EMISSION TRADING POTENTIAL OF ISTANBUL METROPOLITAN MUNICIPALITY

by

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EMISSION TRADING POTENTIALS OF ISTANBUL METROPOLITAN MUNICIPALITY

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ABSTRACT

EMISSION TRADING POTENTIALS OF ISTANBUL METROPOLITAN MUNICIPALITY

Cities play a significant role in the climate crisis, causing approximately 80% of the world's total GHG emissions. But besides all their destructive effects, cities can take major steps to combat climate change, especially Istanbul as a metropolis. In this study, the renewable energy production potential was examined of Istanbul Metropolitan Municipality, which serves a population exceeding 16 million, has more than 85 thousand employees, and currently has 2 subsidiaries and 30 affiliates. And according to this examination, its emission trading potential was calculated. The study highlights that from 2019 to 2023, IMM's highest carbon trading capacity is also within the EU ETS, valued at USD 163,246,142. If we look at the total saving potential between 2019 and 2023, IMM's most substantial financial savings are found within the Sweden Carbon Tax System, totaling USD 301,642,712. Crucially, to conduct this analysis with precision, a comprehensive understanding of the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, and Türkiye's engagement in these international frameworks is indispensable.

ÖZET

İSTANBUL BÜYÜKŞEHİR BELEDİYESİ'NİN EMİSYON TİCARETİ POTANSİYELLERİ

Şehirler iklim krizinde önemli bir rol oynamakta ve dünyadaki toplam seragazı salımının yaklaşık %80'ine sebep olmaktadır. Ancak tüm bu yıkıcı etkilerinin yanısıra şehirler, özellikle de bir metropol olan İstanbul, iklim değişikliği ile mücadele konusunda büyük adımlar atabilir. Bu çalışmada 16 milyonu aşan bir nüfusa hizmet eden, toplam 85 binin üzerine çalışanı bulunan ve halihazırda toplam 2 bağlı kuruluşu ve 30 iştirak şirketi bulunan İstanbul Büyükşehir Belediyesi'nin yenilenebilir enerji üretim potansiyeli incelenmiş ve bu incemeler doğrultusunda emiyon ticareti potansiyeli hesaplanmıştır. Çalışma, 2019'dan 2023'e kadar olan dönemde İBB'nin en önemli karbon ticaret kapasitesinin 163.246.142 ABD Doları değerinde AB ETS içerisinde olduğu vurgulanmaktadır. 2019-2023 yılları arasındaki toplam tasarruf potansiyeline bakıldığında ise İBB'nin en önemli mali tasarrufu 301.642.712 ABD Doları ile İsveç Karbon Vergisi Sistemi'ndedir. Bu analizi hassas bir şekilde yürütmek için, Birleşmiş Milletler İklim Değişikliği Çerçeve Sözleşmesi (UNFCCC), Kyoto Protokolü ve Türkiye'nin bu uluslararası çerçevelere katılımının kapsamlı bir şekilde anlaşılması çok önemlidir.

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LIST OF SYMBOLS/ABBREVIATIONS

Symbol	**Explanation**
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
$GtCO_2e$	Gigatons of carbon dioxide equivalent
N_2O	Nitrous oxide
tCO_2	Metric tons of carbon dioxide
tCO_2e	Metric tons of carbon dioxide equivalent

Abbreviation	**Explanation**
AAU	Assigned Amount Units
AR5	5th Assessment Report
C40	C40 Climate Leaders Group
CAP	Climate Action Plan
CDM	Clean Development Mechanism
CER	Certified Emissions Reduction Credits
CoM	Covenant of Mayors for Climate and Energy Initiative
CNG	Compressed Natural Gas
COP	Conference of the Parties
EU	European Union
ERU	Emission Reduction Unit
ET	Emission Trading
ETS	Emission Trading Systems
GCoM	Global Covenant of Mayors for Energy and Climate
GEPA	Türkiye Solar Energy Potential Atlas
GHG	Greenhouse Gas
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
ICLEI	Local Governments for Sustainability
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change

IMM	Istanbul Metropolitan Municipality
IETT	Istanbul Electric Tram and Tunnel Company
IGDAŞ	Istanbul Gas and Natural Gas Distribution Inc.
ISKI	Istanbul Water and Sewerage Administration
ISTAC	Istanbul Waste Management Industry and Trade Inc.
JI	Joint Implementation
kWp	Kilowatt-peak
MW	Megawatt
MWh	Megawatt hours
MWhe	Million tons of oil equivalent
MWhfuel	Fuel in terms of megawatt hours
MRV	Monitoring, Reporting, and Verification
MOP	Meeting of the Parties
OECD	Organization for Economic Co-operation and Development
PV	Photo Voltaic
RBCF	Results-Based Climate Finance
RMU	Removal Units
SECAP	Sustainable Energy and Climate Action Plan
UN	United Nations
UNFCCC	The United Nations Framework Convention on Climate Change
USD	United States dollar
WBCSD	World Business Council for Sustainable Development
WMO	World Meteorological Organization
WRI	World Resources Institute

1. INTRODUCTION

In the contemporary world, it is well-established that cities play a substantial role, contributing to nearly 80% of carbon dioxide (CO_2) emissions. The Paris Agreement, with its target of restricting global temperature rise to 1.5-2°C, has underscored the pivotal role of local governments in the battle against climate change—a recognition that marks a significant departure in emphasis (Anjos et al., 2022).

The Intergovernmental Panel on Climate Change (IPCC) further reinforces the urgency of achieving the Paris goals. In its "Special Report on Global Warming of 1.5ºC," the IPCC outlines the potentially devastating consequences of failing to meet these targets. Specifically, the report warns of severe outcomes if the global temperature rises by 2°C above preindustrial levels (IPCC, Special Report: Global Warming of 1.5ºC, 2018).

The recent global extreme climate change events have accentuated the importance of local authorities in times of crisis. Cities have been assumed to be causes and potential solvers of the climate change crisis. This period of global upheaval has prompted a reassessment of the resilience of local authorities in the face of disasters.

In response to these challenges, metropolitan municipalities must urged to take bold and proactive measures to curtail greenhouse gas emissions. By doing so, they can position themselves as leaders and pioneers for other local authorities.

The fundamental purpose of this study is to prepare the institutional inventories of Istanbul Metropolitan Municipality and its affiliate companies, which have great goals in combating climate change, and to find their potential in the emissions trading systems with the help of the prepared institutional inventory.

Istanbul has a critical role in combating climate change as the most populous city in Europe and Türkiye. Istanbul is the financial capital of Türkiye and has a significant impact on the country's overall economic performance, with its population exceeding 16 million.

With these responsibilities, Istanbul Metropolitan Municipality (IMM) is the first and only member in Türkiye of the C40 Big Cities Climate Leadership Group (C40 Cities), one of the most

important local government networks. The "Deadline 2020" Commitment was signed, and Istanbul's goal of becoming a "Carbon Neutral and Resilient City" for 2050 was accepted with C40 membership.

After the Deadline 2020 Commitment, Istanbul improved its target and has been selected by EU Missions: Net Zero Cities as one of the 100 leading cities committed to being a climate-neutral and smart city by 2030.

First, we need to understand The United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol, and Türkiye's place in these conventions to investigate emission trading potentials of Istanbul Metropolitan Municipality and its Affiliate Firms. And then, we must calculate IMM's renewable energy production and emission trading potentials.

2. LITERATURE REVIEW

For the last ten years, approximately 80% of the increasing energy demand has been met by fossil fuels. Carbon dioxide gas, produced from burning fossil fuels, slows the release of heat into space and causes greenhouse gas formation(IEA, World Energy Outlook, 2022) .

Greenhouse gas emissions cause climate change, and air pollution, destroy plant and animal species, and irreversibly damage the functioning of nature. Concern about these possible consequences has encouraged the acceleration of scientific studies on energy efficiency and renewable energy (Narin, 2010). In this direction, while studies on new and renewable energy sources have rapidly intensified, international initiatives such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol have been made to find solutions to climate change and adapt to its effects (Doğan et al., 2021).

While the world economy has grown by an average of 3% per annum since the 1980s, the growth rate slowed after the 2008 global crisis. In 2011, the growth rate was 2.7%. The economic growth rate, which was 3.5% by 2022, is expected to decline to 3.0% in 2023 and 2.9% in 2024 due to the war between Russia and Ukraine and the energy crisis it caused (IMF, World Economic Outlook, 2023).

According to the World Bank, the world population, which was around 5 billion in 1990, reached approximately 8 billion in 2022, and the portion of the urban population increased considerably compared to 1990. The share of the urban population was 42.9% in 1990, reaching 56% in 2022. This share has increased much faster, especially in developing countries. As of 2022, 77% of Türkiye's population lives in cities (World Bank, Carbon Pricing Dashboard, 2023).

The most critical impact of global temperature increase occurs on the climate system. Climate change, which arises due to global warming, also causes changes in the densities of some gases naturally found in the atmosphere, called greenhouse gases, and accordingly, the overheating of the earth and the emergence of some ecological imbalances. (Narin, 2010)

The greenhouse effect intensifies when there is an elevated concentration of certain greenhouse gases in the atmosphere. Primary contributors include carbon dioxide (CO_2) generated through the combustion of fossil fuels, as well as methane (CH_4), nitrous oxide (N_2O), and long-lived industrial

gases released due to land use changes and agricultural activities. Among these gases, CO_2 stands out as the primary gas responsible for magnifying the greenhouse effect. The accumulation of these gases traps heat in the Earth's atmosphere, leading to an increase in global temperatures and contributing to climate change. Addressing and mitigating the impact of these greenhouse gasses are critical components of efforts to combat climate change and promote environmental sustainability (Narin, 2010).

In the United Nations Framework Convention on Climate Change (UNFCCC), climate change is defined as "a change in climate as a result of human activities that directly or indirectly degrade the composition of the global atmosphere, in addition to natural climate changes observed in comparable periods" (United Nations, UNFCCC, 1992).

The notion that changes in the climate could be influenced by an increase in carbon dioxide (CO_2) emissions in the atmosphere was initially proposed by the Nobel Prize-winning Swedish scientist Svante Arrhenius in 1896. Arrhenius, a pioneering physical chemist, was one of the early scientists who investigated the potential connection between industrial activities and global climate patterns (Türkeş, 2006).

In his groundbreaking work, Arrhenius hypothesized that the combustion of fossil fuels, such as coal, could release substantial amounts of CO_2 into the atmosphere, contributing to the greenhouse effect. He suggested that this could lead to an increase in global temperatures over an extended period. Arrhenius's insights laid the foundation for further research and understanding of the link between human activities and climate change, marking a pivotal moment in the history of climate science (Arrhenius, 1896).

Scientific studies on this subject continued until the 1970s, but a climate conference was held for the first time in 1979 under the leadership of the World Meteorological Organization (WMO). As the most important output of the conference, it was announced that the CO_2 gas released due to dependence on fossil fuels would be dangerous. (Narin, 2010)

In 1988, the WMO established the Intergovernmental Panel on Climate Change (IPCC), the first international scientific committee on climate change. In the same year, the Climate Change Decision was taken at the United Nations Assembly, and the issue of climate change was included in the UN agenda for the first time.

With the UNFCCC, which entered into force on March 21, 1994, it has been reported that greenhouse gases of anthropological origin cause damage to people and nature by causing an increase in temperature in the atmosphere, and climate change and its damages are the common concern of humanity. In the same contract, it is stated that the largest share of global greenhouse gas emissions belongs to developed countries and that international cooperation is required due to the global dimension of climate change (Ari, 2013)

In the Annex lists of UNFCCC, countries are divided into groups according to their responsibilities. In the Annex-1 list, countries have the largest share in emissions and are held responsible for emission reduction. The list includes 36 countries transitioning to the market economy, EU countries, and Organization for Economic Co-operation and Development (OECD) countries. Türkiye is included in this list by recognizing special conditions. In the Annex-2 list, 25 countries from OECD countries and EU-15, excluding Türkiye, are responsible for financial support and technology transfer. In the list of non-Annex-1 countries, there are countries such as China, India, Pakistan, Mexico, and Brazil, which are not included in the two lists, and these countries do not have obligations. (Başsüllü & Tolunay, 2014; Çelikkol & Özkan, 2011)

At the 7th Conference of the Parties (COP7) held in Marrakech in 2001, the position of Türkiye, which is in a different position from other countries in the Annex-1 list of the Convention, changed. Türkiye has been included in the Annex-1 list because of its unique conditions (UNFCCC, Report of the Conference of the Parties, 2013). Türkiye officially became a party to this Convention on May 24, 2004.

The Kyoto Protocol represents a pivotal international agreement within the framework of the UNFCCC. Its primary objective is to address the challenges posed by global warming and climate change through a collaborative and coordinated effort among participating nations. The Kyoto Protocol was adopted in Kyoto, Japan, on December 11, 1997 (UNFCCC, Kyoto Protocol, 1997). It entered into force on February 16, 2005, after Russia ratified the agreement with a complex process. There are 192 parties to the Kyoto Protocol, including the European Union (Başsüllü & Tolunay, 2014).

The Kyoto Protocol makes the United Nations Framework Convention on Climate Change work by enabling industrialized and industrializing countries to commit to limiting their GHG emissions following agreed reduction targets. The UNFCCC only asks these countries to adopt policies and measures on mitigation and to report periodically. With the Kyoto Protocol, the functioning of the

contract will be ensured legally (UNFCCC, Kyoto Protocol, 1997). Türkiye signed the Kyoto Protocol on August 26, 2009, as a member of Annex-1 with special conditions.

Developed countries on the UNFCCC Annex-1 list have committed to complying with the emission limits set in the Kyoto Protocol Annex-B list. In the 2008-2012 period, the first commitment period, these countries are obliged to reduce their total greenhouse gas emissions by 5% compared to the base year 1990. In the UNFCCC 18th Conference of the Parties (COP18) and the 8th Meeting of the Parties (COP/MOP8) of the Kyoto Protocol held on 7-8 December 2012 in Doha, the capital of Qatar, the only existing official mechanism regulating the international climate change regime Kyoto Protocol was decided to continue (Başsüllü & Tolunay, 2014; Çelikkol & Özkan, 2011).

Accordingly, the second obligation period of the Kyoto Protocol started on January 1, 2013, and continued until December 31, 2020. While Japan, Canada, Russia, and New Zealand have stated they would not participate in the second obligation period, 27 member states of the European Union, Australia, and Switzerland, among developed countries, have set their emission reduction targets for 2020. (Narin, 2010)

It has been decided that the parties on the Annex-B list will reduce their emissions by at least 18% in 2020 compared to 1990, which is different from the first commitment period. To enter into force, the Kyoto Protocol must be accepted by 144 parties. The Commitment Period (Doha Amendment) became effective on December 31, 2020. On the other hand, since the Paris Agreement, which regulates the post-2020 climate regime, came into effect, the Commitment Period was only procedurally accepted. Therefore, the Kyoto Protocol, the first implementation tool of the UNFCCC, has completed its function (Başsüllü & Tolunay, 2014; Narin, 2010).

By enacting Flexible Market Mechanisms, the Kyoto Protocol aims to reduce anthropogenic GHG emissions that cause climate change at the least cost. However, the unit reduction cost of greenhouse gas emissions also differs according to country; for example, Annex-1 countries will be able to benefit from lower prices. (Narin, 2010)

Flexibility mechanisms outlined by the protocol are technical and economic tools that will help Annex-1 countries meet their GHG emission reduction obligations. They are grouped under three headings: emissions trading (carbon market), clean development mechanism, and joint implementation mechanism (Zhang et al., 2020).

The Clean Development Mechanism (CDM), regulated by Article 12 of the Kyoto Protocol, aims to contribute to the greenhouse gas reduction of Annex-1 countries in line with the sustainable development principle of non-Annex-1 countries. To realize the emission reduction commitment of the parties included in the Annex-1 list, they will obtain "Certified Emissions Reduction Credits (CER)" as a result of the projects they will carry out in non-Annex-1 countries. (Narin, 2010; Benessaiah, 2012)

CDM was created with a dual purpose: first, to diminish greenhouse gas emissions by streamlining the exchange of carbon offsets between industrialized nations that endorsed the Kyoto Protocol and developing countries. Second, it aims to play a role in fostering sustainable development within the host nations.(Benessaiah, 2012)

As of 2023, there are 7844 registered projects in CDM. Until March 2023, 2,313,017,607 certified emission reduction units (CER) have been earned from these projects (UNFCCC, CDM Insight, 2023)

Joint Implementation (JI) Mechanism, regulated by Article 6 of the Kyoto Protocol, allows the parties in the Annex-I list to carry out activities to reduce emissions or eliminate greenhouse gases through sinks (Çelikkol & Özkan, 2011)

The amount of reduction recorded in emissions through projects realized through this mechanism is calculated in the "Emission Reduction Unit" (ERU). The parties benefiting from this project earn ERUs, and these units are deducted from the total account. (Narin, 2010)

The Emission Trading (ET) Mechanism regulated by Article 17 of the Kyoto Protocol allows emissions trading between Annex-1 countries. Thus, one of the countries in the Annex-1 list will be able to trade a part of the emission reduction amount determined in Annex-B (Anjos et al., 2022).

Sold emissions are deducted from the selling country's Assigned Amount Units (AAU) and added to the purchasing country's assigned amount unit. Emissions trading also incentivizes countries to reduce their emissions below their obligations. (Yu et al., 2022)

Carbon dynamics are divided into two In the Kyoto Protocol. The first is the Cap and Trade System, and the second is project-based markets (Ubay & Bilgici, 2021).

With the Cap and Trade System, when a company that emits greenhouse gases due to its field of activity has to exceed its greenhouse gas limit, it can extend its limit by obtaining the right to emit from another emitting company and continue its production despite the limit exceeding. If a company does not exceed its emission quota, it can sell the amount it does not exceed in the carbon market or save it for the following year, (Baltar de Souza Leão et al., 2020).

In project-based markets, an emitted company can expand the quota it will obtain through investments made in different regions and countries or sell these loans in the market. (Narin, 2010)

Moreover, Certified Emission Reduction Units (CERs), which are issued for initiatives stemming from Clean Development Mechanism (CDM) projects, and Emission Reduction Units (ERUs), issued for projects arising from Joint Implementation (JI) initiatives, can be actively traded in carbon markets. Additionally, the offsetting of emissions is achievable through the utilization of Removal Units (RMUs), which are obtained through activities related to carbon sink initiatives (World Bank, State and Trends of Carbon Pricing, 2023).

The advent of carbon trading, spurred by the Kyoto Protocol, along with the subsequent proliferation of carbon markets and carbon taxes on a global scale (Aliusta et al., 2016), underscores the essential need for systematically recording, monitoring, reporting, and controlling carbon emissions into the atmosphere (Uyar & Cengiz, 2011). This imperative has given rise to the emergence of the concept of carbon pricing, situated as a sub-branch within the realm of environmental accounting. (Gürbüz et al., 2019)

In essence, the implementation of carbon trading mechanisms and the widespread adoption of carbon markets and taxes underscore the recognition that effective management of carbon emissions requires a systematic approach. This involves not only quantifying the amount of carbon released but also establishing robust mechanisms for ongoing monitoring, accurate reporting, and effective control measures. The integration of carbon pricing into the broader field of environmental accounting reflects the acknowledgment of the economic dimension inherent in addressing and mitigating the environmental impacts of carbon emissions. (Gürbüz et al., 2019)

Carbon pricing is a designed tool to account for the external costs associated with GHG emissions. These external costs represent the public's expenses due to emissions, such as crop damage, healthcare expenses linked to heatwaves and droughts, and property loss caused by flooding

and rising sea levels. The essence of carbon pricing lies in connecting these costs directly to their sources by imposing a price, typically in the form of a fee, on the emitted CO_2 (Gürbüz et al., 2019).

By implementing a carbon price, the intention is to shift the responsibility for the damages resulting from GHG emissions back to the entities responsible for them and capable of mitigating them. Rather than prescribing specific emission reduction measures and locations, a carbon price offers an economic signal to emitters. This enables them to choose either to transform their activities, thereby reducing emissions, or to persist in emitting while shouldering the associated costs. Consequently, the overarching environmental objective is achieved with flexibility and at the least cost to society (Palatnik et al., 2023).

The significance of establishing an appropriate price on GHG emissions cannot be overstated. It plays a fundamental role in internalizing the external costs of climate change across a broad spectrum of economic decision-making processes. By aligning economic incentives with clean development, carbon pricing can mobilize the financial investments necessary to drive innovation in clean technology and markets. This, in turn, can catalyze the emergence of new, low-carbon drivers of economic growth.

Carbon pricing manifests in diverse forms and structures, denoting initiatives explicitly designed to assign a monetary value to GHG emissions. This value is typically expressed as a cost per ton of carbon dioxide equivalent (tCO_2e). Among the various carbon pricing approaches, two prominent methods include emissions trading systems (ETS) and carbon taxes.

An ETS provides a level of certainty regarding the environmental impact of emissions by setting a cap on total emissions and allowing entities to trade allowances. This flexibility in emission trading helps achieve emission reductions cost-effectively. Conversely, a carbon tax ensures a fixed carbon price within the economic system, offering certainty about the cost implications but introducing uncertainty about the resulting environmental outcomes.

Several key factors significantly influence the effectiveness of emission trading systems (ETS). Two primary drivers are (1) the long-term costs associated with emission reduction efforts and (2) the effects of emissions on energy prices and energy demand, as highlighted by (Gulli & Chernyavs'ka, 2013). Notably, the price of carbon emission permits plays a pivotal role in the overall abatement costs for enterprises.

Carbon emission permits represent a critical component of enterprises' abatement costs, and organizations are faced with crucial decisions in response to the pricing dynamics. Enterprises can purchase carbon emission permits or invest in developing their technologies for reducing carbon emissions. This decision-making process is intricately tied to the prevailing carbon price and the desired level of emission reductions. The flexibility provided by the carbon market allows enterprises to strategize and choose the most cost-effective approach—be it acquiring permits or investing in innovative emission reduction technologies—in alignment with the prevailing carbon prices and their specific emission reduction goals. (Chen et al., 2021)

In addition to ETS and carbon taxes, other substantial carbon pricing mechanisms include results-based climate finance (RBCF) and internal carbon prices established by organizations. RBCF involves financial incentives tied to achieving measurable emission reduction outcomes. Internal carbon prices set by organizations serve as an internal mechanism for valuing emissions and steering decision-making towards lower carbon alternatives. (Lin & Huang, 2022)

The imperative to scale up GHG emission reductions and reduce the cost of mitigation is paramount for the successful decarbonization of economies (Araújo et al., 2020). Given the magnitude and urgency of the climate challenge, a comprehensive array of carbon pricing approaches is essential. These approaches should be complemented by supportive policies and regulations to collectively address the complexities of transitioning to a low-carbon future.

The carbon market is an economic platform for trading carbon credits, which are certificates awarded for reducing greenhouse gases like CO_2 to combat global climate change. The carbon market imposes financial disincentives on entities exceeding established emission thresholds while providing economic rewards to those maintaining emissions below these limits. This system aims to minimize GHG emissions cost-effectively (Nguyen et al., 2019).

Furthermore, the carbon market facilitates global carbon trading by assigning property rights to quantified pollution units. This mechanism incentivizes enterprises to adopt clean technologies by economically favoring activities that result in lower greenhouse gas emissions (Nguyen et al., 2019).

Carbon markets are divided into mandatory Kyoto Protocol flexibility mechanisms and voluntary ones. Mandatory carbon markets allow countries to reduce their emissions at low cost with the flexibility mechanisms defined in the Kyoto Protocol. Voluntary Carbon Markets have been established in order to facilitate the balancing of voluntary reduction of greenhouse gas emissions

resulting from the activities of institutions and organizations, companies, and non-governmental organizations (Çelikkol & Özkan, 2011).

Voluntary carbon markets come with both advantages and disadvantages. On the positive side, voluntary markets offer lower business costs, streamline bureaucratic procedures, foster creativity and innovation, especially for smaller projects, and provide flexibility to support limited types of initiatives (Bayon et al., 2009; Benessaiah, 2012). The benefits include a more accessible pathway for various entities to engage in carbon offset projects, encouraging a diverse range of initiatives that may not be feasible under more rigid regulatory frameworks (Ari, 2013).

For example, IMM has sold carbon credits to the International Voluntary Carbon Market, under the supervision of Gold Standard, many times with ISTAC, one of its subsidiaries. ISTAC first contacted the European Carbon Exchanges in March 2020 and made its first sale. ISTAC sold a total of 320 thousand tons of carbon credits in the four months following this sale and increased its total carbon credit sales to 1 million 625 thousand tons by the end of 2020. IMM earned this amount of carbon credits by producing energy from solid waste in landfills (ISTAC, 2020 Annual Report, 2021).

With the Waste Incineration and Energy Production Facility put into service with the Gold Standard project registration in 2021, an average of 1.5 million more tons of carbon credits have been obtained annually. All of these calculations were made according to the Baseline Estimate (ISTAC 2021 Annual Report, 2022).

However, voluntary carbon markets also present notable challenges. One major drawback is fragmentation, where the absence of standardized regulations and oversight mechanisms leads to a decentralized landscape. This can result in poor coordination among different projects and market participants. Additionally, the absence of efficient regulation and monitoring mechanisms can contribute to insufficient information, hindering transparency and trust in the market. The certification, verification, and registration procedures in voluntary carbon markets may lack uniformity, further complicating project assessment of the environmental impact and credibility (Bayon et al., 2009). The absence of standardized practices can potentially undermine voluntary carbon markets' overall effectiveness and integrity (Ari, 2013).

The EU Emissions Trading System forms the basis of EU climate policy and global carbon markets in the face of economic fluctuations (Diaz-Rainey & Tulloch, 2018).

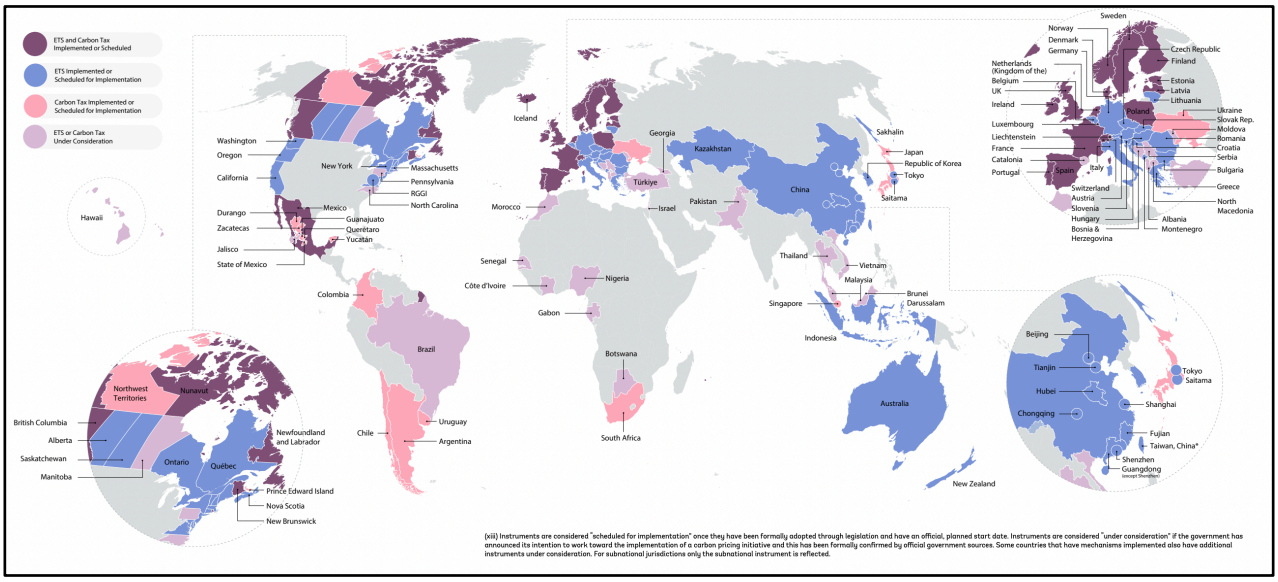


Figure 2.1. Summary map of regional, national, and subnational carbon pricing initiatives. (World Bank, State and Trends of Carbon Pricing, 2023)

Figure 2.1. shows that 73 carbon pricing initiatives were active in 2023. Of these 73 initiatives, 39 are under national jurisdictions, and 33 are under subnational jurisdictions. These initiatives in 2023 represent 11.66 $GtCO_2e$ as 23% of global greenhouse gas emissions (World Bank, Carbon Pricing Dashboard, 2023).

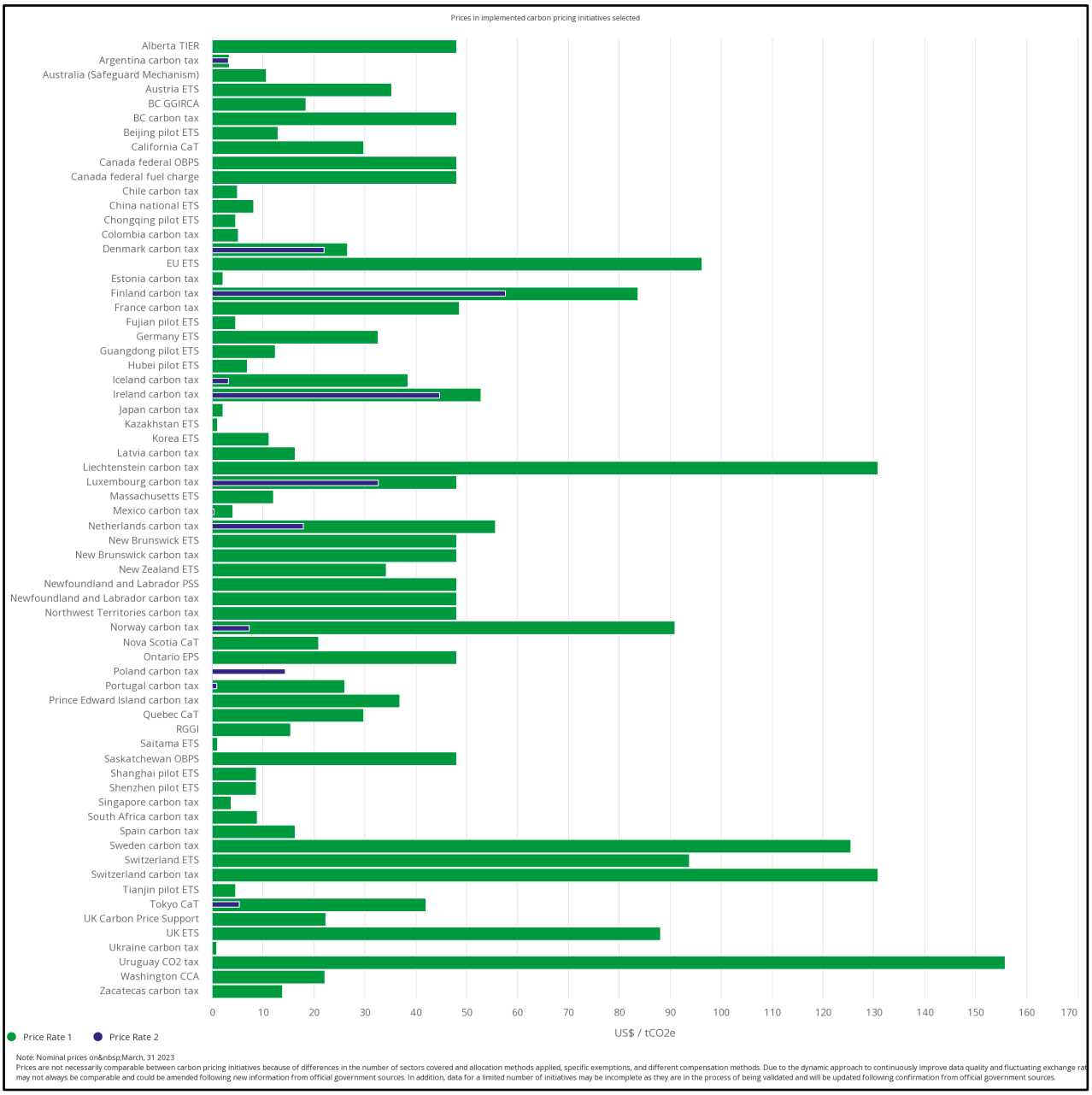


Figure 2.2. Prices in implemented carbon pricing initiatives selected. (World Bank, Carbon Pricing Dashboard, 2023)

Figure 2.2. from the World Bank Carbon Pricing Dashboard was updated in March 2023 and shows the 66 carbon pricing systems and prices currently traded. Of these 66 systems, only the EU Emissions Trading System is regional, and 26 of the remaining 65 are subnational.

Türkiye, not bound by any greenhouse gas reduction commitments under the Kyoto Protocol, cannot leverage the flexibility mechanisms associated with emission trading within the protocol. Despite this limitation, Türkiye has actively engaged in projects within the Voluntary Carbon Markets, operating independently of the Kyoto Protocol's mechanisms. These initiatives are

established based on principles of environmental and social responsibility and have been underway since 2005 (The Republic of Türkiye Ministry of Environment, Urbanization, and Climate Change, Carbon Marketing in Türkiye 2012).

Remarkably, there are currently 308 projects being traded in the Voluntary Carbon Markets. Notably, 42% of these projects are centered around hydroelectric initiatives, while wind projects constitute 39% of the total. This is underscored by Türkiye's commitment to voluntary efforts aimed at environmental and social responsibility, contributing to the broader global efforts in addressing climate change (The Republic of Türkiye Ministry of Environment, Urbanization, and Climate Change, Carbon Marketing in Türkiye 2012).

The Voluntary Carbon Market Project Registration Communiqué, prepared for the registration of projects within the Voluntary Carbon Market developed in Türkiye and for the monitoring of the carbon certificates derived from these projects, officially came into effect following its publication in the Official Gazette No. 28790 on October 9, 2013. This regulatory framework establishes the guidelines and procedures for registering and tracking projects in the Voluntary Carbon Market in Türkiye, adding a structured and official dimension to the country's commitment to managing and mitigating carbon emissions through voluntary initiatives (Başsüllü & Tolunay, 2014).

The policy measures being considered in energy efficiency, renewable energy sources, and urban waste management offer positive prospects for reducing s GHG emissions in Türkiye. Assessments of the cumulative potential for emission mitigation from 2013 to 2020 across these critical sectors have highlighted their pivotal role in national strategies to address climate change (Ari, 2013).

According to Ari's findings, the estimated cumulative emission mitigation potential for the energy efficiency sector during this period stands at 402.66 million tons. Additionally, the renewable energy sector is projected to contribute significantly, with an estimated mitigation potential of 312.93 million tons. The waste sector, including municipal waste management, demonstrates a noteworthy mitigation potential as well, with an estimated 356.24 million tons (Ari, 2013).

When combined, these figures reveal a substantial overall mitigation potential of 1,071.83 million tons cumulatively across the three sectors. This underscores the significance of adopting and implementing policies in energy efficiency, renewable energy, and waste management to effectively mitigate greenhouse gas emissions and contribute to overall environmental sustainability in Türkiye.

Türkiye has taken important steps in addressing GHG emissions through adopting monitoring, reporting, and verification (MRV) legislation in 2012. In 2015, Türkiye initiated the surveillance of GHG emissions from sizable facilities, an essential advancement in the nation's regulatory approach to managing emissions. This legal framework introduces a MRV system at the installation level, focusing on CO_2 emissions. This system encompasses around 900 entities within the energy sector and diverse industrial sectors. (World Bank, Country Climate and Development Report: Türkiye, 2022).

Since 2013, Türkiye has actively collaborated with the Partnership for Market Readiness to enhance MRV regulations. This collaboration involves pilot studies in crucial sectors such as energy, cement, and refineries. A sequence of workshops and analytical research efforts have been undertaken to investigate and enhance market-oriented instruments, centering on the prospective establishment of an ETS (World Bank, Country Climate and Development Report: Türkiye, 2022).

In December 2020, Türkiye took a significant stride by publishing the final draft of the legal and institutional framework for a pilot ETS. Additionally, technical workshops held throughout 2020 played a crucial role in shaping the government's decisions regarding emissions caps, the development of a national allocation plan, the establishment of a transaction registry for the pilot ETS, and the creation of an ETS simulation known as Turk-SIM (World Bank, State and Trends of Carbon Pricing, 2023).

On February 17, 2021, the Republic of Türkiye Ministry of Environment, Urbanization, and Climate Change announced the implementation of a national ETS. However, specific details regarding the start date, including the commencement of a pilot ETS, were not provided then. This indicates Türkiye's commitment to advancing its climate change mitigation efforts by introducing market-based mechanisms and establishing a comprehensive regulatory framework for emissions trading (World Bank, State and Trends of Carbon Pricing, 2023).

3. MATERIALS AND METHODS

Calculating a metropolitan municipality's potential in a carbon emission trading system involves assessing its current emissions, understanding the regulatory environment, estimating potential cost and energy savings or revenue from trading carbon credits, and identifying opportunities for emission reduction.

3.1. Baseline Emission Inventory Calculation

The reference year for a GHG inventory is the year to be compared with the years that the agency's reduction targets have been committed. The EU has committed to reducing emissions by 40% by 2030 compared to 1990, and 1990 is the year that the Kyoto Protocol references. The EU and the signatories of the Covenant of Mayors need a typical reference year to compare emission reductions. Since Istanbul Metropolitan Municipality is a member of GCoM, it has accepted the targeted 40% reduction rate by 2030. The recommended base year for the greenhouse gas emissions inventory by GCoM is 1990. However, the local government does not have data to create an inventory for 1990. In that case, choosing the following year nearest to which the most comprehensive and reliable data can be collected is recommended (GPC, Global Protocol for Community-Scale Greenhouse Gas Inventories, 2021).

Many cities from different regions of the world that are members of the C40 Climate Leaders Group are guiding cities in the combat against climate change. Members in this group have undertaken the Deadline 2020 Commitment that their cities aim to be carbon neutral and resilient by 2050.

Istanbul Metropolitan Municipality, Türkiye's first and only C40 member city, accepted the aim to make Istanbul a carbon-neutral and climate change-resistant city by 2050, signing the Deadline 2020 Commitment in October 2019.

IMM revised the Climate Action Plan (CAP) in 2021 within the scope of the Commitment signed in 2019. The base year of this action plan has been accepted as 2019. For this reason, 2019 was taken as the base year of IMM's and its subsidiaries' institutional inventory. The GHG inventory data included in this study is based on IMM's 2019 Institutional GHG Inventory prepared within the Istanbul Sustainable Energy and Climate Action Plan (SECAP) scope.

Greenhouse gas inventories show the emission levels emitted on activities of different sectors during a year by collecting detailed data on different types of greenhouse gases and their sources. Once the GHG Inventory is obtained, public institutions and private sector members can determine future climate change adaptation, mitigation actions, and commercial use of GHG emissions.

3.1.1. Inventory Methods

GHG Inventory preparation methods vary considerably from one another. This inconsistency makes comparisons between cities, institutions, etc., complex, calls into question data security, and limits the ability to aggregate local, subnational, and national governmental greenhouse gas emissions data.

Greater consistency in GHG accounting is required for reliable and meaningful GHG inventory reporting. While preparing the institutional inventory of IMM, the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) Basic Method, which is used based on cities worldwide, was used.

GPC is a protocol created by the World Resources Institute (WRI), C40, and Local Governments for Sustainability (ICLEI). The GPC is designed to account for greenhouse gas emissions in a single reporting year and covers the seven gases the Kyoto Protocol covers. The GPC provides a clear framework for controlling and reporting citywide greenhouse gas emissions.

3.1.2. Categorizing Emissions By Scopes

Activities within a city or institution may release greenhouse gas emissions within and outside the city/institution's boundaries. To differentiate them, GPC groups emissions according to their source into three categories: Scope 1, Scope 2, and Scope 3 emissions.

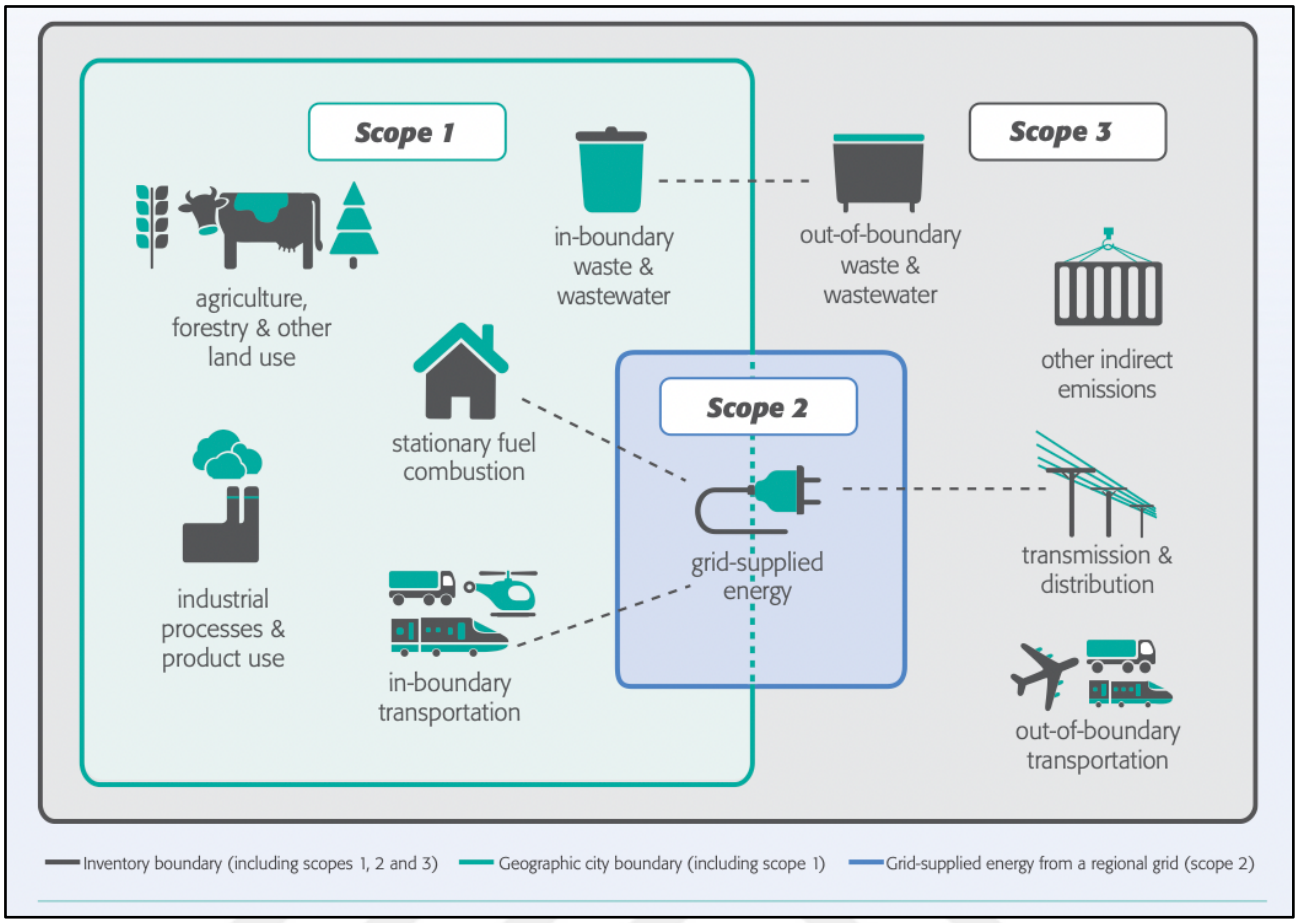


Figure 3.1. Main scopes of GHG inventory according to GPC. (GPC, Global Protocol for Community-Scale Greenhouse Gas Inventories, 2021)

Sectors and sub-sectors	Scope 1	Scope 2	Scope 3
STATIONARY ENERGY			
Residential buildings	✓	✓	✓
Commercial and institutional buildings and facilities	✓	✓	✓
Manufacturing industries and construction	✓	✓	✓
Energy industries	✓	✓	✓
Energy generation supplied to the grid	✓		
Agriculture, forestry, and fishing activities	✓	✓	✓
Non-specified sources	✓	✓	✓
Fugitive emissions from mining, processing, storage, and transportation of coal	✓		
Fugitive emissions from oil and natural gas systems	✓		
TRANSPORTATION			
On-road	✓	✓	✓
Railways	✓	✓	✓
Waterborne navigation	✓	✓	✓
Aviation	✓	✓	✓
Off-road	✓	✓	
WASTE			
Disposal of solid waste generated in the city	✓		✓
Disposal of solid waste generated outside the city	✓		
Biological treatment of waste generated in the city	✓		✓
Biological treatment of waste generated outside the city	✓		
Incineration and open burning of waste generated in the city	✓		✓
Incineration and open burning of waste generated outside the city	✓		
Wastewater generated in the city	✓		✓
Wastewater generated outside the city	✓		
INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)			
Industrial processes	✓		
Product use	✓		
AGRICULTURE, FORESTRY AND OTHER LAND USE (AFOLU)			
Livestock	✓		
Land	✓		
Aggregate sources and non-CO_2 emission sources on land	✓		
OTHER SCOPE 3			
Other Scope 3			

✓ Sources covered by the GPC

Sources required for BASIC reporting

Sources required for BASIC+ reporting

Sources required for territorial total but not for BASIC/BASIC+ reporting (*italics*)

Sources included in Other Scope 3

Non-applicable emissions

Figure 3.2. Scopes and sources of GHG inventory covered by GPC. (GPC, Global Protocol for Community-Scale Greenhouse Gas Inventories, 2021)

- Scope 1: Direct Emissions Vehicles, facilities, buildings, etc., in the city. fuel consumption in places
- Scope 2: Indirect Emissions Electricity purchased from the grid and consumed in the city energy for heating/cooling
- Scope 3: Indirect (Consumption Based) Emissions Products or services purchased by residents of the city production/shipping

During the preparation of the inventory, it was tried to reach the maximum amount of data by scanning all emission sources within the jurisdiction of the municipality, but since the data under Scope 3 could not be compared, the emissions classified under Scope 1 and Scope 2 were included in the inventory.

3.1.3. Selection of sectors included in the GHG inventory

Local governments can include all relevant sectors in the GHG inventory preparation process. However, according to C40 and GCoM, local governments should consist of greenhouse gas emissions from at least three main sectors in their inventory: buildings/stationary energy, transportation, and waste/other non-energy sectors.

While preparing IMM's institutional GHG inventory, Building-Stationary Energy, Transportation, Waste, and Water-Wastewater sectors were included to meet C40 and GCoM standards.

In the IMM’s Institutional GHG Inventory, all final energy consumption and related greenhouse gas emissions occurring in IMM and affiliates' management buildings and facilities, all final energy consumption (and associated GHG emissions) resulting from the operation of the Municipal water supply system, solid waste, and wastewater treatment and disposal facilities.) and greenhouse gases from public lighting are included in the Buildings/Stationary Energy sector.

In the institutional inventory of IMM, the transportation sector includes all GHG emissions from the use of fuel and energy supplied from the grid for transportation by the Municipality's fleet, as well as all GHG emissions from the use of fuel and energy provided by the grid for transportation by land, rail, and sea public vehicles, which are the responsibility of IMM.

GHG emissions unrelated to energy consumption, such as CH_4 and N_2O released from wastewater treatment plants, are included in the water/wastewater sector's institutional inventory of IMM.

Greenhouse gas emissions unrelated to energy consumption, such as CH_4 originating from landfills, are included in the IMM waste sector institutional inventory.

Activity data quantify social service and personnel activities occurring within the institutional boundaries of IMM. The total energy consumption amount was obtained by converting the energy and fuel consumed by IMM and its subsidiaries into MWh. Activity data include electricity and natural gas consumed in municipal buildings and oil consumed by enterprise vehicles.

Emission factors are coefficients that quantify emissions per unit of activity. Emissions are estimated by multiplying the emission factor with the relevant activity data. Examples of emission factors are:

- The amount of CO_2 released per MWh of natural gas consumed
- The amount of CO_2 released per MWh of electricity consumed
- The amount of CO_2 released per MWh of fuel consumed

IMM had 28 subsidiaries and two affiliates in 2019. Energy, transportation, waste management, and water/wastewater consumption data were collected from these subsidiaries and affiliates during the institutional GHG inventory process.

While preparing the institutional inventory of IMM, the Building and Stationary Energy sector data were obtained from the IMM “Support Services Department,” İGDAS, and “Energy Management and Lighting Directorate.” Also, the Energy Management and Lighting Directorate, Istanbul Energy, Istanbul Transportation, IMM Transportation Department, IMM Rail Systems Department, Metro Istanbul., IETT, Sehir Hatları, and IMM Support Services Department provided the data on the transportation sector. Data on the Waste and Water/Wastewater sectors were obtained from IMM Waste Management Directorate, ISTAC ., and ISKI.

The analysis of institutional-scale GHG emissions representing local government activities includes GHG emissions from all major organizations and services under the municipality. All

emissions from the actions of local government and subsidiaries are included in the IMM's Institutional GHG Inventory, regardless of where the emissions occur.

IMM is responsible for services such as public transportation, waste management and transportation to the disposal area, drinking water supply, sewage system and wastewater treatment, green areas and recreation areas, road construction/maintenance/repair, city and regional planning. IMM also has power generation facilities (primarily solar and waste energy is produced); on the other hand, urban electricity generation, transmission, distribution, or public street lighting is not the responsibility of IMM.

3.1.4. Computational Approach

The institutional greenhouse gas emission inventory of IMM was calculated with an approach according to the GHG Protocol developed by WRI and the World Business Council for Sustainable Development (WBCSD), and GCoM Reporting Guidelines.

In these protocols, emissions are classified into three categories:

- Scope 1 – direct greenhouse gas emissions: These are emissions from all fixed and mobile emission sources owned or directly controlled by the organization. These resources include assets owned, leased, or financed. The scope limit is all controllable emission sources.

- Scope 2 – indirect energy consumption GHG emissions: Emissions from energy purchased for the organization's operations, electricity supplied from the grid, and other energy used for heating/cooling purposes.

- Scope 3 – other indirect greenhouse gas emissions: Emissions from the organization's core activities, employee travel, or outsourced activities. The level and quality of data available should determine activities included in this scope.

Scope 3 is not included in the IMM's Institutional GHG Inventory since detailed and sub-categorized data for 2019 are unavailable in IMM directorates and affiliates, and data cannot be obtained. The IMM's Institutional Inventory was prepared for stationary energy, transportation, and waste-wastewater sectors following Scope 1 and Scope 2.

In the stationary energy sector, the energy consumption of all commercial and institutional buildings and facilities, production and construction services, agricultural irrigation, and natural gas systems leakage of IMM, its subsidiaries, and affiliates are included.

In the transportation sector, the amount of fuel consumed in the vehicle fleets of IMM, its subsidiaries, and affiliates on the road, maritime, and railways, and in the public transportation services they provide are included. In particular, the data of IETT, which is responsible for Istanbul's road public transportation, Sehir Hatları, which is responsible for Istanbul's maritime public transportation, and Metro Istanbul, which is responsible for Istanbul's railway's public transportation, were used.

The waste sector includes greenhouse gas emissions from the disposal of total wastes produced by IMM, its subsidiaries, and affiliates with solid waste treatment, incineration, and biological treatment, and the treatment of total wastewater produced by IMM's subsidiaries and affiliates.

3.1.5. Emission Factors

The institutional greenhouse gas emission inventory of IMM and its subsidiaries has been calculated using the formula adapted from the Intergovernmental Panel on Climate Change (IPCC) "Tier-1" and "Tier-2" methodology within the framework of IMM's and IMM affiliates' responsibilities.

Carbon Dioxide Emissions (t CO_2) = $\Sigma_s\Sigma_f$ { fuel consumption $_{sf}$ (MWh) x CO_2 emission factor $_f$ (t CO_2/MWh), (3.1)

s = sector
f = energy carrier

Fuel consumption data given as unit mass or volume are converted into MWh units by multiplying the net calorific values.

IMM's Institutional GHG Inventory was prepared to cover CO_2, CH_4, and N_2O gases. CH_4 and N_2O emissions from solid waste disposal activities were calculated separately. The greenhouse gas emissions and global warming potentials included in the inventory are taken from the IPCC 5th Assessment Report (AR5).

Emission factors used in the inventory are taken from IPCC Emission Factors, except for the national electricity grid emission factor calculated for Türkiye. The average emission factor from electricity is taken from the Primary Energy and Greenhouse Gas Emission Coefficients of Electricity.

3.2. Renewable Energy Production and Energy Saving Amounts of IMM

IMM uses solar, biomass and wind energies as renewable energy sources. IMM's renewable energy production activities are carried out by IMM Energy Management and Lighting Directorate, İSTAÇ, and Istanbul Energy affiliate.

At this stage of the thesis, these relevant units were contacted, and the necessary data was obtained in order to learn the amount of energy produced by Istanbul Metropolitan Municipality from renewable energy. These data were collected and analyzed from 2019 to the 2023.

IMM and its affiliates and subsidiaries have 46 renewable energy production systems and facilities as of the end of 2022. These 46 systems and facilities include 40 Solar Power Plants, 2 Biomethanization Facilities, 3 Landfill Gas Electricity Production Facilities, and 1 Solid Waste Incineration Facility.

The annual estimated energy production amounts of these energy production systems and facilities were calculated differently for different energy sources.

3.2.1. Waste Sourced Electricity Production Facilities

The annual electricity production amounts data of 2 Biomethanization Facilities, 3 Landfill Gas Electricity Production Facilities, and 1 Solid Waste Incineration Facility operated by IMM and its subsidiaries were obtained directly from the relevant departments, and no calculations were made.

3.2.2. Solar Power Plants

We can calculate the amount of energy a solar energy facility produces in two different ways.

First,

Daily Energy (kWh)=Solar Panel Efficiency × Solar Irradiance × System Capacity × Performance Ratio × Derate Factor (3.2)

(Morcillo-Herrera et al., 2015)

Solar Panel Efficiency: This represents the efficiency of the solar panels in converting sunlight into electricity. It is usually expressed as a percentage. For example, if you have solar panels with 18% efficiency, you would use 0.18 in the equation.

Solar Irradiance: Solar irradiance is the amount of sunlight that reaches the solar panels per unit area. It is typically measured in kilowatt-hours per square meter per day (kWh/m²/day). The solar irradiance value depends on the location and can be obtained from solar resource maps or databases.

System Capacity: This is the capacity of the solar panel system, usually expressed in kilowatts (kW) or megawatts (MW). It represents the total peak power that the solar panels can generate under ideal conditions.

Performance Ratio: The performance ratio accounts for losses in the system, including shading, inverter losses, temperature losses, and other factors. It is a dimensionless factor, usually ranging from 0.75 to 0.85. A typical value is 0.80.

Derate Factor: The derate factor further adjusts for other losses that might occur over time, such as the degradation of solar panels. It is also a dimensionless factor, often ranging from 0.95 to 0.80. A common value is 0.85.

Secondly,

Daily Energy (kWh) = System Capacity (kW) x Hours of Sunlight x Solar Panel Efficiency (3.3)

(Muhammad, et al., 2019)

Hours of Sunlight: The daily sunlight exposure of a solar energy panel varies depending on its location and climate conditions.

This study used the second method to calculate the yearly energy production amounts of IMM's solar power plants. The installed power information of the 40 solar energy panels included in this thesis was obtained from the relevant IMM units, subsidiaries, and affiliates.

According to the Türkiye Solar Energy Potential Atlas (GEPA) dated 26 August 2022, prepared by the Ministry of Energy and Natural Resources of the Republic of Türkiye, the average annual total sunlight duration was 2,741 hours, and the average annual total solar irradiance value was calculated as 1,527.46 kWh/m^2 (The Republic of Türkiye Ministry of Energy and Natural Resources, GEPA, 2022).

In this study, while calculating the annual energy production potential of solar energy panels, the installed power of the panels was multiplied by 2741, which is the yearly sunlight hours.

The efficiency of Solar Power Panels in converting solar energy into electrical energy varies between 6% and 20%. The efficiency of the solar power plants studied in this thesis is accepted as 16% by the relevant units of the municipality (Selbaş & Çetin, 2022; Bhol et al., 2015).

In this study, the annual electricity production potential of a solar power plant with an installed power of 169 kWp was calculated as follows.

$$\textbf{Yearly Produced Energy (kWh) = 169 kWp x 2741 } \frac{\textbf{hr}}{\textbf{year}} \textbf{ x \%16 = 74,117 } \frac{\textbf{kWh}}{\textbf{year}}$$

3.2.3. Total Amount of Renewable Energy Production and Energy Saving of IMM

While calculating the yearly total amount of renewable energy and energy savings produced by IMM, the years in which the established renewable energy facilities were put into operation were considered.

This study made separate calculations for 2019, 2020, 2021, 2022, and 2023, starting from 2019, which is the base year of this study. While calculating the potential renewable energy production and energy savings amounts in 2019, the facilities established before 2019 were evaluated, while those established before 2023 were assessed in 2023.

3.3. Examination of Renewable Energy Production Trends of Türkiye and IMM between 2018 and 2023

In this study, the Innovative Sen Trend Method was used to examine the renewable energy production trends of Türkiye and IMM between 2018-2023.

In the context of the "Innovative Sen Trend Method," the dataset undergoes a bifurcation into two equitably proportioned segments. Subsequently, each segment is arranged in ascending order, with the first segment (Xi) aligned along the X-axis and the second segment (Xj) positioned on the Y-axis within the Cartesian coordinate system. The absence of a discernible trend is indicated when the data lies above the 1:1 line. Conversely, if the data occupies the lower triangular region relative to the 1:1 line, it signifies a low-level trend; within the central region, a moderate-level trend is observed, while placement in the upper triangular area denotes a highly diminishing trend. Similarly, data residing in the upper triangular segment of the 1:1 line suggests a low-level increasing trend, while the middle area indicates a moderate-level trend, and positioning in the uppermost region signifies a highly escalating trend (Şen, 2012; Ceribasi, 2019).

3.4. Calculation of Carbon Emission Trading Potential of IMM

According to the World Bank's Carbon Pricing Dashboard, dated March 31, 2023, 66 carbon pricing systems are implemented and scheduled worldwide. Thirty-three of these systems are Emission Trading Systems, and the remaining thirty-three are Carbon Taxes. While sixty-five of sixty-six carbon pricing systems have been implemented, one is scheduled for 2023.

Each carbon pricing system has different prices and rules. In this study, the emission trading potential of Istanbul Metropolitan Municipality was calculated.

IMM's annual saved CO_2 amount was calculated by multiplying IMM's renewable energy production amounts calculated for 2019, 2020, 2021, 2022, and 2023 with the CO_2 emission saved by 1 MWh of renewable electricity production. According to the Turkish National Electricity Grid Emission Factor prepared by the Republic of Türkiye Ministry of Energy and Natural Resources, 0.6488 tons of CO_2 emissions will be saved for every 1 MWh of electricity produced by a solar or wind power plant. And 0.5552 tons of CO_2 emissions will be saved for every 1 MWh of electricity produced by other renewable energy sources such as biomass and biomethanization etc.

$$\textbf{Yearly Saved } CO_2 = 74{,}117\ \frac{\text{kWh}}{\text{year}}\ \text{x}\ \frac{1\ \text{MWh}}{1000\ \text{kWh}}\ \text{x}\ 0{,}6488\ \frac{tCO_2e}{\text{MWh}}\ =\ 48.1\ \frac{tCO_2e}{\text{year}}$$

While calculating the potential of IMM in the EU ETS, the amount of saved CO_2 for each year was multiplied by the price of the EU ETS that year. If we assume that the total saved CO_2 emission amount by IMM for 2019 is 253,527 tonsCO_2e/year, and the 2019 price of EU ETS is 24.51 USD/tCO_2e, IMM's EU ETS potential in 2019 will be calculated as follows.

$$\textbf{IMM's EU ETS potential} = 253{,}527\ \frac{tCO_2e}{\text{year}}\ \text{x}\ 24.51\ \frac{\text{USD}}{tCO_2e} = 6{,}213{,}959\ \frac{\text{USD}}{\text{year}}$$

4. RESULTS AND DISCUSSION

Detailed sectoral data of the institutional greenhouse gas inventory of IMM, its subsidiaries, and affiliates are given in Figure 4.1.

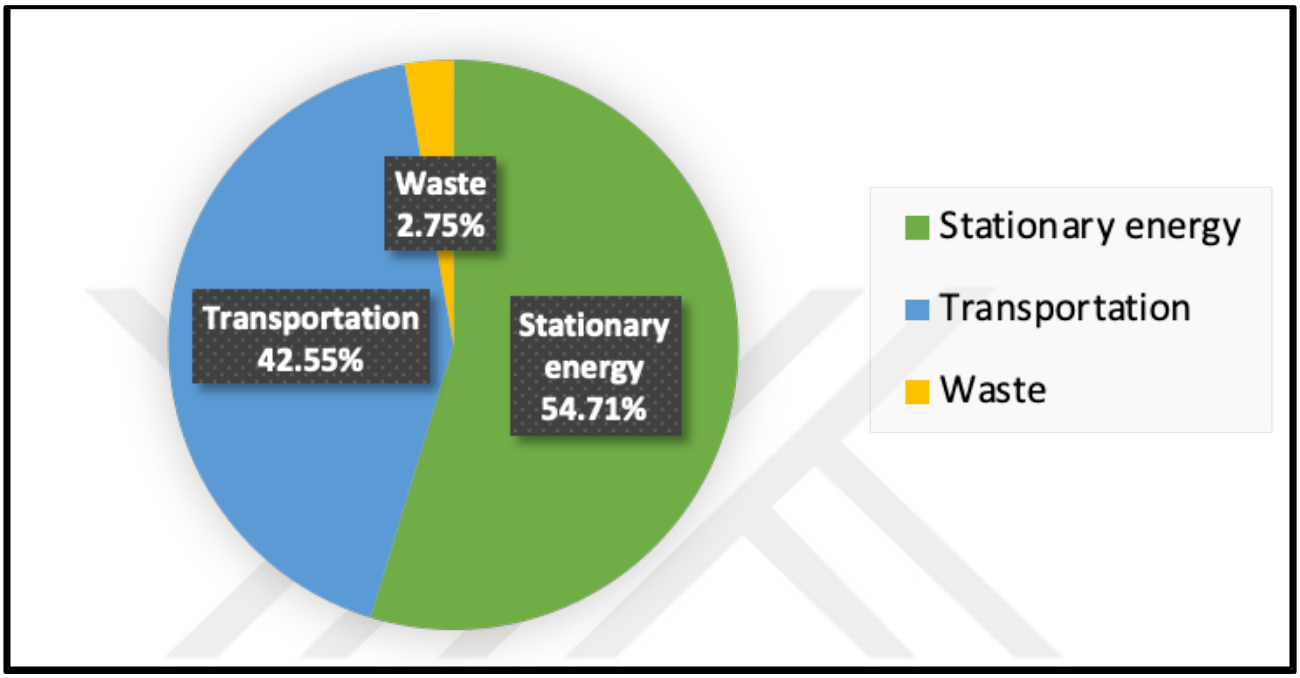


Figure 4.1. Sectoral distribution of IMM's institutional GHG inventory.

According to Figure 4.1., 54.71% of IMM's institutional greenhouse gas emissions in 2019 resulted from the stationary energy sector, 42.55% from the transportation sector, and 2.75% from the waste-wastewater sector.

Table 4.1. Institutional GHG emissions of IMM by sectors.

GHG Emissions Source (By Sectors)		Total GHGs (metric tons CO_2e)			
		Scope 1	**Scope 2**	**Scope 3**	**TOTAL**
STATIONARY ENERGY	Energy use	73,421	771,731	-	845,152
TRANSPORTATION	(all emissions)	487,849	169,448	-	657,297
WASTE	Waste generated in the city	42,459	-	-	42,459
	Waste generated outside city	-	-	-	-
TOTAL		603,729	941,179	-	1,544,908

According to Table 4.1., the total amount of greenhouse gas emissions emitted by IMM in 2019 is 1,544,908 tCO_2e.

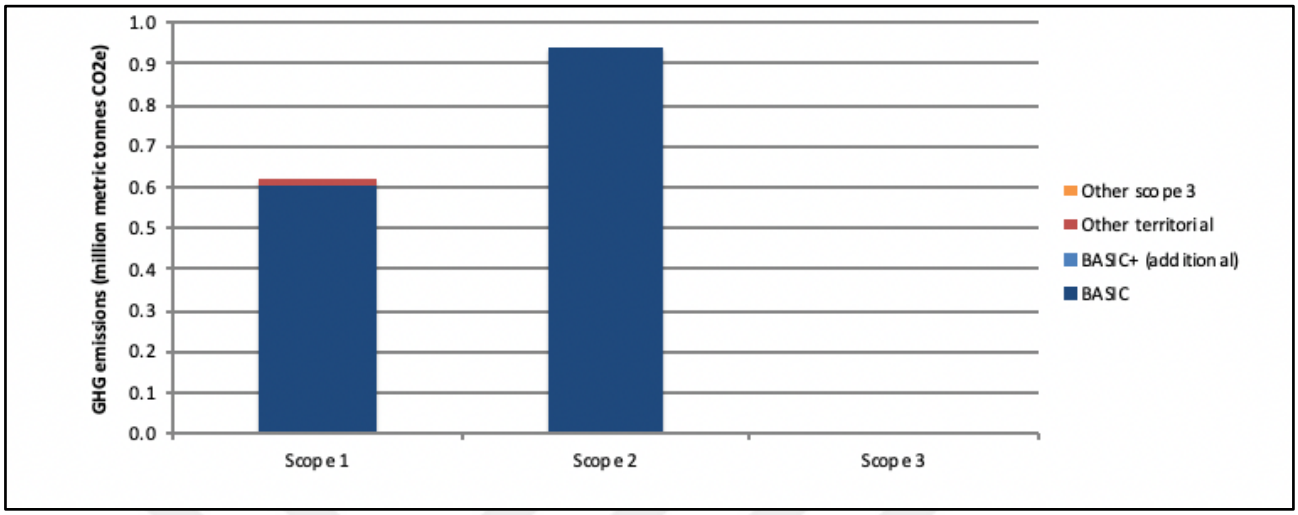


Figure 4.2. Institutional GHG emissions distribution of IMM by scopes.

You can see of these emissions, 603,729 tCO_2e originates from scope 1 and 941,179 tCO_2e from scope 2 in Figure 4.2.

Table 4.2. Institutional GHG emissions distribution of IMM by sub-sectors.

GHG Emissions Source (By Sector and Sub-sector)	Total GHGs (metric tons CO_2e)			
	Scope 1	Scope 2	Scope 3	Total
STATIONARY ENERGY				
Residential buildings	0	0	NE	0
Commercial and institutional buildings and facilities	71,508	764,773	NE	836,281
Manufacturing industries and construction	0	6,758	NE	6,758
Energy industries	IE	IE	NE	0
Agriculture, forestry and fishing activities	IE	200	NE	200
Non-specified sources	0	NO	NE	0
Fugitive emissions from mining, processing, storage, and transportation of coal	NO	-	-	0
Fugitive emissions from oil and natural gas systems	1,913	-	-	1,913
(city induced framework only)	**73,421**	**771,731**	**0**	**845,152**
TRANSPORTATION				
On-road transportation	449,415	IE	NE	449,415
Railways	0	169,448	NE	169,448
Waterborne navigation	38,434	IE	NE	38,434
Aviation	IE	IE	NE	0
Off-road transportation	IE	IE	NE	0
(city induced framework only)	**487,849**	**169,448**	**0**	**657,297**
WASTE				
Solid waste generated in the city	11,252	-	NO	11,252
Biological waste generated in the city	113	-	NO	113
Incinerated and burned waste generated in the city	29,110	-	NO	29,110
Wastewater generated in the city	1,984	-	NO	1,984
Solid waste generated outside the city	NO	-	-	-
Biological waste generated outside the city	NO	-	-	-
Incinerated and burned waste generated outside city	NO	-	-	-
Wastewater generated outside the city	NO	-	-	-
(city induced framework only)	**42,459**	**-**	**0**	**42,459**
TOTAL	**603,729**	**941,179**	**0**	**1,544,908**

* NE: Not Estimated, NO: Not Occurring, IE: Included Elsewhere

According to Table 4.2., the stationary energy sector has a share of 54.7% in the total inventory with 845,152 tCO_2e. In the stationary energy sector, 838,394 tCO_2e has been emitted using IMM's institutional and commercial buildings and facilities. In other words, 99.2% of greenhouse gases originate from the fixed energy sector was emitted from institutional and commercial buildings and

facilities. The remaining 6,758 tCO_2e was emitted from the manufacturing industries and construction with a share of 0.8%.

Furthermore, the transportation sector has a share of 42.6% in the total GHG emission inventory with 657,297 tCO_2e. In the transportation sector, 449,415 tCO_2e has been emitted using on-road transportation with a 68.4% share. 169,448 tCO_2e was emitted from railways usage with a share of 25.8%. And the remaining 38,434 tCO_2e was emitted from waterborne navigation with a share of 5.8%.

The waste sector has a share of 2.7% in the IMM's emission inventory with 42,459 tCO_2e. In the waste sector, 29,110 tCO_2e was emitted from incineration and burned of institutional waste with a 68.6% share. Then, 11,252 tCO_2e originated from solid waste generation with a 26.5% share. 1,984 tCO_2e was emitted from wastewater generation, with a share of 4.7%. Furthermore, the remaining 113 tCO_2e was emitted from biological waste generated in the IMM.

tCO2e	BASIC	Scope 1	Scope 2	Scope 3
	Stationary	73.421	771.731	
	Transportation	487.849	169.448	
	Waste	42.459		0
	IPPU			
	AFOLU			
	Other Scope 3			
	TOTAL	1.544.908		

Figure 4.3. Summary of institutional GHG inventory of IMM.

Figure 4.3. summarizes the institutional inventory of Istanbul Metropolitan Municipality prepared for 2019 by making sectoral and scope distinctions.

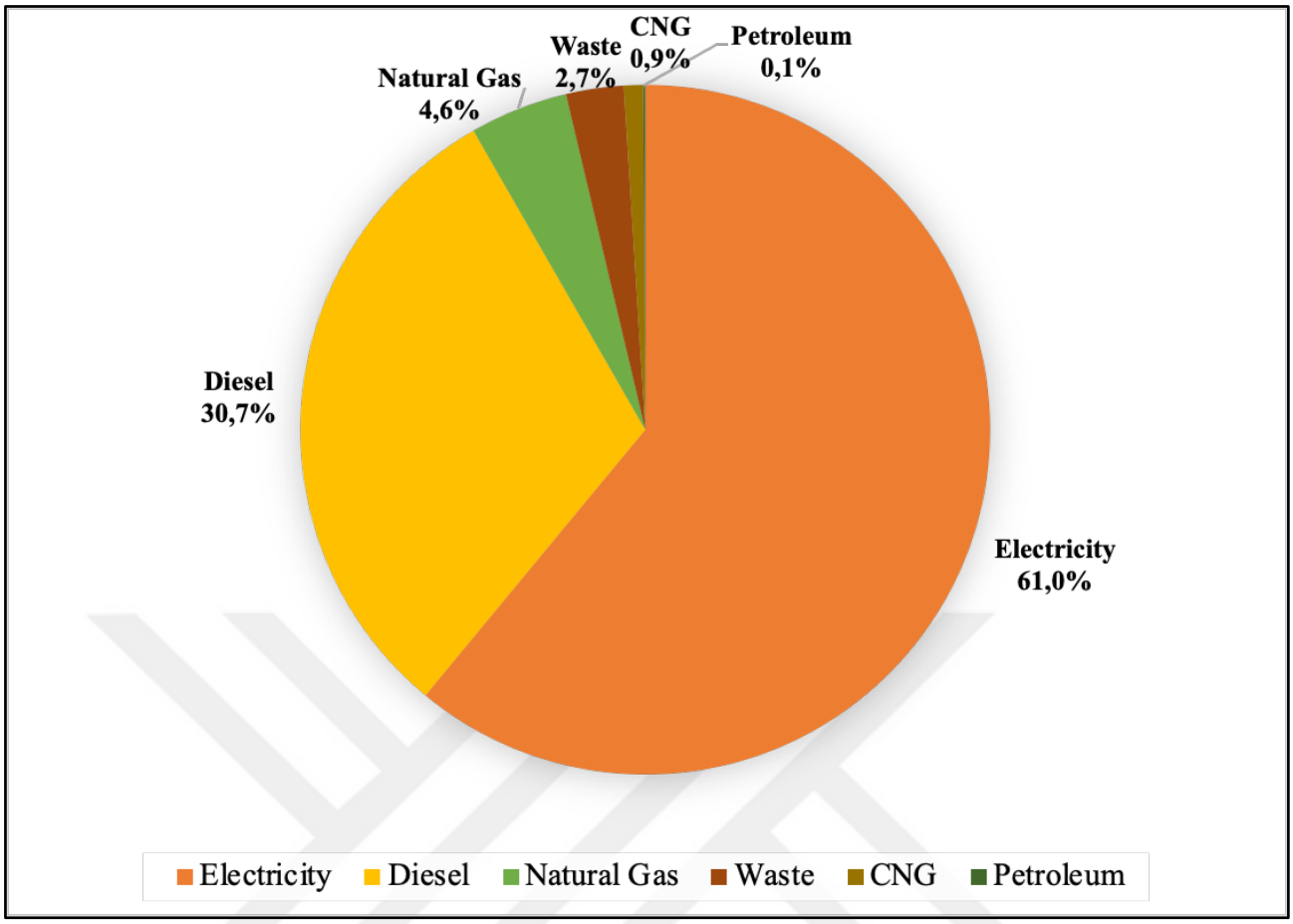


Figure 4.4. IMM's institutional greenhouse gas emissions from different energy sources.

According to Figure 4.4., 61% of IMM's institutional greenhouse gas emissions are from electricity consumption, 30.7% from diesel consumption, 4.6% from natural gas consumption, 2.7% from waste, 0.9% from CNG, and 0.1% from petroleum consumption.

IMM, along with its associated companies and subsidiaries, possesses 46 operational renewable energy production systems and facilities as of the conclusion of 2022. Within this count, there are 40 Solar Power Plants, 2 Biomethanization Facilities, 3 Landfill Gas Electricity Production Facilities, and 1 Solid Waste Incineration Facility.

The estimated annual energy production figures for these diverse energy sources were computed using distinct methodologies. The calculations considered the years in which the respective renewable energy facilities were commissioned while determining the yearly cumulative output of renewable energy and energy savings generated by IMM.

Table 4.3. Emission reduction amounts by IMM's renewable energy production facilities.

Year in Service	Name of the System	Installed Power (MWp)	Annual Estimated Energy Production (MWh)	Amount of Prevented Emission (tCO_2e/year)
2008	LFG Electricity Production Facility 1	26.60	188,800	104,822
2008	LFG Electricity Production Facility 2	43.40	267,561	148,550
2021	Solid Waste Incineration Facility	85.00	583,175	323,779
2021	Biomethanization Facility 1	1.40	1,067	592
2021	Biomethanization Facility 2	16.80	23,899	13,269
2020	LFG Electricity Production Facility 3	36.40	241,165	133,895
2016	Solar Power Plant 1	0.12	53	29
2016	Solar Power Plant 2	0.17	74	41
2017	Solar Power Plant 3	0.01	4	2
2017	Solar Power Plant 4	0.01	5	3
2017	Solar Power Plant 5	0.24	105	58
2019	Solar Power Plant 6	1.26	550	306
2019	Solar Power Plant 7	0.02	9	5
2019	Solar Power Plant 8	1.19	523	290
2020	Solar Power Plant 9	0.22	96	53
2020	Solar Power Plant 10	0.46	201	112
2020	Solar Power Plant 11	0.77	337	187
2020	Solar Power Plant 12	0.51	226	125
2020	Solar Power Plant 13	0.36	158	88
2020	Solar Power Plant 14	0.26	113	63
2020	Solar Power Plant 15	0.24	105	58
2020	Solar Power Plant 16	0.13	56	31
2020	Solar Power Plant 17	0.01	3	1
2020	Solar Power Plant 18	0.02	7	4
2021	Solar Power Plant 19	0.02	9	5
2021	Solar Power Plant 20	0.11	46	26
2021	Solar Power Plant 21	0.05	22	12
2022	Solar Power Plant 22	0.03	12	7
2022	Solar Power Plant 23	0.11	46	26
2022	Solar Power Plant 24	0.10	42	23
2022	Solar Power Plant 25	0.11	46	26
2022	Solar Power Plant 26	0.06	28	15
2022	Solar Power Plant 27	0.06	28	15
2022	Solar Power Plant 28	0.11	49	27
2022	Solar Power Plant 29	0.11	46	26
2022	Solar Power Plant 30	0.22	94	52
2022	Solar Power Plant 31	0.10	43	24

Year in Service	Name of the System	Installed Power (MWp)	Annual Estimated Energy Production (MWh)	Amount of Prevented Emission (tCO_2e/year)
2022	Solar Power Plant 32	0.41	181	100
2022	Solar Power Plant 33	0.55	241	134
2022	Solar Power Plant 34	0.45	198	110
2022	Solar Power Plant 35	0.57	252	140
2022	Solar Power Plant 36	0.05	21	12
2022	Solar Power Plant 37	0.08	35	19
2022	Solar Power Plant 38	0.30	133	74
2022	Solar Power Plant 39	0.31	134	74
2022	Solar Power Plant 40	0.02	7	4
TOTAL		219.49	1,310,005	727,315

Table 4.3. outlines the emission reduction amounts by Istanbul Metropolitan Municipality's renewable energy production facilities measured in tons of carbon dioxide equivalent (CO_2e) per year. Additionally, the table provides the installed power capacities in megawatts peak (MWp) and information on the annual estimated energy production in megawatt-hours (MWh).

Conclusively, this study calculated the total annual estimated renewable energy production amount of 1,310,005 megawatt-hours (MWh). This calculation is based on Istanbul Metropolitan Municipality's cumulative installed power capacity of renewable energy systems as of the conclusion of 2022. Considering the estimated annual renewable energy production of 46 facilities, the total emissions that IMM will prevent for 2023 is 727,721 tCO_2e.

Considering the years the 46 facilities were put into service, IMM's potential annual estimated renewable energy production amounts for 2019, 2020, 2021, 2022, and 2023, saved CO_2 emission amounts for each year, and the potentials in the EU Emission Trading System were calculated.

Table 4.4. Annual estimated energy production and saved CO_2 amounts of IMM.

Year	Annual Estimated Energy Production (MWh)	Amount of Prevented Emission (tons CO_2e/year)
2019	456,601	253,505
2020	457,684	254,106
2021	569,277	388,723

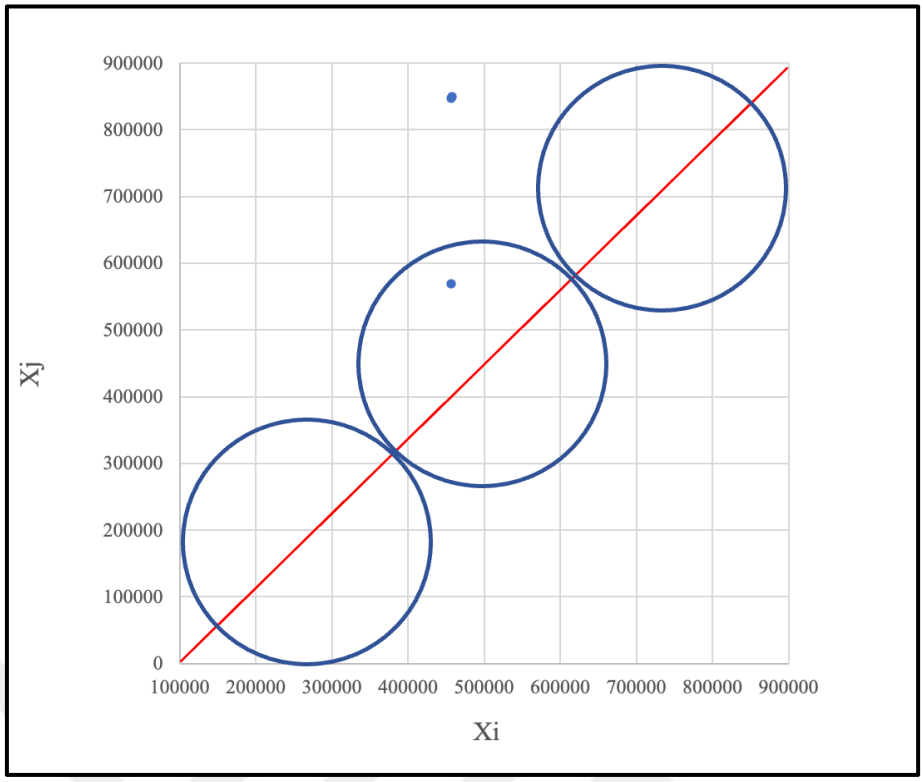
2022	847,475	726,406
2023	849,113	727,315

As shown in Table 4.4., annual estimated energy production amounts and CO_2 amounts to be saved have been calculated since 2019, the base year of this study. Renewable energy production systems put into service in previous years were evaluated for each year. For example, in the 2021 calculations, energy production systems that were put into service before 2021 were included. The estimated annual renewable energy production amount for 2019 is 456,602 MWh, and the amount of CO_2 saved is 253,505 tCO_2e. For 2020; 457,684 MWh and 254,106 tCO_2e, for 2021; 569,277 MWh and 388,723 tCO_2e, for 2022; 847,475 MWh and 726,406 tCO_2e, and for 2023; 849,113 MWh and 727,315 tCO_2e.

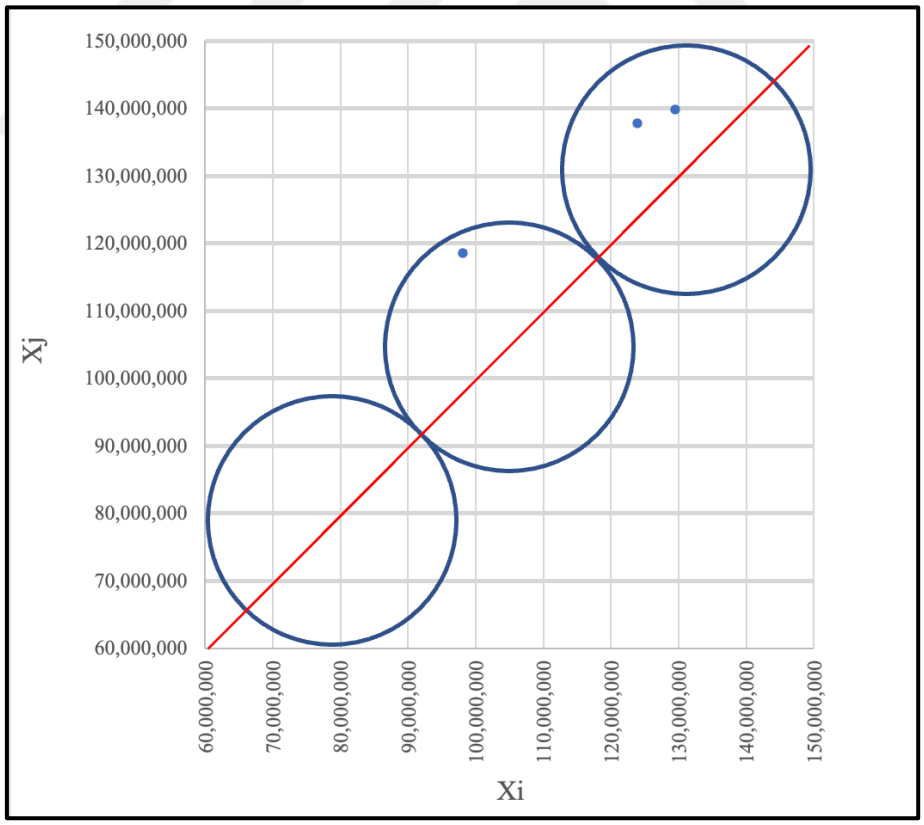
Table 4.5. Electricity generation amount of Türkiye and IMM from renewable resources.

Year	**Türkiye's Electricity Generation (MWh)**	**IMM's Potential Electricity Production (MWh)**
2018	98,124,349	456,601
2019	123,876,870	456,601
2020	129,469,610	457,684
2021	118,514,469	569,277
2022	137,770,257	847,475
2023	139,817,584	849,113

Table 4.5 shows Türkiye's and IMM's renewable energy production amounts between 2018 and 2023. Since the amount of electricity generated by renewable energy in Türkiye in 2023 has not yet been calculated, that data was assumed. 2023 electricity production data have been assumed by multiplying the 2022 electricity generation data with a renewable energy installed power ratio of 2023 to 2022. Türkiye produced 98,124,349 MWh in 2018, 123,876,870 MWh in 2019, 129,469,610 MWh in 2020, 118,514,469 MWh in 2021, 137,770,257 in 2022, and 139,817,584 MWh of renewable electricity in 2023 (EPDK, Electricity Market Sector Report 2019 to 2022).



(a)



(b)

Figure 4.5. Renewable energy production trend results of IMM (a) and Türkiye (b) by Sen Method.

Istanbul's renewable energy production trend results by year, analyzed according to the Sen Method, are shown in Figure 4.5.a, and Türkiye's renewable energy production trend results by year are shown in Figure 4.5.b.

Upon scrutiny of Figure 4.5., it becomes apparent that an ascending trend exists in the production of renewable energy for both Türkiye and IMM during the period spanning 2018 to 2023. In a detailed analysis of Figure 4.5., it was observed that IMM exhibits a moderate increasing trend in renewable energy production. In contrast, Türkiye demonstrates a moderate to high-increasing trend in the same domain.

Table 4.6. IMM's financial emission trading potential between 2019 and 2021.

Emission Trading Systems	**2019**		**2020**		**2021**	
	Price (USD /tCO_2e)	**IMM Potential (USD)**	**Price (USD /tCO_2e)**	**IMM Potential (USD)**	**Price (USD /tCO_2e)**	**IMM Potential (USD)**
Alberta TIER	22.49	5,701,833	21.1	5,364,247	31.83	12,380,872
Austria ETS	-	-	-	-	-	-
BC GGIRCA	-	-	-	-	19.9	7,740,476
Beijing pilot ETS	10.4	2,636,686	12.2	3,101,603	4.32	1,680,345
California CaT	15.77	3,998,129	15.3	3,889,715	17.94	6,978,098
Canada federal OBPS	-	-	-	-	31.83	12,380,872
China national ETS	-	-	-	-	-	-
Chongqing pilot ETS	-	-	5.31	1,349,960	3.71	1,443,074
EU ETS	24.51	6,213,959	18.54	4,713,419	49.78	19,362,860
Fujian pilot ETS	1.52	385,362	1.28	325,414	1.25	486,211
Germany ETS	-	-	-	-	29.37	11,424,009
Guangdong pilot ETS	2.92	740,300	4.13	1,049,969	5.72	2,224,901
Hubei pilot ETS	4.13	1,047,069	3.57	907,600	4.41	1,715,352
Kazakhstan ETS	-	-	1.11	282,195	1.18	458,983
Korea ETS	23.46	5,947,755	32.79	8,336,193	15.89	6,180,712

Emission Trading Systems	2019		2020		2021	
	Price (USD /tCO_2e)	IMM Potential (USD)	Price (USD /tCO_2e)	IMM Potential (USD)	Price (USD /tCO_2e)	IMM Potential (USD)
Massachusetts ETS	-	-	8.2	2,084,684	6.5	2,528,296
New Brunswick ETS	-	-	-	-	-	-
New Zealand ETS	17.53	4,444,337	14.3	3,635,485	25.76	10,019,833
Newfoundland and Labrador ETS	-	-	-	-	23.88	9,288,572
Nova Scotia CaT	-	-	-	-	19.66	7,647,124
Ontario EPS	-	-	-	-	-	-
Quebect CaT	15.77	3,998,129	15.3	3,889,715	17.94	6,978,098
RGGI	4.94	1,252,426	5.13	1,304,199	8.69	3,380,138
Saitama ETS	5.85	1,483,136	5.58	1,418,602	5.42	2,108,210
Saskatchewan OBPS	-	-	-	-	31.83	12,380,872
Shanghai pilot ETS	6.09	1,543,982	5.07	1,288,945	6.32	2,458,282
Shenzhen pilot ETS	0.55	139,440	2.38	605,067	1.12	435,645
Switzerland ETS	7.18	1,820,327	18.8	4,779,519	41.49	16,138,310
Tianjin pilot ETS	2.08	527,337	2.82	716,928	3.8	1,478,081
Tokyo CaT Price 1	5.85	1,483,136	5.58	1,418,602	4.87	1,894,277
Tokyo CaT Price 2	-	-	-	-	-	-
UK ETS	-	-	-	-	-	-
Washington CCA	-	-	-	-	-	-

As we mentioned above, this study focuses on the emissions trading potential of IMM. Table 4.6. lists IMM's financial potential in 33 emission trading systems registered in the World Bank carbon trading system between 2019 and 2021. These 33 systems serve in different countries.

Currently, we can't participate in many of them. However, with the Republic of Türkiye becoming a party to the Paris Agreement, our inclusion in the European Union Emissions Trading System has become possible. At the same time, with the announcement to the world public that the Republic of Türkiye aims to be carbon neutral in 2053, preparations for the creation of an emission trading system unique to Türkiye have accelerated.

Table 4.7. IMM's financial emission trading potential 2022 and 2023.

Emission Trading Systems	**2022**		**2023**	
	Price (USD/tCO_2e)	**IMM Potential (USD)**	**Price (USD/tCO_2e)**	**IMM Potential (USD)**
Alberta TIER	39.96	29,037,267	48.03	34,952,973
Austria ETS	-	-	35.34	25,720,386
BC GGIRCA	19.98	14,518,634	18.47	13,443,451
Beijing pilot ETS	6.53	4,745,079	12.96	9,429,593
California CaT	30	21,799,750	29.84	21,715,192
Canada federal OBPS	0.82	595,860	48.03	34,952,973
China national ETS	9.2	6,685,257	8.15	5,933,227
Chongqing pilot ETS	5.66	4,112,886	4.66	3,390,415
EU ETS	86.53	62,877,746	96.30	70,078,158
Fujian pilot ETS	1.83	1,329,785	4.66	3,390,415
Germany ETS	33.16	24,095,991	32.63	23,741,894
Guangdong pilot ETS	12.51	9,090,496	12.34	8,981,423
Hubei pilot ETS	7.24	5,261,006	6.96	5,066,552
Kazakhstan ETS	1.08	784,791	1.12	818,595
Korea ETS	18.75	13,624,844	11.24	8,176,953
Massachusetts ETS	0.5	363,329	12.05	8,769,037
New Brunswick ETS	39.96	29,037,267	48.03	34,952,973
New Zealand ETS	52.62	38,236,762	34.20	24,887,145
Newfoundland and Labrador ETS	39.96	29,037,267	48.03	34,952,973
Nova Scotia CaT	23.1	16,785,808	20.87	15,191,100
Ontario EPS	31.97	23,231,267	48.03	34,952,973
Quebect CaT	30.83	22,402,877	29.84	21,715,192
RGGI	13.89	10,093,284	15.39	11,198,349
Saitama ETS	3.84	2,790,368	1.08	785,075
Saskatchewan OBPS	39.96	29,037,267	48.03	34,952,973
Shanghai pilot ETS	9.28	6,743,389	8.72	6,346,434
Shenzhen pilot ETS	-	-	8.77	6,381,398
Switzerland ETS	64.22	46,665,999	93.81	68,265,860

Emission Trading Systems	2022		2023	
	Price (USD/tCO_2e)	IMM Potential (USD)	Price (USD/tCO_2e)	IMM Potential (USD)
Tianjin pilot ETS	4.4	3,197,297	4.60	3,350,154
Tokyo CaT Price 1	4.42	3,211,830	41.95	30,530,694
Tokyo CaT Price 2	-	-	5.24	3,816,337
UK ETS	98.99	71,931,909	88.13	64,131,085
Washington CCA	-	-	22.20	16,155,404

IMM's financial potential in 33 emission trading systems registered in the World Bank carbon trading system in 2022 and 2023 are shown in Table 4.7. Considering the year 2023, IMM has the highest carbon trading potential in the EU Emissions Trading System, with 70,078,158 USD, and has the slightest carbon trading potential in the Saitama ETS, with 785,075 USD.

Table 4.8. IMM's total financial emission trading potential between 2019 and 2023.

Emission Trading Systems	2019-2023
	TOTAL POTENTIAL (USD)
Alberta TIER	87,437,194
Austria ETS	25,720,386
BC GGIRCA	35,702,561
Beijing pilot ETS	21,593,305
California CaT	58,380,883
Canada federal OBPS	47,929,705
China national ETS	12,618,484
Chongqing pilot ETS	10,296,335
EU ETS	163,246,142
Fujian pilot ETS	5,917,187
Germany ETS	59,261,894
Guangdong pilot ETS	22,087,088
Hubei pilot ETS	13,997,579
Kazakhstan ETS	2,344,564
Korea ETS	42,266,457
Massachusetts ETS	13,745,346
New Brunswick ETS	63,990,240
New Zealand ETS	81,223,562
Newfoundland and Labrador ETS	73,278,812
Nova Scotia CaT	39,624,031
Ontario EPS	58,184,240
Quebect CaT	58,984,010
RGGI	27,228,396
Saitama ETS	8,585,391

Emission Trading Systems	2019-2023
	TOTAL POTENTIAL (USD)
Saskatchewan OBPS	76,371,113
Shanghai pilot ETS	18,381,033
Shenzhen pilot ETS	7,561,549
Switzerland ETS	137,670,015
Tianjin pilot ETS	9,269,797
Tokyo CaT Price 1	38,538,539
Tokyo CaT Price 2	3,816,337
UK ETS	136,062,994
Washington CCA	16,155,404

Table 4.8. shows IMM's total financial potential in 33 emission trading systems registered in the World Bank carbon trading system between 2019 and 2023. If we look at the total potential between 2019 and 2023, IMM has the highest carbon trading potential in the EU Emissions Trading System, with 163,246,142 USD, and has the slightest carbon trading potential in the Kazakhstan ETS, with 2,344,564 USD.

When we look at Table 4.4., Table 4.5., and Table 4.6. we see that although IMM's renewable energy production and CO_2 saving amounts have increased over the years, its financial emission trading potential has decreased in some years. The reason is that carbon prices in emission trading systems fluctuate in parallel with the world economy. For example, while the price for 1 tone of CO_2e in the EU ETS was 24.51 USD in 2019, it decreased by 18.54 USD in 2020 and increased to 49.78 USD in 2021. One of the main reasons for these carbon price fluctuations in the 2020s is the COVID-19 pandemic, which deeply shook the world economy.

However, if we look at the other side of the coin, we can say that the prices of tone CO_2 equivalent are increasing every year around the world, and this upward trend will continue in line with the increasingly damaging effects of climate change. Countries will have to establish carbon trading systems to keep up with the world's economic and trading trends. Many countries, such as Türkiye, are in the process of establishing the emission trading system right now.

Although this study focuses on the potential of IMM in carbon emission trading systems, we also examined the savings potential of IMM in carbon tax systems implemented between 2019 and 2023 in the World to make a more accurate comparison

Table 4.9. IMM's financial saving potential between 2019 and 2021.

Carbon Tax Systems	2019		2020		2021	
	Price (USD /tCO_2e)	IMM Potential (USD)	Price (USD /tCO_2e)	IMM Potential (USD)	Price (USD /tCO_2e)	IMM Potential (USD)
Alberta TIER	22.49	5,701,833	-	-	-	-
Austria ETS	6.24	1,582,012	5.94	1,510,125	5.54	2,154,886
BC GGIRCA	1.00	253,527	1.19	302,533	0.01	3,890
Beijing pilot ETS	-	-	-	-	-	-
California CaT	29.99	7,603,290	28.14	7,154,025	35.81	13,928,968
Canada federal OBPS	15.00	3,802,912	21.10	5,364,247	31.83	12,380,872
China national ETS	5.00	1,267,637	5.00	1,271,149	5.00	1,944,843
Chongqing pilot ETS	5.17	1,310,737	4.24	1,077,934	5.00	1,944,843
EU ETS	26.39	6,690,591	25.93	6,592,177	28.14	10,945,578
Fujian pilot ETS	22.58	5,724,651	21.98	5,587,970	23.65	9,199,109
Germany ETS	2.25	570,437	2.19	556,763	2.35	914,076
Guangdong pilot ETS	69.66	17,660,725	67.80	17,236,776	72.83	28,328,587
Hubei pilot ETS	59.55	15,097,562	57.96	14,735,156	62.25	24,213,299
Kazakhstan ETS	50.11	12,704,263	48.77	12,398,784	52.39	20,378,068
Korea ETS	31.34	7,945,552	29.88	7,596,385	34.83	13,547,778

Carbon Tax Systems	2019		2020		2021	
	Price (USD /tCO_2e)	IMM Potential (USD)	Price (USD /tCO_2e)	IMM Potential (USD)	Price (USD /tCO_2e)	IMM Potential (USD)
Massachusetts ETS	-	-	8.82	2,242,306	19.79	7,697,690
New Brunswick ETS	22.47	5,696,763	28.43	7,227,751	39.35	15,305,917
New Zealand ETS	-	-	21.87	5,560,004	23.49	9,136,874
Newfoundland and Labrador ETS	2.60	659,171	2.69	683,878	2.61	1,015,208
Nova Scotia CaT	5.06	1,282,849	9.84	2,501,621	14.10	5,484,458
Ontario EPS	96.46	24,455,262	99.44	25,280,605	101.47	39,468,650
Quebect CaT	-	-	-	-	40.12	15,605,423
RGGI	-	-	-	-	23.49	9,136,874
Saitama ETS	2.99	758,047	2.42	615,236	3.18	1,236,920
Saskatchewan OBPS	0.37	93,805	0.30	76,269	0.36	140,029
Shanghai pilot ETS	-	-	-	-	35.24	13,707,255
Shenzhen pilot ETS	-	-	-	-	-	-
Switzerland ETS	-	-	21.10	5,364,247	31.83	12,380,872
Tianjin pilot ETS	15.00	3,802,912	14.07	3,577,012	23.88	9,288,572
Tokyo CaT Price 1	-	-	14.07	3,577,012	23.88	9,288,572

Carbon Tax Systems	2019		2020		2021	
	Price (USD /tCO_2e)	IMM Potential (USD)	Price (USD /tCO_2e)	IMM Potential (USD)	Price (USD /tCO_2e)	IMM Potential (USD)
Tokyo CaT Price 2	59.22	15,013,898	52.89	13,446,211	69.33	26,967,197
UK ETS	3.38	856,923	3.01	765,232	3.87	1,505,309
Washington CCA	-	-	-	-	-	-

Table 4.9. shows IMM's financial saving potential in 33 carbon tax systems registered in the World Bank carbon trading system between 2019 and 2021. These 33 taxes are applied in different countries, and some of them have two different prices.

Table 4.10. IMM's financial saving potential 2022 and 2023.

Carbon Tax Systems	2022		2023	
	Price (USD /tCO_2e)	IMM Potential (USD)	Price (USD /tCO_2e)	IMM Potential (USD)
Alberta carbon tax	-	-	-	-
Argentina carbon tax Price 1	4.90	3,560,626	3.34	2,429,868
Argentina carbon tax Price 2	-	-	3.27	2,378,961
Australia (Safeguard Mechanism)	-	-	10.64	7,741,873
BC carbon tax	39.96	29,037,267	48.03	34,952,973
Canada federal fuel charge	39.96	29,037,267	48.03	34,952,973
Chile carbon tax	5.00	3,633,292	5.00	3,638,604
Colombia carbon tax	5.01	3,640,558	5.06	3,679,219
Denmark carbon tax Price 1	26.62	19,343,645	26.53	19,305,450

Carbon Tax Systems	2022		2023	
	Price (USD /tCO_2e)	IMM Potential (USD)	Price (USD /tCO_2e)	IMM Potential (USD)
Denmark carbon tax Price 2	22.29	16,197,214	21.90	15,937,355
Estonia carbon tax	2.21	1,605,915	2.18	1,582,793
Finland carbon tax Price 1	85.10	61,838,625	83.74	60,937,529
Finland carbon tax Price 2	58.58	42,567,646	57.64	41,944,013
France carbon tax	49.29	35,816,990	48.50	35,296,283
Iceland carbon tax Price 1	34.25	24,888,048	38.53	28,042,629
Iceland carbon tax Price 2	19.46	14,140,771	3.22	2,342,667
Ireland carbon tax Price 1	45.31	32,924,889	52.74	38,382,729
Ireland carbon tax Price 2	37.02	26,900,892	44.59	32,447,256
Japan carbon tax	2.36	1,714,914	2.17	1,575,602
Latvia carbon tax	16.58	12,047,995	16.31	11,870,947
Liechtenstein carbon tax	129.86	94,363,852	130.81	95,194,318
Luxembourg carbon tax Price 1	43.35	31,500,639	48.11	35,011,380
Luxembourg carbon tax Price 2	27.63	20,077,570	32.63	23,741,894
Mexico carbon tax Price 1	3.72	2,703,169	4.07	2,962,272
Mexico carbon tax Price 2	0.42	305,197	0.41	300,099
Netherlands carbon tax Price 1	46.14	33,528,016	55.59	40,456,188

Carbon Tax Systems	2022		2023	
	Price (USD /tCO_2e)	IMM Potential (USD)	Price (USD /tCO_2e)	IMM Potential (USD)
Netherlands carbon tax Price 2	-	-	17.84	12,978,902
New Brunswick carbon tax	39.96	29,037,267	48.03	34,952,973
Newfoundland and Labrador carbon tax	39.96	29,037,267	48.03	34,952,973
Northwest Territories carbon tax	31.97	23,231,267	48.03	34,952,973
Norway carbon tax Price 1	87.61	63,662,537	90.86	66,123,611
Norway carbon tax Price 2	8.81	6,401,860	7.35	5,348,233
Poland carbon tax Price 1	-	-	0.08	57,629
Poland carbon tax Price 2	-	-	14.44	10,508,850
Portugal carbon tax Price 1	26.44	19,212,847	26.01	18,930,204
Portugal carbon tax Price 2	-	-	0.92	672,687
Prince Edward Island carbon tax	23.98	17,425,267	36.95	26,886,902
Singapore carbon tax	3.69	2,681,369	3.77	2,741,978
Slovenia carbon tax	19.12	13,893,707	-	-
South Africa carbon tax	9.84	7,150,318	8.93	6,495,356
Spain carbon tax	16.58	12,047,995	16.31	11,870,947
Sweden carbon tax	129.89	94,385,652	125.56	91,370,128

Carbon Tax Systems	2022		2023	
	Price (USD /tCO_2e)	IMM Potential (USD)	Price (USD /tCO_2e)	IMM Potential (USD)
Switzerland carbon tax	129.86	94,363,852	130.81	95,194,318
UK Carbon Price Support	23.65	17,185,470	22.28	16,210,638
Ukraine carbon tax	1.03	748,458	0.82	597,005
Uruguay CO_2 tax	137.30	99,770,190	155.87	113,428,656
Washington CCA	-	-	22.20	16,155,404
Zacatecas carbon tax	12.60	9,155,895	13.86	10,083,986

IMM's financial saving potential in 33 carbon tax systems registered in the World Bank carbon trading system in 2022 and 2023 are shown in Table 4.10. Considering the year 2023, IMM has the highest financial savings in the Uruguay CO_2 Tax System, with 113,428,656 USD, and has the slightest carbon financial savings in the Poland Carbon Tax System Price 1 with 57,629 USD.

Table 4.11. IMM's total financial saving potential between 2019 and 2023.

Carbon Tax Systems	2019-2023
	TOTAL POTENTIAL (USD)
Alberta carbon tax	5,701,833
Argentina carbon tax Price 1	11,237,517
Argentina carbon tax Price 2	2,938,911
Australia (Safeguard Mechanism)	7,741,873
BC carbon tax	92,676,522
Canada federal fuel charge	85,538,273
Chile carbon tax	11,755,526
Colombia carbon tax	11,653,292
Denmark carbon tax Price 1	62,877,441
Denmark carbon tax Price 2	52,646,299
Estonia carbon tax	5,229,984
Finland carbon tax Price 1	186,002,243

Carbon Tax Systems	2019-2023
	TOTAL POTENTIAL (USD)
Finland carbon tax Price 2	138,557,676
France carbon tax	116,594,388
Iceland carbon tax Price 1	82,020,392
Iceland carbon tax Price 2	26,423,434
Ireland carbon tax Price 1	99,538,050
Ireland carbon tax Price 2	74,045,025
Japan carbon tax	5,648,773
Latvia carbon tax	33,187,870
Liechtenstein carbon tax	278,762,688
Luxembourg carbon tax Price 1	82,117,442
Luxembourg carbon tax Price 2	52,956,338
Mexico carbon tax Price 1	8,275,644
Mexico carbon tax Price 2	915,399
Netherlands carbon tax Price 1	87,691,459
Netherlands carbon tax Price 2	12,978,902
New Brunswick carbon tax	81,735,360
Newfoundland and Labrador carbon tax	80,658,737
Northwest Territories carbon tax	71,049,824
Norway carbon tax Price 1	185,213,454
Norway carbon tax Price 2	14,877,556
Poland carbon tax Price 1	57,629
Poland carbon tax Price 2	10,508,850
Portugal carbon tax Price 1	59,302,809
Portugal carbon tax Price 2	672,687
Prince Edward Island carbon tax	62,767,901
Singapore carbon tax	8,694,284
Slovenia carbon tax	31,536,152
South Africa carbon tax	18,999,599
Spain carbon tax	39,213,876
Sweden carbon tax	301,642,712
Switzerland carbon tax	278,762,688

Carbon Tax Systems	2019-2023
	TOTAL POTENTIAL (USD)
UK Carbon Price Support	54,687,483
Ukraine carbon tax	1,579,297
Uruguay CO_2 tax	213,198,846
Washington CCA	16,155,404
Zacatecas carbon tax	30,292,548

Table 4.11. shows IMM's total financial saving potential in 33 carbon tax systems registered in the World Bank carbon trading system between 2019 and 2023. If we look at the total saving potential between 2019 and 2023, IMM has the highest financial savings in the Sweden Carbon Tax System, with 301,642,712 USD, and has the slightest financial savings in the Poland Carbon Tax System Price 1, with 57,629 USD.

5. CONCLUSIONS AND RECOMMENDATIONS

Istanbul is the largest city in Europe and Türkiye. Also has one of the largest municipalities in the world. Istanbul Metropolitan Municipality is a living laboratory in the field of the municipality for Türkiye and the World with its 30 affiliates, 2 subsidiaries, and more than 85 thousand employees.

In this study, the potential of IMM in emission trading systems, which has an important place in combating with greenhouse gas emissions, which is one of the main causes of climate change in the world, was examined.

In addition, this study also calculated how much money IMM can save with the renewable energy it produces based on carbon taxes applied worldwide.

IMM has a total of 46 renewable energy production facilities. According to these facilities, annual estimated energy production amounts and CO_2 amounts to be saved have been calculated since 2019, the base year of this study. The estimated annual renewable energy production amount for 2019 is 456,602 MWh, and the amount of CO_2 saved is 253,505 tCO_2e. For 2020; 457,684 MWh and 254,106 tCO_2e, for 2021; 569,277 MWh and 388,723 tCO_2e, for 2022; 847,475 MWh and 726,406 tCO_2e, and for 2023; 849,113 MWh and 727,315 tCO_2e.

This study shows us that IMM has the highest carbon trading potential in the EU Emissions Trading System, with 70,078,158 USD in 2023. If we look at the total potential between 2019 and 2023, IMM has the highest carbon trading potential in the EU Emissions Trading System, with 163,246,142 USD.

Besides the emission trading systems, carbon taxes have been used for GHG emission control worldwide. IMM has the highest financial savings in the Uruguay CO_2 Tax System, with 113,428,656 USD in 2023. If we look at the total saving potential between 2019 and 2023, IMM has the highest financial savings in the Sweden Carbon Tax System, with 301,642,712 USD.

As a result of this study, looking at the Sen Method analysis results, an increasing trend in renewable energy production was observed for both Türkiye and IMM. This result revealed that there may be a rising trend in renewable energy production amounts in the following years for both Türkiye and IMM.

As a result of the Sen Trend Analysis, we can say that the amount of CO_2 saved will increase in the coming years for both Türkiye and IMM, in parallel with the renewable energy production trend, so we can expect an increasing trend in emission trading potentials.

Many municipalities in Türkiye, such as Istanbul Metropolitan Municipality, are conducting progressive studies on renewable energy and low emissions. Our country's great potential cannot be realized and used with voluntary emission trading systems and certificates. For this reason, establishing a local emission trading system and carrying out carbon trading through state regulations have great importance.

In December 2020, Türkiye took a significant stride by publishing the final draft of the legal and institutional framework for a pilot ETS. Additionally, technical workshops held throughout 2020 played a crucial role in shaping the government's decisions regarding emissions caps, the development of a national allocation plan, the establishment of a transaction registry for the pilot ETS, and the creation of an ETS simulation known as Turk-SIM (World Bank, State and Trends of Carbon Pricing, 2023).

On February 17, 2021, the Republic of Türkiye Ministry of Environment, Urbanization, and Climate Change announced the implementation of a national ETS. However, specific details regarding the start date, including the commencement of a pilot ETS, were not provided then. This indicates Türkiye's commitment to advancing its climate change mitigation efforts by introducing market-based mechanisms and establishing a comprehensive regulatory framework for emissions trading (World Bank, State and Trends of Carbon Pricing, 2023).

Establishing effective carbon markets in Türkiye requires the development and connection of institutions dedicated to fairly defining carbon rights. These institutions should have the independence to promote the exchange of knowledge, closely monitor progress, and ensure investments in efforts to reduce emissions and achieve sustainable development goals. They should also be flexible enough to adapt to the changing dynamics of social and environmental systems.

Public institutions and the private sector will get many opportunities from a newly established local ETS. Such as;

- With the low-emission economy, companies with emissions below the industry average will be able to increase their market shares.

- With the established ETS, green financing will increase in our country. The state, national, and international banks will create incentives for low emissions by giving advantageous loans and grants to low-emission companies.

- New markets will be created with low-emission advanced manufacturing processes.

- Green sectors will grow rapidly, and new job opportunities will be created.

The emission trading subject has recently been a hot topic in our country. Local governments and the private sector should contribute to the ETS, which the central government will outline.

Unfortunately, the number of competent personnel in emission trading is insufficient in our country. For this reason, public institutions and the private sector should give their personnel the necessary training to gain opportunities and adapt the emission trading system as soon as possible. Thus, institutions can benefit from ETS more efficiently by calculating their emission trading potential.

In addition to preparing their emission trading potential, institutions can integrate their sustainability strategies into their management plans, perform sectoral risk analysis, establish energy management systems, plan alternative green investments by re-evaluating their high-emission investments, apply to grants and incentives scope of green financing, and integrate their institutions by following legal regulations.

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