EDITORS

Prof. Dr. Bülent KARA

Doç. Dr. Abdullah KARATAŞ

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gecekitapligi@gmail.com

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İÇİNDEKİLER

CHAPTER 1

ENVIRONMENTAL PROBLEMS AND POLICIES RELATED TO URBANIZATION IN TURKIYE AND THE WORLD

Sabit MENTEŞE[1]

1 Prof. Dr., Munzur University, Faculty of Economics and Administrative Sciences, Department Of Polıtıcal Scıence And Publıc Admınıstratıon, Department Of Management Scıences, Tunceli, Turkey,

Orcid: 0000-0003-4901-4481,

smentese@munzur.edu.tr

INTRODUCTION

Urbanization is advancing at a rapid pace globally (Liu et al., 2020). By 2050, it is estimated that 68% of the global population will reside in urban areas (Economic and Affairs, 2019). While urbanization has significantly contributed to economic growth, it has also presented several environmental challenges, primarily due to the increasing population density and the expansion of impervious surfaces (Wu et al., 2021). These challenges include air pollution (Liu et al., 2022), urban heat islands (Ren et al., 2022), and water scarcity (Wang et al., 2021).

Urbanization is a complex process that encompasses demographic, economic, social, and spatial dimensions. At a macro level, studies have demonstrated a substantial negative correlation between urbanization and Environmental Equality (EEQ) (Li et al., 2021). However, the ecological deterioration caused by urbanization does not follow a linear pattern.

Environmental Impact Assessment (EIA) is a critical process that evaluates the consequences of environmental changes or development activities across several domains, including the natural environment, human health and well-being, and broader societal factors. Its goal is to foster more sustainable development models (Bond et al., 2024).

Urbanization is widely regarded as a significant societal transformation, closely linked to environmental and social processes (Bai et al., 2014). In the 21st century, rapid urbanization and industrialization have driven economic prosperity and material well-being, but they have also presented considerable environmental challenges (Zhou et al., 2023). The conversion of non-urban land into urban landscapes triggers various environmental changes, such as the loss of natural land (Bloom et al., 2008), ecological degradation, pollution, and shifts in atmospheric and climatic conditions (Seto et al., 2012). These transformations, including the reduction of green spaces, are associated with declines in individual well-being and quality of life (Zhong and Chen, 2022), along with broader negative effects like nature deficit (Dong and Geng, 2023). Therefore, understanding the impact of rapid urbanization on individuals is crucial for conducting effective Environmental Impact Assessments (EIA), which in turn are essential for improving well-being and promoting sustainable, high-quality development (Chen et al., 2023).When discussing the historical development of urbanization:

Eray Settlements and the Agricultural Revolution (10,000 BCE – 3,000 BCE)

Humans transitioned from a hunter-gatherer lifestyle to agriculture, establishing the first settled communities. The early civilizations in Mesopotamia, Egypt, India, and China increased agricultural production through irrigation systems, which allowed their populations to grow. During this period, the first cities, such as Çatalhöyük, Ur, Babylon, and Mohenjo-Daro, emerged.

Urbanization in Antiquity (3000 BCE – 500 CE)

The civilizations of Ancient Greece and Rome accelerated urbanization by establishing city-states (polis) and empires. Cities such as Athens, Rome, and Alexandria boasted advanced urban infrastructure, including roads, aqueducts, and public buildings. The development of trade routes transformed these cities into economic centers.

Urbanization in the Middle Ages (500 CE – 1500 CE)

Following the fall of the Roman Empire, urbanization slowed in Europe; however, the Islamic world saw the rise of developed cities such as Baghdad, Córdoba, and Istanbul. The feudal system dominated rural life, yet cities situated along trade routes (Venice, Florence, Paris) gained prominence. These cities were typically surrounded by walls, and hygiene conditions were poor.

Industrial Revolution and Modern Urbanization (1750 – 1900)

The Industrial Revolution initiated modern urbanization by increasing rural-to-urban migration. Industrial cities such as London, Manchester, and New York expanded rapidly in England, Germany, and the United States. Railways, factories, residential areas, and workers' neighborhoods were established. The rapid population growth in cities led to issues such as slums and environmental pollution.20. Yüzyılda Kentleşme ve Mega Kentler (1900 – 2000)

With post-industrial societies, the service sector developed, and large metropolitan areas emerged. From the 1950s onwards, waves of migration led to the rise of megacities (Tokyo, São Paulo, Istanbul, Beijing, Mumbai). Transportation, infrastructure, and skyscrapers accelerated urbanization. The use of automobiles, public transportation systems, and environmental issues became prominent concerns.

Urbanization in the 21st Century and Smart Cities (2000 - Present)

A significant portion of the global population began living in urban areas. Sustainable and green city projects gained importance (e.g., Singapore, Copenhagen). Smart city technologies (IoT, transportation systems, renewable energy use) were developed. Urbanization began to be shaped by new environmentally-friendly policies aimed at combating climate change.

Environmental Issues of Rapid Urbanization in Turkey and Worldwide

Humans have had a measurable impact on Earth's systems for thousands of years, but these changes have intensified significantly since the Industrial Revolution, which began approximately 250 years ago (Dong et al., 2021). Lake sediments act as natural archives, preserving records of ecological shifts, climate variations, changes in air and water chemistry, hydrologic flow alterations, and dominant geomorphic processes over time in a given region (Balascio et al., 2019).

Rapid urbanization refers to the swift expansion of cities driven by population growth and migration. However, this rapid growth also gives rise to numerous environmental challenges. Some of the most pressing environmental issues include:

Air Pollution

Air pollution increases due to industrial facilities, traffic congestion, and the use of fossil fuels for heating. This contributes to respiratory diseases and global warming. In large cities, rising vehicle traffic, industrial plants, and fossil fuel usage have escalated air pollution to serious levels (Xu et al., 2022). In cities like Ankara, Istanbul, and Bursa, air quality sometimes drops to levels that threaten human health.

Water Pollution and Depletion of Water Resources

With population growth, water consumption increases, and water resources face the risk of depletion. When wastewater is released into nature without treatment, rivers, lakes, and groundwater become polluted (Bashir et al., 2020). In Turkey, rapid urbanization leads to excessive consumption and contamination of water resources. The mucilage problem in the Sea of Marmara is directly related to the discharge of untreated wastewater

into the sea. In large cities, pressure on reservoirs and underground water resources is steadily increasing.

Soil Pollution and Loss of Green Spaces

Agricultural land is converted into settlement and industrial areas, negatively affecting food production. Green spaces decrease, and ecosystems suffer damage. Due to rapid urbanization, forests, agricultural lands, and natural habitats are being transformed into residential areas (Chen and Ye, 2014). Projects such as the construction in the Northern Forests of Istanbul and skyscraper developments in Ankara threaten natural ecosystems. The reduction of green spaces strengthens the "urban heat island effect," leading to increased air pollution and temperature rise.

Waste Management Issues

With the increase in urban population, the amount of plastic, metal, glass, and organic waste also rises. Insufficient waste management leads to environmental pollution and potential health problems. The volume of waste generated in large cities continues to increase daily, making its management increasingly challenging (Abegaz et al., 2021). Plastic waste, electronic waste, and hazardous materials harm the environment. Marine pollution, periodically observed on the shores of the Sea of Marmara and Aegean, results from improper waste management.

Impacts on Climate Change

Urbanization leads to deforestation and increased carbon emissions. The concrete nature of cities creates the "urban heat island effect," causing temperatures in urban areas to be higher than in rural regions (Ming et al., 2024). Unplanned urbanization in Turkey is one of the factors accelerating global warming. Deforestation and the depletion of water resources contribute to the rise in droughts and floods. Recent flood disasters, heavy rainfall, and heatwaves in Turkey demonstrate the negative environmental impacts of urbanization.

Loss of Biodiversity

The destruction of natural habitats can lead to the extinction of plant and animal species. Urbanization has led to the loss of natural habitats, threatening many species of animals and plants (Garcia et al., 2013). For instance, the loss of wetlands in Istanbul reduces the living spaces for migratory birds. Large infrastructure projects, such as the Black Sea coas-

tal highway and hydropower plant projects, place significant pressure on ecosystems.

Global Urbanization-Related Environmental Policies

Sustainable Urban Policies and Example Countries

Some countries that implement sustainable urban policies stand out for their emphasis on eco-friendly city planning, the use of green energy, and the importance they place on public transportation. Below are successful examples of sustainable urbanization:

Copenhagen, Denmark

Copenhagen is considered one of the most environmentally friendly cities in the world, with a goal to become carbon neutral by 2025. About 50% of transportation in the city is done by bicycle. Significant investments are being made in renewable energy sources.

Key Policies:

- Development of urban bike lanes and bike-sharing systems.
- Strong focus on wind energy utilization.
- More than 75% of buildings are heated with green energy.
- Zero waste goals are set for recycling and waste management.

Stockholm, Sweden

Stockholm, one of Europe's greenest cities, was chosen as the European Green Capital in 2010. The city aims to become fossil fuel-free by 2040. Sustainable housing projects are being implemented to reduce the carbon footprint.

Key Policies:

- Creation of ecological neighborhoods (e.g., Hammarby Sjöstad).
- 99% of waste is recycled or used in energy production.
- Promotion of smart transportation systems and electric buses.
- Conservation of nature and green spaces within the city to enhance biodiversity.

Singapore

Known as the "Garden City," Singapore has adopted an urbanization model that integrates nature into city life. Smart city technologies are used to improve water and energy efficiency. A large portion of buildings is equipped with green roof systems.

Key Policies:

- Green building certification is mandatory.
- Water conservation through water recycling systems.
- Public transportation is encouraged, and private car ownership is limited.
- Vertical gardens and ponds are incorporated to preserve natural habitats within the city.

Freiburg, Germany

Freiburg is one of the most environmentally friendly cities in Germany, known for its zero-carbon neighborhoods. High energy-efficient passive houses are used extensively.

Key Policies:

- Promotion of solar energy utilization.
- Well-developed public transportation system, with minimal car use.
- Expansion of bike lanes and pedestrian-friendly areas.
- Nature-friendly approaches in urban planning.

Curitiba, Brazil

One of the most sustainable cities in South America, Curitiba is renowned for having one of the most successful public transportation systems in the world. The city boasts a high per capita green space ratio of 52 m^2.

Key Policies:

- Traffic congestion reduced by rapid bus transit systems (BRT).
- Large park areas have been created throughout the city.

- Recycling programs to raise environmental awareness.
- Low-cost social housing projects built in an environmentally conscious manner.

These countries and cities provide successful models for sustainable urbanization. Through the use of green energy, public transportation, recycling, and nature-friendly urban planning, they are building livable cities while protecting the environment. By increasing the implementation of such practices, Turkey can also achieve its sustainable urban development goals.

International Agreements and Environmental Protection Strategies

Numerous international agreements and protocols have been signed globally to address environmental protection. These agreements aim to solve global environmental issues such as climate change, biodiversity conservation, carbon emissions reduction, deforestation, and environmental pollution (He and Quan, 2024). Here are some of the most important international environmental agreements:

Ramsar Convention (1971)

The Ramsar Convention, signed in 1971 in Ramsar, Iran, and coming into force in 1975, is an international environmental agreement aimed at preserving wetlands and ensuring their sustainable use to maintain biodiversity and ecological balance.

The Ramsar Convention focuses on the protection of ecosystems such as lakes, rivers, swamps, deltas, coastal lagoons, and coral reefs. Wetlands provide vital ecosystem services, including habitat for waterfowl, regulation of water cycles, and carbon sequestration. Therefore, this convention plays a crucial role in maintaining the continuity of natural life.

Under the Ramsar Convention, the ecological functions of wetlands are encouraged to be preserved, and countries develop national policies for sustainable management of wetlands. Wetlands of international importance are designated as “Ramsar Sites” to gain protected status.

Bern Convention (1979)

The Bern Convention, signed in 1979 in Bern, Switzerland, and entering into force in 1982, is an international environmental agreement. Under this convention, lists of protected species were created, and countries were

expected to safeguard the habitats of these species and make the necessary legal arrangements. The Bern Convention is one of Europe's most important nature conservation agreements and has led to the establishment of many national parks and conservation areas across Europe. Its aim is to protect wild fauna (animals) and flora (plants) species and their natural habitats in Europe. The main objectives of the Bern Convention include protecting endangered plant and animal species, supporting biodiversity to ensure the sustainability of ecosystems, encouraging European countries to develop common conservation policies, and preventing illegal hunting, illegal trade, and harmful human activities.

Montreal Protocol (1987)

The Montreal Protocol is an international environmental agreement adopted in 1987 and coming into force in 1989. Its aim is to gradually reduce and ultimately eliminate the production and use of substances that deplete the ozone layer. Under this protocol, the use of ozone-depleting chemicals such as chlorofluorocarbons (CFCs), halons, hydrochlorofluorocarbons (HCFCs), and methyl bromide has been banned or restricted. The protocol has been updated over time with various amendments, and the most recent, the Kigali Amendment (2016), also included restrictions on hydrofluorocarbons (HFCs). The Montreal Protocol is considered one of the most successful international environmental agreements. According to scientific research, due to this protocol, the ozone layer has started to recover, and it is expected to return to its original state by the 2060s.

Basel Convention (1989)

The Basel Convention is an international environmental agreement adopted in 1989 and coming into force in 1992. Its aim is to control the transboundary movements of hazardous wastes and ensure that these wastes are managed without causing harm to the environment. The main objectives of the Basel Convention include limiting the transportation and export of hazardous wastes, ensuring that waste management is environmentally sound, fostering cooperation between countries, and reducing waste production. The convention specifically addresses hazardous materials such as electronic waste, chemical waste, biomedical waste, and heavy metals that can damage the environment and human health. The Basel Convention is one of the most significant international regulations aimed at preventing developed countries from exporting hazardous waste to developing countries without proper control.

United Nations Convention on Biological Diversity (1992)

The United Nations Convention on Biological Diversity (CBD) is an international agreement adopted during the United Nations Conference on Environment and Development (the Rio Earth Summit) in 1992 in Rio de Janeiro. This convention came into force in 1993, and its three main objectives are:

1. The conservation of biological diversity,
2. The sustainable use of its components, and
3. The fair and equitable sharing of the benefits arising from the use of genetic resources.

The convention promotes global cooperation in the protection of ecosystems and encourages countries to develop national strategies related to biodiversity. The Aichi Biodiversity Targets and the 2022 Kunming-Montreal Global Biodiversity Framework are key global action plans created under the guidance of this convention.

Kyoto Protocol (1997)

The Kyoto Protocol is an international agreement adopted in 1997 in Kyoto, Japan, and entered into force in 2005. Its main goal is to combat climate change by reducing the emissions of greenhouse gases responsible for global warming. The protocol specifically required industrialized countries and economies in transition to reduce emissions of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxides (N_2O), in line with set targets. Additionally, the protocol provided market-based solutions like carbon trading and clean development mechanisms, enabling countries to meet their targets flexibly. The Kyoto Protocol was succeeded by the Paris Agreement in 2015, which included broader and more binding goals.

Stockholm Convention (2001)

The Stockholm Convention is an international environmental agreement adopted in 2001 and coming into force in 2004. Its purpose is to restrict and eliminate the production, use, and release of Persistent Organic Pollutants (POPs), which are harmful to human health and the environment. The main objectives of the Stockholm Convention are to ban and gradually eliminate dangerous chemicals, promote safer chemical alternatives, clean up contaminated areas, and reduce environmental impacts. Initially, the convention targeted 12 harmful chemicals, known as the "Dirty Dozen." The list has since been expanded to include more toxic substan-

ces. The Stockholm Convention is an important step in environmental health and sustainable development, contributing to the global prevention of chemical pollution.

Paris Climate Agreement (2015)

The Paris Agreement aims to limit global temperature rise to well below 2°C above pre-industrial levels, with efforts to keep it below 1.5°C. The agreement, with participation from 195 countries (Turkey ratified it officially in 2021), involves countries submitting Nationally Determined Contributions (NDCs) outlining targets for reducing carbon emissions. A key goal of the agreement is for countries to achieve carbon neutrality by 2050. It encourages investments in renewable energy, accelerating policies to transition away from fossil fuels. Turkey has set a goal to become carbon neutral by 2053, with increasing investments in renewable energy projects.

Turkey's Urbanization and Environmental Policies

History of Turkey's Environmental Policies

Turkey's environmental policies have evolved from development-focused approaches to ecological sustainability-oriented strategies. Significant steps have been taken in areas like participation in global agreements, renewable energy projects, and waste management. Today, combating climate change and pursuing green development are key environmental policy goals. Turkey's environmental policies have changed in line with global developments. Initially, environmental issues were given limited attention within development policies, but since the 1980s, environmental protection and sustainable development have gained more importance.

Before 1970: Development of Environmental Awareness

- Environmental regulations in Turkey date back to the late 19th century, but modern environmental policies began to emerge in the mid-20th century.
- The 1924 Constitution and the 1930 Public Health Law included regulations related to public health and environmental cleanliness.
- The 1956 Building Code marked an important step in urbanization and environmental regulation.

1970-1980: First Institutional and Legal Steps

- Following the 1972 Stockholm Conference, global environmental awareness increased, and Turkey aligned with this process.
- In 1978, the Ministry of Environment was established, placing environmental issues within a more institutional framework.
- In 1980, the first draft of the Environmental Law was prepared, laying the legal foundations for environmental policies.

1980-2000: Environmental Law and International Participation

- The 1982 Constitution included the principle of environmental protection. Article 56 guaranteed the right to live in a healthy and balanced environment.
- In 1983, the Environmental Law came into effect, forming the foundation of Turkey's modern environmental policies.
- In 1989, the Directorate General of Environment was established, followed by the Ministry of Environment in 1991.
- Turkey signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1994.
- In 1996, the UN Habitat II Conference was held in Istanbul, marking Turkey's increased participation in global discussions on the environment and sustainable urbanization.

After 2000: EU Process and Sustainable Development

- In 2003, the Ministry of Environment was merged with the Ministry of Forestry, forming the Ministry of Environment and Forestry.
- In 2004, Turkey signed the Kyoto Protocol, taking a more active role in combating climate change.
- In 2009, the Ministry of Environment and Urbanization was established, bringing together urban planning and environmental management.
- In 2015, Turkey participated in the Paris Climate Agreement negotiations but officially ratified it in 2021.
- In 2021, Turkey declared the Green Development Revolution and adopted the goal of achieving net-zero emissions by 2053.

Current Green Transformation and Climate Policies

- Initiatives such as the Zero Waste Project support sustainable waste management.
- Investments in renewable energy (solar, wind, hydroelectric) are increased to reduce dependence on fossil fuels.
- Emission reduction, energy efficiency, and carbon market activities are prioritized.
- With the Green Deal Action Plan (2021), Turkey aims to align with the European Union's environmental policies.

Green Urbanism and Ecological Urban Planning in Turkey

Green urbanism and ecological urban planning aim to create environmentally friendly, sustainable, and energy-efficient cities. In Turkey, significant steps have been taken in recent years to address climate change, promote environmental sustainability, and make cities more livable.

Green Urbanism

Green urbanism refers to the design of cities that conserve natural resources, reduce carbon emissions, increase energy and water efficiency, and prioritize human health (Li et al., 2025). The key components of green urbanism practices in Turkey include the use of green energy, renewable energy adoption, zero-waste policies, recycling projects, increasing green spaces, promoting smart transportation systems and public transit, water conservation, sustainable management, ecological buildings, and sustainable housing projects.

Notable Green Urbanism Practices and Projects

Zero Waste Project

- Launched in 2017, this project aims to improve waste management and reduce environmental pollution.
- Municipalities, public institutions, and the private sector collaborate to encourage recycling and waste reduction.

Smart and Sustainable Transportation Systems

- In major cities like Istanbul, Ankara, and Izmir, electric buses and bike lanes are becoming more widespread.

- Initiatives to encourage public transportation (such as Istanbulkart integration, expansion of bus and metro lines) contribute to reducing carbon emissions.
- Smart transportation systems (for example, the Smart Traffic Management System in Istanbul) aim to reduce traffic congestion and improve the efficiency of city transport.

Ecological Cities and Green Spaces

- **Basaksehir (Istanbul)**: This city is a prominent example of green cities with its Zero Carbon City Project, aiming for sustainable urban living.
- **Ankara**: The Gölbaşı Special Environmental Protection Area and the Millet Gardens projects are helping to increase nature-friendly spaces in the capital.
- **Eskisehir, Konya, and Bursa**: These cities are working on urban green space projects to maintain ecological balance.

Smart Buildings and Green Architecture

- **LEED and BREEAM Certified Buildings**: The number of buildings with environmental certifications such as LEED and BREEAM is rapidly increasing in Turkey, reflecting the trend toward more sustainable building practices.
- **TOKİ (Housing Development Administration of Turkey)**: The institution is building energy-efficient housing projects, contributing to eco-friendly structures.
- **Public Buildings**: New public buildings are incorporating sustainable solutions, such as solar panels and rainwater harvesting systems.

Renewable Energy-Focused Cities

- **Konya Karapınar Solar Power Plant**: This is Turkey's largest solar power plant, supplying clean energy to cities.
- **Izmir, Balıkesir, and Çanakkale**: These cities have become major centers for wind energy production, furthering Turkey's move toward sustainable energy solutions.

Solutions for Sustainable Urbanization

Ecological Urban Planning and Green Space Initiatives Ecological urban planning is an approach to urban development that focuses on preserving natural resources, improving energy efficiency, and offering environmentally conscious solutions. This planning model, based on sustainable development principles, aims for urban growth without disrupting ecosystems. Key principles of ecological urban planning include sustainability, green infrastructure, energy efficiency, waste management, public transportation and bike paths, water management, biodiversity conservation, and green space development (Zheng et al., 2023).

Green spaces play a vital role in urban ecosystems by improving air quality, regulating temperature, and providing social spaces for residents. Some key elements of green space initiatives include city parks, vertical gardens, green roofs, urban forests, botanical gardens, and green corridors.

Examples of Ecological Cities and Projects:

- **Başakşehir (Istanbul)**: A model for green cities with its sustainable design and Zero Carbon City Project.
- **Konya Karapınar**: A solar energy hub with one of the largest solar power plants in Turkey.
- **Green Urban Initiatives in Various Cities**: From Eskişehir's ecological urban projects to İzmir's renewable energy focus, these cities demonstrate a shift towards more sustainable urban landscapes.

Freiburg (Germany): A model of sustainable urban development renowned for its focus on renewable energy, bicycle infrastructure, and green spaces. Copenhagen (Denmark): A city committed to achieving carbon neutrality, with a strong emphasis on renewable energy and extensive bicycle lanes. Masdar City (UAE): A pioneering urban project designed to achieve zero carbon emissions, powered by solar energy and characterized by sustainable architecture.

Ecological urban planning and green space initiatives are crucial for transforming cities into more livable environments, both environmentally and socially. Such initiatives are expected to play a significant role in combating climate change and enhancing urban quality of life in the future.

Urban Agriculture and Sustainable Food Policies

Urban agriculture refers to agricultural activities conducted within or around urban areas. This approach was developed to support sustainable food production in response to the challenges posed by urbanization. Urban farming can take place on rooftops, in gardens, vacant lots, or other available spaces within the city. This method not only allows urban residents to meet their food needs but also provides environmental benefits (Eiter et al., 2023). The advantages of urban agriculture are categorized as local food production, reduction of greenhouse gas emissions, the optimization of vacant land, soil fertility, biodiversity preservation, and societal benefits (Azunre et al., 2019).

Types of Urban Agriculture

- **Vertical Farming**: This involves farming on the exterior walls of tall buildings, balconies, or rooftops. Plants are grown vertically, saving space while utilizing urban areas.
- **Community Gardens**: These are collective agricultural efforts organized by communities in vacant urban lots.
- **Greenhouse Farming**: Small-scale greenhouse projects in urban areas can support year-round food production.
- **Aquaponics and Hydroponics**: These are water-based farming techniques where hydroponic farming involves growing plants without soil, directly in nutrient-rich solutions.

Results and Discussion

Urbanization is an important process for individuals seeking better living conditions and creating economic opportunities, but it must be approached sustainably, considering its environmental impacts (Liang et al., 2019). This approach aims to develop an environmentally conscious urbanization model that conserves natural resources while ensuring a more livable world for future generations. Environmental responsibility holds great significance both at the individual and societal levels, and future urbanization strategies must be shaped to fulfill this responsibility (Larson et al., 2015).

Adopting a sustainable urbanization approach is crucial for managing the environmental impacts of urbanization and fulfilling our responsibility to nature. Environmental responsibility involves not only preserving the environment but also passing on natural resources to future generations and improving the quality of life (Ramizo et al., 2025).

The future of global environmental policies will be shaped by efforts to combat global environmental threats such as climate change, resource depletion, biodiversity loss, water crises, and pollution. As a result, environmental policies will need to develop more effective, comprehensive, and innovative solutions in the coming years (Satrovic et al., 2025).

The future indicates a period where environmental policies will be applied more effectively and holistically on a global scale. Both Turkey and the world must take more innovative, conscious, and sustainable steps to overcome environmental challenges. In this process, national and international collaborations, the development of environmentally friendly technologies, and public awareness will play a crucial role. Policies regarding urbanization, climate change, and natural resource conservation will form the foundation for a healthier and more sustainable future.

Eco-friendly urbanization is a set of practices and policies aimed at making cities more sustainable by conserving natural resources, reducing energy consumption, and enhancing biodiversity. In this process, the responsibilities of individuals and institutions are of great importance. Contributions made at both the individual and institutional levels play a key role in achieving eco-friendly urbanization goals.

Individuals and institutions can make significant contributions at different levels for eco-friendly urbanization. On an individual level, changing daily habits can reduce environmental impacts. Institutions, on the other hand, can contribute to eco-friendly urbanization through infrastructure projects, energy efficiency initiatives, and sustainable production methods. Both parties must collaborate to create a strong foundation for developing more livable and sustainable cities (Bu et al., 2023).

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CHAPTER 2

USE OF RARE EARTH ELEMENTS IN URBANIZATION POLICIES IN TURKEY

Gökhan Önder ERGÜVEN[1]

1 Assoc. Prof. Dr., Munzur University, Faculty of Economics and Administrative Sciences, Department of Urbanization and Environmental Issues, Tunceli, Turkey

Orcid: 0000-0003-1573-080X

goerguven@munzur.edu.tr

INTRODUCTION

Rare earth elements (REEs), encompassing atomic numbers 57 to 71, belong to the lanthanide group and are classified into light rare earth elements (LREEs) and heavy rare earth elements (HREEs) based on their atomic number. Lanthanum (La), neodymium (Nd), samarium (Sm), cerium (Ce), and praseodymium (Pr) are representative LREEs, whereas terbium (Tb), lutetium (Lu), holmium (Ho), erbium (Er), yttrium (Y), ytterbium (Yb), and thulium (Tm) are categorized as HREEs (McLemore, 2015). Despite their designation, REEs are not inherently rare; rather, they are widely dispersed in the Earth's crust and seldom found in economically viable concentrations (de Boer, 2013). The distribution of LREEs and HREEs varies within the Earth's crust, with LREEs generally being more abundant than HREEs (Omodara et al., 2019).

Rare earth elements (REEs) are essential components of modern technologies and sustainable development projects. Analyzing their role in urbanization processes and environmental policies highlights their significance, particularly in smart cities, renewable energy systems, and environmentally friendly technologies. Additionally, discussions focus on the mining, recycling, and environmental impact of REEs (Li et al., 2025).

REEs comprise 17 elements, including lanthanum, cerium, neodymium, and dysprosium, among others. Due to their exceptional magnetic and electrical properties, these elements have a broad range of industrial applications and play critical roles across various technological domains. In recent years, REEs have significantly contributed to sustainable development through innovative applications aimed at addressing environmental challenges. Notably, REEs are integral to green technologies and urbanization processes (Cheisson and Schelter, 2019) (Figure 1).

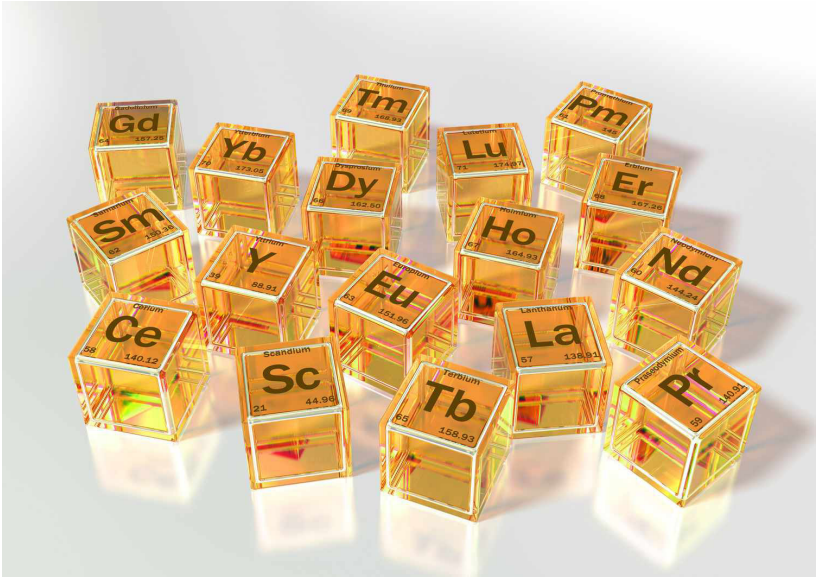

Figure 1. Rere earth elements (https://www.thoughtco.com/rare-earth-elements-list-606660)

With an estimated rare earth element (REE) reserve of approximately 694 million tons, Türkiye holds the world's second-largest REE reserves after China. To capitalize on this strategic advantage, Türkiye has taken significant steps in recent years to explore, extract, and process REEs.

In Beylikova, Eskişehir, a pilot processing facility established by Eti Maden aims to achieve an annual production capacity of 10,000 tons of rare earth oxides. This facility is expected to enhance Türkiye's REE processing capacity, thereby strengthening its competitive position in the global market (Figure 2).

Figure 2. Eti Maden Facility

Furthermore, Türkiye has joined the Minerals Security Partnership (MSP), which includes the United States, the European Union, and 13 other countries. This partnership seeks to foster international cooperation in the production of critical raw materials and rare earth elements.

The Minerals Security Partnership (MSP)

The Minerals Security Partnership (MSP) is an international platform established in June 2022 to ensure a secure and sustainable supply of critical minerals. MSP aims to support projects that adhere to responsible mining principles in the extraction, processing, and recycling of critical minerals (Figure 3).

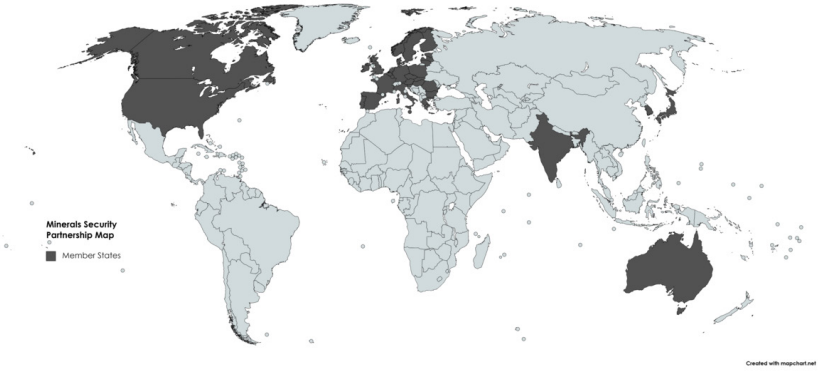

Figure 3. Minerals Security Partnership map (https://en.wikipedia.org/wiki/Minerals_Security_Partnership)

Türkiye joined MSP in January 2025, a move that presents opportunities for attracting foreign investment into the mining sector, improving infrastructure, and enhancing technological capacity. Additionally, Türkiye's participation in MSP may strengthen its influence in global energy and resource policies while fostering deeper diplomatic and economic relations with MSP partners.

The primary objective of MSP is to diversify critical mineral supply chains and develop the necessary infrastructure by identifying suitable investment opportunities. As of January 2023, MSP had assessed over 170 projects, demonstrating its commitment to achieving these goals.

Türkiye's participation in the Minerals Security Partnership (MSP) has the potential to attract foreign direct investment into the mining sector, support infrastructure development, and enhance technological capacity. This, in turn, could contribute to economic growth and job creation in mineral-rich regions.

Moreover, by strengthening its ties with major economies through MSP, Türkiye can enhance its geopolitical influence as a reliable supplier of strategic materials essential for the energy transition. This increased role in global energy and resource policies may facilitate deeper diplomatic and economic relations with MSP partners.

Additionally, alignment with MSP's environmental, social, and governance (ESG) standards could promote sustainability in Türkiye's mining practices and reinforce its reputation as a responsible producer in the critical minerals market.

In summary, MSP serves as a platform that fosters international cooperation to ensure the secure supply of critical minerals. Türkiye's participation in MSP presents significant opportunities in the mining sector while also enhancing its influence in global energy and resource policies.

Türkiye's REE policies aim to strengthen energy security and support economic development by ensuring the effective utilization and processing of these strategic resources.

Properties and Applications of Rare Earth Elements

Due to their magnetic, catalytic, and optical properties, rare earth elements (REEs) play a crucial role in various environmentally friendly Technologies (Figure 4).

*Figure 4. Key applications of rare earth materials (*https://www.stanfordmaterials.com/applications.html*)*

Some of their key applications include:

1. Renewable Energy Technologies

Wind Turbines: REEs such as neodymium (Nd) and dysprosium (Dy) are essential for the production of high-efficiency magnets, which enhance the performance of direct-drive wind turbines. These REE-based magnets are lighter and more durable, reducing maintenance requirements while improving energy conversion efficiency (Cheilas et al., 2025).

Solar Panels: Elements such as lanthanum (La) and cerium (Ce) enhance the efficiency of photovoltaic cells, thereby improving the overall performance of solar panels. Additionally, yttrium (Y), neodymium (Nd), and gallium (Ga) contribute to increasing solar energy generation capacity. Indium (In) and gallium (Ga) are utilized in thin-film solar cells, making panels lighter and more flexible (Ding and Ge, 2025).

2. Electric and Hybrid Vehicles

Lithium-Ion Batteries: While rare earth elements (REEs) are not directly used in lithium-ion batteries, they play a crucial role in electric motors and power transmission systems, enhancing vehicle battery capacity, extending driving range, and increasing energy density. Neodymium (Nd), dysprosium (Dy), and praseodymium (Pr) are essential for producing strong magnets used in electric motors. These REE-based magnets enable the development of lighter and more efficient motors, thereby improving

vehicle range. Additionally, rare earth magnets enhance motor efficiency, reducing overall energy consumption (Ilkhani et al., 2024).

3. Water and Air Purification Systems

Catalysts: Cerium oxide is widely used in automotive exhaust gas purification and industrial air filtration systems.

Water Treatment: REEs serve as effective components in filtration systems designed to remove heavy metal ions and contaminants from water sources (Haque et al., 2014).

4. Waste Management and Recycling

E-Waste Recycling: The recovery of REEs from used electronic devices contributes to the conservation of natural resources and improves waste management practices.

Radioactive Waste Management: Rare earth elements play a significant role in stabilizing and isolating nuclear waste, ensuring safer long-term disposal solutions (Dagwar et al., 2025).

The Role of Rare Earth Elements in Urbanization

Modern urbanization processes are planned based on the principle of sustainability. Smart cities, energy-efficient transportation systems, and renewable energy infrastructures rely on technologies enabled by rare earth elements (REEs).

REE Utilization in Smart Cities: Various components of smart cities, such as data collection, energy management, and transportation systems, are dependent on technologies incorporating REEs. For instance, smart lighting systems utilize LEDs that contain REEs such as lanthanum (La) and cerium (Ce) (Yandem et al., 2025).

The Role of REEs in Transportation: Electric and hybrid vehicles require strong and efficient magnets, which rely on REEs such as neodymium (Nd) and dysprosium (Dy) to achieve high performance. Additionally, REEs are used in charging stations for electric vehicles and in smart traffic systems.

Rare Earth Elements and Environmental Policies

Environmental policies promote the use of renewable energy sources to support sustainable development. In this context, REEs serve as critical

components in wind turbines, solar panels, and energy storage systems, playing a key role in advancing green technologies.

Environmental Impacts and Sustainability

The global transition driven by population growth, digital transformation, and industrialization is steering economies toward a greener and more sustainable future, thereby increasing the demand for technological advancements on a global scale (Modiga et al., 2023). Technology has witnessed significant growth across various sectors, including healthcare, transportation, defense, information technology, renewable energy, aerospace, and environmental science. Each of these sectors has an escalating demand for Rare Earth Elements (REEs), leading to a substantial rise in their utilization (Ji and Zhang, 2022).

The extraction and processing of REEs can pose environmental challenges; however, these impacts can be minimized through sustainable mining techniques and advanced recycling methods.

Mining and processing activities associated with REEs may result in significant environmental consequences, including:

Radioactive Waste: REEs are often found in conjunction with radioactive elements such as thorium (Th) and uranium (U). During the separation process, radioactive waste can be generated, posing potential environmental hazards. If not properly managed, these wastes may contaminate water sources and soil, leading to long-term ecological damage (Su et al., 2021).

Water Pollution: The chemicals used in REE mining, including acids and solvents, can infiltrate underground and surface water systems. The leaching of heavy metals into water sources poses a serious threat to drinking water safety and aquatic ecosystems. The discharge of acidic wastewater into rivers and lakes can lead to the degradation of aquatic habitats (Palanisami et al., 2025).

Soil Degradation and Erosion: Large amounts of soil excavation are required for REE mining, leading to soil infertility and the loss of vegetation. Deforestation and land degradation contribute to a reduction in biodiversity, disrupting the balance of ecosystems (Zhu et al., 2011).

Air Pollution: Chemicals such as sulfuric acid and hydrofluoric acid are used during the processing of ores, which can result in harmful gas emissions. Radioactive dust can become airborne, potentially causing respiratory diseases (Sun et al., 2024).

Carbon Footprint and Energy Consumption: REE mining and refining require substantial energy, especially through the use of fossil fuels such as coal, which increases carbon emissions. Processing activities can contribute to greenhouse gas emissions, accelerating climate change (Hu et al., 2017).

Proposed Solutions

- Develop more sustainable mining methods.
- Recover REEs from electronic waste through recycling.
- Improve waste management through the use of environmentally friendly technologies.
- Strictly monitor mining activities with solid environmental policies and regulations.

While REEs are critical for technological advancement, sustainable solutions must be developed with consideration of their environmental impacts.

Renewable Energy and REEs

- **Wind Turbines:** Magnets containing neodymium (Nd) and praseodymium (Pr) are used in wind turbine generators to enhance energy efficiency (Wu et al., 2024).
- **Solar Panels:** REEs are used to increase the efficiency of photovoltaic cells (Essahili et al., 2022).
- **Energy Storage and Battery Technologies:** REEs play a critical role in enhancing the performance of lithium-ion batteries. They are used primarily to increase energy density and extend battery lifespan (Ahsan et al., 2023).

REE Mining and Environmental Impacts

The mining of REEs can lead to significant environmental challenges. Issues such as acid drainage, radioactive waste, and habitat destruction highlight the necessity for sustainable management of mining activities (Han et al., 2024).

Environmental Impacts and Risks:

The chemical waste generated during REE mining can contaminate water sources and harm ecosystems. Therefore, sustainable mining methods and recycling techniques are of paramount importance (Hua et al., 2023).

Recycling and Alternative Sources:

Recycling REEs is crucial for reducing environmental impacts and ensuring resource sustainability. For example, numerous studies are being conducted on the recovery of rare earth elements from electronic waste.

RESULTS

Rare Earth Elements and Their Role in Sustainable Technologies

Rare earth elements (REEs) ensure that renewable energy technologies are more efficient, durable, and sustainable. However, it is critical to minimize the environmental impact of mining processes and to develop recycling technologies in order to ensure the sustainable use of these strategic resources.

REEs enhance energy efficiency by providing stronger magnets and lighter motors, thereby improving overall performance. Materials containing REEs are resistant to wear and tear, leading to the production of longer-lasting systems. Due to their ability to reduce carbon footprints, they contribute to the efficient operation of renewable energy systems, thereby reducing dependency on fossil fuels.

Rare earth elements play a significant role in sustainable urbanization and environmental policies. As their use increases in smart cities, renewable energy, and eco-friendly transportation systems, the environmental impacts of mining processes must also be considered. In the future, the development of recycling and sustainable mining policies will be crucial to minimizing the environmental impacts of REEs.

Rare earth elements contribute significantly to renewable energy, environmental purification systems, and sustainable technologies. By developing innovative approaches to address environmental challenges, ensuring the effective and sustainable use of these valuable elements is of utmost importance.

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