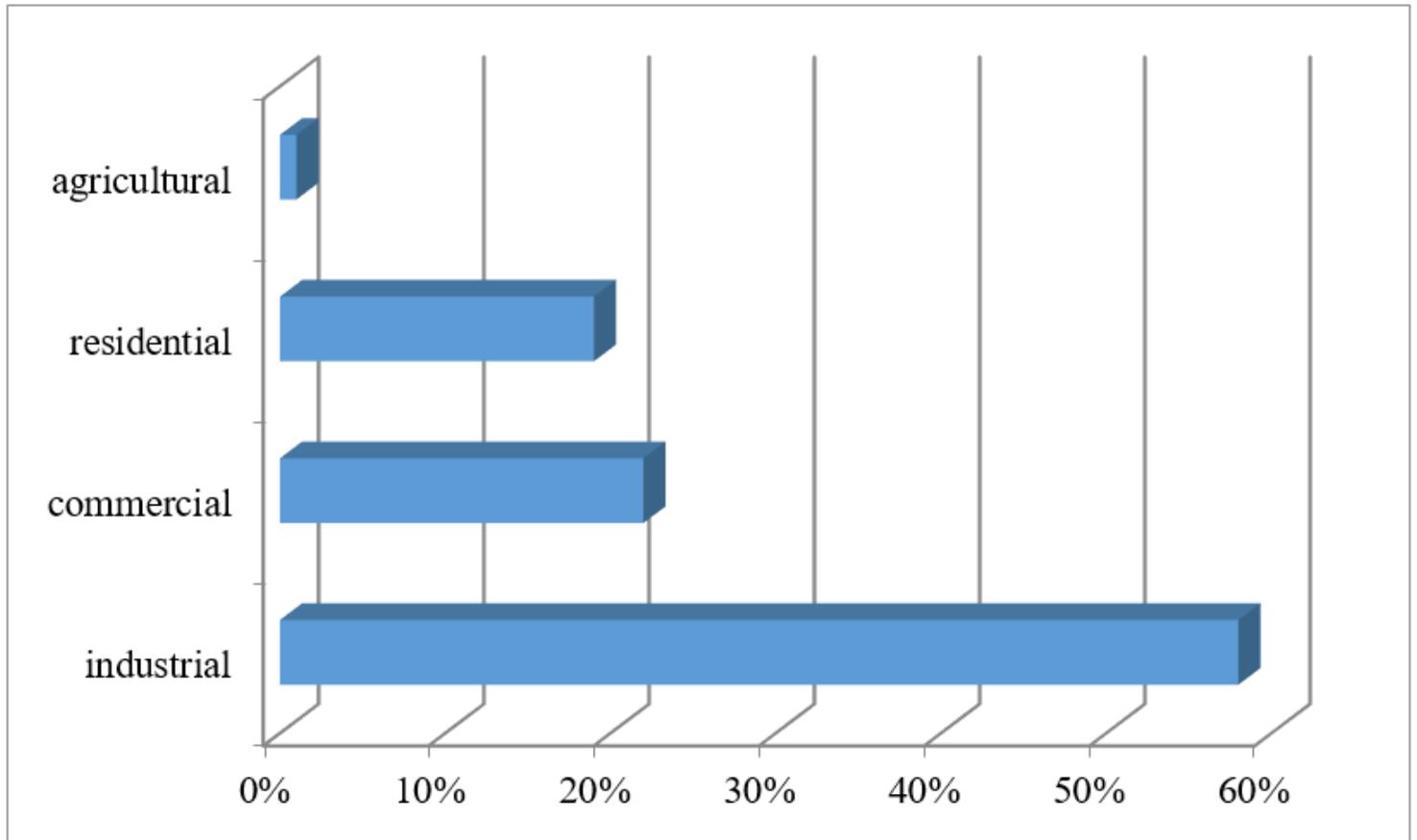
**Figure 3**

Sectoral shares of building based greenhouse gas emissions



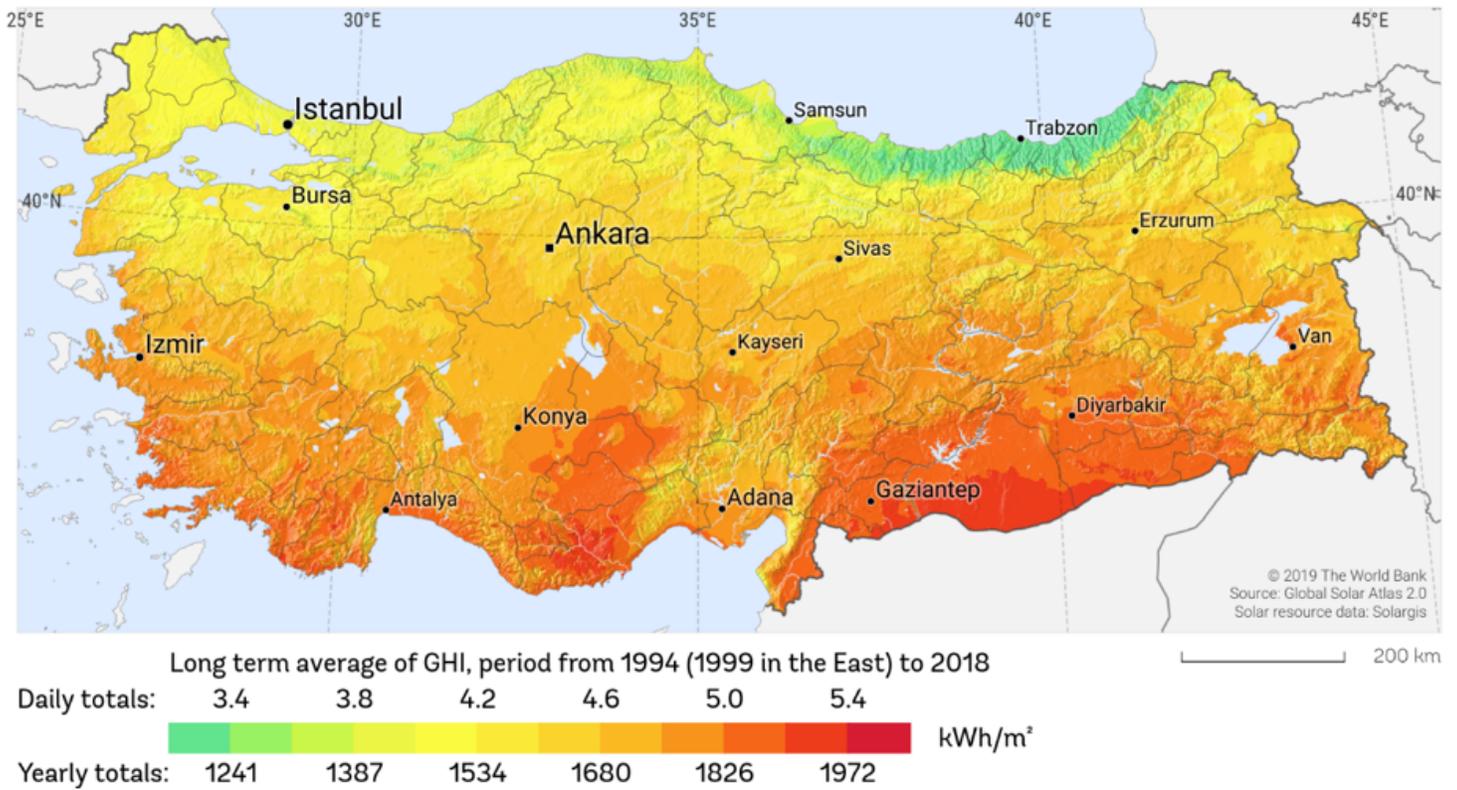
**Figure 4**

Greenhouse Gas Emissions by Buildings Sector of 2017, 2030 Bau and 2030 Proposed Scenario



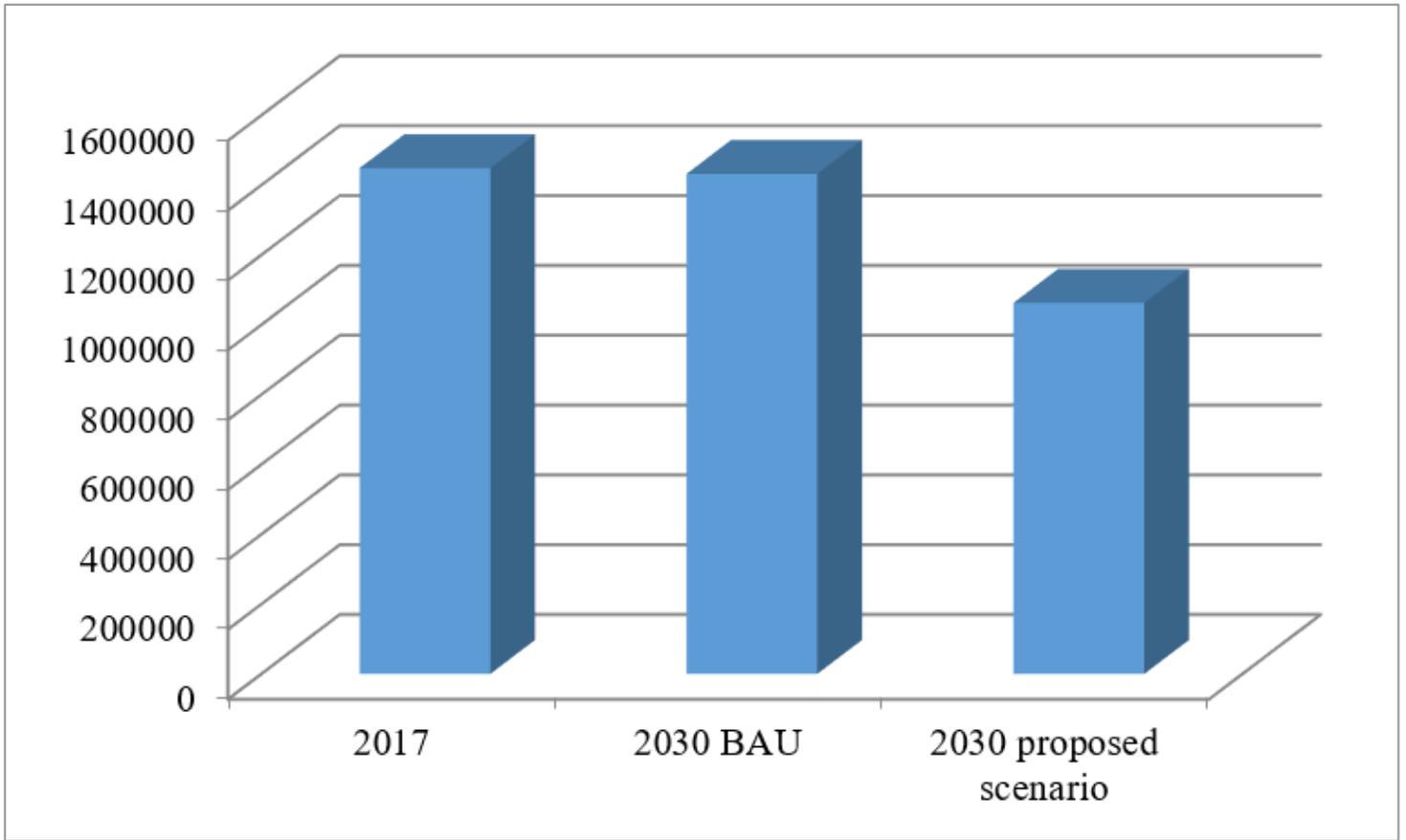
**Figure 5**

Sectoral Shares of Electricity Consumption Based Greenhouse Gas Emissions



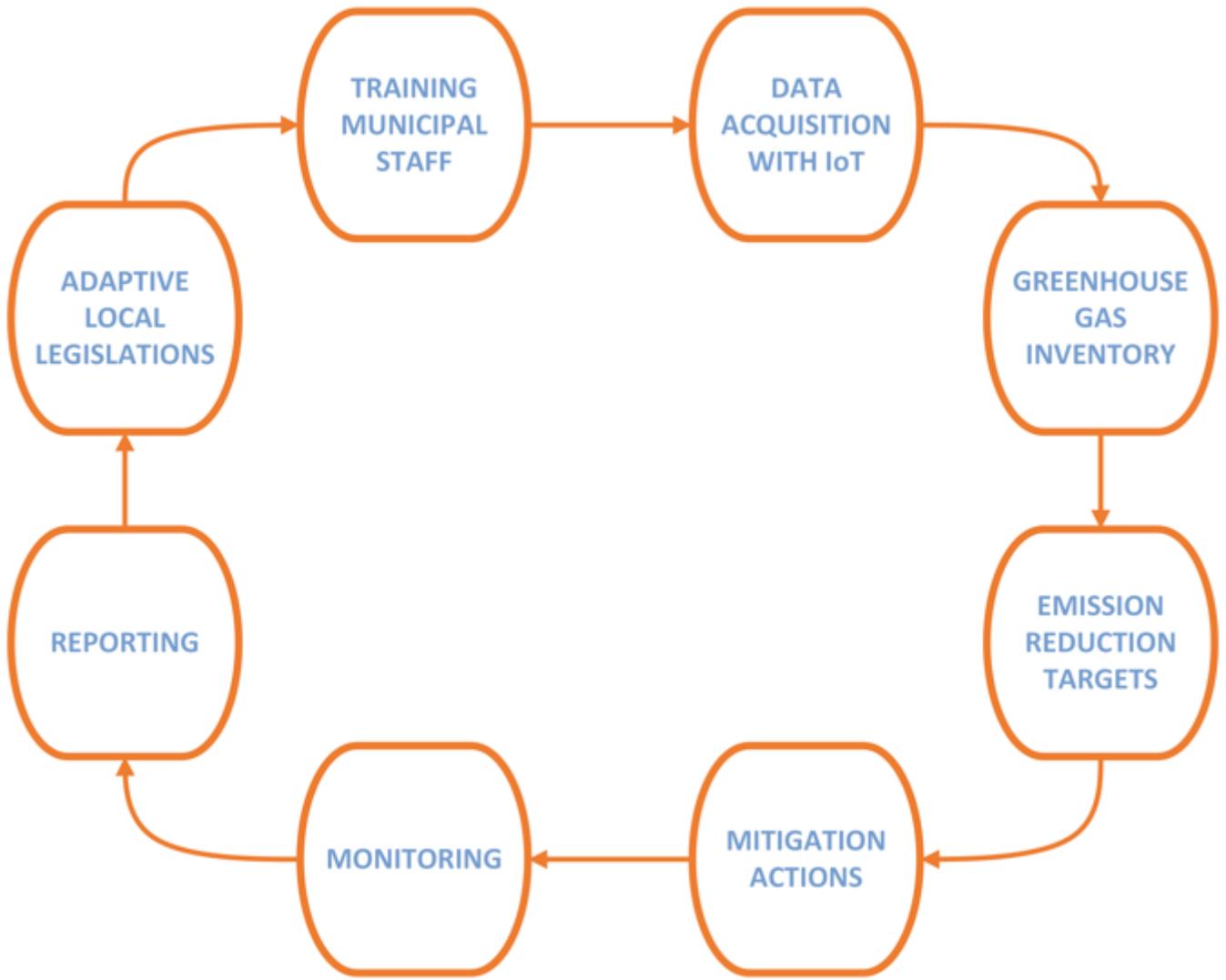
**Figure 6**

Global solar irradiation of Turkey [30] Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.



**Figure 7**

Total Greenhouse Gas Emissions of 2017, 2030 BAU and 2030 Proposed Scenario



**Figure 8**

The proposed local climate change policy cycle